

**NISTIR 8106**

# **2014 NIST Assessment of Phasor Measurement Unit Performance**

Allen Goldstein

This publication is available free of charge from  
<http://dx.doi.org/10.6028/NIST.IR.8106>

**NISTIR 8106**

# **2014 NIST Assessment of Phasor Measurement Unit Performance**

Allen Goldstein  
*Physical Measurement Laboratory*

This publication is available free of charge from:  
<http://dx.doi.org/10.6028/NIST.IR.8106>

February 2016



U.S. Department of Commerce  
*Penny Pritzker, Secretary*

National Institute of Standards and Technology  
*Willie May, Acting Under Secretary of Commerce for Standards and Technology and Acting Director*

## Foreword

In 2005, the Institute of Electrical and Electronic Engineers Standards Association (IEEE SA) published IEEE Std. C37.118.1-2005 Standard for Synchrophasors for Power Systems. This standard replaced IEEE Std. 1344-1995. These standards define a Phasor Measurement Unit (PMU) as a device that produces synchronized phasor, frequency, and rate of change of frequency (ROCOF) estimates from voltage and/or current signals and a time synchronizing signal. The 1995 standard required that a PMU have less than 1  $\mu$ s error in timing. The 2005 standard removed the timing error limit and instead set amplitude and phase angle limits using a combined metric called Total Vector Error (TVE). The limits were placed only on the performance of the phasor measurements and not on frequency or rate of change of frequency (ROCOF) measurements. Also the performance limits were only given for “steady state” power system conditions: conditions where the magnitude and frequency of the power system signal were unchanging but not for “dynamic” conditions where frequency and/or magnitude were changing.

In 2005, NIST began to develop test methods for synchrophasors and in 2006, NIST began to measure the performance of PMUs sponsored with supplemental funding from the Department of Energy (DOE). Working closely with DOE, the IEEE working group responsible for the synchrophasor standard (IEEE Power and Energy Society (PES), Power System Relaying Committee (PSRC) Working Group H11), and with the Bonneville Power Administration’s (BPA’s) PMU lab, NIST developed tests for PMUs. In 2007, NIST began to offer special test services for PMUs.

In 2009, NIST was contracted to create a Report of Special Test for Operador Nacional do Sistema Eléctrica (ONS), Brazil. The contract required that PMUs be tested for accuracy of frequency and ROCOF measurements as well as performance under some dynamic system conditions. As a result of this testing, NIST made proposals to IEEE PSRC H11 for dynamic tests to be performed on PMUs.

In 2010, NIST awarded an American Recovery and Reinvestment Act (ARRA) grant to Fluke Calibration<sup>1</sup> to develop a commercially available PMU calibration system. A prototype of this system is on loan to the NIST Power System Synchro metrology Lab. It is one of four PMU test systems in operation at NIST today.

In 2011, IEEE SA published C37.118.1-2011 IEEE Standards for Synchrophasor Measurements for Power Systems which incorporated many of the dynamic tests developed by NIST and BPA. The standard eliminated the PMU “levels” and implemented M and P classes of PMU. It revised the steady state performance limits, added performance limits for frequency and ROCOF measurements, and added a set of dynamic performance limits. Many of the limits chosen were based on extensive testing of actual and simulated PMUs performed at NIST.

In 2012, NIST invited all known PMU manufacturers to participate in a performance assessment of their PMU products. Tests were performed and the data were provided to the vendors. When the performance data were shared with the PMU vendors many of them upgraded their PMU hardware and/or software, and NIST re-tested them. Some of the vendors provided prototype equipment that has not been released to production at the time of this publication.

---

<sup>1</sup> *Certain commercial equipment, instruments, or materials are identified in this paper to foster understanding. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose*

In 2014, acting upon lessons learned through PMU testing at NIST, BPA, and other locations, IEEE SA amended the synchrophasor standard with IEEE Std. C37.118.1a-2014, clarifying some tests, resolving some ambiguities, and adjusting some performance limits.

This NISTIR reports on the performance of ten prototype and commercially available PMUs, as well as the C37.118.1a-2014 amended Annex C Reference Signal Processing Model against the limits of the 2014 amended IEEE synchrophasor standard. The purpose of this study was to establish a baseline range of performance for commercial PMUs and to provide generic PMU performance information to the IEEE PSRC H11 Working Group to support further improvement of the synchrophasor standards. The identities of the PMU models and manufacturers are therefore withheld.

NIST continues to work closely with IEEE and with IEC, who are now working to create a joint synchrophasor standard. NIST is also working closely with IEEE SA to create a Synchrophasor Conformity Assessment Program which will use third-party independent laboratories to test PMUs for compliance certification to meet power industry needs. NIST also continues to test PMUs from manufacturers to help them prepare for certification of compliance against the synchrophasor standards.



Table of Contents

1. Performance Overview ..... 1

2. Steady state signal frequency range..... 14

3. Steady state signal magnitude range ..... 96

4. Steady state harmonic distortion ..... 177

5. Steady state out-of-band interfering signals..... 258

6. Dynamic ramp of system frequency ..... 352

7. Dynamic measurement bandwidth: phase modulation ..... 510

8. Dynamic measurement bandwidth: amplitude modulation ..... 592

9. Dynamic step change in phase..... 672

10. Dynamic step change in magnitude..... 875

11. Conclusion ..... 1073

## 1. Performance overview

1. Performance overview .....	1
1.1 C37.118.1 Annex C signal processing model performance overview .....	3
1.2 PMU A performance overview .....	4
1.3 PMU B performance overview .....	5
1.4 PMU C performance overview .....	6
1.5 PMU D Performance overview .....	7
1.6 PMU E performance overview .....	8
1.7 PMU F performance overview .....	9
1.8 PMU G performance overview .....	10
1.9 PMU H performance overview .....	11
1.10 PMU I performance overview .....	12
1.11 PMU J performance overview .....	13

The sections of the overview provide tables of pass, fail, or indeterminate results for each of the PMUs in the assessment. These results are for IEEE<sup>(TM)</sup> Std. C37.118.1-2011 amended by IEEE Std. C37.118.1a-2014.

The rows of the tables provide results for each of the test types required by the synchrophasor standard. The tests are:

- Steady state frequency range tests
- Steady state harmonic distortion tests
- Steady state out-of-band interfering signals tests
- Steady state magnitude tests
- Dynamic test of ramp of system frequency
- Dynamic bandwidth modulation tests
  - Phase modulation tests
  - Magnitude modulation tests
- Dynamic step tests
  - Phase step tests
  - Magnitude step tests

The columns of the tables show pass/fail/indeterminate results for Total Vector Error (TVE), Frequency Error (FE) and Rate of Change of Frequency Error (RFE) for each of the reporting rates required for 60 Hz nominal system frequency. Fifty Hz nominal system frequency was not tested for this assessment.

- P indicates the PMU passes the test by performing within the limits set by the standard.
- F indicates the PMU fails the test by performing outside the limits set by the standard.
- I indicates the result is indeterminate because the PMU performance is close enough to the limits to be within the test system's range of uncertainty.
- - (dash) indicates that a test was not required or that performance limits have not been established for the test type, class, and reporting rate.

## 1.1 C37.118.1 Annex C signal processing model performance overview

**Table 1: Annex C signal processing model TVE, FE, and RFE**

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T	FE	RF	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R			
	V		E	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F			
	E			E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		
SS Freq. Range	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
SS Harmonic	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P
SS OOB Interf.	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-
SS Magnitude	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-
Dyn Ramp	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
Dyn Phase Mod	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
Dyn Ampl Mod	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	

**Table 2: Annex C signal processing model response time, delay time, and overshoot pass/fail**

Fs (FPS)		10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
Phase Step	Phasor Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	ROCOF Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
Magnitude Step	Phasor Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Magnitude Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	ROCOF Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P

## 1.2 PMU A performance overview

PMU A is a commercially available PMU.

**Table 3: PMU A TVE, FE, RFE pass/fail**

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T V E	FE	RF E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E
SS Freq. Range	P	P	P	P	F	F	P	P	P	P	F	F	P	P	P	P	F	F	P	P	P	P	F	F	P	P	F	P	F	F	P	F	F	P	F	F
SS Harmonic	P	P	-	P	P	F	P	P	-	P	P	F	P	P	-	P	P	F	P	P	-	P	P	F	P	P	-	P	P	F	P	P	-	P	P	F
SS OOB Interf.	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-
SS Magnitude	P	-	-	P	P	P	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-
Dyn Ramp	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	F	P	P	F
Dyn Phase Mod	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	P	P	P	F	P	P	P	P	P	P	P	P	P
Dyn Ampl Mod	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P

**Table 4: PMU A response time, delay time and overshoot pass/fail**

Fs (FPS)		10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
Phase Step	Phasor Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	ROCOF Resp. Time	P	F	P	F	P	F	P	F	P	F	F	F
Magnitude Step	Phasor Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Magnitude Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	ROCOF Resp. Time	P	F	P	F	P	F	P	F	P	F	F	F

### 1.3 PMU B performance overview

PMU B is a commercially available PMU.

**Table 5: PMU B TVE, FE, RFE pass/fail**

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T V E	FE	RF E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E			
SS Freq. Range	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
SS Harmonic	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P
SS OOB Interf.	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-
SS Magnitude	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-
Dyn Ramp	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P
Dyn Phase Mod	P	P	P	P	P	P	P	P	P	P	P	P	P	F	P	P	P	P	P	F	F	P	P	P	P	F	F	P	P	P	P	F	F	P	P	P
Dyn Ampl Mod	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P

**Table 6: PMU B response time, delay time and overshoot pass/fail**

Fs (FPS)		10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
Phase Step	Phasor Resp. Time	P	F	P	F	P	F	P	F	P	F	P	F
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Overshoot	F	F	F	F	F	F	F	F	F	F	F	F
	Freq Resp. Time	P	F	P	F	P	F	P	F	P	F	P	F
	ROCOF Resp. Time	P	F	P	F	P	F	P	F	P	F	P	F
Magnitude Step	Phasor Resp. Time	P	F	P	F	P	F	P	F	P	F	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Magnitude Overshoot	F	F	F	F	F	F	F	F	F	F	F	F
	Freq Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	ROCOF Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P

## 1.4 PMU C performance overview

PMU C is a commercially available PMU.

**Table 7: PMU C TVE, FE, RFE pass/fail**

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T V E	FE E	RF E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E
SS Freq. Range	P	F	F	P	P	P	P	F	F	P	P	P	P	F	F	P	P	P	P	F	F	P	P	P	P	F	F	P	P	P	P	F	F	P	F	F
SS Harmonic	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	F	F
SS OOB Interf.	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	P	F	-	-	-	-
SS Magnitude	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-
Dyn Ramp	P	F	P	P	F	P	P	F	P	P	F	P	P	F	F	P	F	F	P	F	F	P	F	P	P	F	F	P	F	P	P	F	F	P	F	F
Dyn Phase Mod	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	P	P	P	P
Dyn Ampl Mod	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P

**Table 8: PMU C response time, delay time and overshoot pass/fail**

Fs (FPS)		10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
Phase Step	Phasor Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	F	P	F	P	F	P	F	P	P	P	F
	ROCOF Resp. Time	P	F	P	F	P	F	P	F	P	F	P	F
Magnitude Step	Phasor Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Magnitude Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	F	P	F	P	F	P	F	P	P	P	F
	ROCOF Resp. Time	P	P	P	P	P	P	P	F	P	P	P	P

## 1.5 PMU D Performance overview

PMU D is a prototype PMU and is not yet commercially available

**Table 9: PMU D TVE, FE, RFE pass/fail**

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P			
Test	T	FE	RF	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R				
	V		E	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F				
	E			E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E			
SS Freq. Range	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
SS Harmonic	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	P	P	P	P	P	P	P	-	P	P	-	P	P	-	P	P	P
SS OOB Interf.	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	
SS Magnitude	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	
Dyn Ramp	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
Dyn Phase Mod	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
Dyn Ampl Mod	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	

**Table 10: PMU D response time, delay time and overshoot pass/fail**

Fs (FPS)		10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
Phase Step	Phasor Resp. Time	P	I	P	I	P	I	P	I	P	I	P	I
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	ROCOF Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
Magnitude Step	Phasor Resp. Time	P	I	P	I	P	I	P	I	P	I	P	I
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Magnitude Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	ROCOF Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P



## 1.6 PMU E performance overview

PMU E is a commercially available PMU. PMU E does not support P class. Data for reporting rate Fs = 12 FPS, M class was corrupted and could not be recovered.

**Table 11: PMU E TVE, FE, RFE pass/fail**

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T	FE	RF	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R			
	V		E	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F			
	E			E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E			
SS Freq. Range	P	P	P	-	-	-	-	-	-	-	-	-	P	P	P	-	-	-	P	P	P	-	-	-	P	P	P	-	-	-	P	P	P	-	-	-
SS Harmonic	P	P	-	-	-	-	-	-	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-
SS OOB Interf.	F	F	-	-	-	-	-	-	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	P	F	-	-	-	-
SS Magnitude	P	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	I	-	-	-	-	-	P	-	-	-	-	-	F	-	-	-	-	-
Dyn Ramp	P	F	P	-	-	-	-	-	-	-	-	-	P	F	P	-	-	-	P	F	P	-	-	-	P	F	P	-	-	-	P	F	P	-	-	-
Dyn Phase Mod	P	I	P	-	-	-	-	-	-	-	-	-	P	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-
Dyn Ampl Mod	P	P	P	-	-	-	-	-	-	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-

**Table 12: PMU E response time, delay time and overshoot pass/fail**

Fs (FPS)		10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
Phase Step	Phasor Resp. Time	P	-	-	-	P	-	P	-	P	-	F	-
	Phasor Delay Time	P	-	-	-	P	-	P	-	P	-	P	-
	Phasor Overshoot	P	-	-	-	P	-	P	-	P	-	P	-
	Freq Resp. Time	P	-	-	-	P	-	P	-	P	-	P	-
	ROCOF Resp. Time	P	-	-	-	P	-	P	-	P	-	P	-
Magnitude Step	Phasor Resp. Time	P	-	-	-	P	-	P	-	P	-	F	-
	Phasor Delay Time	P	-	-	-	P	-	P	-	P	-	P	-
	Magnitude Overshoot	P	-	-	-	P	-	P	-	P	-	P	-
	Freq Resp. Time	P	-	-	-	P	-	P	-	P	-	P	-
	ROCOF Resp. Time	P	-	-	-	P	-	P	-	P	-	P	-

## 1.7 PMU F performance overview

PMU F is a prototype PMU and is not yet commercially available.

**Table 13: PMU F TVE, FE, RFE pass/fail**

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T V E	FE	RF E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E			
SS Freq. Range	P	P	I	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	I	P	P	F	P	P	F	P	P	P			
SS Harmonic	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-			
SS OOB Interf.	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	P			
SS Magnitude	P	P	-	-	-	-	P	I	-	-	-	-	P	I	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	
Dyn Ramp	P	P	F	P	P	P	P	P	P	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	P			
Dyn Phase Mod	P	P	F	P	P	P	P	P	F	P	P	P	I	P	F	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			
Dyn Ampl Mod	P	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			

**Table 14: PMU F response time, delay time and overshoot pass/fail**

Fs (FPS)		10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
Phase Step	Phasor Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	I	P	P	P	F	P	F	P	F	P	F
	ROCOF Resp. Time	P	F	P	I	P	F	P	F	P	F	P	F
Magnitude Step	Phasor Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Magnitude Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	P	P	P	P	F	P	I	P	I	P	F
	ROCOF Resp. Time	P	P	P	P	P	F	P		P	P	P	F

## 1.8 PMU G performance overview

PMU G is a commercially available PMU. PMU G does not support P class. **PMU G ROCOF measurements are always equal to 0.**

**Table 15: PMU G TVE, FE, RFE pass/fail**

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T	FE	RF	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R			
	V		E	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F			
SS Freq. Range	P	P	P	-	-	-	P	P	P	-	-	-	P	P	P	-	-	-	I	P	P	-	-	-	F	P	P	-	-	-	-	-	-	-		
SS Harmonic	I	P	P	-	-	-	I	P	P	-	-	-	I	P	P	-	-	-	I	P	P	-	-	-	P	P	P	-	-	-	-	-	-	-		
SS OOB Interf.	F	F	P	-	-	-	F	F	P	-	-	-	F	F	P	-	-	-	F	F	P	-	-	-	F	F	P	-	-	-	-	-	-	-		
SS Magnitude	F	-	-	-	-	-	F	-	-	-	-	-	F	-	-	-	-	-	F	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-		
Dyn Ramp	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	-	-	-	-		
Dyn Phase Mod	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	F	F	P	-	-	-	-	-	-	-		
Dyn Combi Mod	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	F	F	P	-	-	-	-	-	-	-		

**Table 16: PMU G response time, delay time and overshoot pass/fail**

Fs (FPS)		10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
Phase Step	Phasor Resp. Time	F	-	P	-	P	-	F	-	F	-	-	-
	Phasor Delay Time	P	-	P	-	P	-	P	-	P	-	-	-
	Phasor Overshoot	F	-	F	-	F	-	F	-	F	-	-	-
	Freq Resp. Time	P	-	P	-	P	-	P	-	P	-	-	-
	ROCOF Resp. Time	P	-	P	-	P	-	P	-	P	-	-	-
Magnitude Step	Phasor Resp. Time	P	-	P	-	P	-	F	-	F	-	-	-
	Phasor Delay Time	P	-	P	-	P	-	P	-	P	-	-	-
	Magnitude Overshoot	F	-	F	-	F	-	P	-	F	-	-	-
	Freq Resp. Time	P	-	P	-	P	-	P	-	P	-	-	-
	ROCOF Resp. Time	P	-	P	-	P	-	P	-	P	-	-	-

## 1.9 PMU H performance overview

PMU H is a prototype PMU and is not yet commercially available.

**Table 17: PMU H TVE, FE, RFE pass/fail**

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T	FE	RF	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R			
	V		E	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F			
	E			E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		
SS Freq. Range	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
SS Harmonic	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P
SS OOB Interf.	P	P	-	-	-	-	P	P	P	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-
SS Magnitude	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-
Dyn Ramp	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
Dyn Phase Mod	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
Dyn Ampl Mod	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	

**Table 18: PMU H response time, delay time and overshoot pass/fail**

Fs (FPS)		10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
Phase Step	Phasor Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	ROCOF Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
Magnitude Step	Phasor Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Magnitude Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	ROCOF Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P

## 1.10 PMU I performance overview

PMI I is a commercially available PMU. PMU I does not support P class.

**Table 19: PMU I TVE, FE, RFE pass/fail**

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T	FE	RF	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R			
	V		E	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F			
	E			E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		
SS Freq. Range	P	P	P	-	-	-	P	P	P	-	-	-	P	P	P	-	-	-	P	P	P	-	-	-	P	P	F	-	-	-	P	P		-	-	-
SS Harmonic	F	P	-	-	-	-	F	I	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-
SS OOB Interf.	P	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-
SS Magnitude	P	-	-	-	-	-	P	-	-	-	-	-	P	-	-	-	-	-	P	-	-	-	-	-	P	-	-	-	-	-	P	-	-	-	-	-
Dyn Ramp	F	F	P	-	-	-	F	F	P	-	-	-	F	F	P	-	-	-	F	F	F	-	-	-	P	F	P	-	-	-	P	F	F	-	-	-
Dyn Phase Mod	F	I	I	-	-	-	F	I	I	-	-	-	F	I	I	-	-	-	F	I	I	-	-	-	F	P	I	-	-	-	P	P	P	-	-	-
Dyn Combi Mod	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	P	P	P	-	-	-

**Table 20: PMU I response time, delay time and overshoot pass/fail**

Fs (FPS)		10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
Phase Step	Phasor Resp. Time	P	-	P	-	P	-	P	-	P	-	P	-
	Phasor Delay Time	P	-	P	-	P	-	P	-	P	-	P	-
	Phasor Overshoot	P	-	P	-	P	-	P	-	P	-	P	-
	Freq Resp. Time	P	-	P	-	P	-	P	-	P	-	P	-
	ROCOF Resp. Time	P	-	P	-	P	-	P	-	P	-	F	-
Magnitude Step	Phasor Resp. Time	P	-	P	-	P	-	P	-	P	-	P	-
	Phasor Delay Time	P	-	P	-	P	-	P	-	P	-	P	-
	Magnitude Overshoot	P	-	P	-	P	-	P	-	P	-	P	-
	Freq Resp. Time	P	-	P	-	P	-	P	-	P	-	P	-
	ROCOF Resp. Time	P	-	P	-	P	-	P	-	P	-	P	-

## 1.11 PMU J performance overview

PMU J is a prototype PMU and is not yet commercially available.

**Table 21: PMU J TVE, FE, RFE pass/fail**

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T	FE	RF	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R			
	V		E	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F			
	E			E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		
SS Freq. Range	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
SS Harmonic	P	P	P	P	P	P	P	P	P	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P
SS OOB Interf.	-	-	-	-	-	-	-	-	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-
SS Magnitude	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-
Dyn Ramp	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
Dyn Phase Mod	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
Dyn Combi Mod	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	

**Table 22: PMU J response time, delay time and overshoot pass/fail**

Fs (FPS)		10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
Phase Step	Phasor Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	ROCOF Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
Magnitude Step	Phasor Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	Phasor Delay Time	P	P	P	P	P	P	P	P	P	P	P	P
	Magnitude Overshoot	P	P	P	P	P	P	P	P	P	P	P	P
	Freq Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P
	ROCOF Resp. Time	P	P	P	P	P	P	P	P	P	P	P	P

## 2. Steady state frequency range

2. Steady state frequency range .....	14
2.1 Steady state frequency range test voltage TVE .....	20
2.1.1 C37.118.1 Annex C steady state frequency range voltage TVE:, M class .....	20
2.1.2 PMU A steady state frequency range voltage TVE, M class .....	21
2.1.3 PMU B steady state frequency range voltage TVE:, M class .....	22
2.1.4 PMU C steady state frequency range voltage TVE: M class .....	23
2.1.5 PMU D steady state frequency range voltage TVE: M class .....	24
2.1.6 PMU E steady state frequency range voltage TVE: M class.....	25
2.1.7 PMU F steady state frequency range voltage TVE: M class.....	26
2.1.8 PMU G steady state frequency range voltage TVE: M class .....	27
2.1.9 PMU H steady state frequency range voltage TVE: M class .....	28
2.1.10 PMU I steady state frequency range voltage TVE: M class.....	29
2.1.11 PMU J steady state frequency range voltage TVE: M class .....	30
2.2 Steady state frequency range current TVE: M class.....	31
2.2.1 C37.118.1 Annex C steady state frequency range current TVE: M class .....	31
2.2.2 PMU A steady state frequency range current TVE: M class .....	32
2.2.3 PMU B steady state frequency range current TVE: M class .....	33
2.2.4 PMU C steady state frequency range current TVE:, M class .....	34
2.2.5 PMU D steady state frequency range current TVE: M class .....	35
2.2.6 PMU E steady state frequency range current TVE: M class.....	36
2.2.7 PMU F steady state frequency range current TVE: M class.....	37
2.2.8 PMU G steady state frequency range current TVE: M class .....	38
2.2.9 PMU H steady state frequency range current TVE: M class .....	39
2.2.10 PMU I steady state frequency range current TVE: M class.....	40
2.2.11 PMU J steady state frequency range current TVE: M class .....	41
2.3 Steady state frequency range frequency error: M class .....	42
2.3.1 C37.118.1 Annex C steady state frequency range frequency error: M class.....	42
2.3.2 PMU A steady state frequency range frequency error: M class.....	43
2.3.3 PMU B steady state frequency range frequency error: M class.....	44
2.3.4 PMU C steady state frequency range frequency error: M class.....	45
2.3.5 PMU D steady state frequency range frequency error: M class.....	46
2.3.6 PMU E steady state frequency range frequency error: M class .....	47
2.3.7 PMU F steady state frequency range frequency error: M class .....	48
2.3.8 PMU G steady state frequency range frequency error: M class.....	49
2.3.9 PMU H steady state frequency range frequency error: M class.....	50
2.3.10 PMU I steady state frequency range frequency error: M class .....	51
2.3.11 PMU J steady state frequency range frequency error: M class.....	52
2.4 Steady state frequency range ROCOF error: M class .....	53
2.4.1 C37.118.1 Annex C steady state frequency range ROCOF error: M class.....	53
2.4.2 PMU A steady state frequency range ROCOF error: M class.....	54

2.4.3 PMU B steady state frequency range ROCOF error: M class .....	55
2.4.4 PMU C steady state frequency range ROCOF error: M class .....	56
2.4.5 PMU D steady state frequency range ROCOF error: M class .....	57
2.4.6 PMU E steady state frequency range ROCOF error: M class .....	58
2.4.7 PMU F steady state frequency range ROCOF error: M class .....	59
2.4.8 PMU G* steady state frequency range ROCOF error: M class .....	60
2.4.9 PMU H steady state frequency range ROCOF error: M class .....	61
2.4.10 PMU I steady state frequency range ROCOF error: M class .....	62
2.4.11 PMU J steady state frequency range ROCOF error: M class .....	63
2.5 Steady state frequency range voltage TVE: P class .....	64
2.5.1 C37.118.1 Annex C steady state frequency range voltage TVE: P class .....	64
2.5.2 PMU A steady state frequency range voltage TVE: P class .....	65
2.5.3 PMU B steady state frequency range voltage TVE: P class .....	66
2.5.4 PMU C steady state frequency range voltage TVE: P class .....	67
2.5.5 PMU D steady state frequency range voltage TVE: P class .....	68
2.5.6 PMU E steady state frequency range voltage TVE: P class .....	68
2.5.7 PMU F steady state frequency range voltage TVE: P class .....	69
2.5.8 PMU G steady state frequency range voltage TVE: P class .....	69
2.5.9 PMU H steady state frequency range voltage TVE: P class .....	70
2.5.10 PMU I steady state frequency range voltage TVE: P class .....	70
2.5.11 PMU J steady state frequency range voltage TVE: P class .....	71
2.6 Steady state frequency range current TVE: P class .....	72
2.6.1 C37.118.1 Annex C steady state frequency range current TVE: P class .....	72
2.6.2 PMU A steady state frequency range current TVE: P class .....	73
2.6.3 PMU B steady state frequency range current TVE: P class .....	74
2.6.4 PMU C steady state frequency range current TVE: P class .....	75
2.6.5 PMU D steady state frequency range current TVE: P class .....	76
2.6.6 PMU E steady state frequency range current TVE: P class .....	76
2.6.7 PMU F steady state frequency range current TVE: P class .....	77
2.6.8 PMU G steady state frequency range current TVE: P class .....	77
2.6.9 PMU H steady state frequency range current TVE: P class .....	78
2.6.10 PMU I steady state frequency range current TVE: P class .....	78
2.6.11 PMU J steady state frequency range current TVE: P class .....	79
2.7 Steady state frequency range frequency error: P class .....	80
2.7.1 C37.118.1 Annex C steady state frequency range frequency error; $F_0 = 60$ Hz, P class .....	80
2.7.2 PMU A steady state frequency range frequency error: P class .....	81
2.7.3 PMU B steady state frequency range frequency error: P class .....	82
2.7.4 PMU C steady state frequency range frequency error: P class .....	83
2.7.5 PMU D steady state frequency range frequency error: P class .....	84
2.7.6 PMU E steady state frequency range frequency error: P class .....	84
2.7.7 PMU F steady state frequency range frequency error: P class .....	85
2.7.8 PMU G steady state frequency range frequency error: P class .....	85
2.7.9 PMU H steady state frequency range frequency error: P class .....	86



2.7.10 PMU I steady state frequency range frequency error: P class .....	86
2.7.11 PMU J steady state frequency range frequency error: P class .....	87
2.8 Steady state frequency range ROCOF error: P class.....	88
2.8.1 C37.118.1 Annex C steady state frequency range ROCOF error: P class .....	88
2.8.2 PMU A steady state frequency range ROCOF error: P class .....	89
2.8.3 PMU B steady state frequency range ROCOF error: P class .....	90
2.8.4 PMU C steady state frequency range ROCOF error: P class .....	91
2.8.5 PMU D steady state frequency range ROCOF error: P class .....	92
2.8.6 PMU E steady state frequency range ROCOF error: P class .....	92
2.8.7 PMU F steady state frequency range ROCOF error: P class.....	93
2.8.8 PMU G steady state frequency range ROCOF error: P class .....	93
2.8.9 PMU H steady state frequency range ROCOF error:, P class .....	94
2.8.10 PMU I steady state frequency range ROCOF error:, P class .....	94
2.8.11 PMU J steady state frequency range ROCOF error:, P class .....	95

The steady state frequency range is tested by a series of individual steady state tests where the input signal magnitude and frequency are fixed for duration of 5 seconds. During this period, the total vector error (TVE), frequency error (FE) and rate of change of frequency error (RFE) are measured. A series of individual tests are run at 0.1 Hz increments across the signal frequency range which is determined by the PMU's reporting rate ( $F_s$ ) given in frames per second (FPS) and class. The maximum TVE, FE and RFE of all the test runs is compared against the limits for TVE, FE and RFE to determine if the unit passes or fails the test.

- a) Apply input signals at nominal magnitude at the frequency range limit: nominal frequency minus the lesser of  $F_s/5$  or 5 Hz.
- b) Wait for the system to settle.
- c) Capture the PMU output for 5 s.
- d) Calculate the errors: ME, PE, FE and RFE for each report.
- e) Calculate the Max TVE, FE and RFE.
- f) Increase the frequency by 0.1 Hz.
- g) Repeat step b) through step g) until the upper frequency range limit is reached.

For M class:

- signal frequency range is  $\pm F_s/5$  Hz for  $10 \leq F_s \leq 25$  FPS and  $\pm 5$  Hz for  $F_s > 25$  FPS.
- TVE limit is 1%
- FE limit is 0.005 Hz
- RFE limit is 0.1 Hz/s

For P class:

- signal frequency range is  $\pm 2$  Hz
- TVE limit is 1%
- FE limit is .005 Hz
- RFE limit is 0.4 Hz/s

To illustrate an example of one PMU's response to one test run, the below plots of maximum TVE, FE and RFE are shown from a single test run on PMU E at  $F_s = 30$  FPS at 63.3 Hz input frequency:

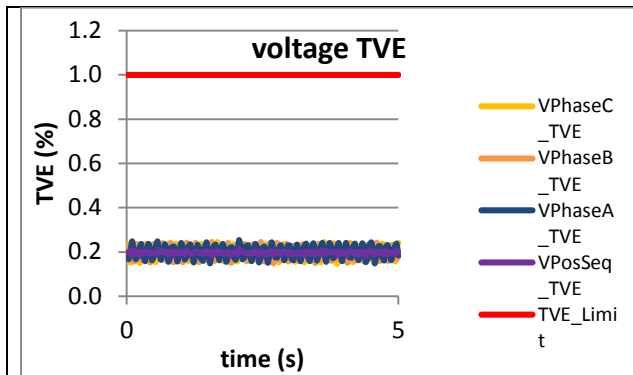


Figure 1: voltage TVE for one input frequency

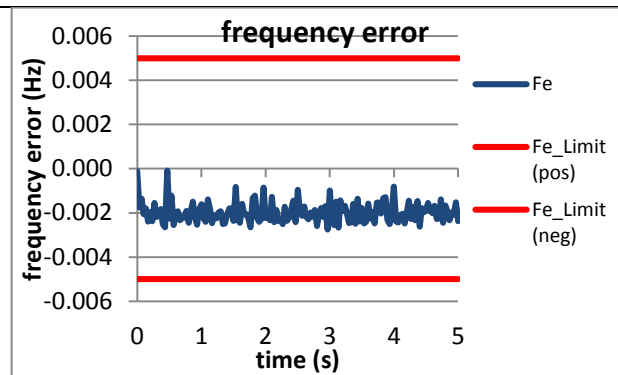


Figure 2: frequency error for one input frequency

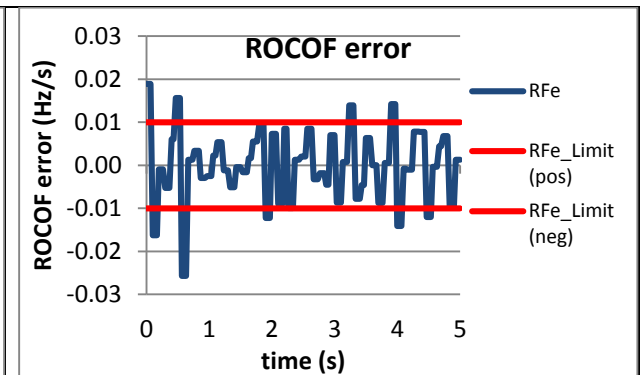


Figure 3: ROCOF error for one input frequency

The plots in the body of this section are made from maximum values of TVE, FE and RFE from each test run. The tests are run at 0.1 Hz intervals across the signal frequency range. The x-axis shows the test input signal frequency and the Y axis shows the maximum value for each tests. Red lines show the limits. The y-axis of the frequency error and ROCOF error plots show the maximum and minimum errors reached over all test runs. The FE and RFE limits for both the positive and negative errors are shown as red horizontal lines. An arrow shows the maximum value data point from the above example at 63.3 Hz.

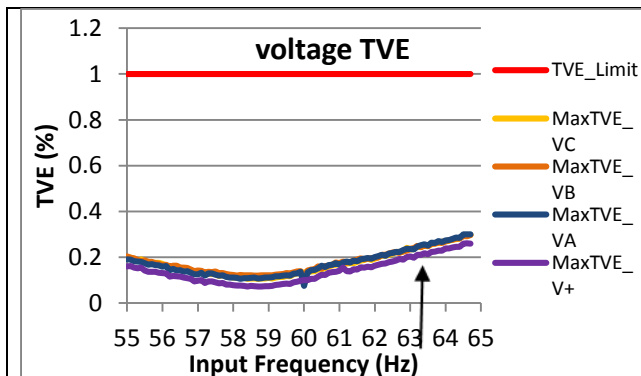


Figure 4: voltage TVE for frequency range tests from 55 Hz to 65 Hz at 0.1 Hz increments

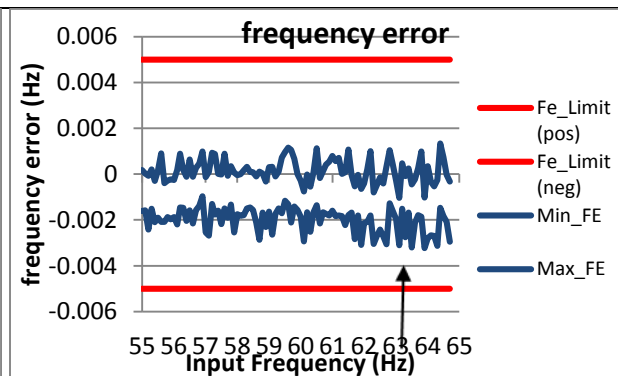


Figure 5: frequency error for frequency range tests from 55 Hz to 65 Hz at 0.1 Hz increments

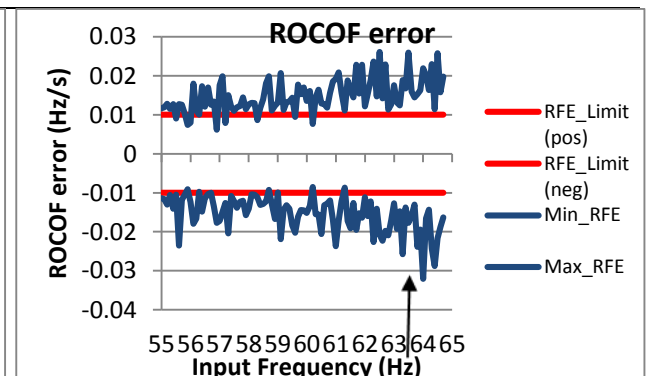


Figure 6: ROCOF error for frequency range tests from 55 Hz to 65 Hz at 0.1 Hz increments

For Frequency and ROCOF error, graphing the maximum and minimum errors along with positive and negative limit lines allows us to see if the error is symmetrical or has a mean offset from 0 and whether the offset is positive or negative; this is important for frequency ramp and modulation tests to be shown later in this report. C37.118.1-2011 specifies that frequency and ROCOF errors be expressed as absolute numbers, meaning that the *absolute value* of FE and RFE shall not exceed a single limit. However showing the maximum and minimum errors and limits can provide useful information as explained above.

**Steady state frequency range test results**

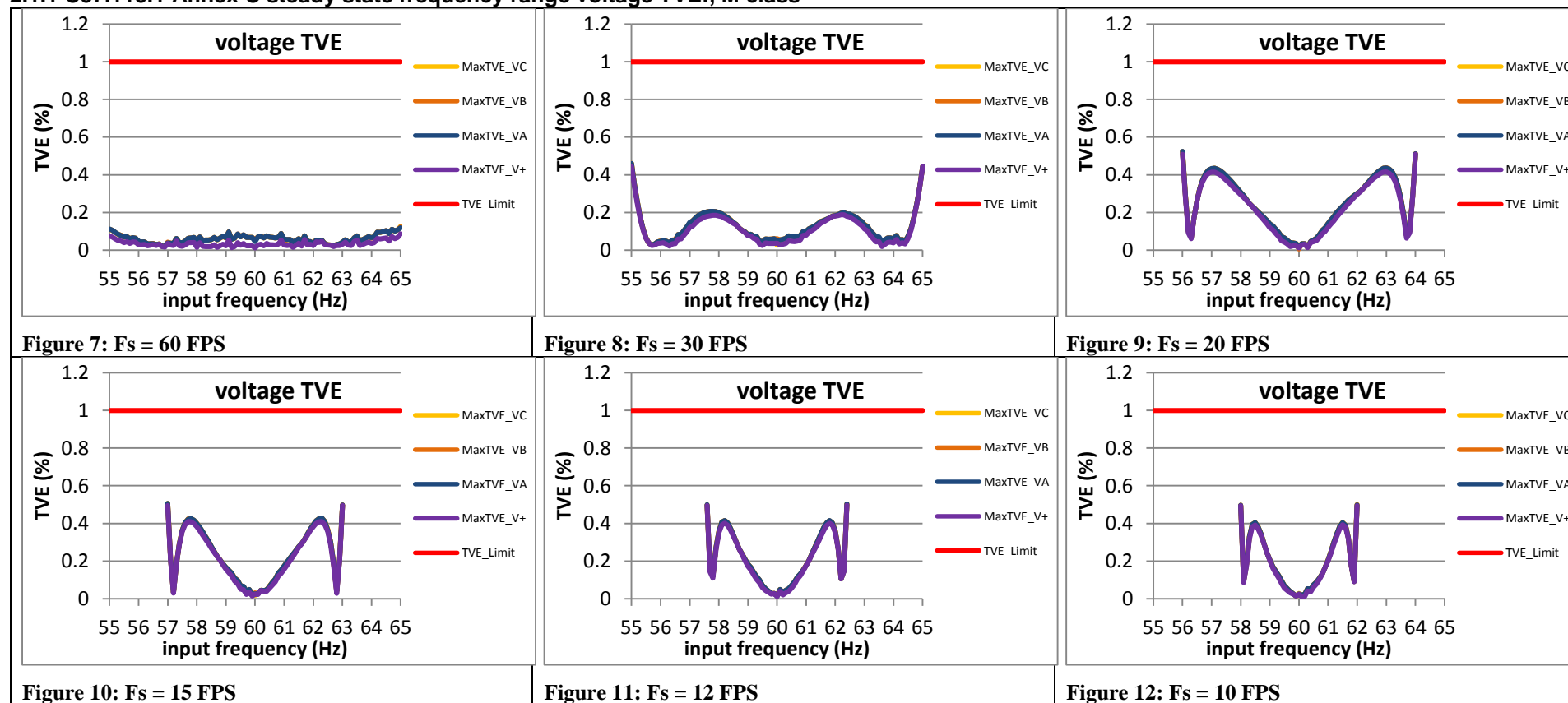
Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P			
Test	T V E	F E	R E	T V E	F E	R E	T V E	F E	R E	T V E	F E	R E	T V E	F E	R E	T V E	F E	R E	T V E	F E	R E	T V E	F E	R E	T V E	F E	R E	T V E	F E	R E	T V E	F E	R E				
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			
PMU A	P	P	F	P	F	F	P	P	F	P	F	F	P	P	F	P	F	F	P	P	F	P	F	F	P	P	F	P	F	F	P	F	F	P	F	F	
PMU B	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
PMU C	P	F	F	P	P	P	P	F	F	P	P	P	P	F	F	P	P	P	P	F	F	P	P	P	P	F	F	P	P	P	P	F	F	P	F	F	
PMU D	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
PMU E	P	P	P	-	-	-	-	-	-	-	-	-	-	P	P	P	-	-	-	P	P	P	-	-	-	P	P	P	-	-	-	P	P	P	-	-	-
PMU F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	P	
PMU G*	P	P	P	-	-	-	P	P	P	-	-	-	P	P	P	-	-	-	I	P	P	-	-	-	F	P	P	-	-	-	-	-	-	-	-	-	
PMU H	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
PMU I	P	P	P	-	-	-	P	P	P	-	-	-	P	P	P	-	-	-	P	P	P	-	-	-	P	P	F	-	-	-	P	P	P	-	-	-	
PMU J	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		

P = pass (measurement is within the limit), F = fail (measurement is outside the limit), I = indeterminate (measurement is within the test system uncertainty of the limit)

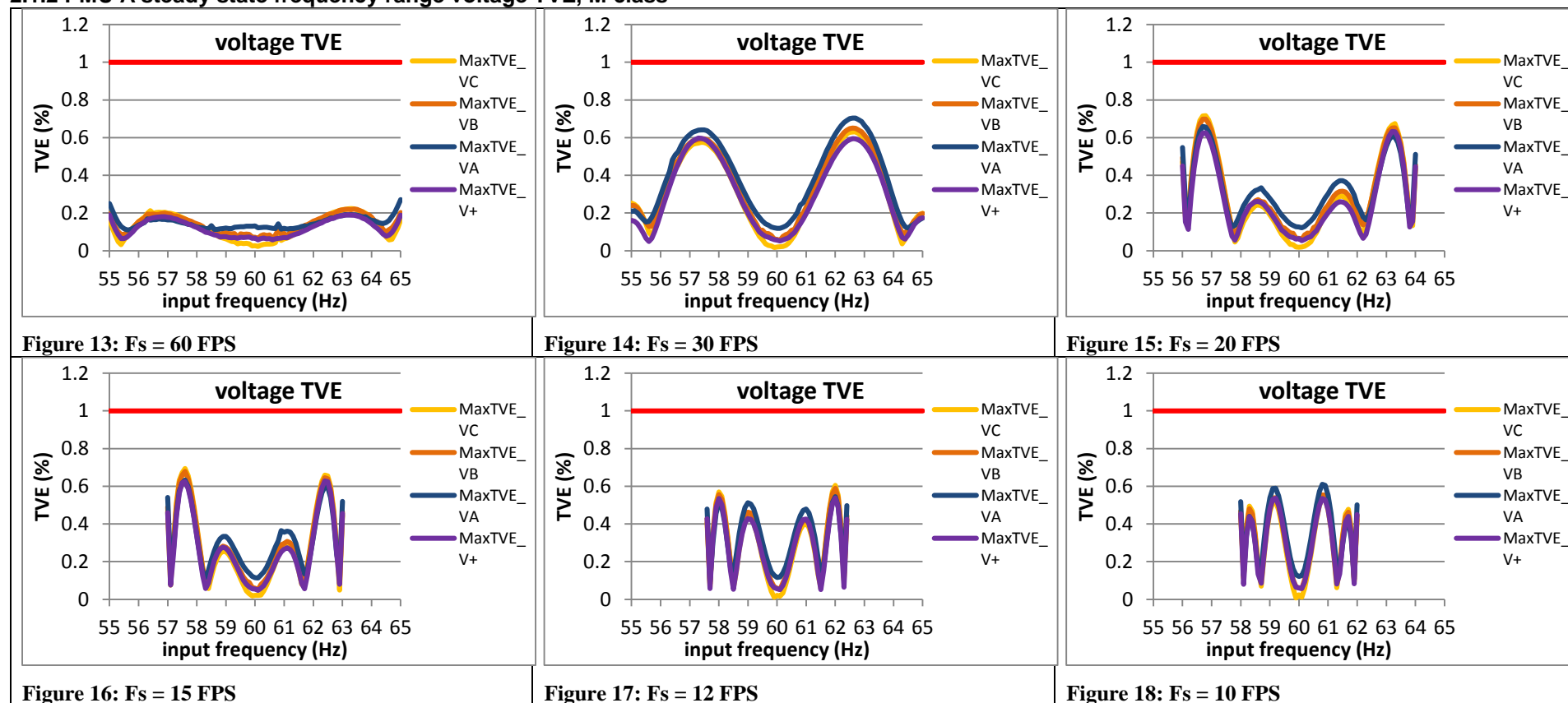
\* PMU G always outputs ROCOF = 0.

## 2.1 Steady state frequency range test voltage TVE

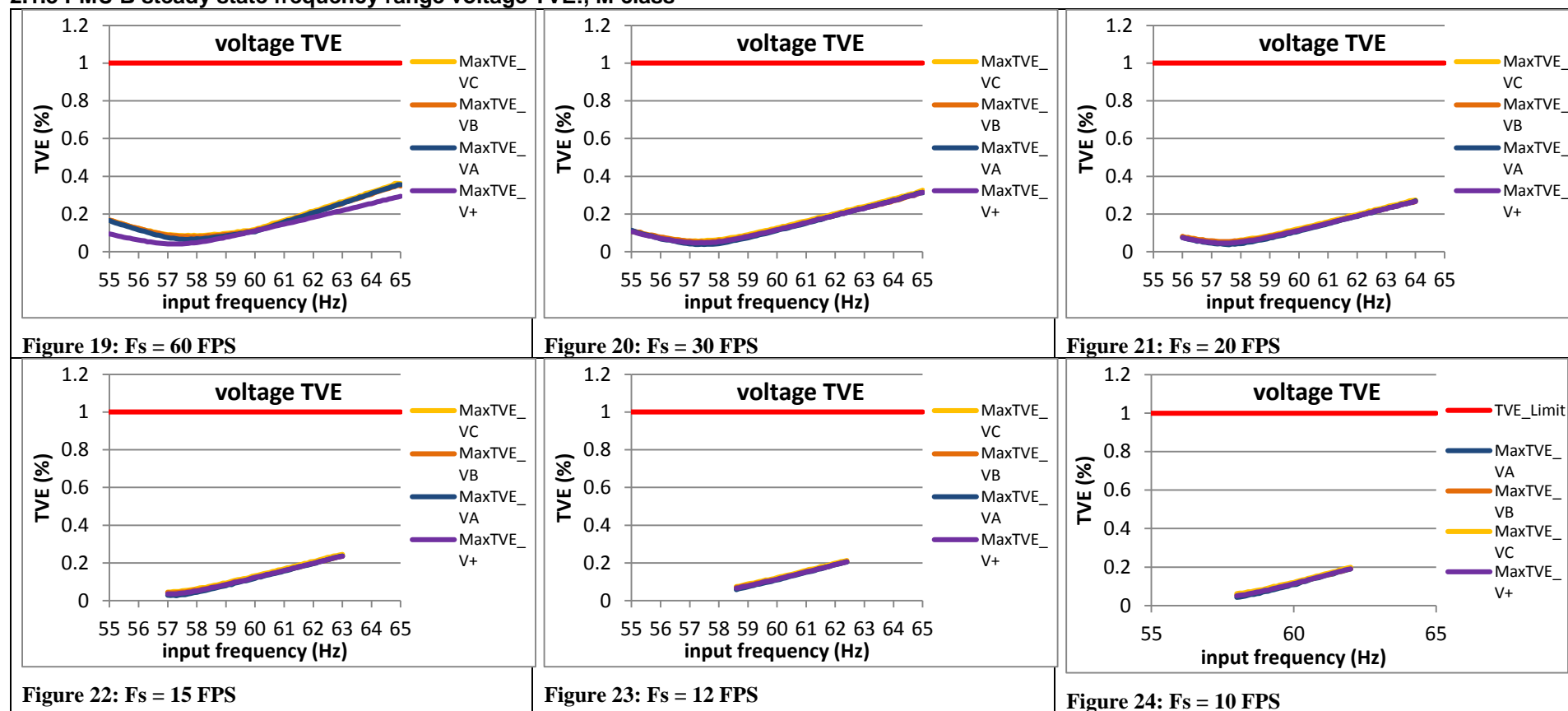
### 2.1.1 C37.118.1 Annex C steady state frequency range voltage TVE:, M class



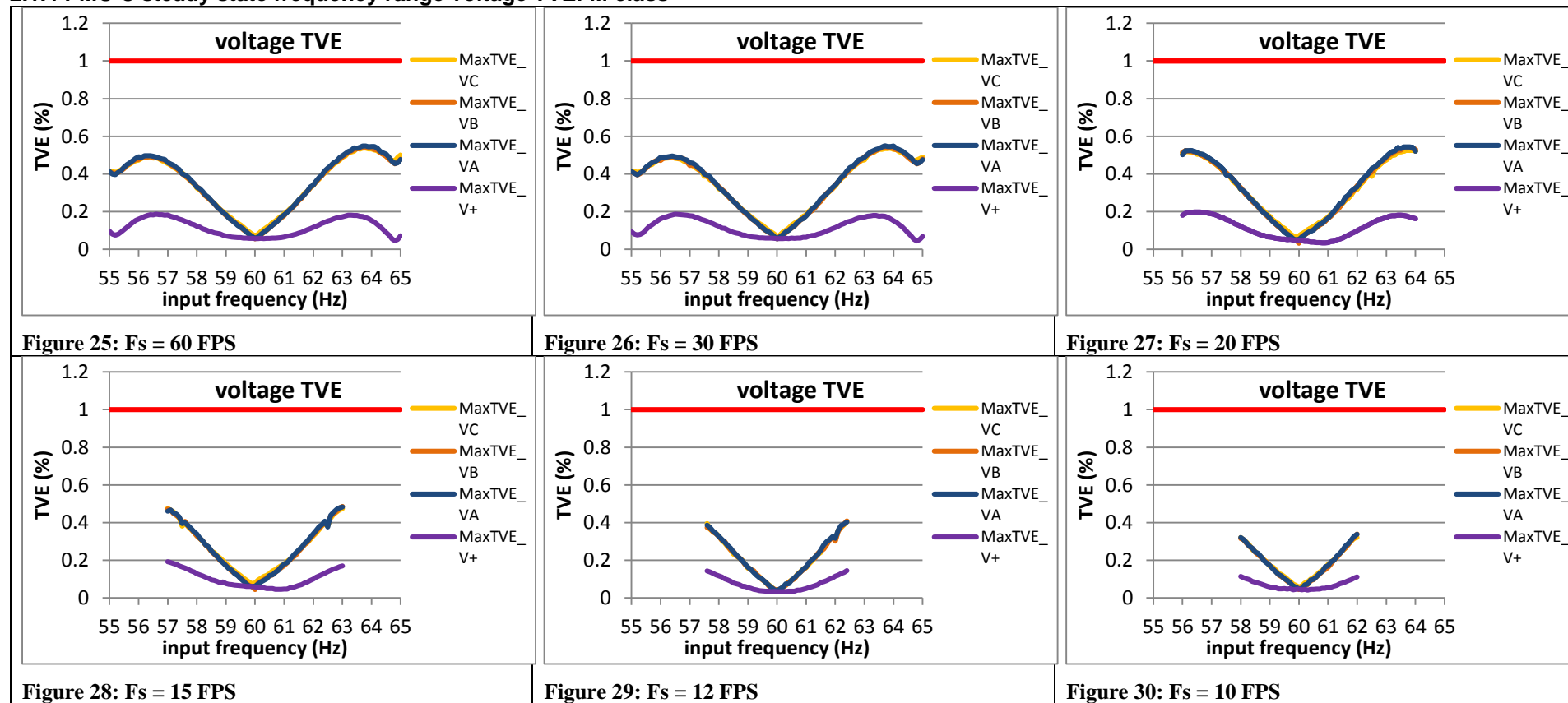
### 2.1.2 PMU A steady state frequency range voltage TVE, M class



### 2.1.3 PMU B steady state frequency range voltage TVE:, M class

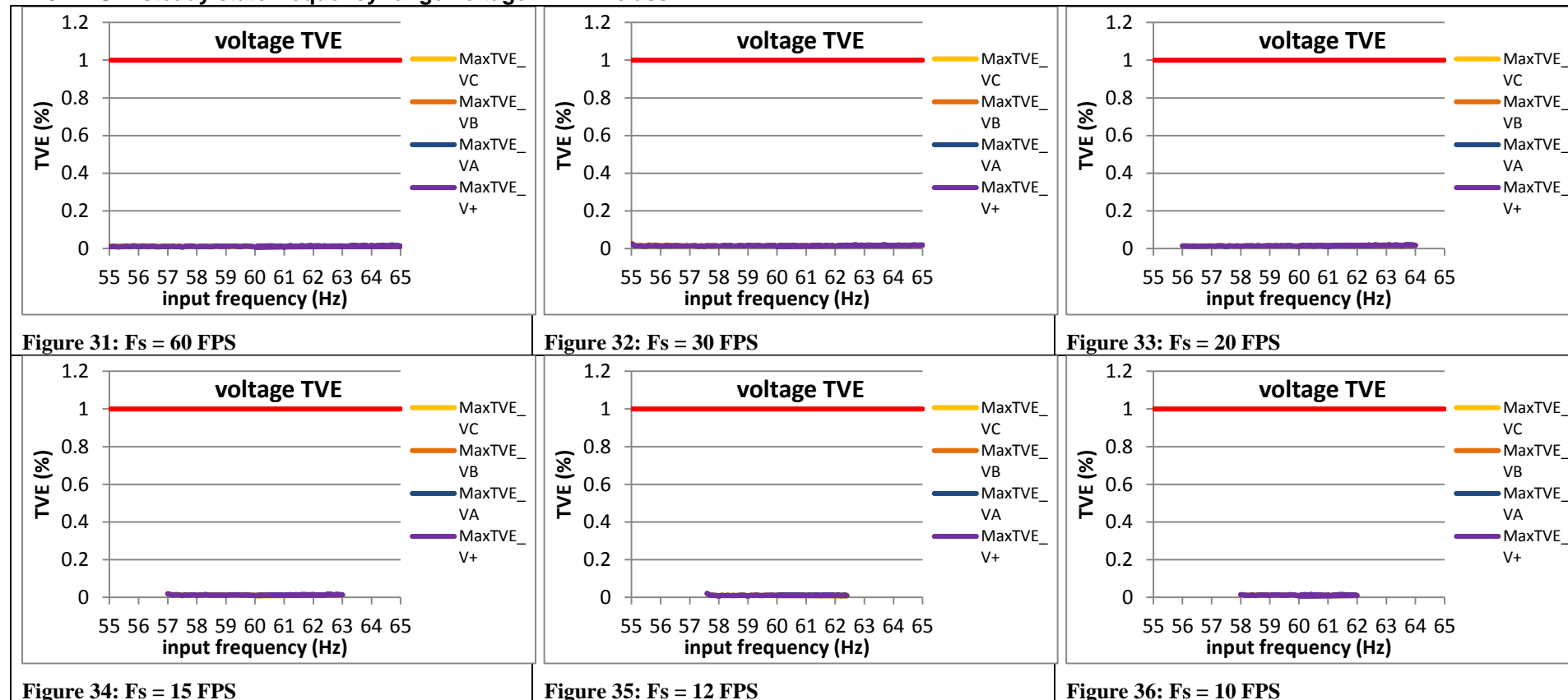


#### 2.1.4 PMU C steady state frequency range voltage TVE: M class

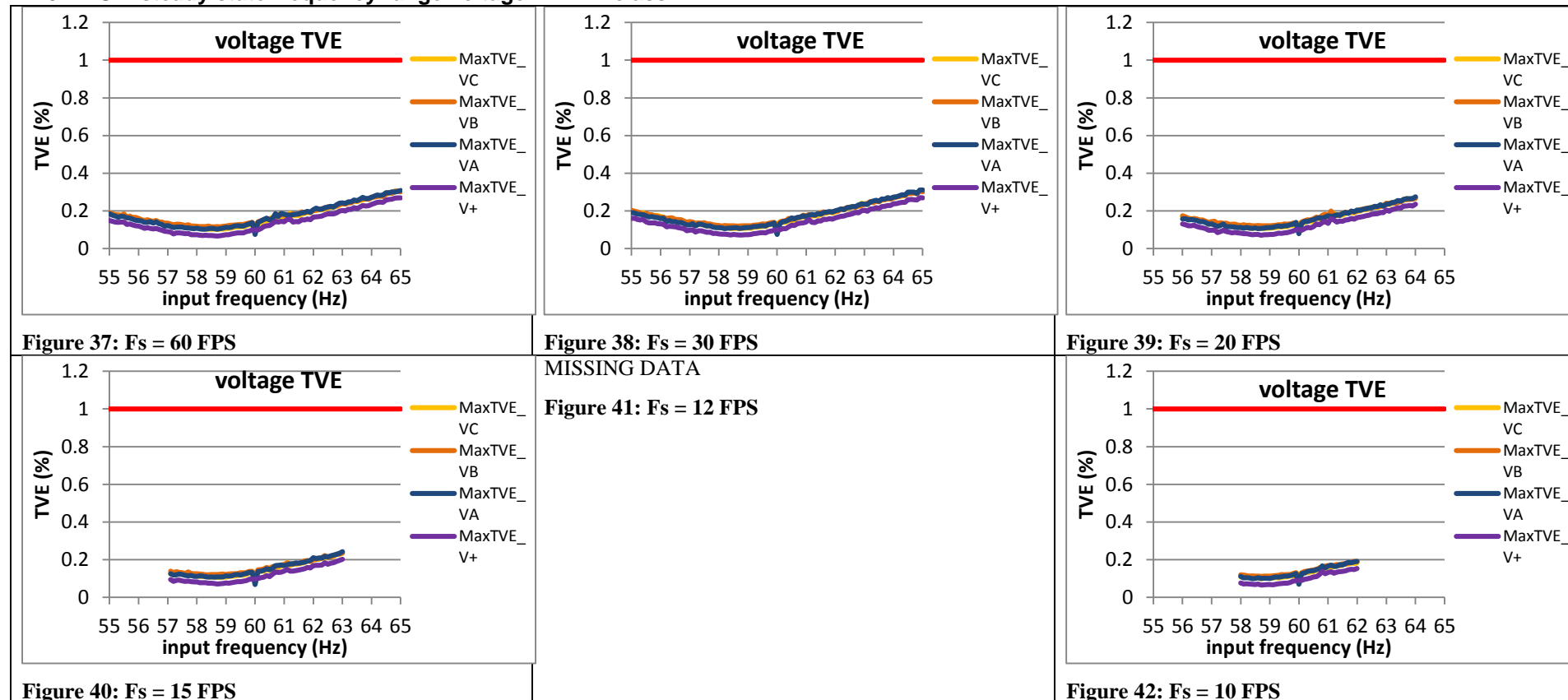




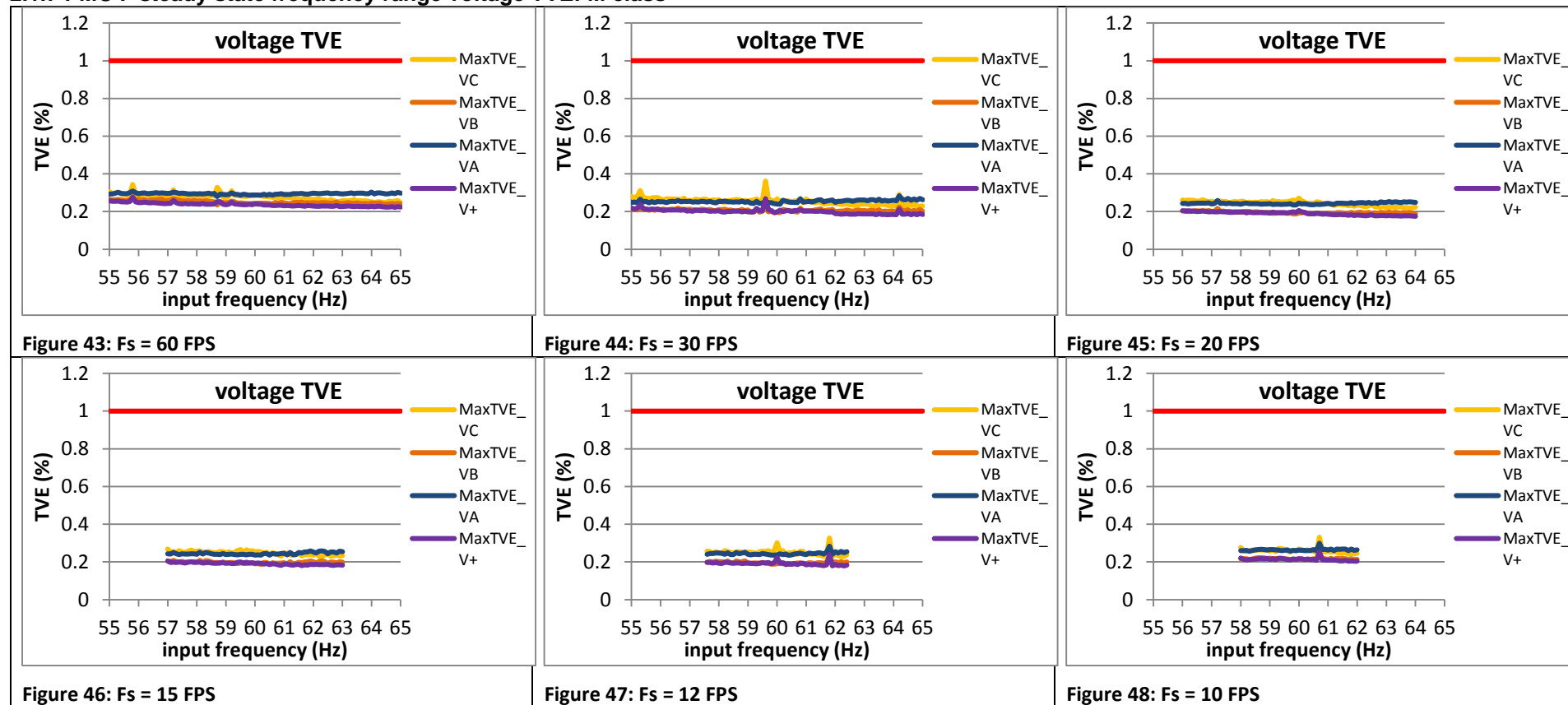
### 2.1.5 PMU D steady state frequency range voltage TVE: M class



## 2.1.6 PMU E steady state frequency range voltage TVE: M class



### 2.1.7 PMU F steady state frequency range voltage TVE: M class



## 2.1.8 PMU G steady state frequency range voltage TVE: M class

Figure 49:  $F_s = 60$  FPS not supported by this PMU

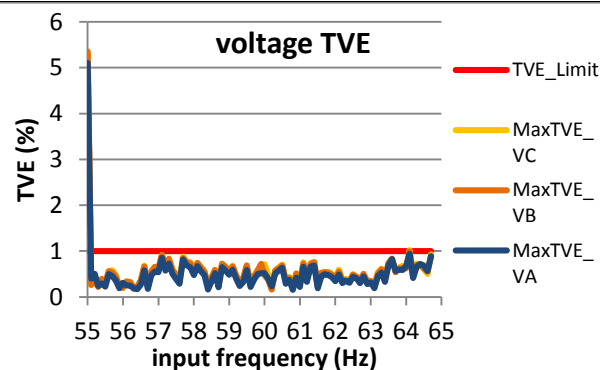


Figure 50:  $F_s = 30$  FPS

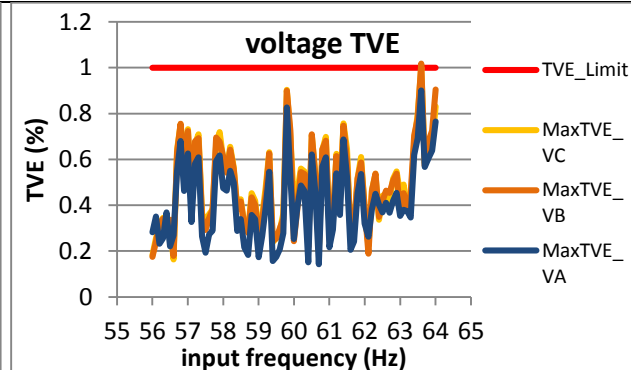


Figure 51:  $F_s = 20$  FPS

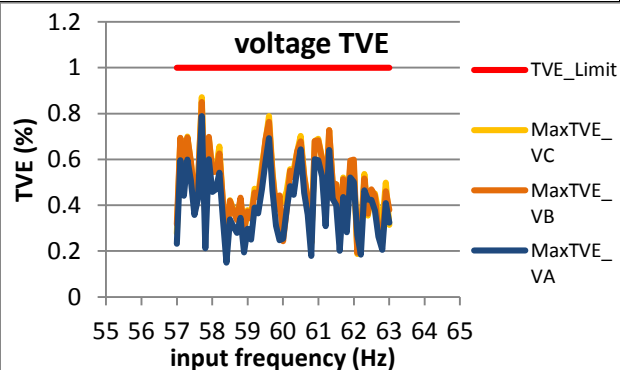


Figure 52:  $F_s = 15$  FPS

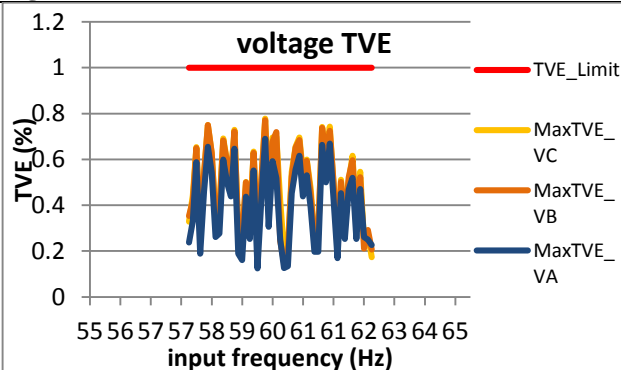


Figure 53:  $F_s = 12$  FPS

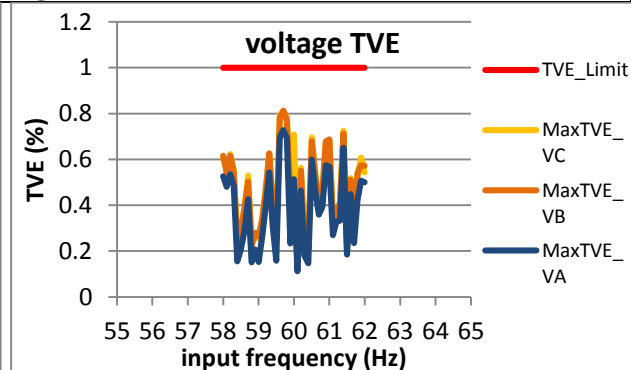
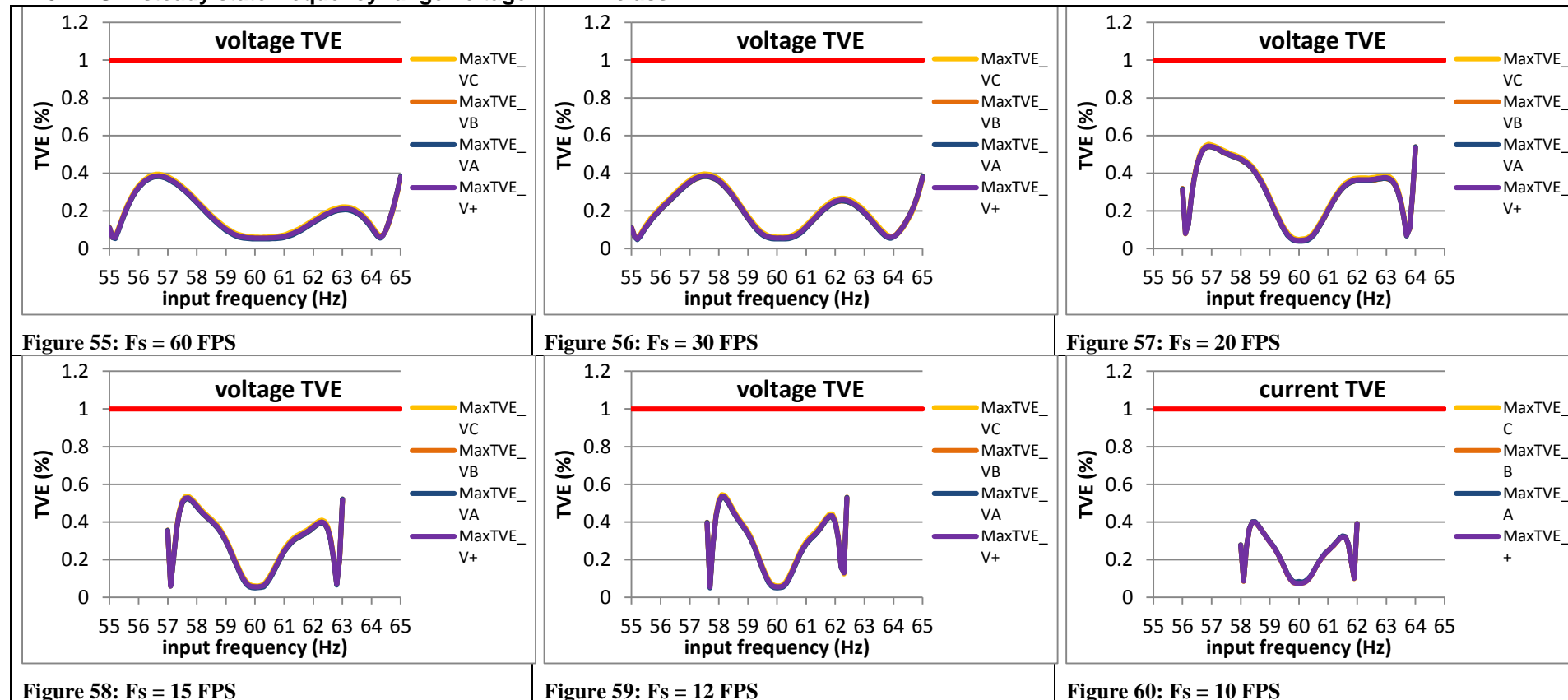
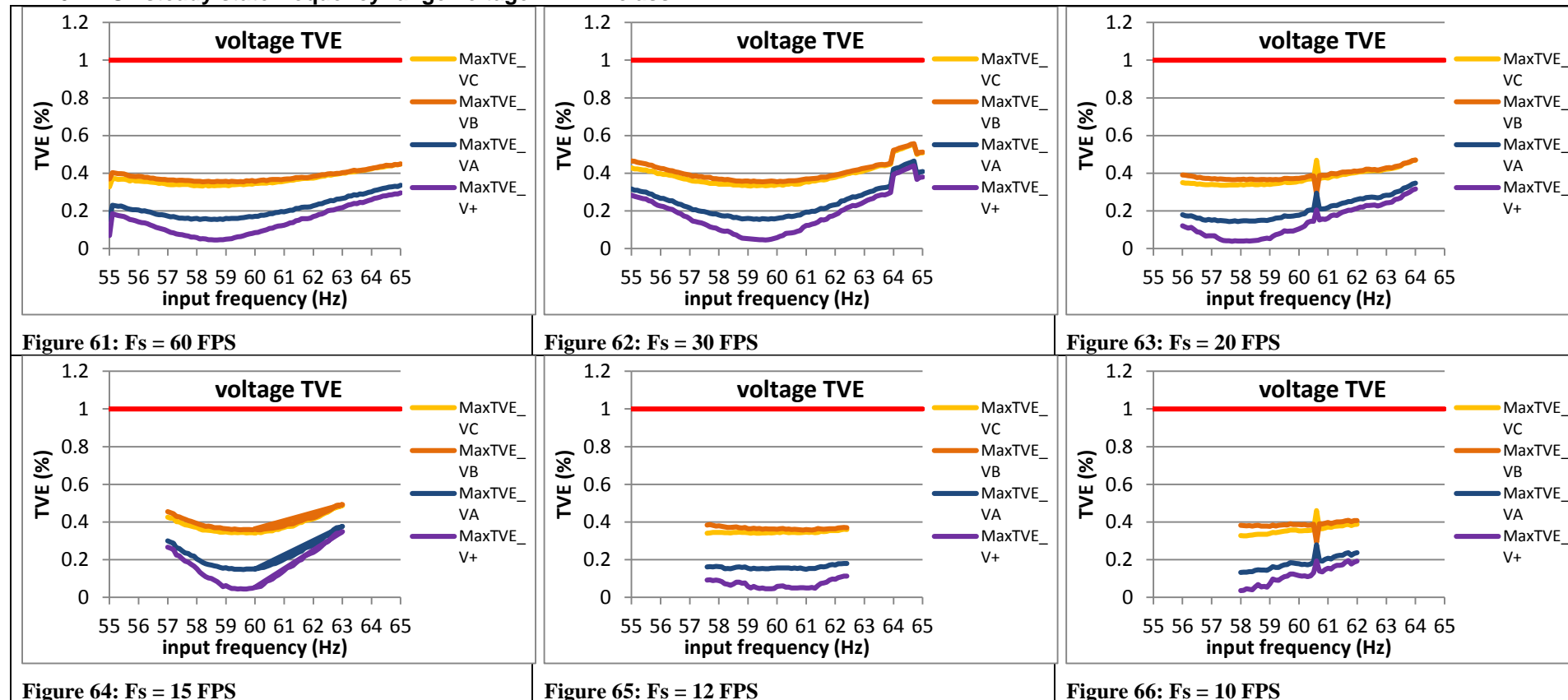


Figure 54:  $F_s = 10$  FPS

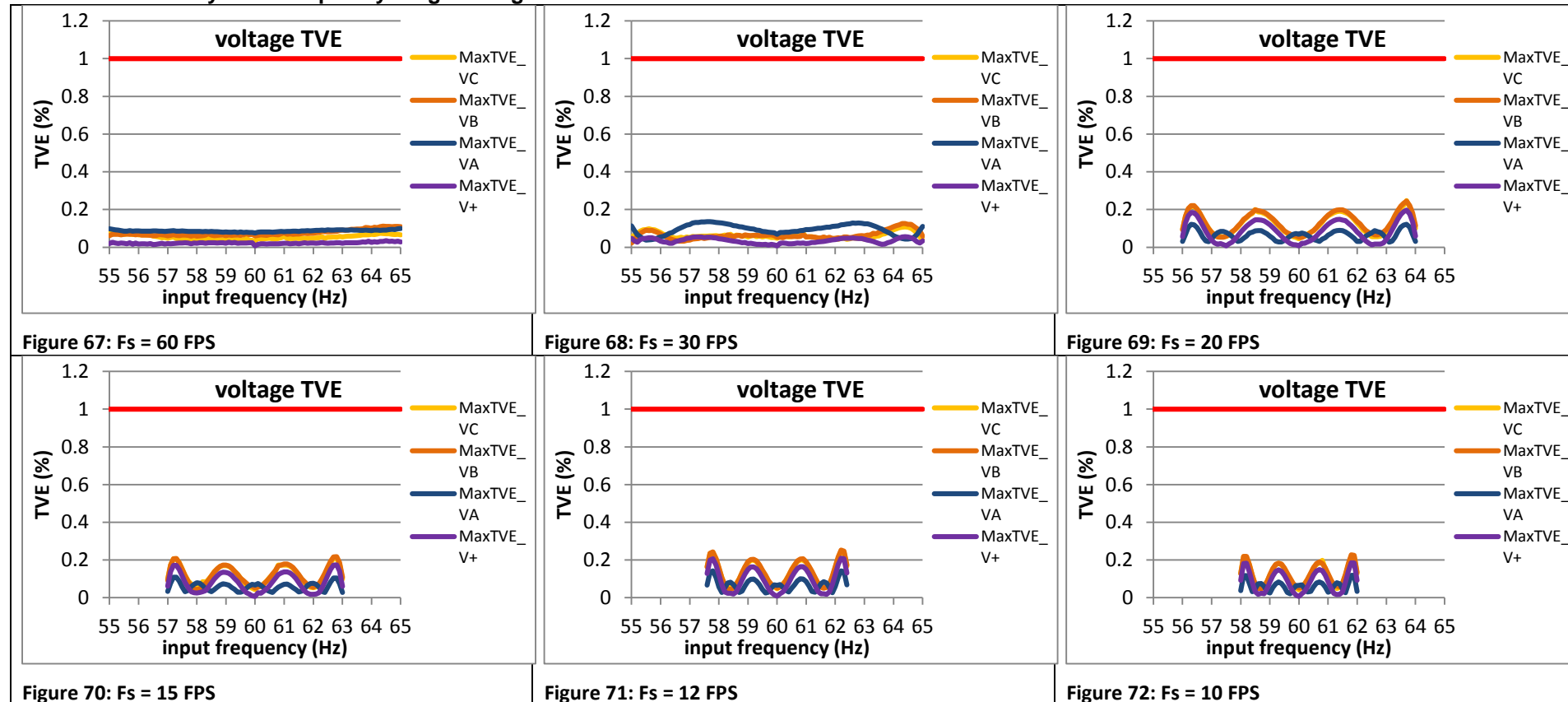
### 2.1.9 PMU H steady state frequency range voltage TVE: M class



### 2.1.10 PMU I steady state frequency range voltage TVE: M class

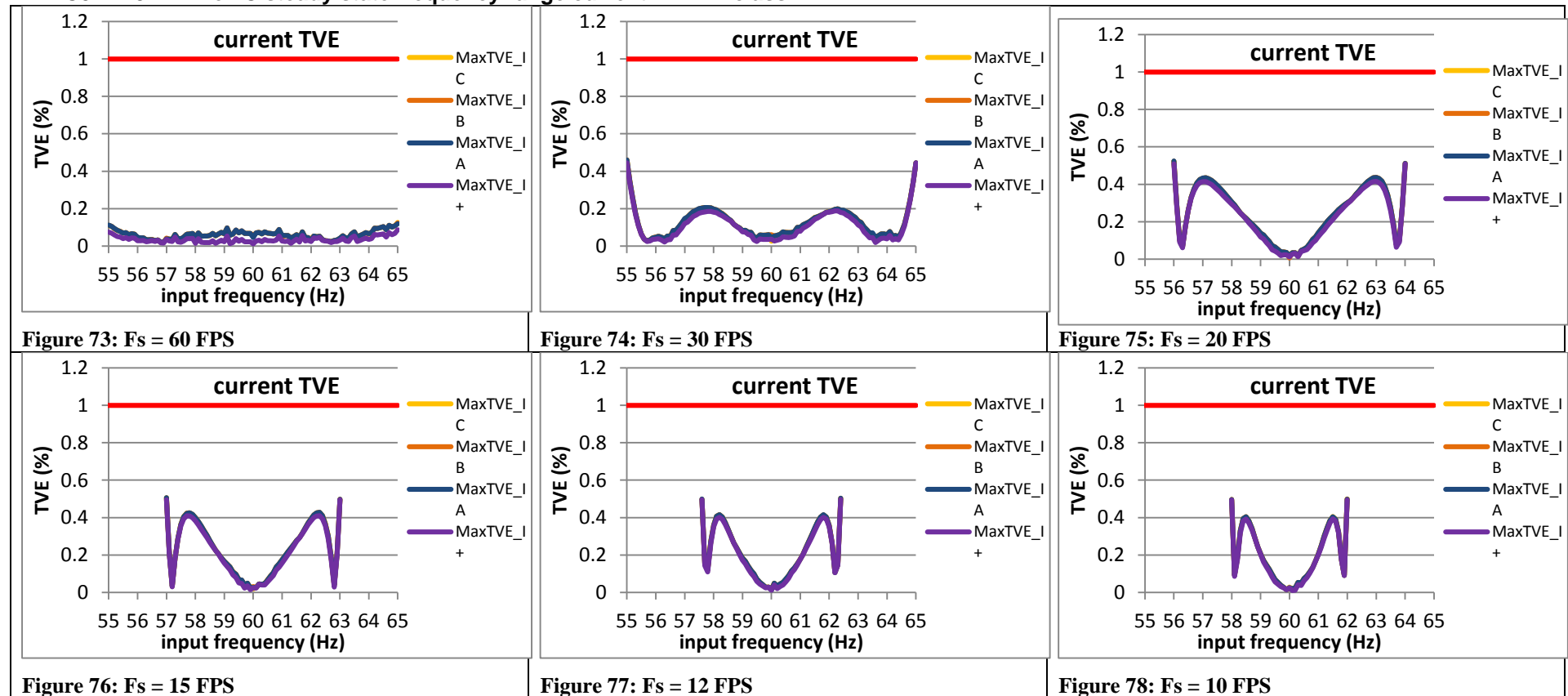


### 2.1.11 PMU J steady state frequency range voltage TVE: M class



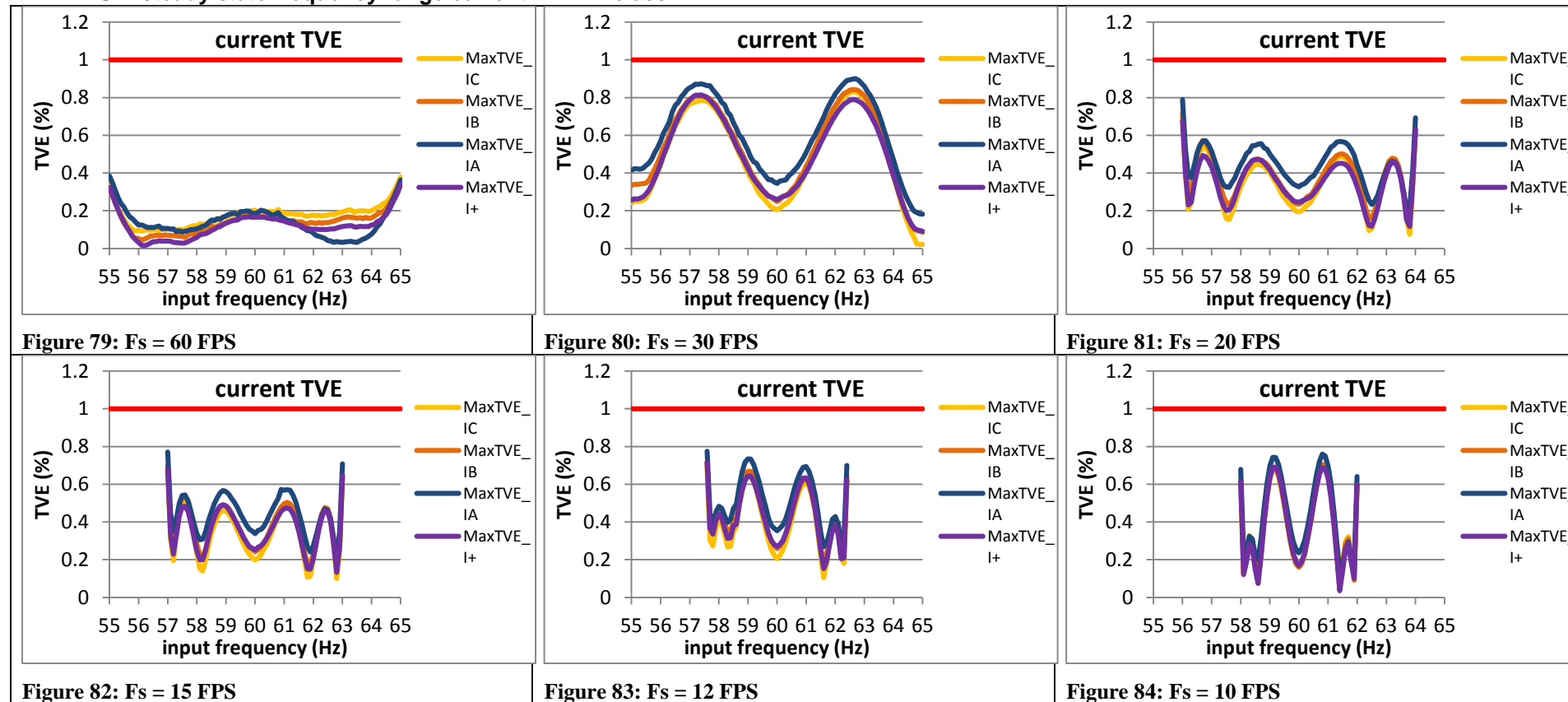
## 2.2 Steady state frequency range current TVE: M class

### 2.2.1 C37.118.1 Annex C steady state frequency range current TVE: M class

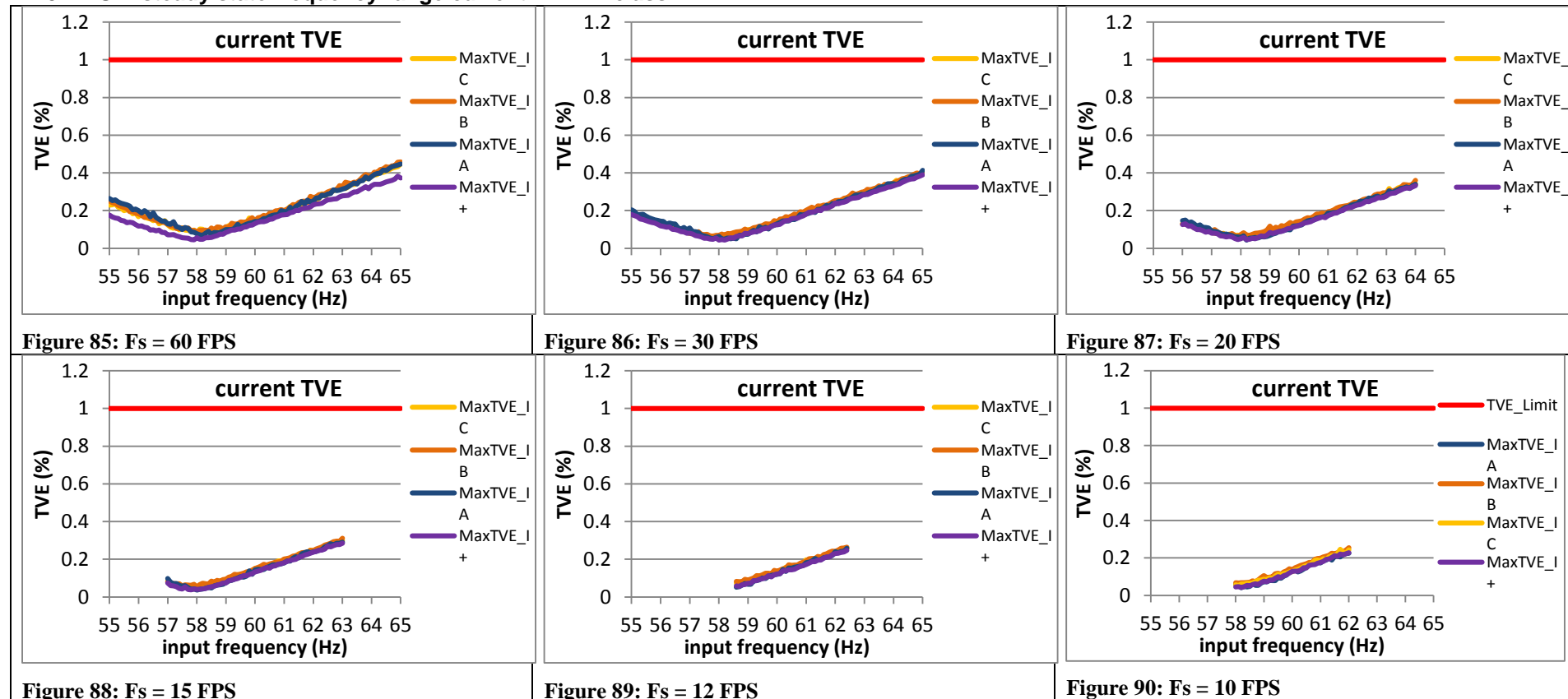




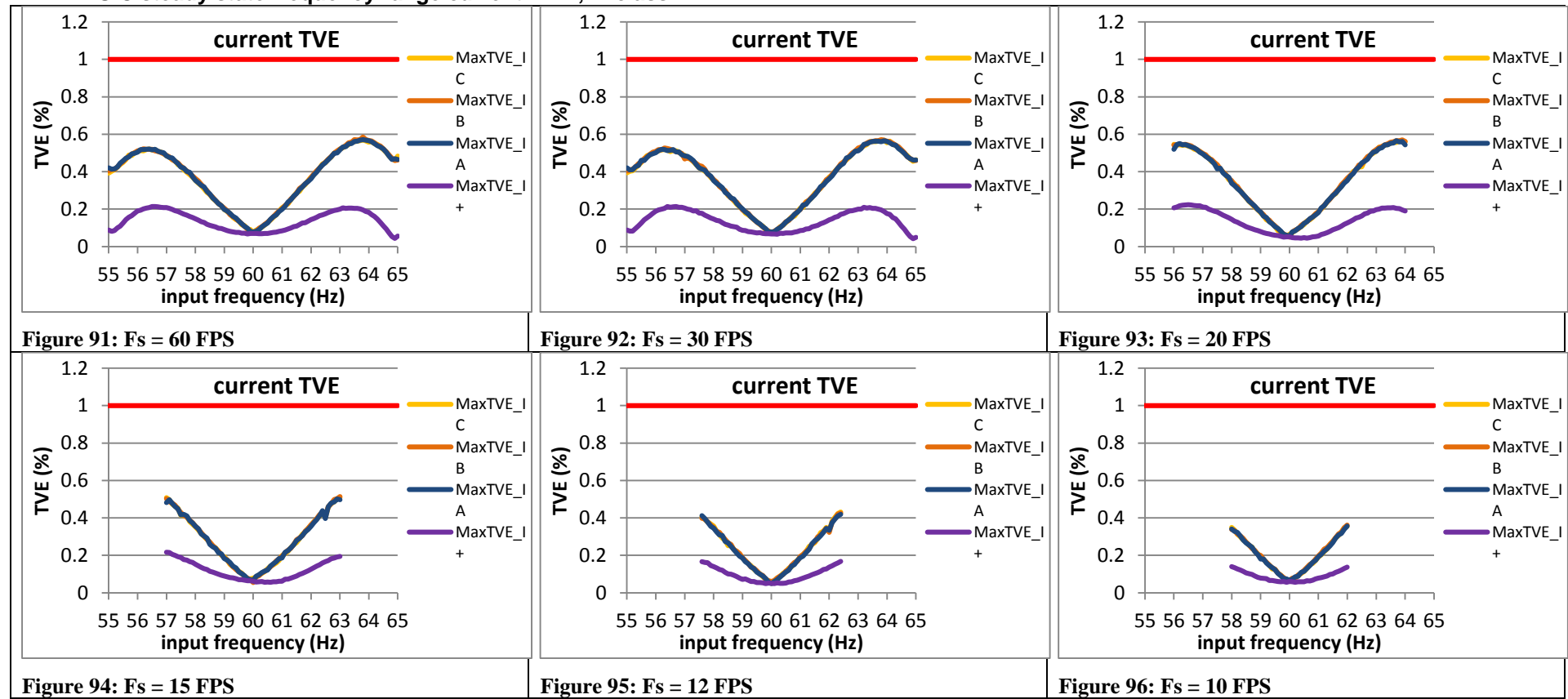
## 2.2.2 PMU A steady state frequency range current TVE: M class



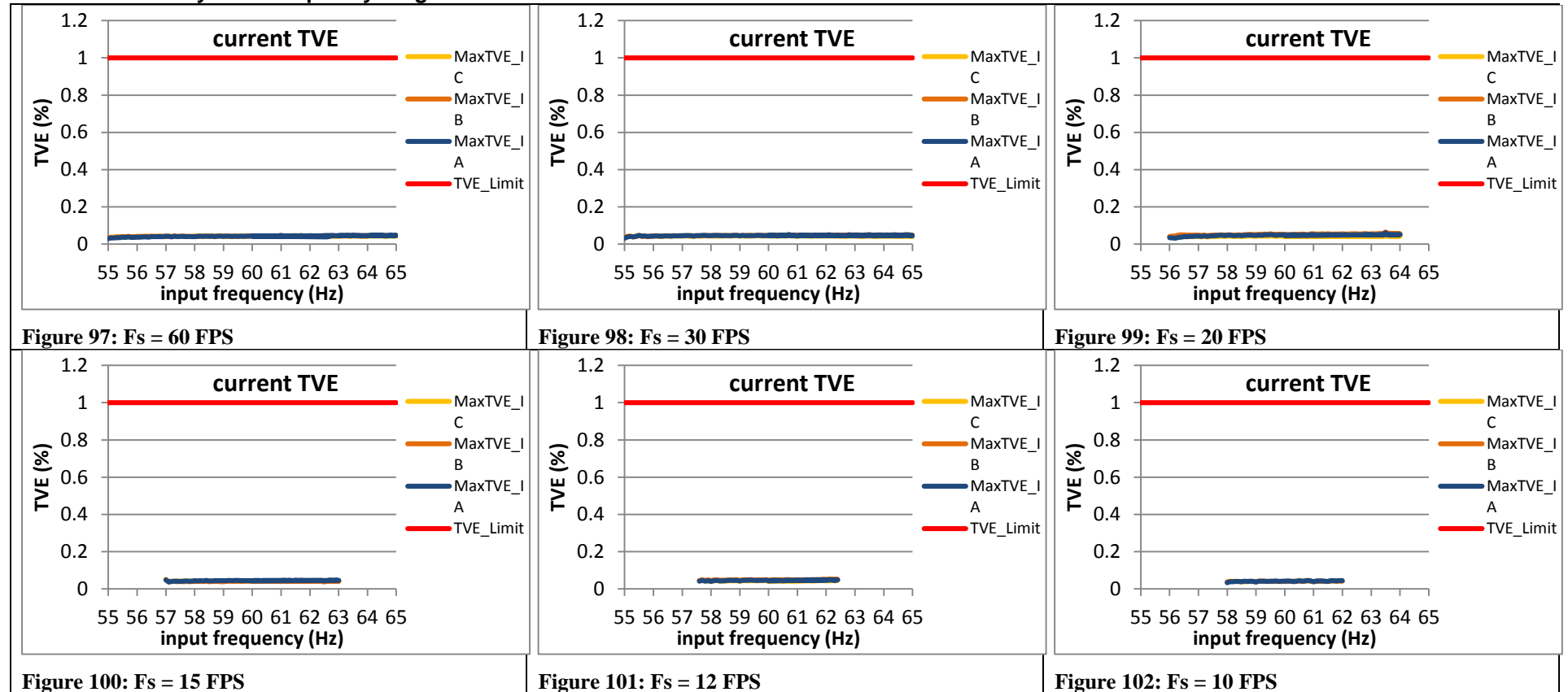
### 2.2.3 PMU B steady state frequency range current TVE: M class



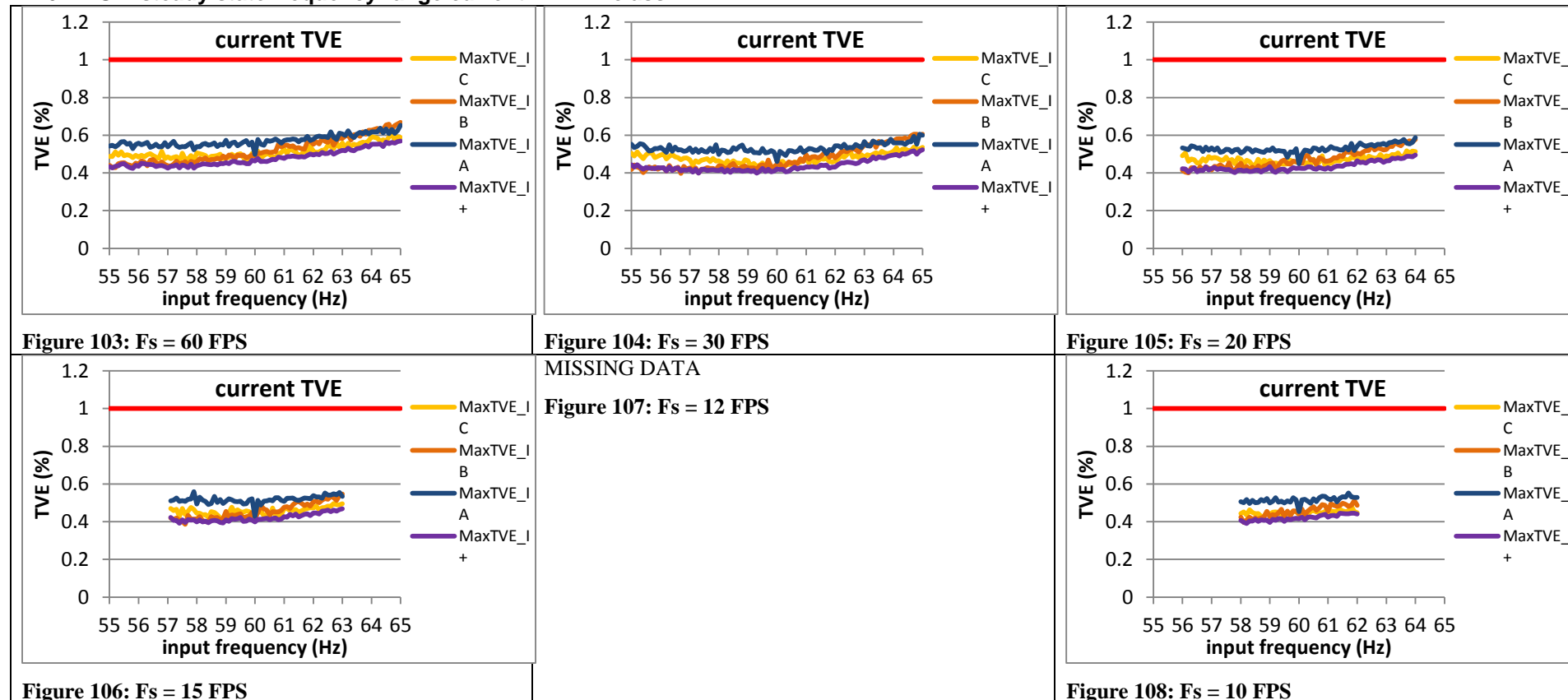
## 2.2.4 PMU C steady state frequency range current TVE:, M class



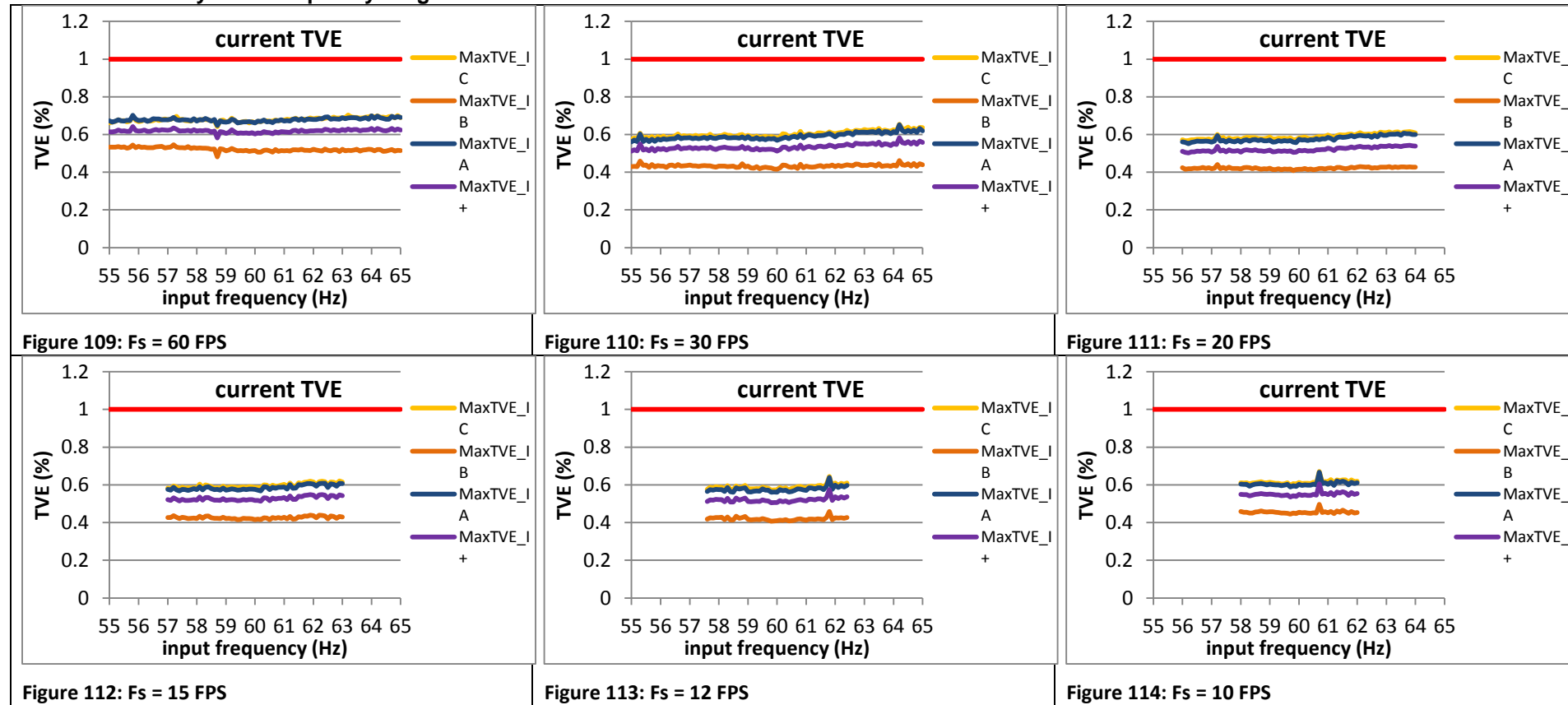
### 2.2.5 PMU D steady state frequency range current TVE: M class



## 2.2.6 PMU E steady state frequency range current TVE: M class



## 2.2.7 PMU F steady state frequency range current TVE: M class



## 2.2.8 PMU G steady state frequency range current TVE: M class

Figure 115:  $F_s = 60$  FPS is not supported by this PMU

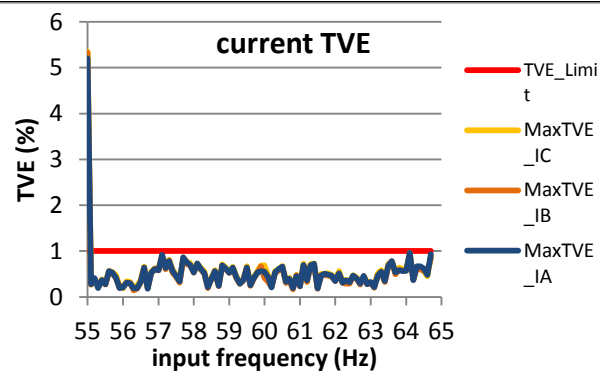


Figure 116:  $F_s = 30$  FPS

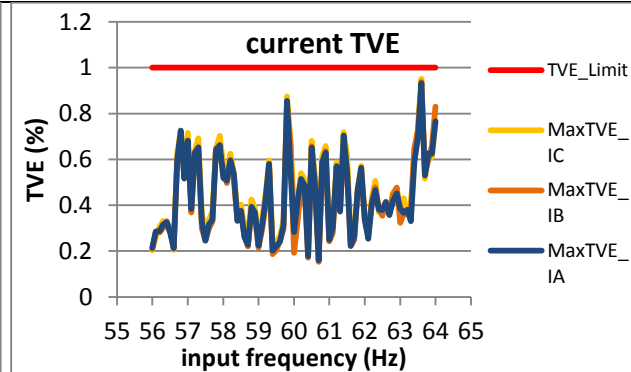


Figure 117:  $F_s = 20$  FPS

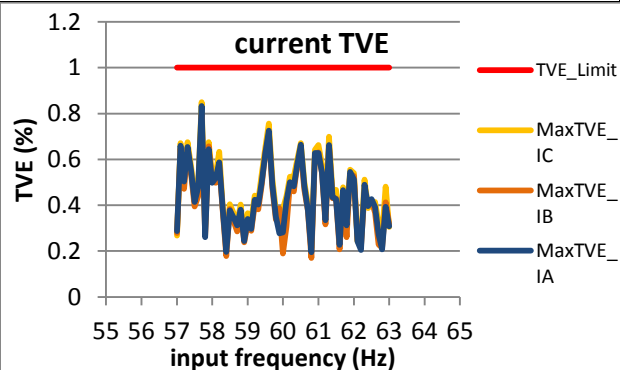


Figure 118:  $F_s = 15$  FPS

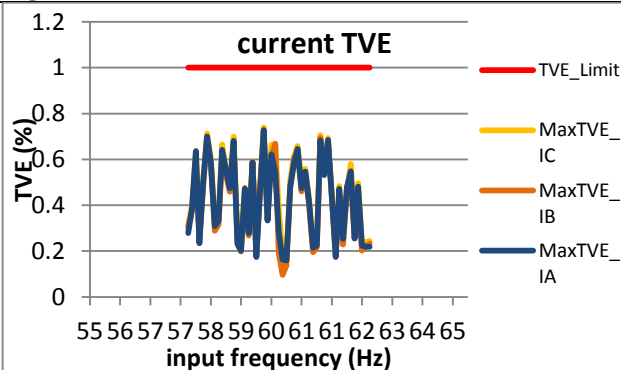


Figure 119:  $F_s = 12$  FPS

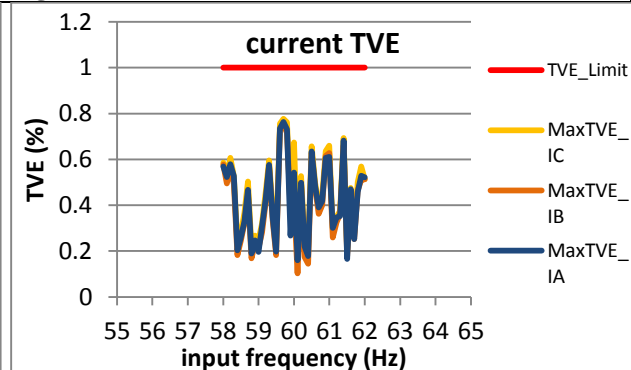
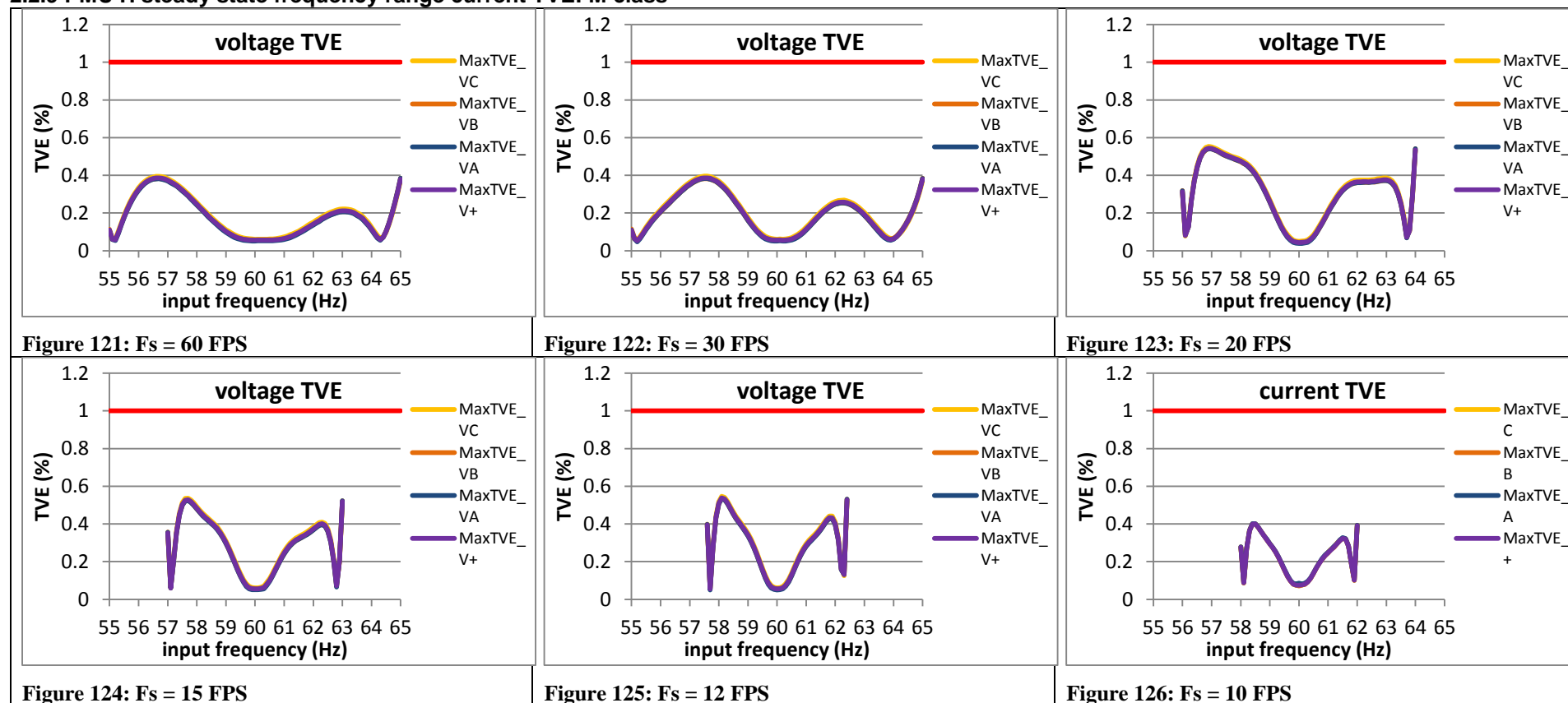


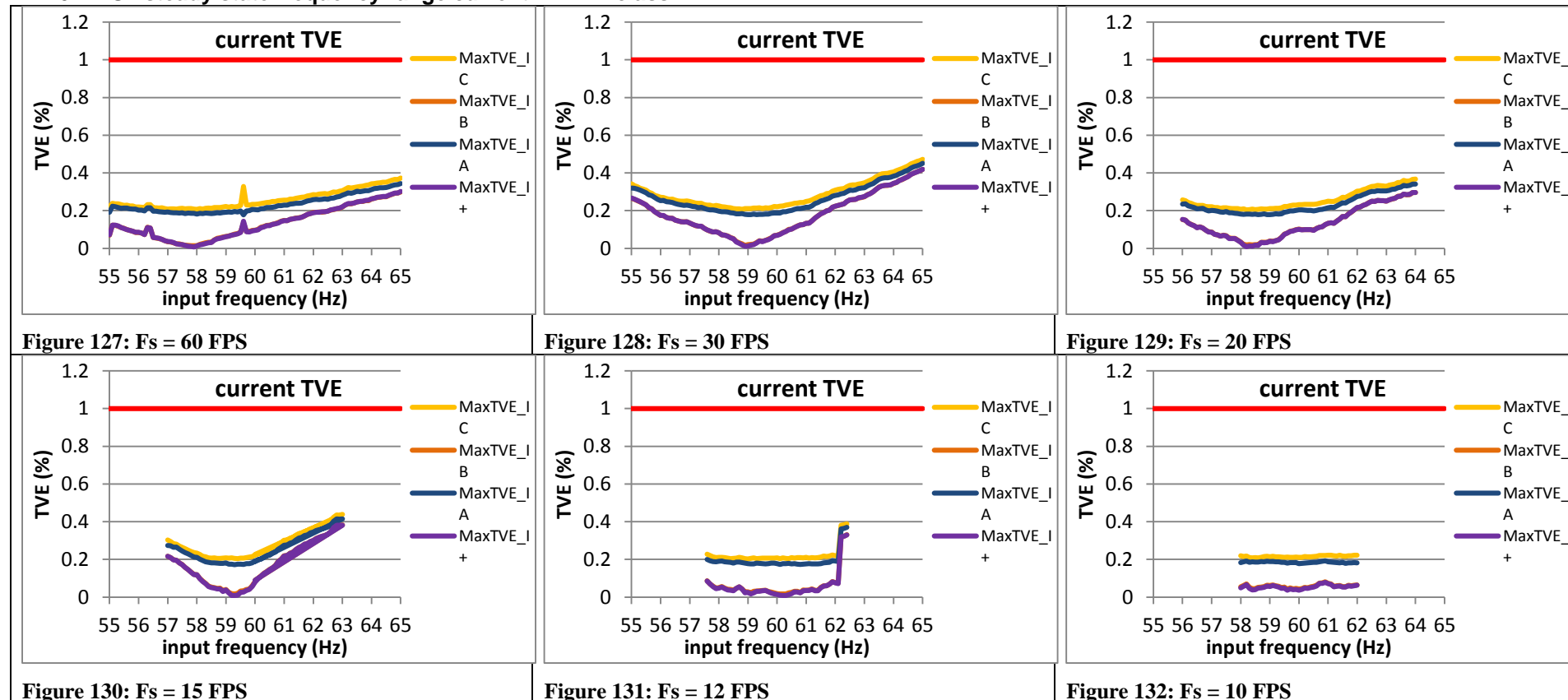
Figure 120:  $F_s = 10$  FPS

### 2.2.9 PMU H steady state frequency range current TVE: M class

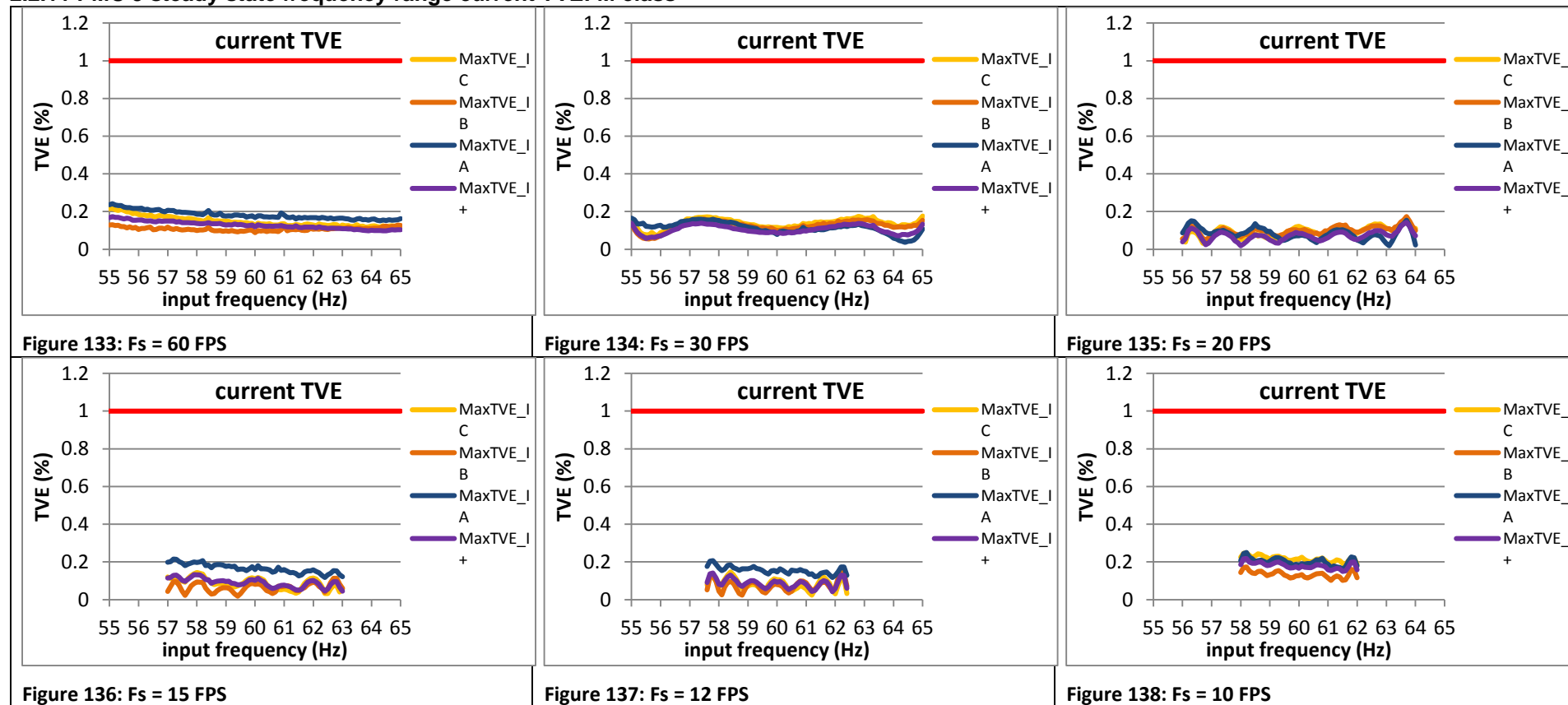




## 2.2.10 PMU I steady state frequency range current TVE: M class

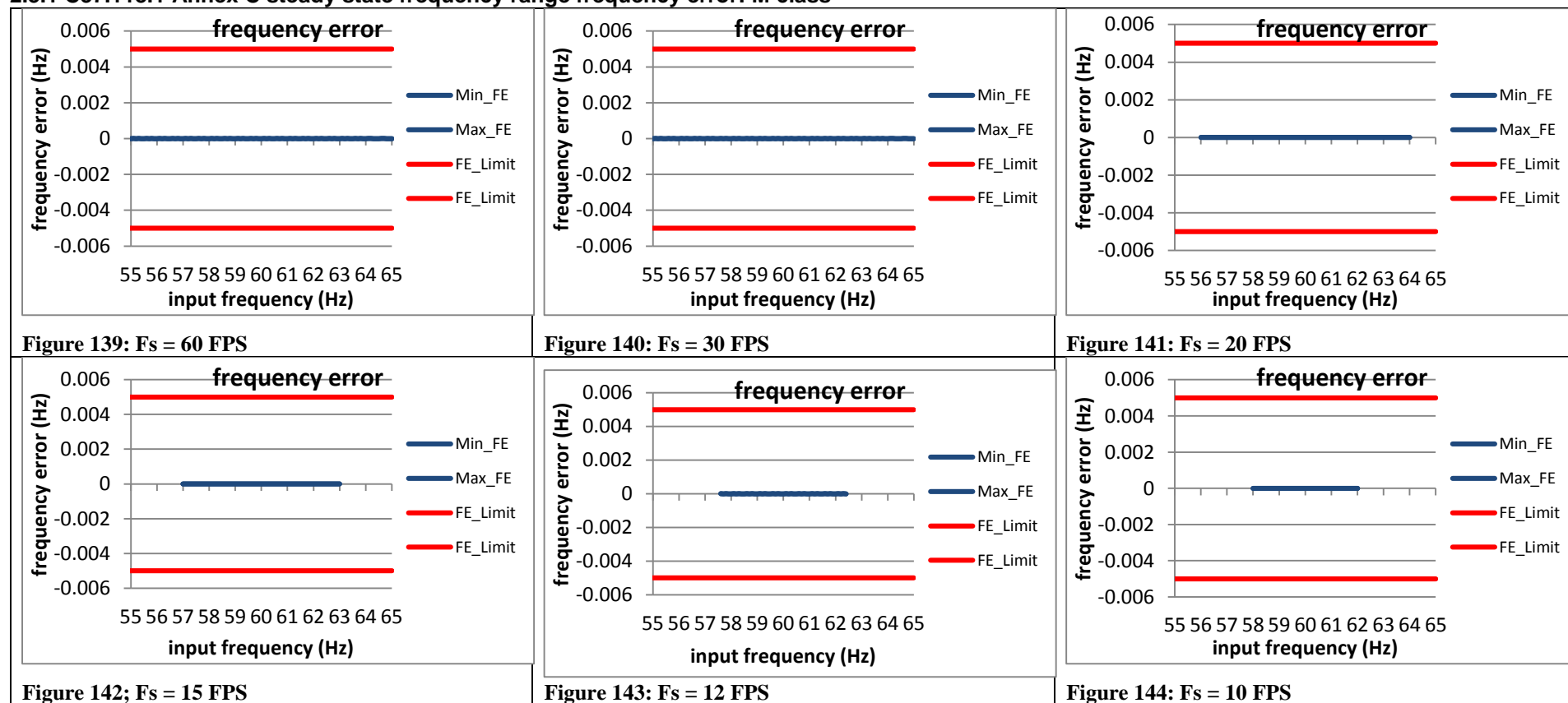


### 2.2.11 PMU J steady state frequency range current TVE: M class

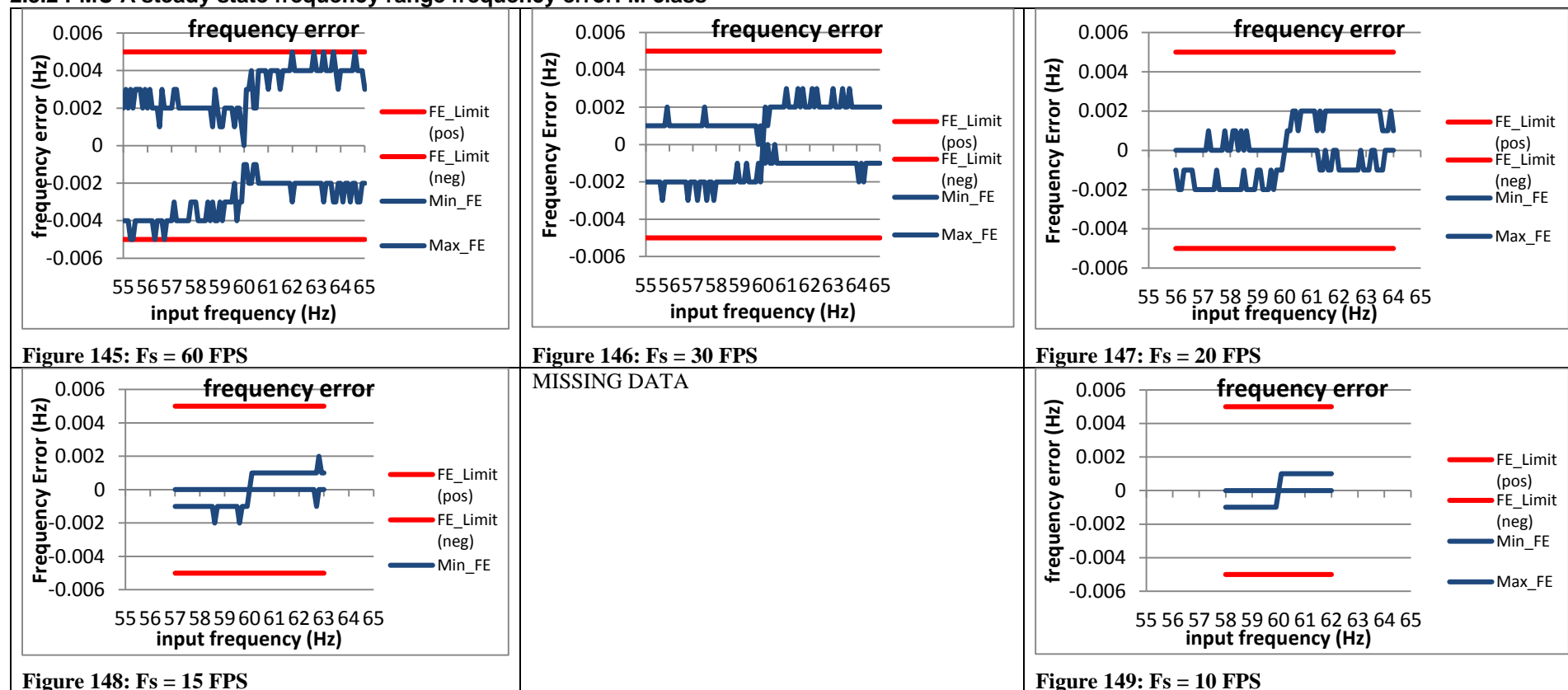


## 2.3 Steady state frequency range frequency error: M class

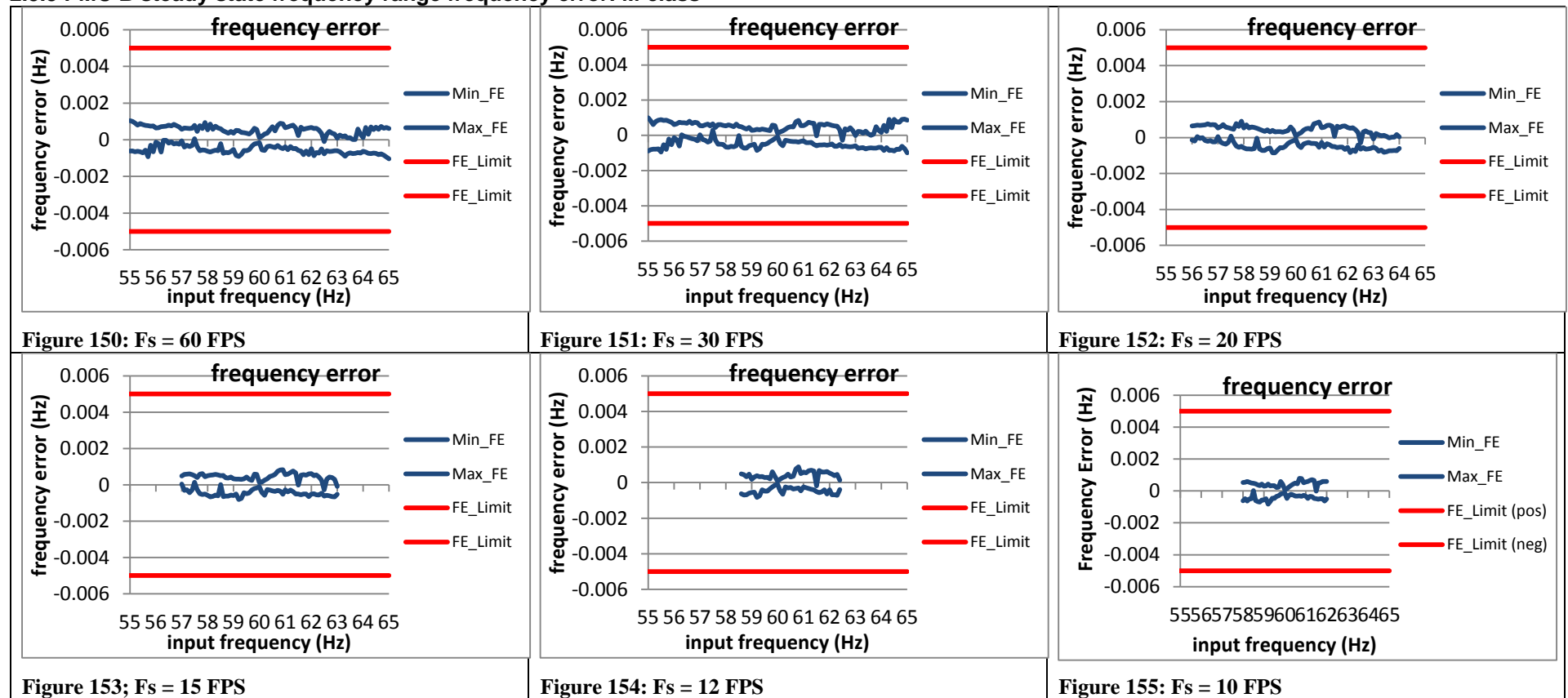
### 2.3.1 C37.118.1 Annex C steady state frequency range frequency error: M class



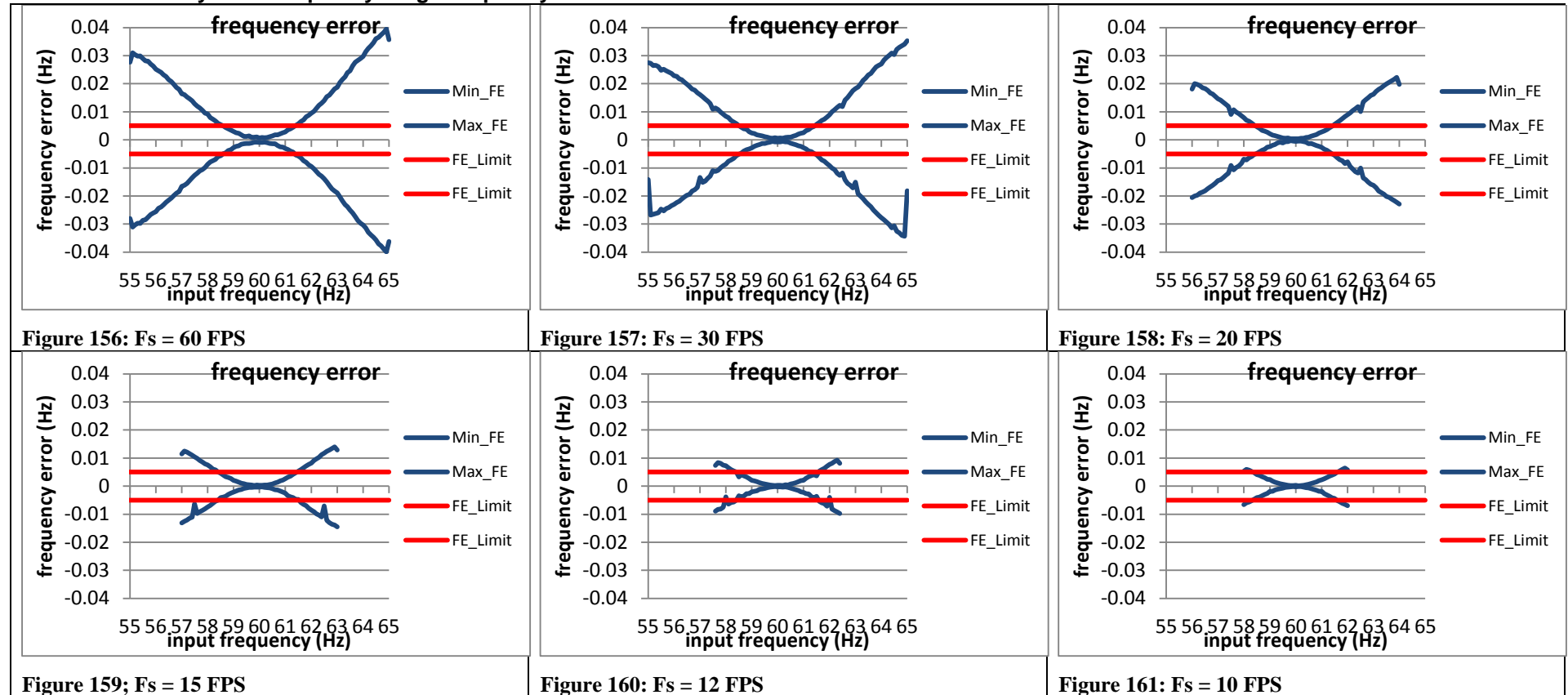
### 2.3.2 PMU A steady state frequency range frequency error: M class



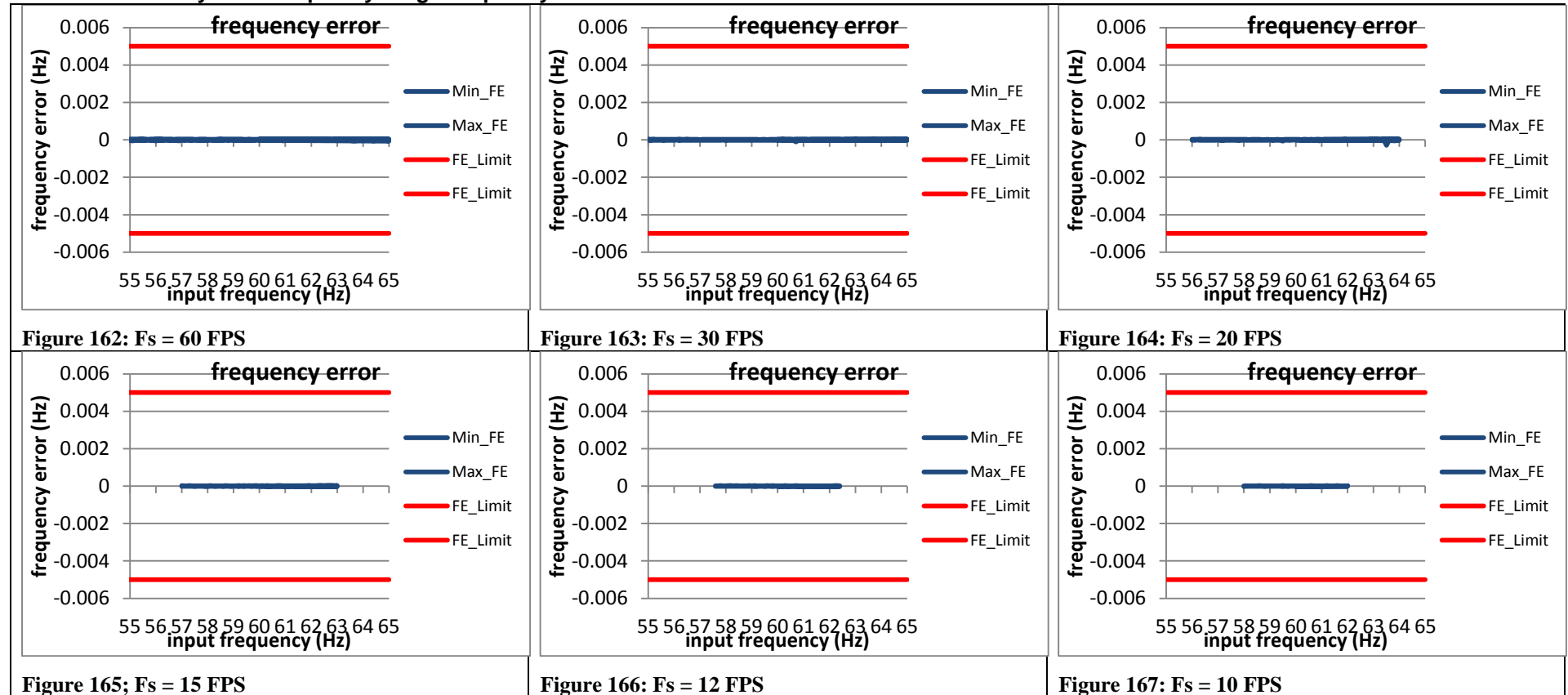
### 2.3.3 PMU B steady state frequency range frequency error: M class



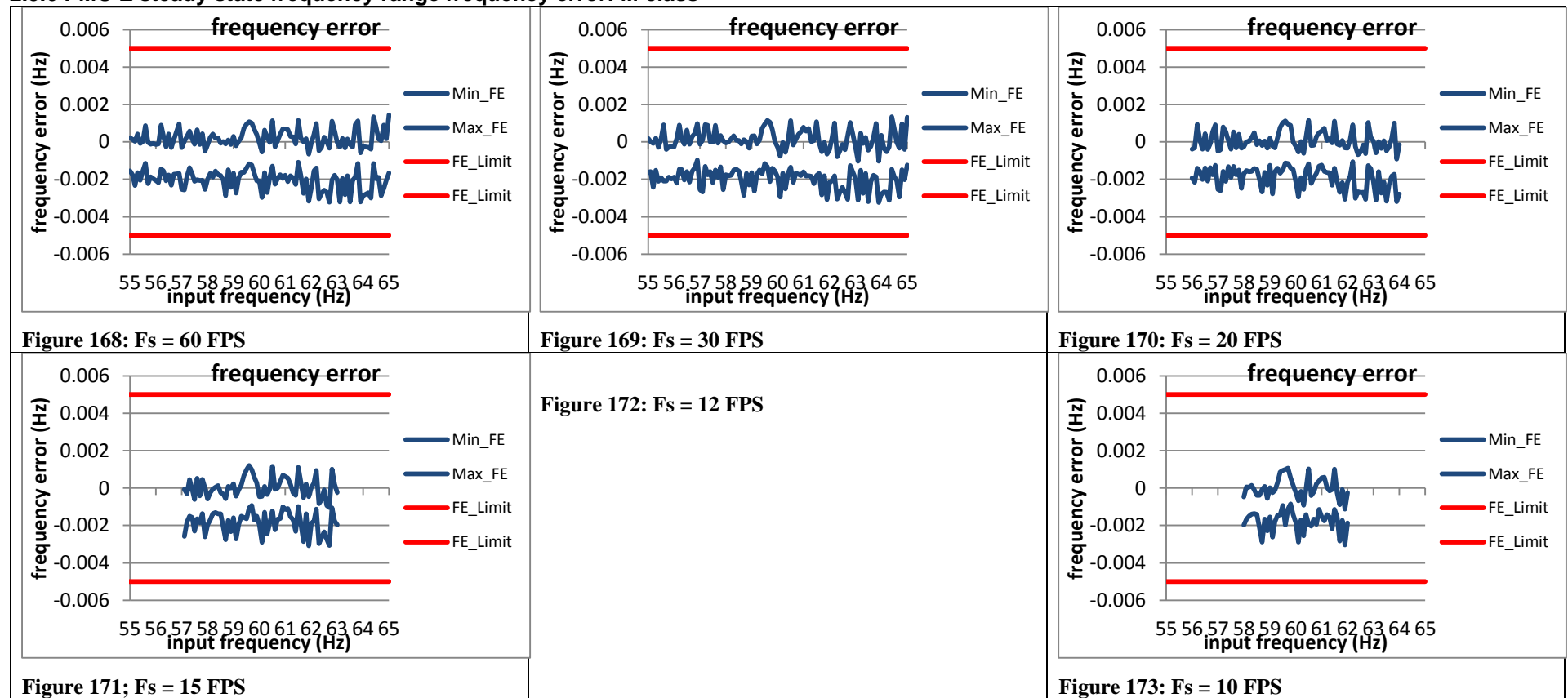
### 2.3.4 PMU C steady state frequency range frequency error: M class



### 2.3.5 PMU D steady state frequency range frequency error: M class

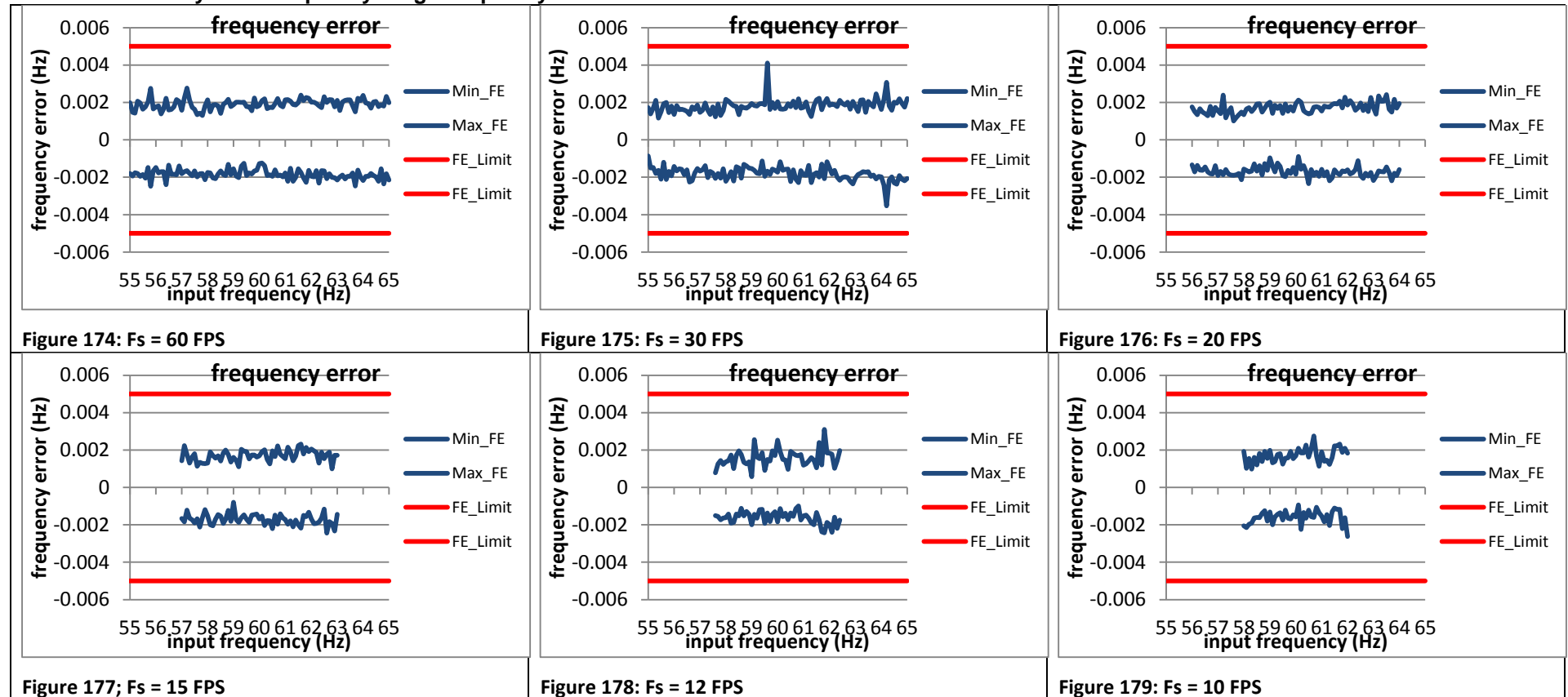


### 2.3.6 PMU E steady state frequency range frequency error: M class



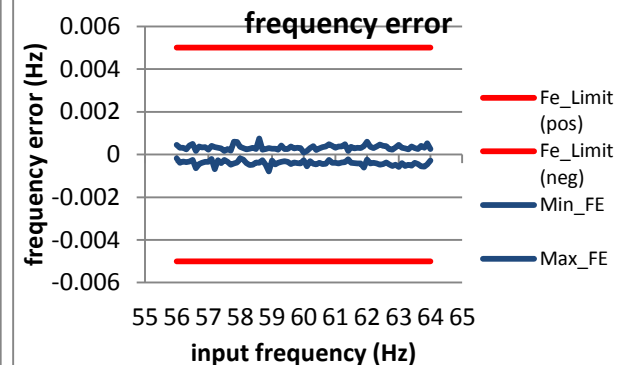
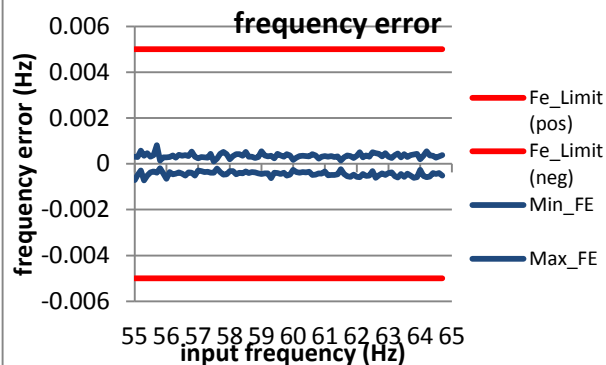


### 2.3.7 PMU F steady state frequency range frequency error: M class



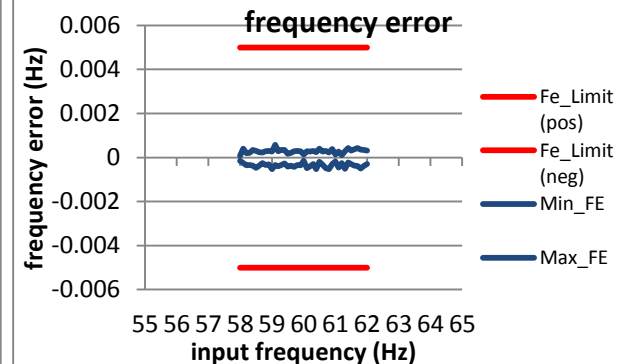
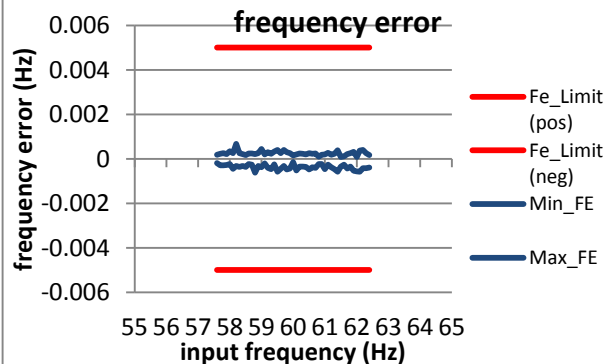
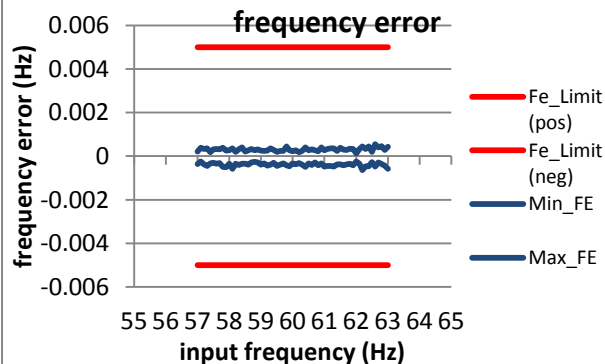
### 2.3.8 PMU G steady state frequency range frequency error: M class

**Figure 180:  $F_s = 60$  FPS not supported by this PMU**



**Figure 181:  $F_s = 30$  FPS**

**Figure 182:  $F_s = 20$  FPS**

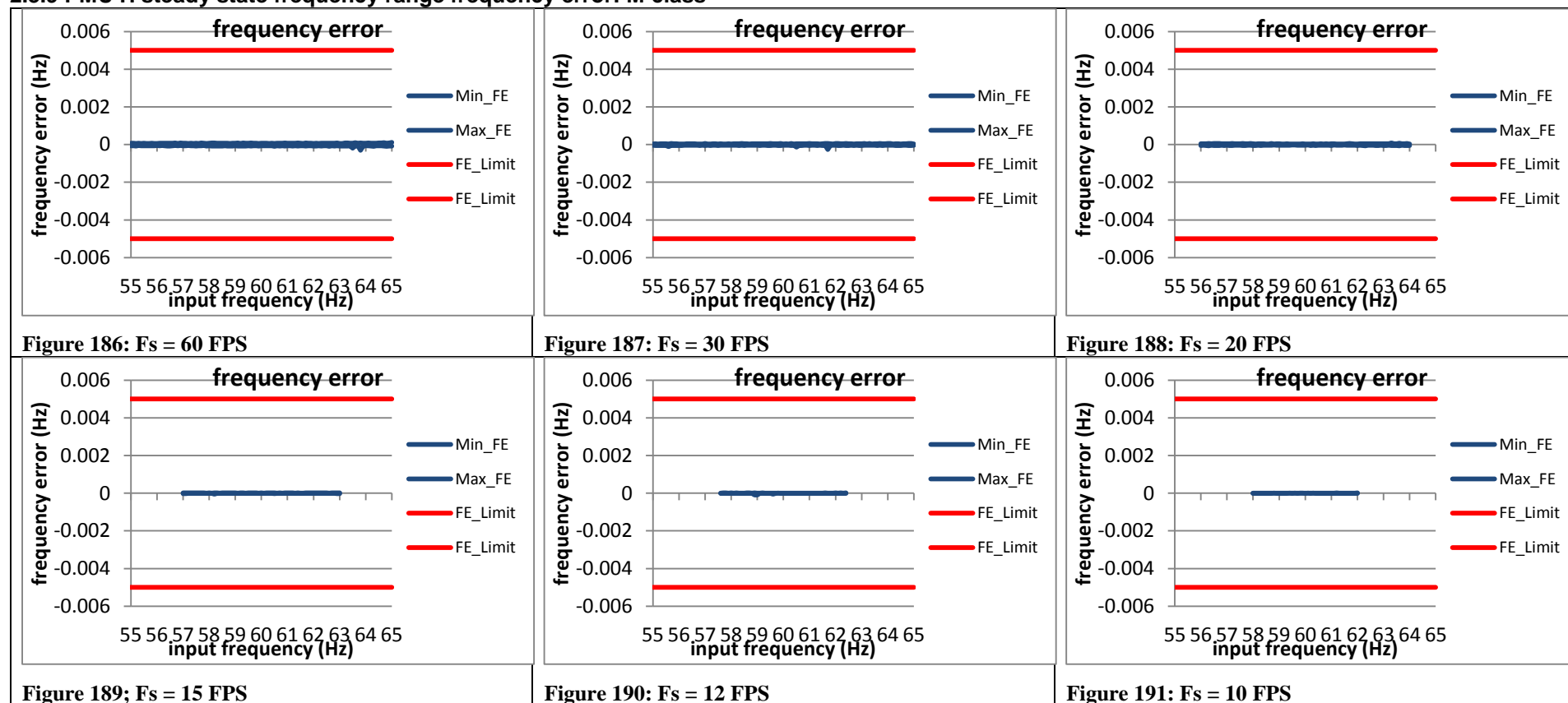


**Figure 183:  $F_s = 15$  FPS**

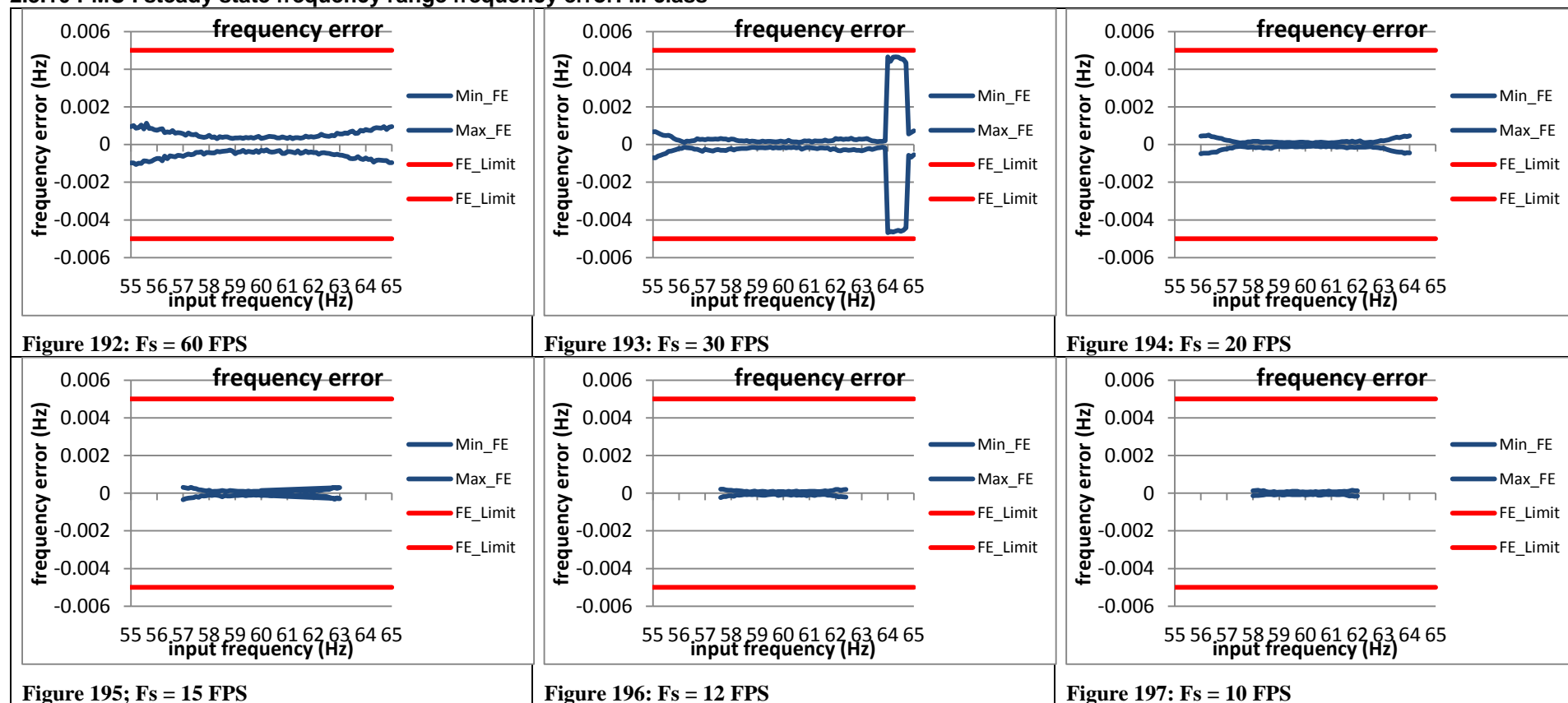
**Figure 184:  $F_s = 12$  FPS**

**Figure 185:  $F_s = 10$  FPS**

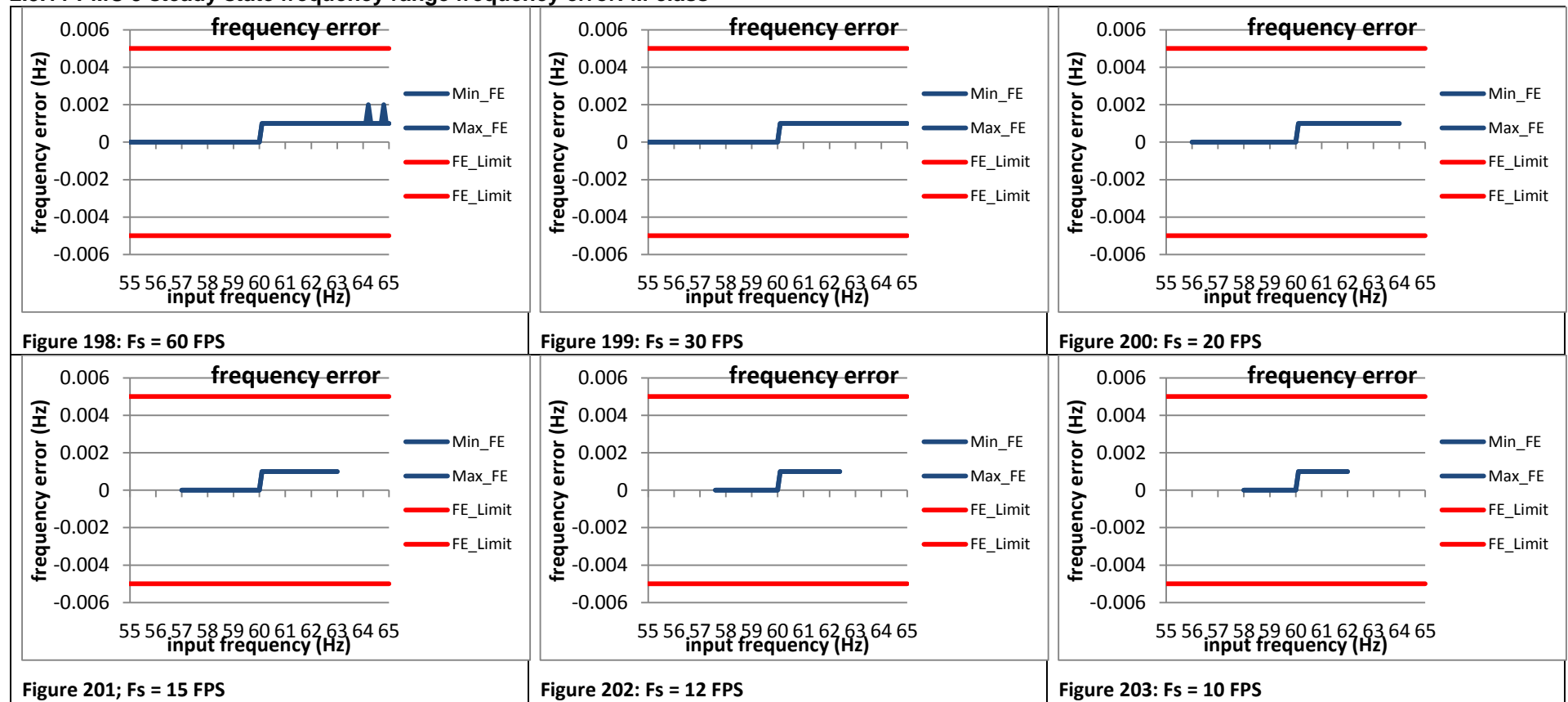
### 2.3.9 PMU H steady state frequency range frequency error: M class



### 2.3.10 PMU I steady state frequency range frequency error: M class

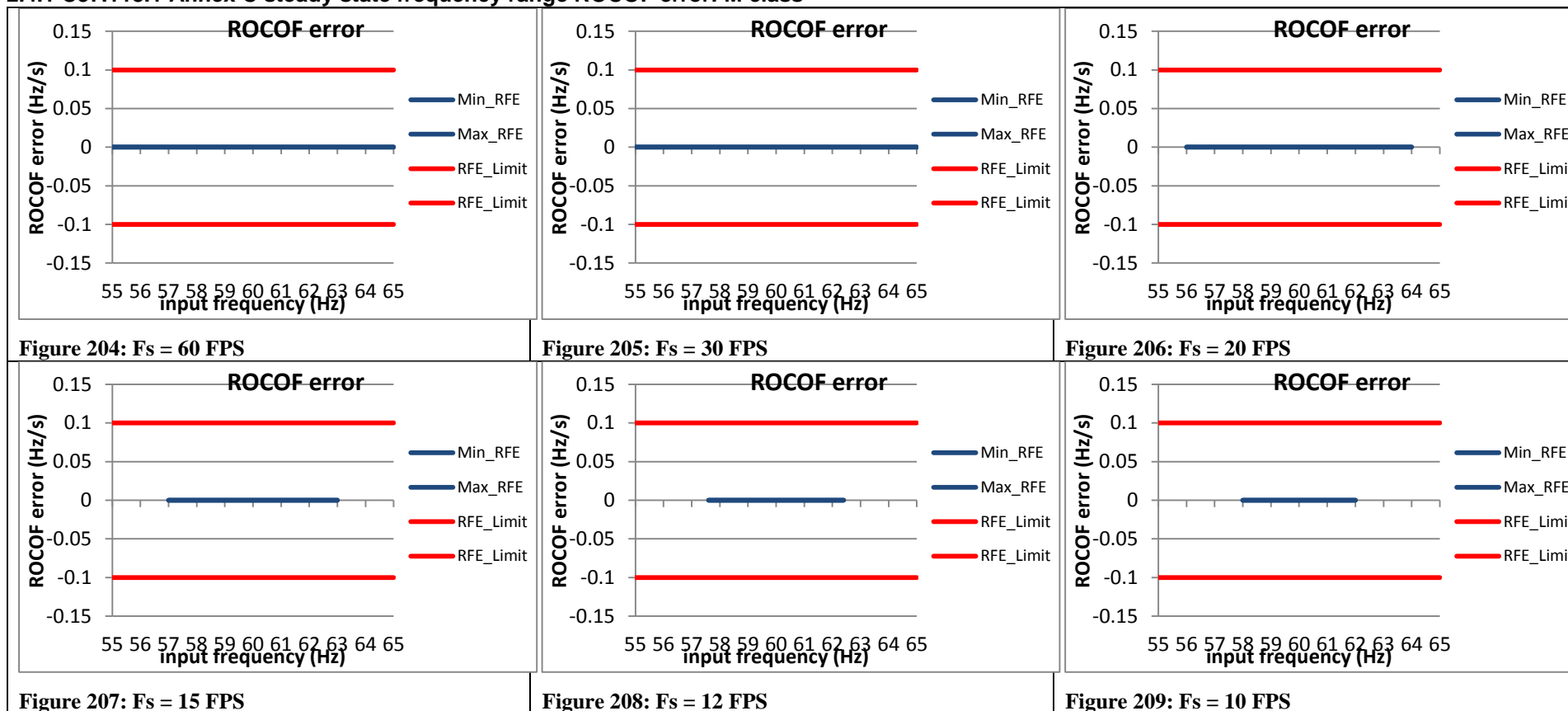


### 2.3.11 PMU J steady state frequency range frequency error: M class

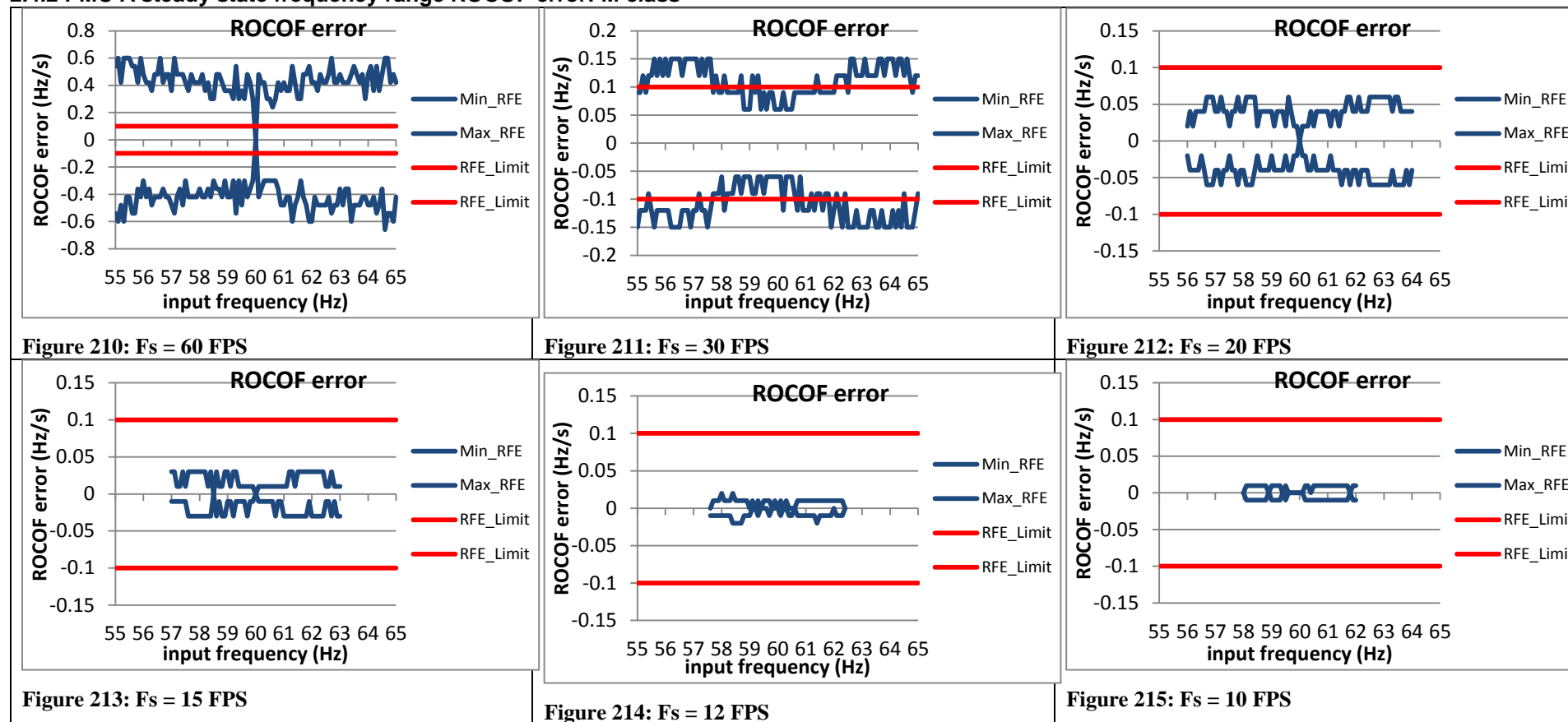


## 2.4 Steady state frequency range ROCOF error: M class

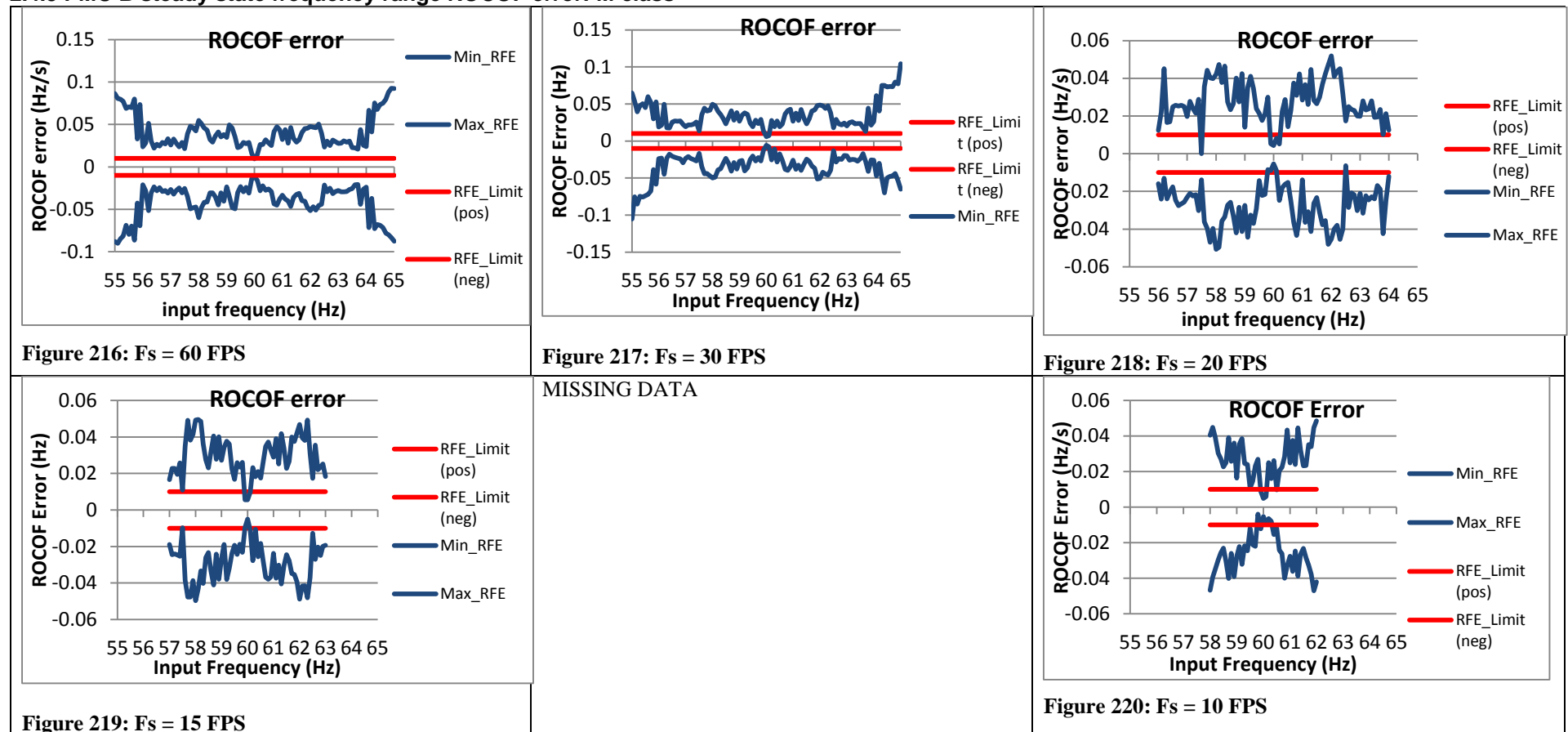
### 2.4.1 C37.118.1 Annex C steady state frequency range ROCOF error: M class



#### 2.4.2 PMU A steady state frequency range ROCOF error: M class

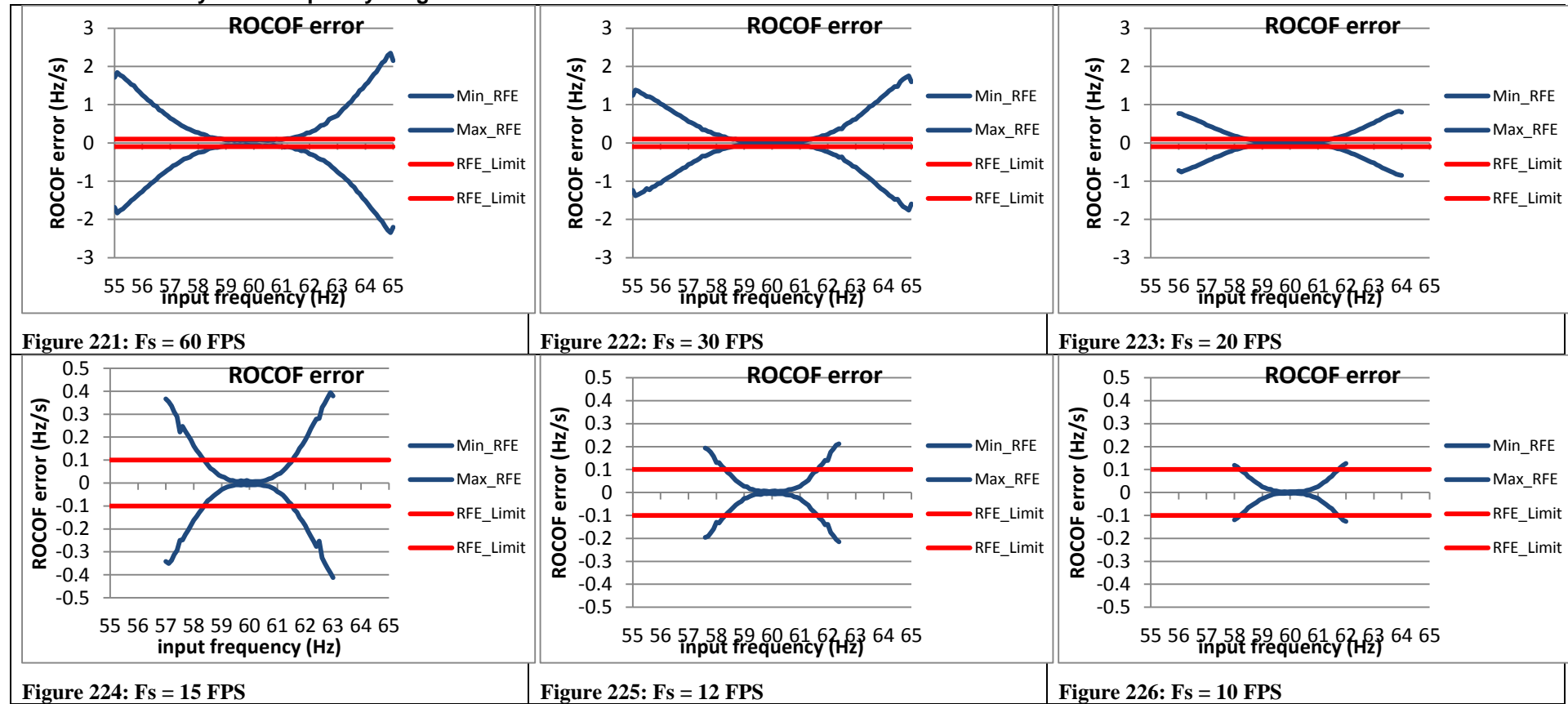


### 2.4.3 PMU B steady state frequency range ROCOF error: M class

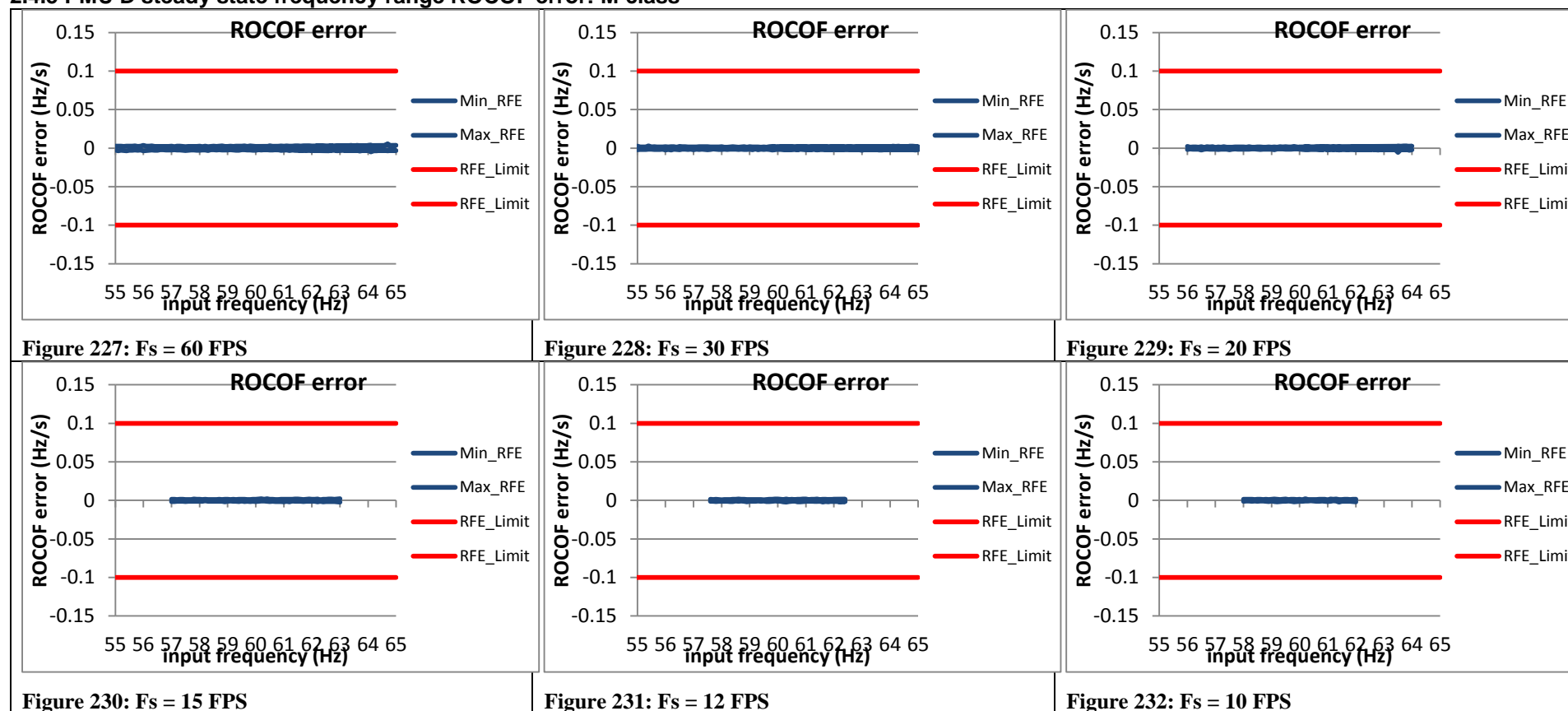




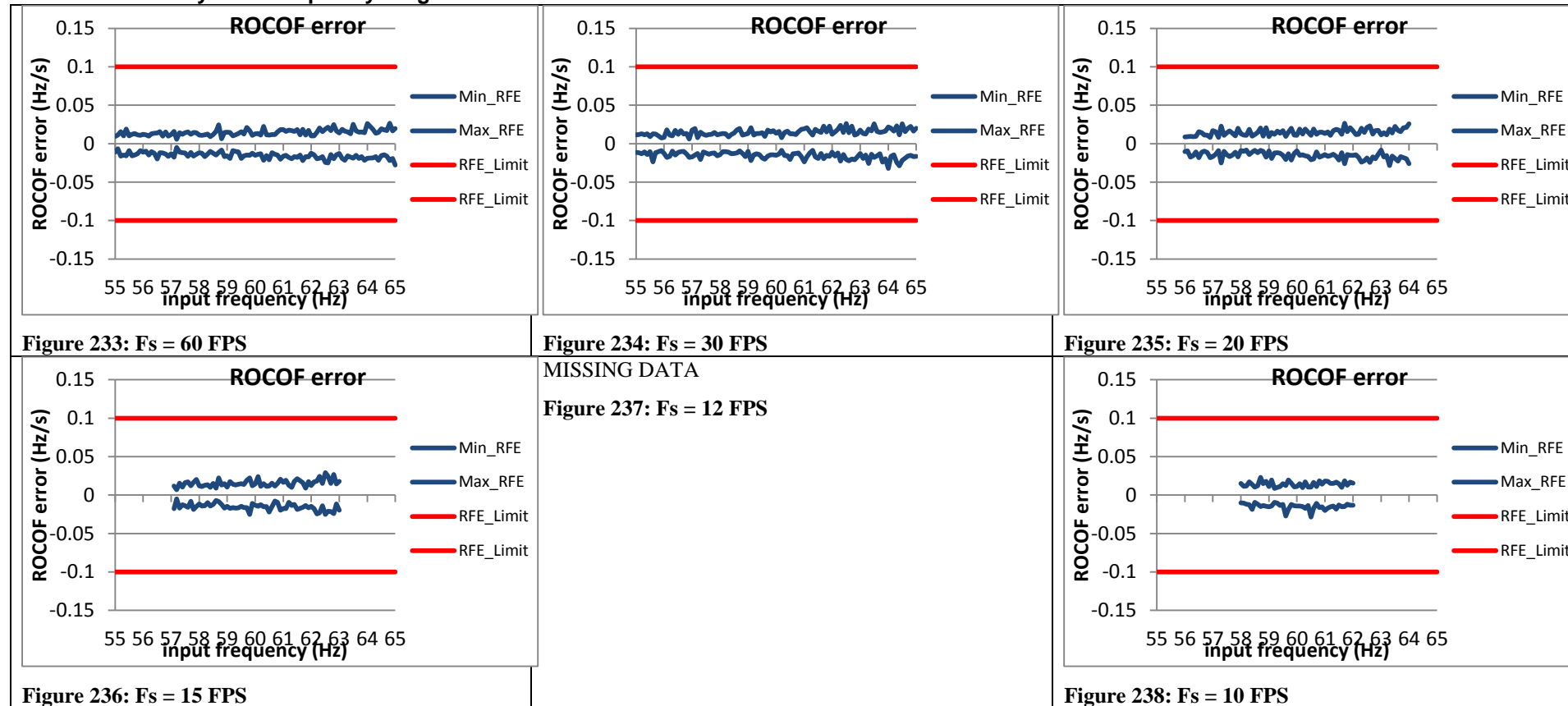
#### 2.4.4 PMU C steady state frequency range ROCOF error: M class



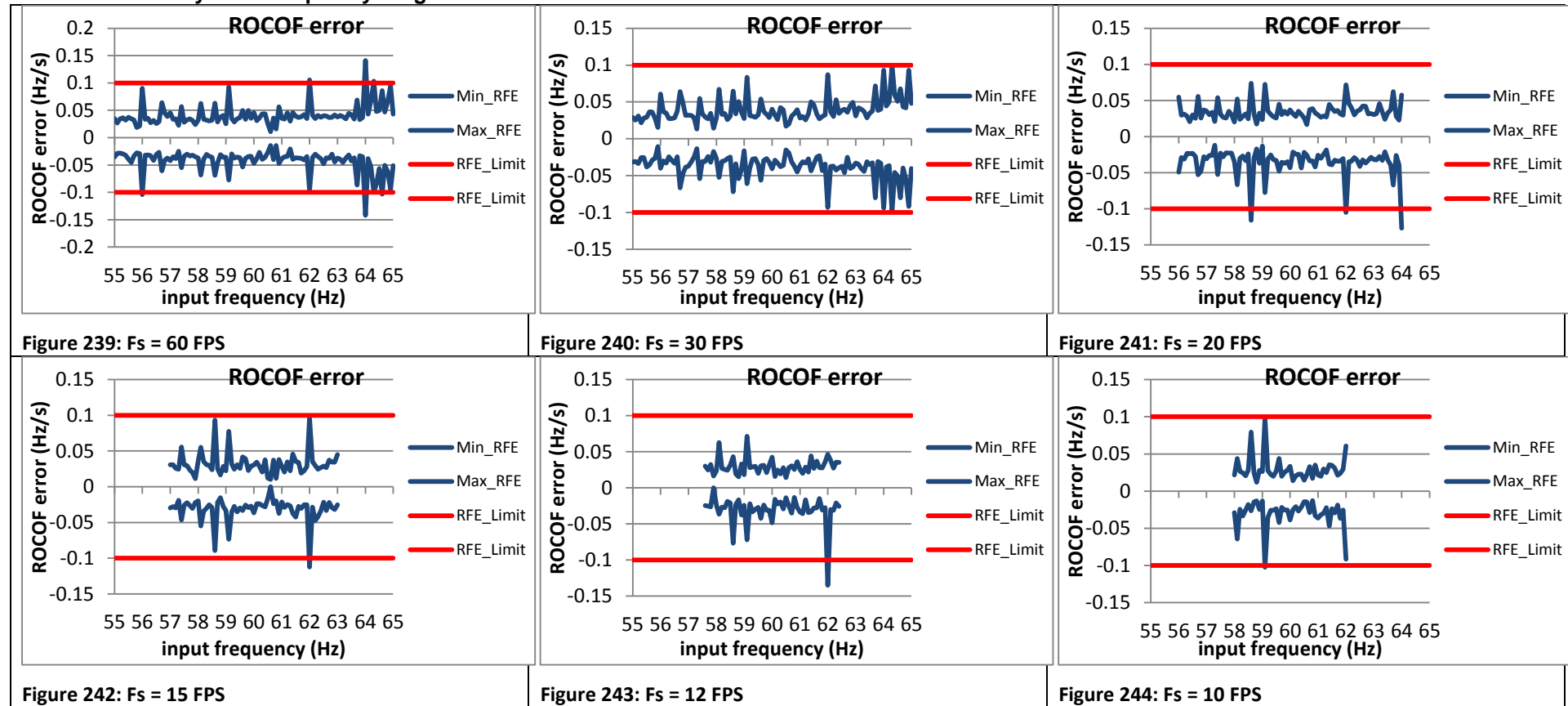
## 2.4.5 PMU D steady state frequency range ROCOF error: M class



#### 2.4.6 PMU E steady state frequency range ROCOF error: M class



#### 2.4.7 PMU F steady state frequency range ROCOF error: M class



#### 2.4.8 PMU G\* steady state frequency range ROCOF error: M class

Figure 245:  $F_s = 60$  FPS is not supported by this PMU

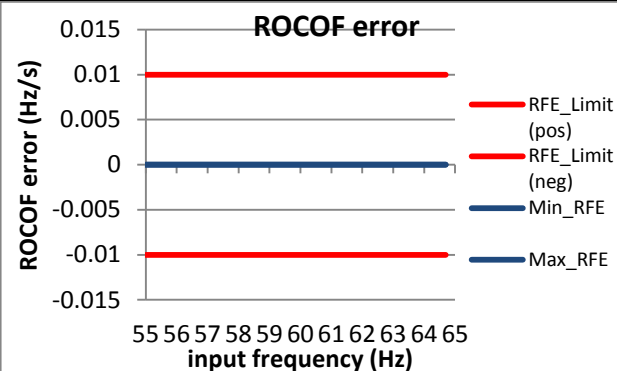


Figure 246:  $F_s = 30$  FPS

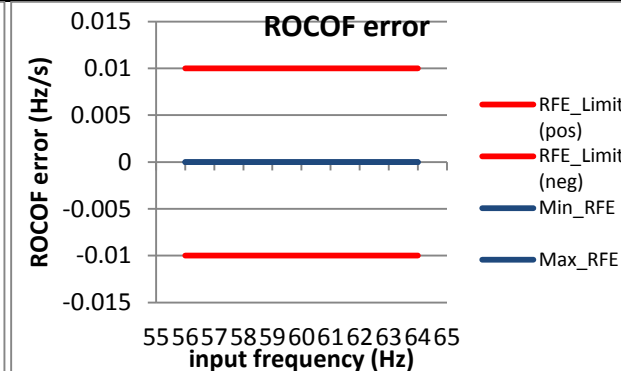


Figure 247:  $F_s = 20$  FPS

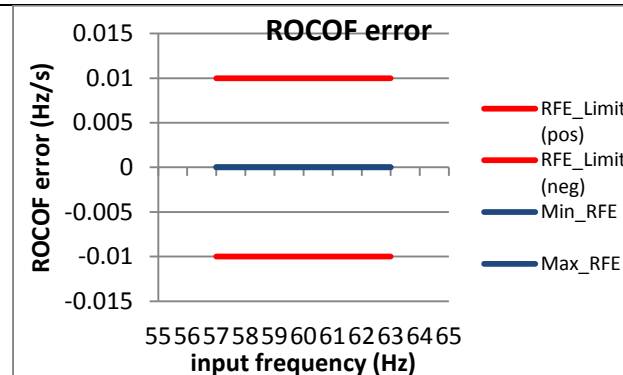


Figure 248:  $F_s = 15$  FPS

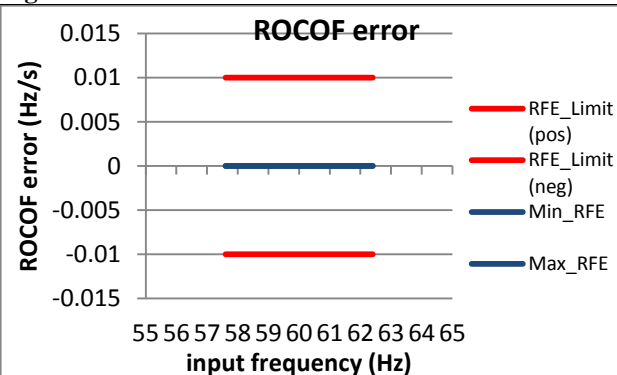


Figure 249:  $F_s = 12$  FPS

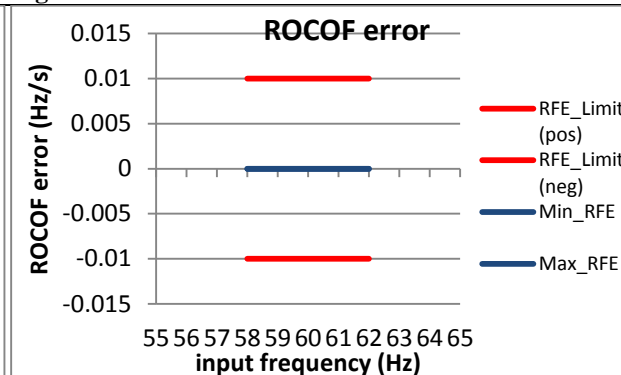
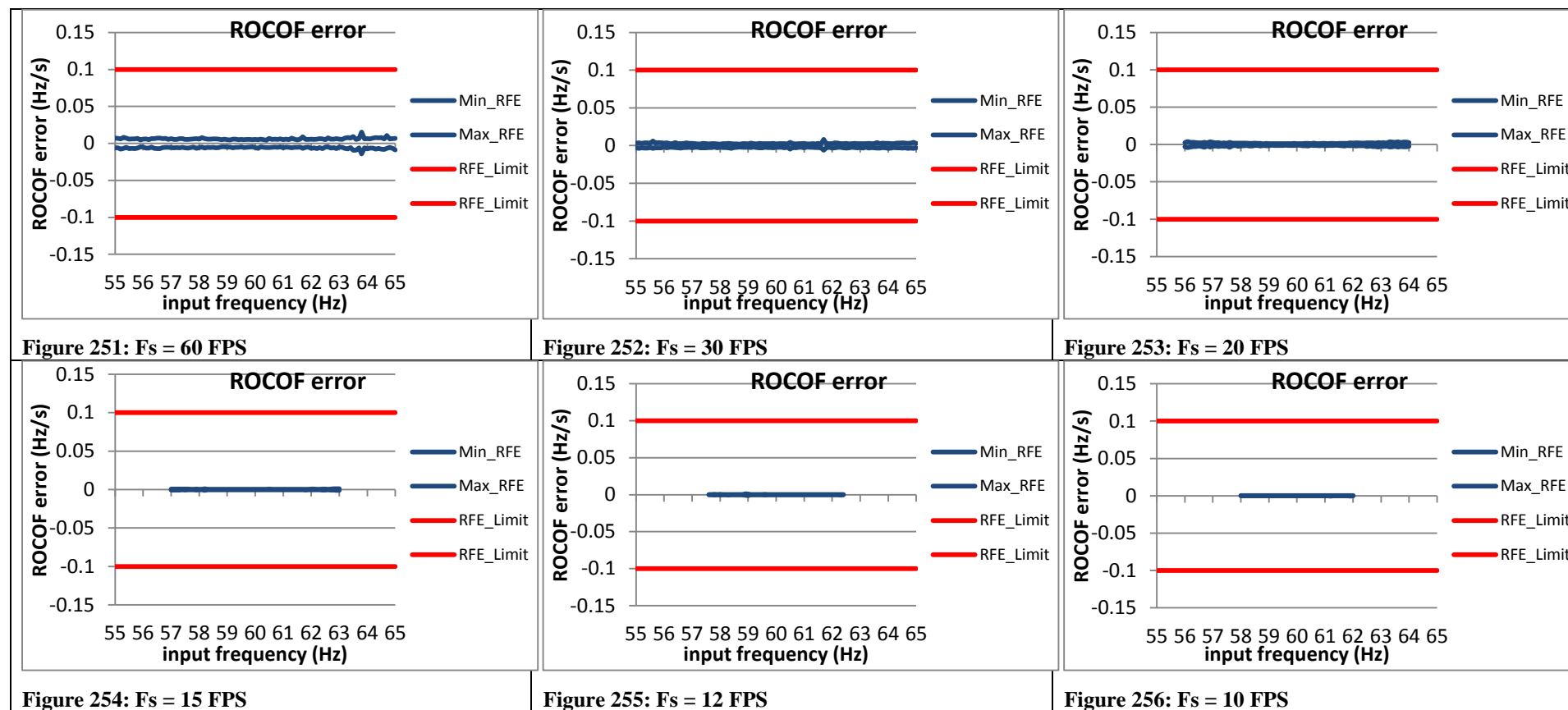
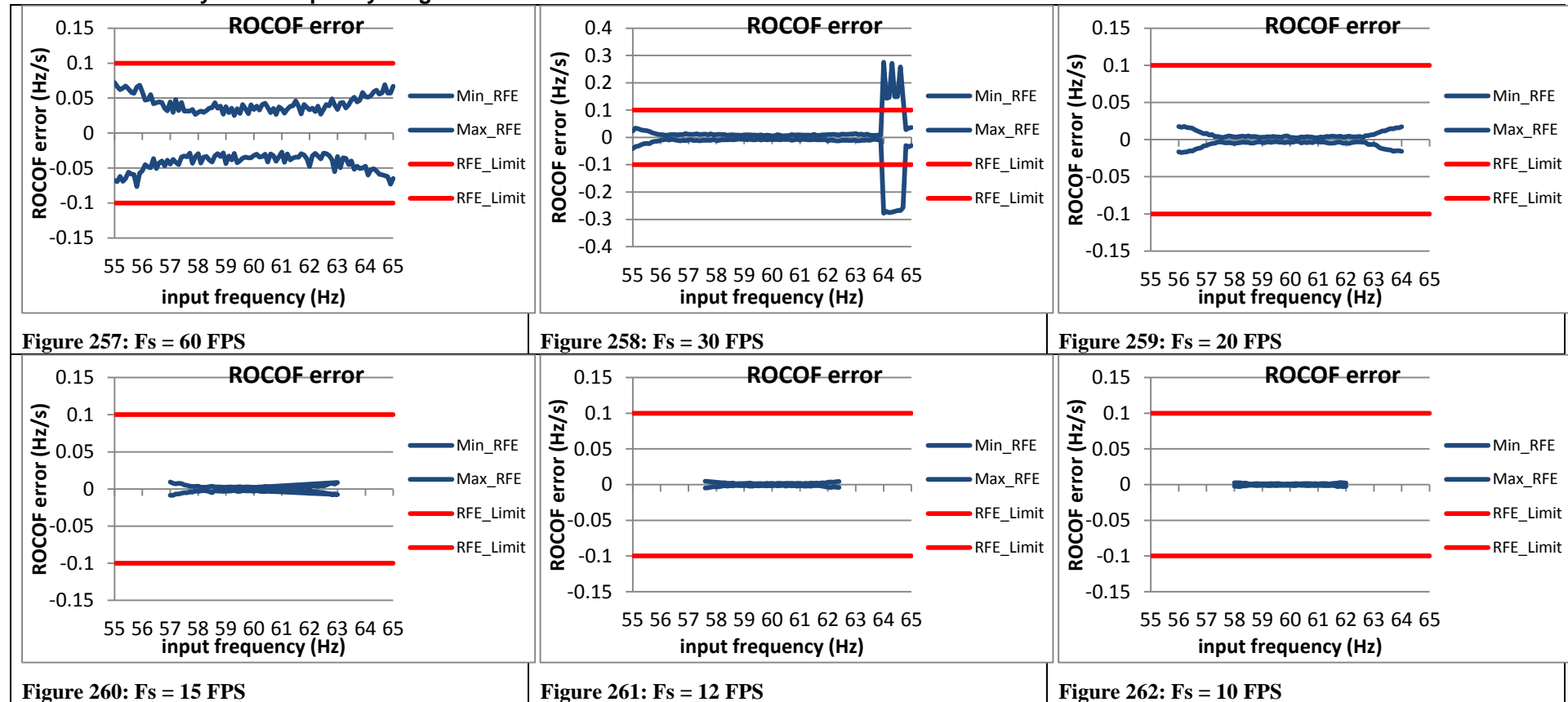


Figure 250:  $F_s = 10$  FPS

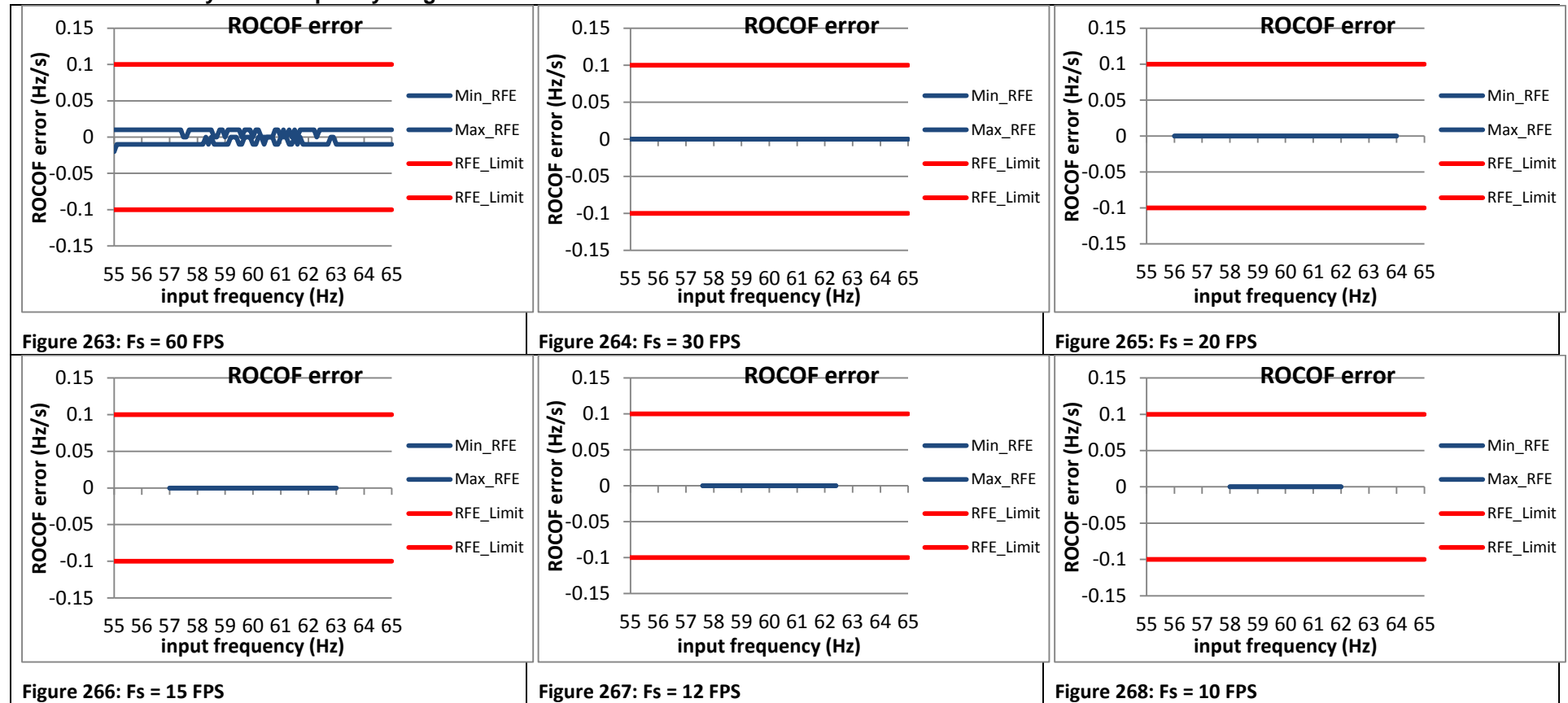
#### 2.4.9 PMU H steady state frequency range ROCOF error: M class



#### 2.4.10 PMU I steady state frequency range ROCOF error: M class



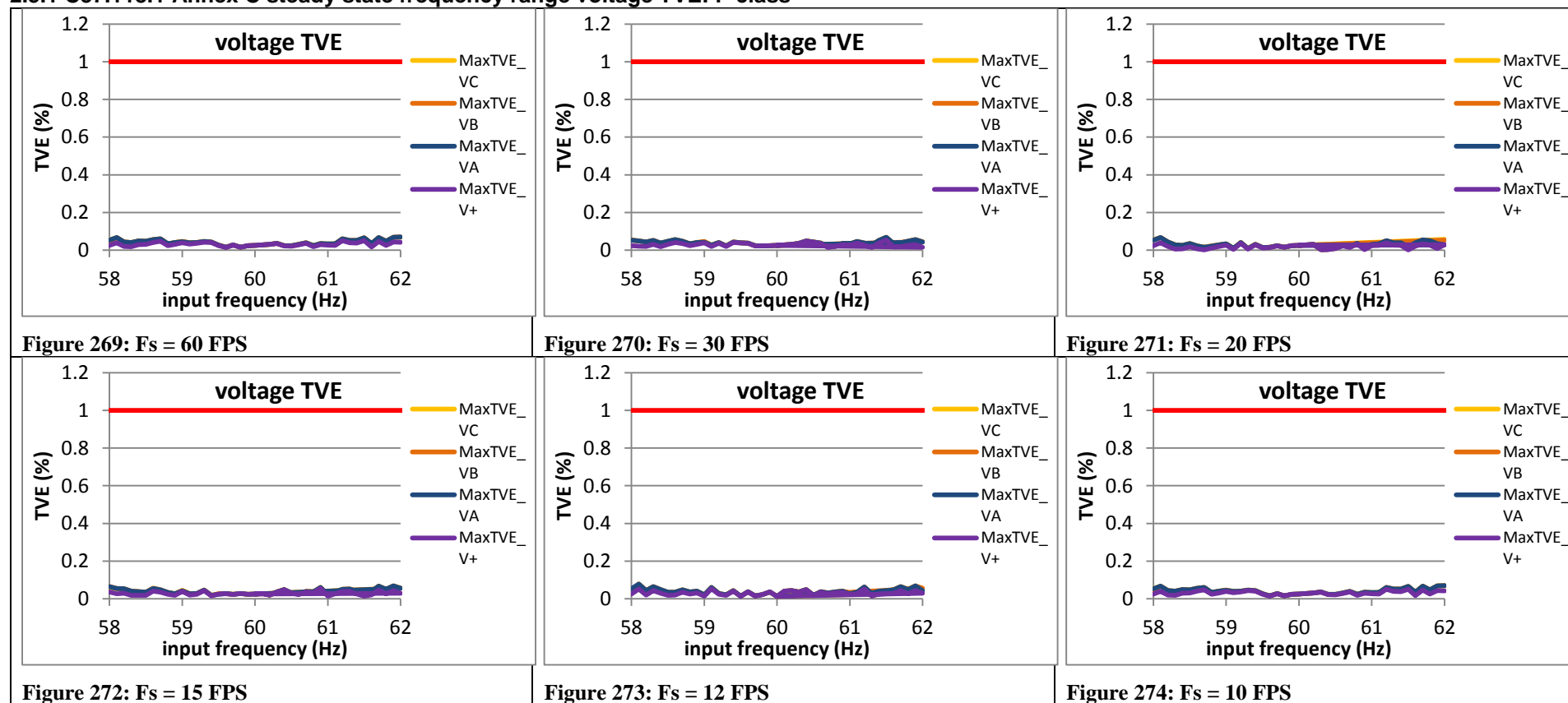
#### 2.4.11 PMU J steady state frequency range ROCOF error: M class



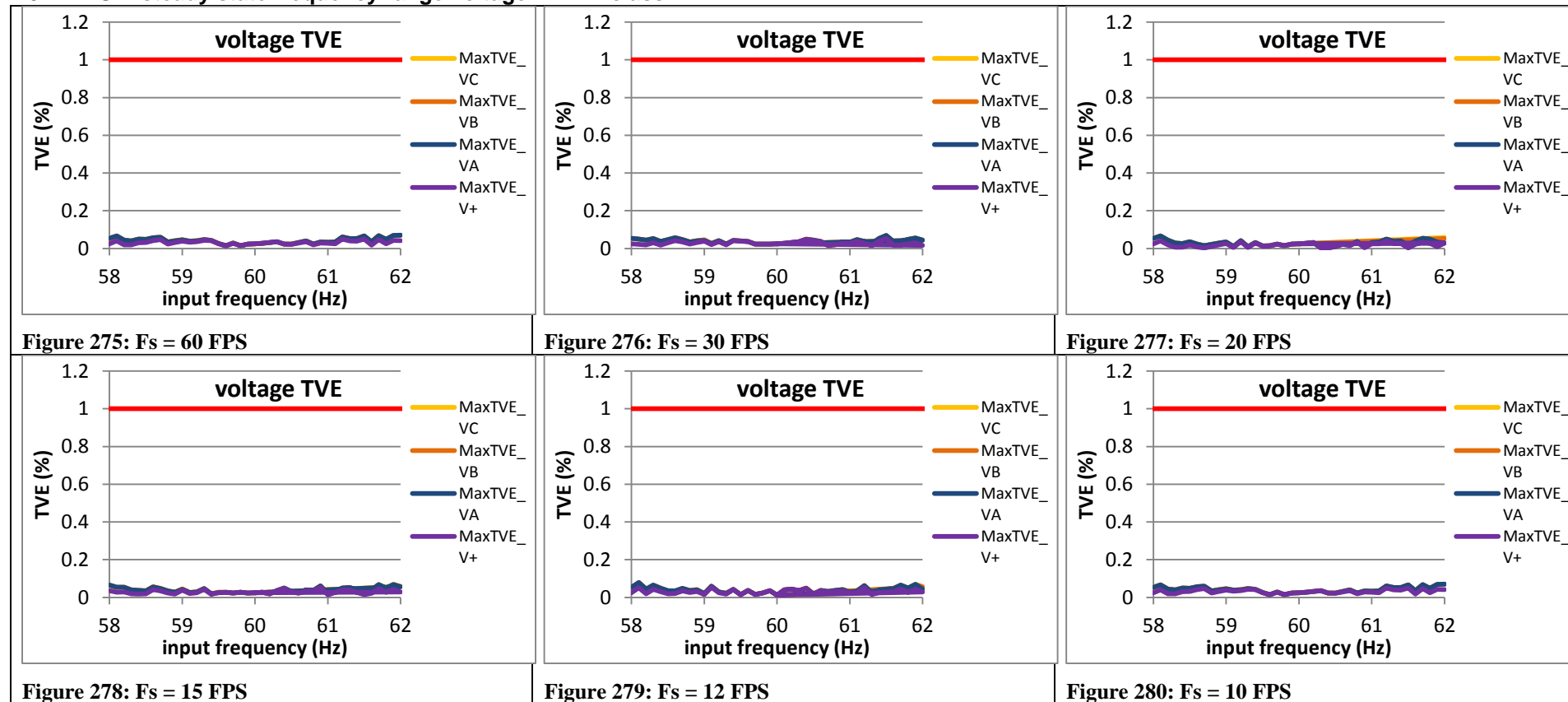


## 2.5 Steady state frequency range voltage TVE: P class

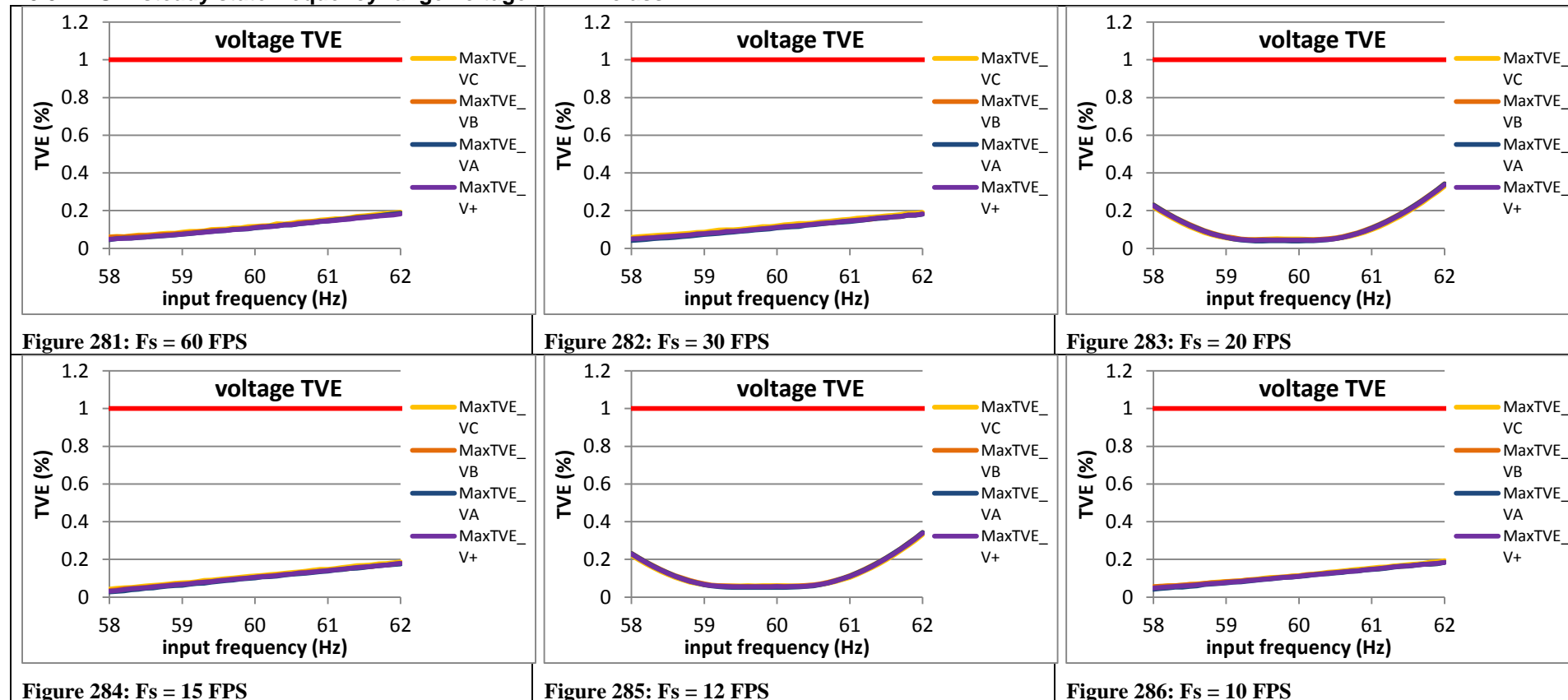
### 2.5.1 C37.118.1 Annex C steady state frequency range voltage TVE: P class



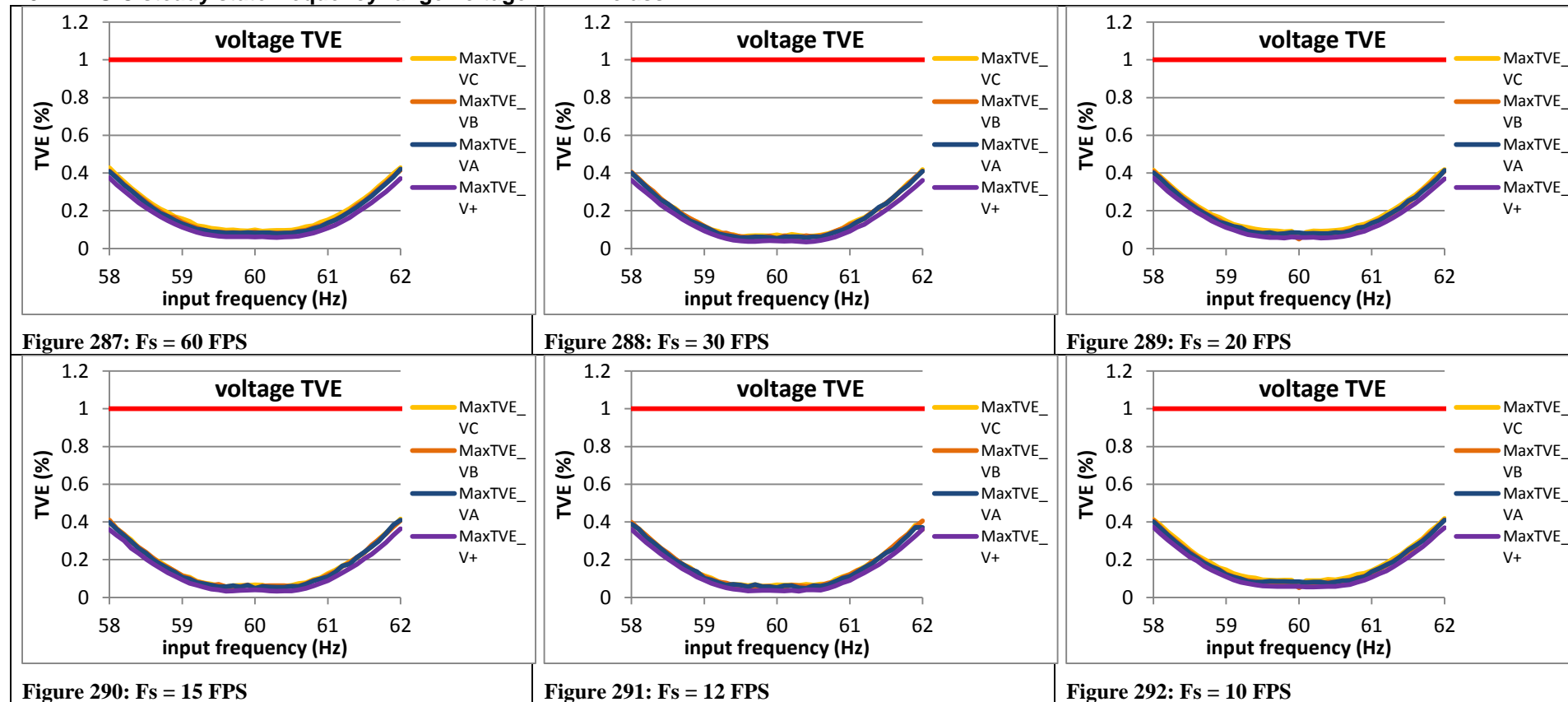
## 2.5.2 PMU A steady state frequency range voltage TVE: P class



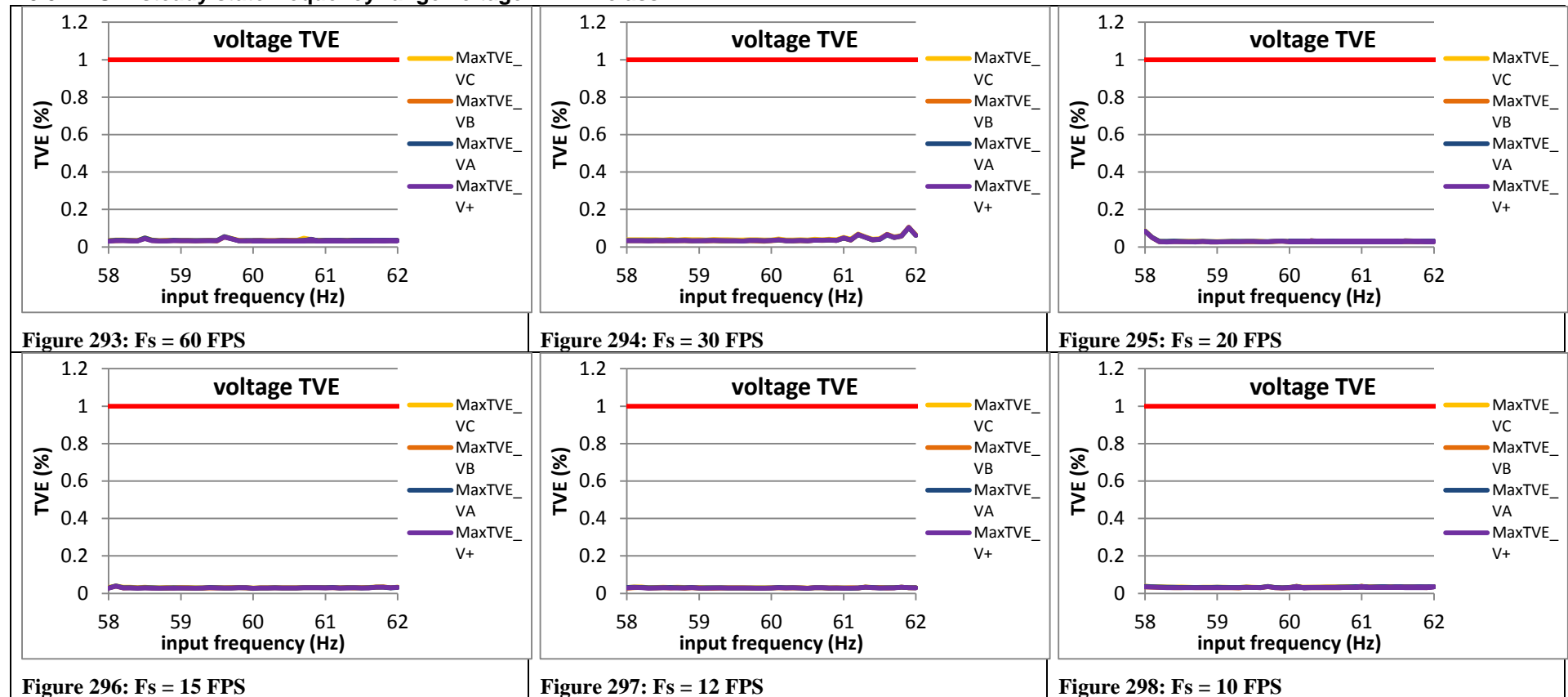
### 2.5.3 PMU B steady state frequency range voltage TVE: P class



## 2.5.4 PMU C steady state frequency range voltage TVE: P class



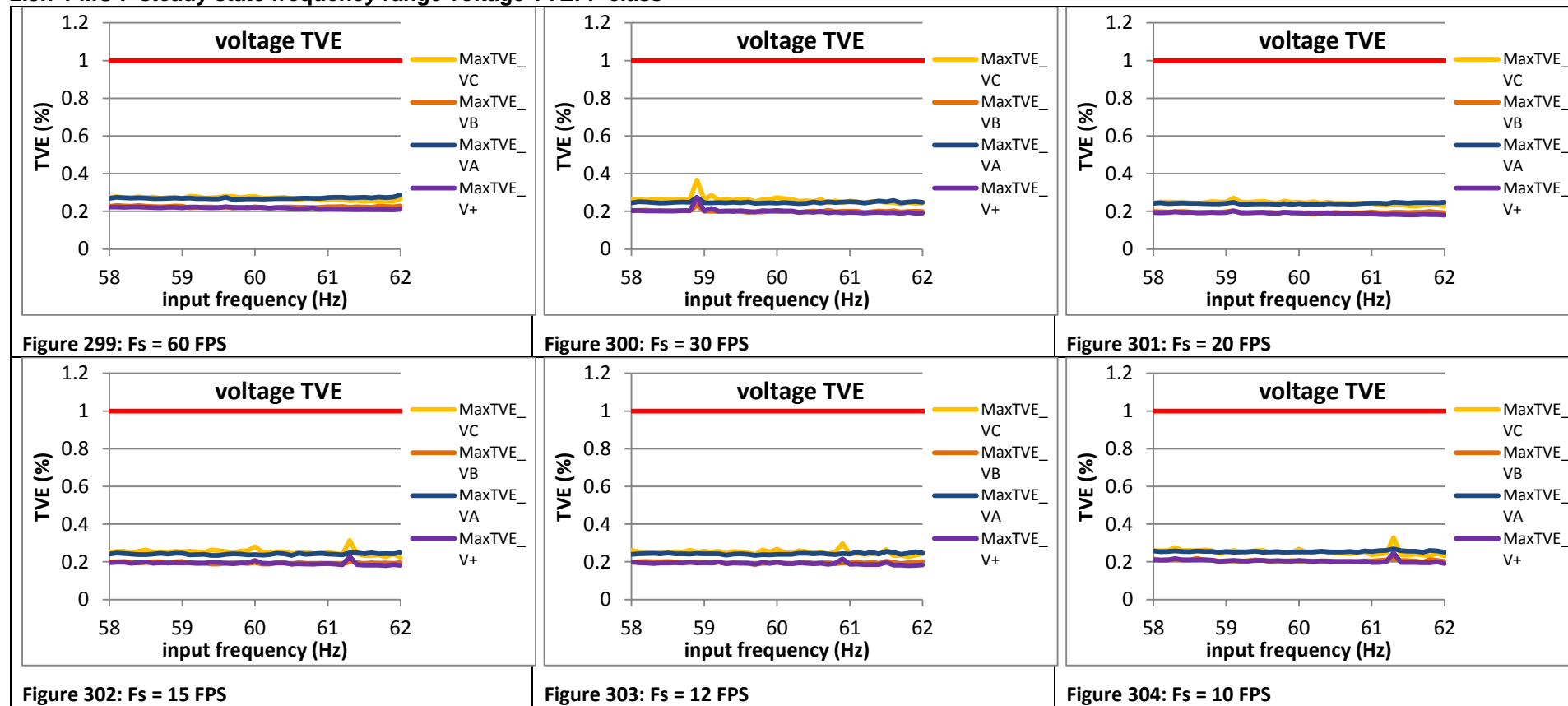
### 2.5.5 PMU D steady state frequency range voltage TVE: P class



### 2.5.6 PMU E steady state frequency range voltage TVE: P class

This PMU does not support P class

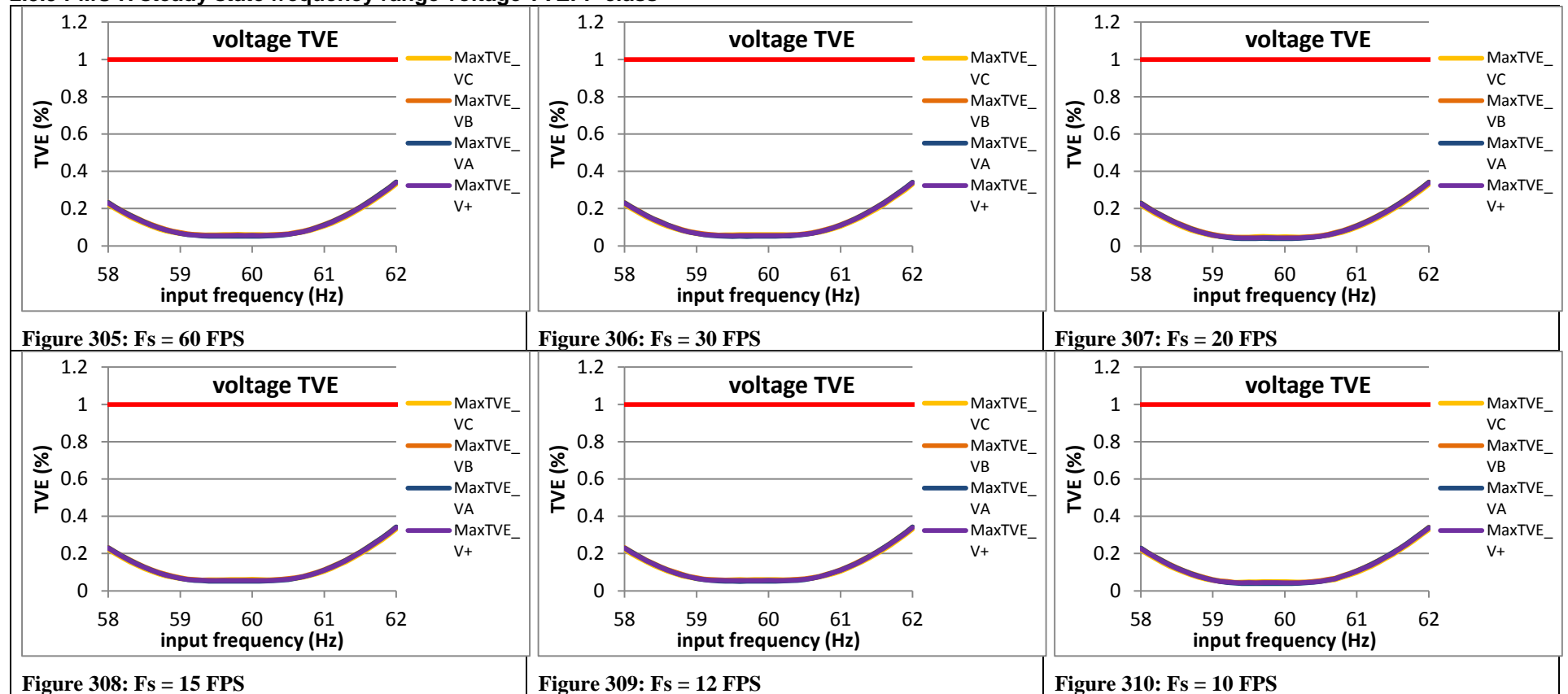
### 2.5.7 PMU F steady state frequency range voltage TVE: P class



### 2.5.8 PMU G steady state frequency range voltage TVE: P class

This PMU does not support P class

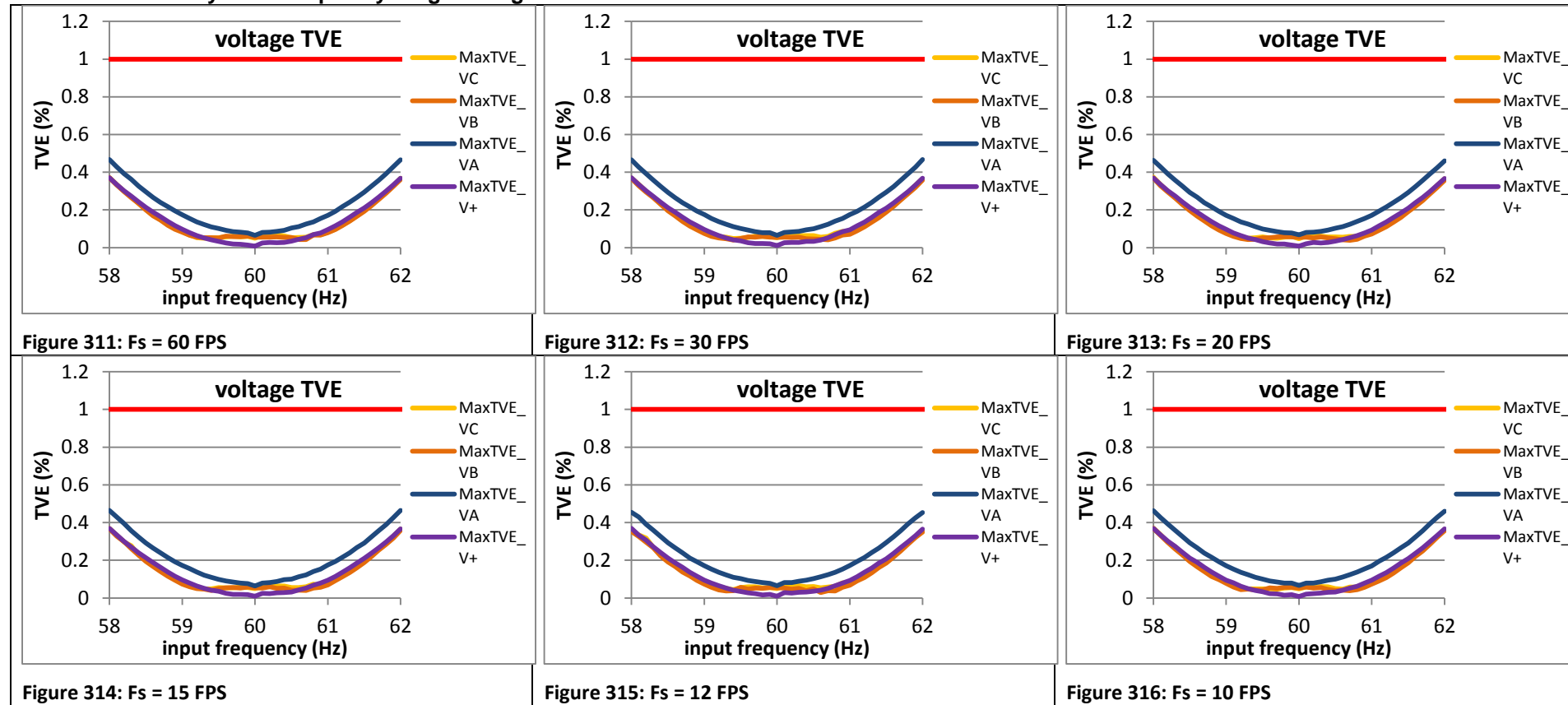
### 2.5.9 PMU H steady state frequency range voltage TVE: P class



### 2.5.10 PMU I steady state frequency range voltage TVE: P class

PMU I does not support P class

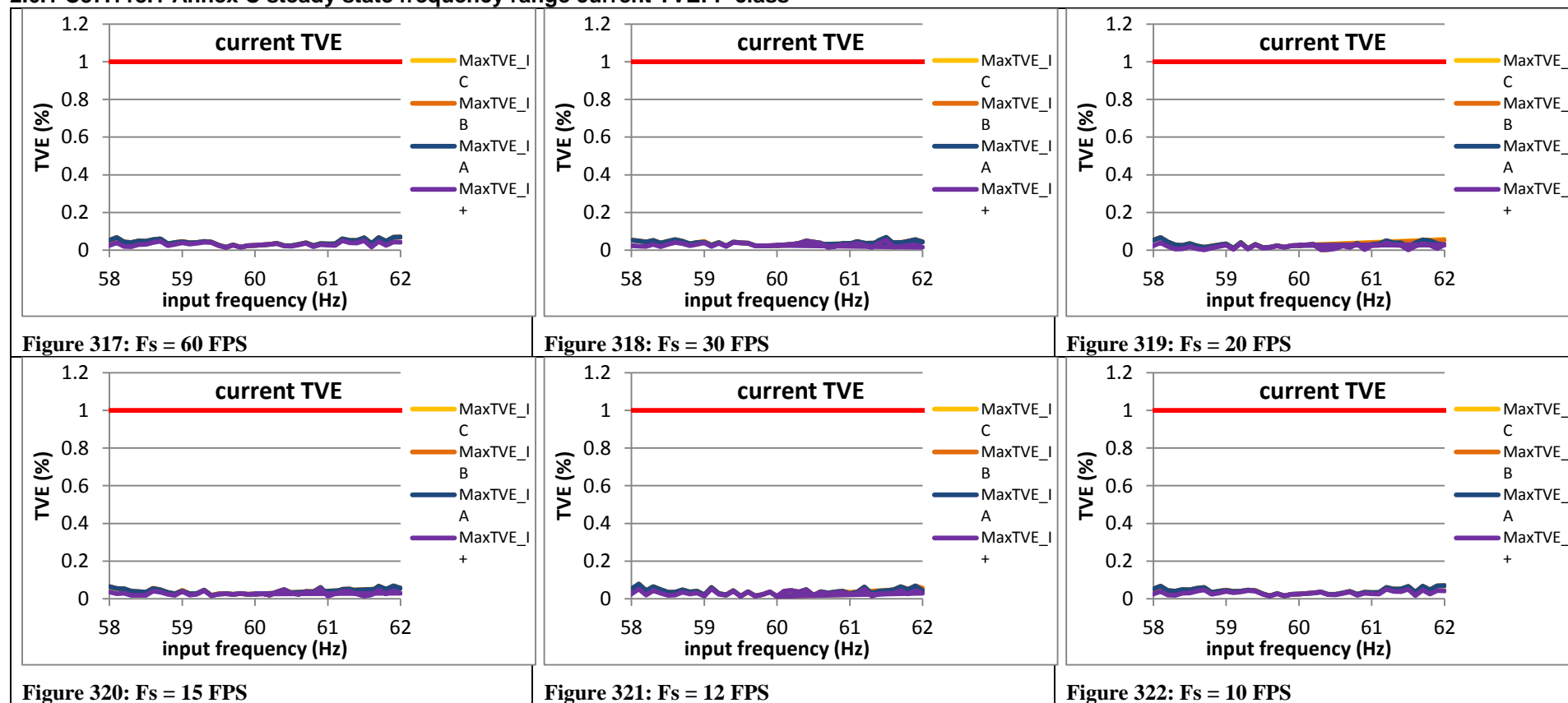
### 2.5.11 PMU J steady state frequency range voltage TVE: P class



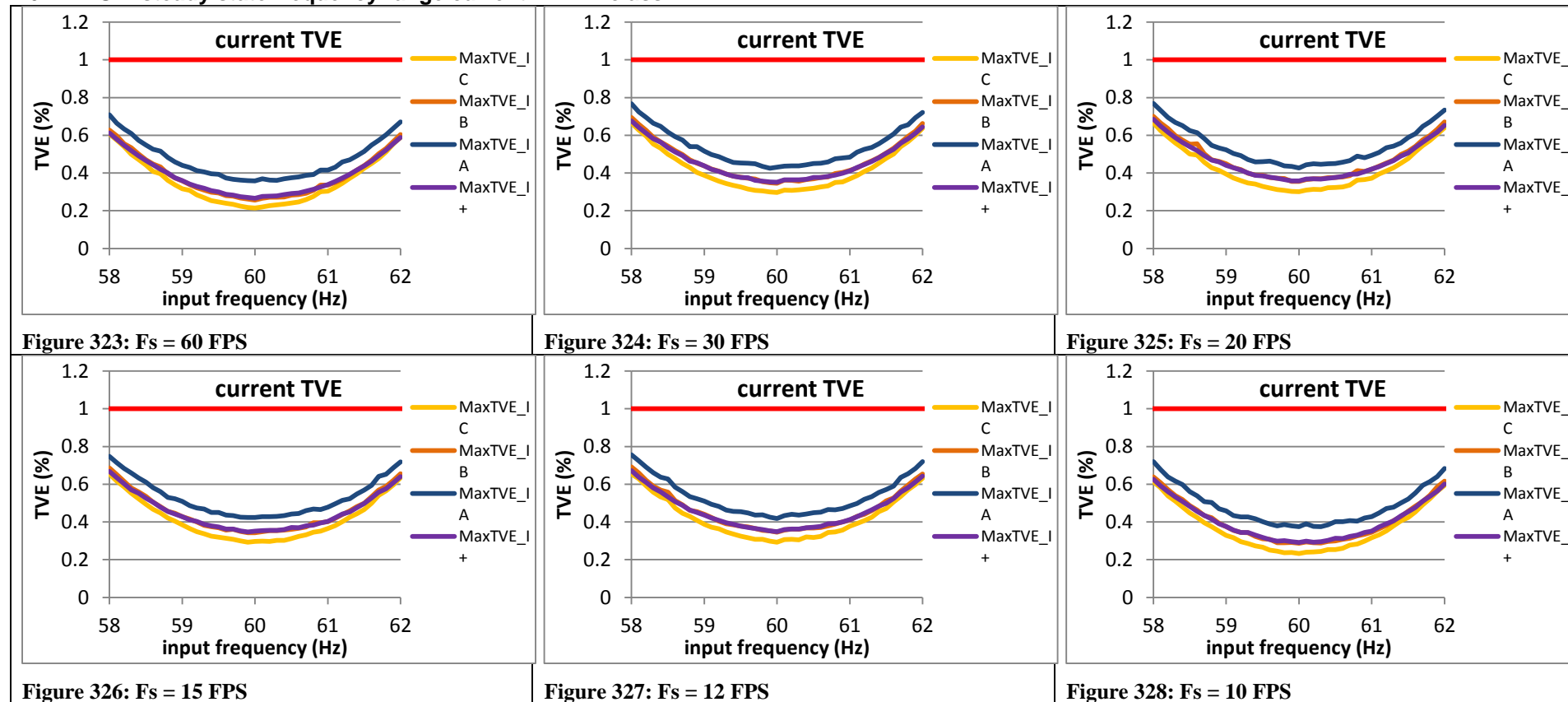


## 2.6 Steady state frequency range current TVE: P class

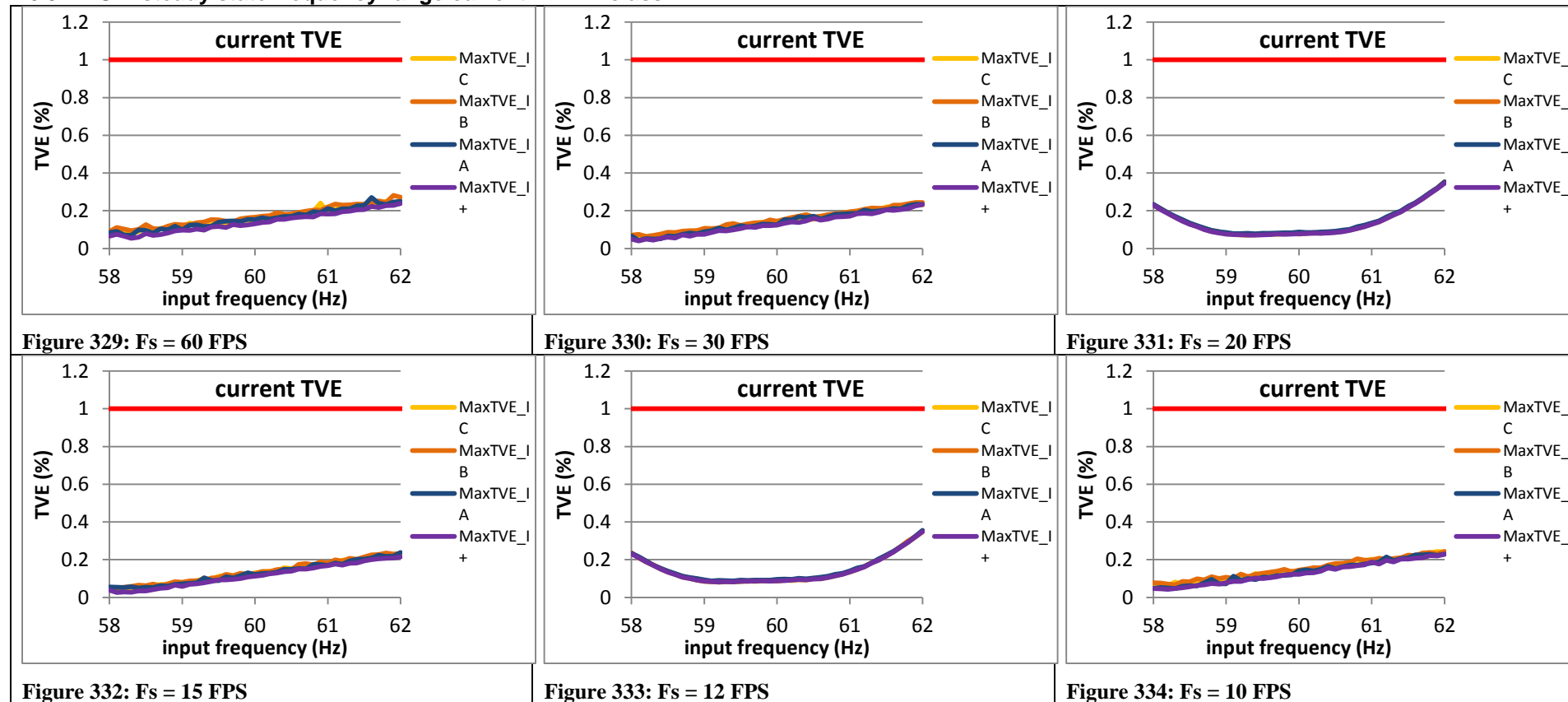
### 2.6.1 C37.118.1 Annex C steady state frequency range current TVE: P class



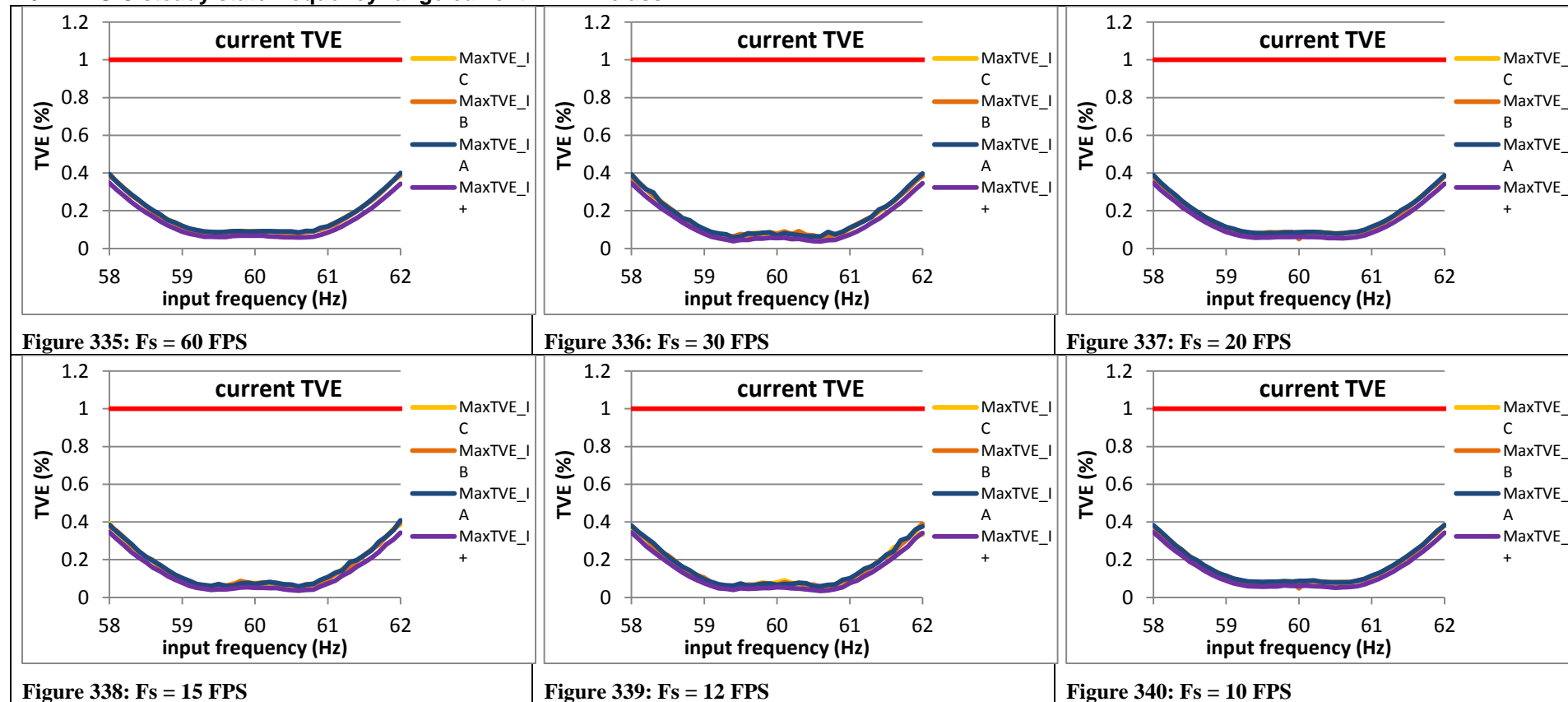
## 2.6.2 PMU A steady state frequency range current TVE: P class



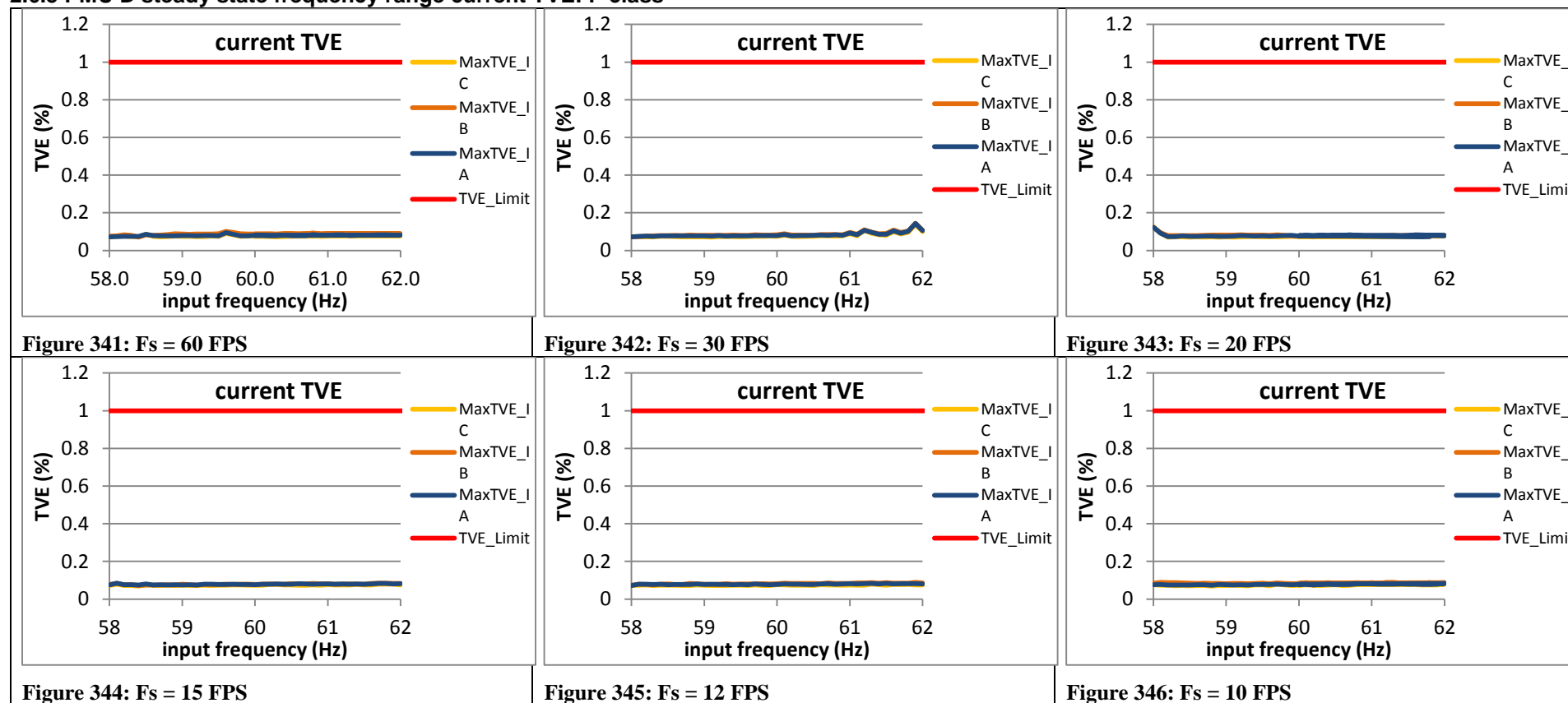
### 2.6.3 PMU B steady state frequency range current TVE: P class



## 2.6.4 PMU C steady state frequency range current TVE: P class



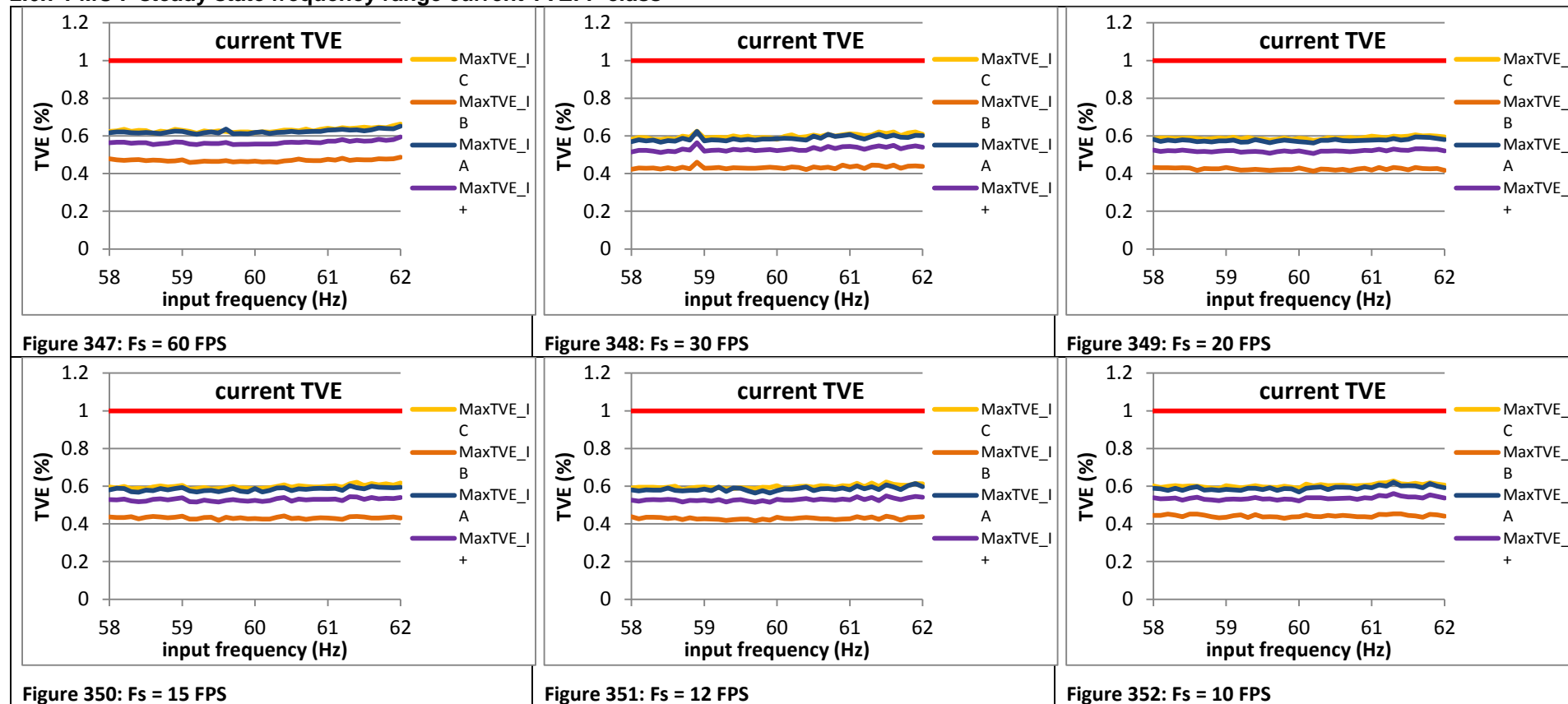
### 2.6.5 PMU D steady state frequency range current TVE: P class



### 2.6.6 PMU E steady state frequency range current TVE: P class

This PMU does not support P class

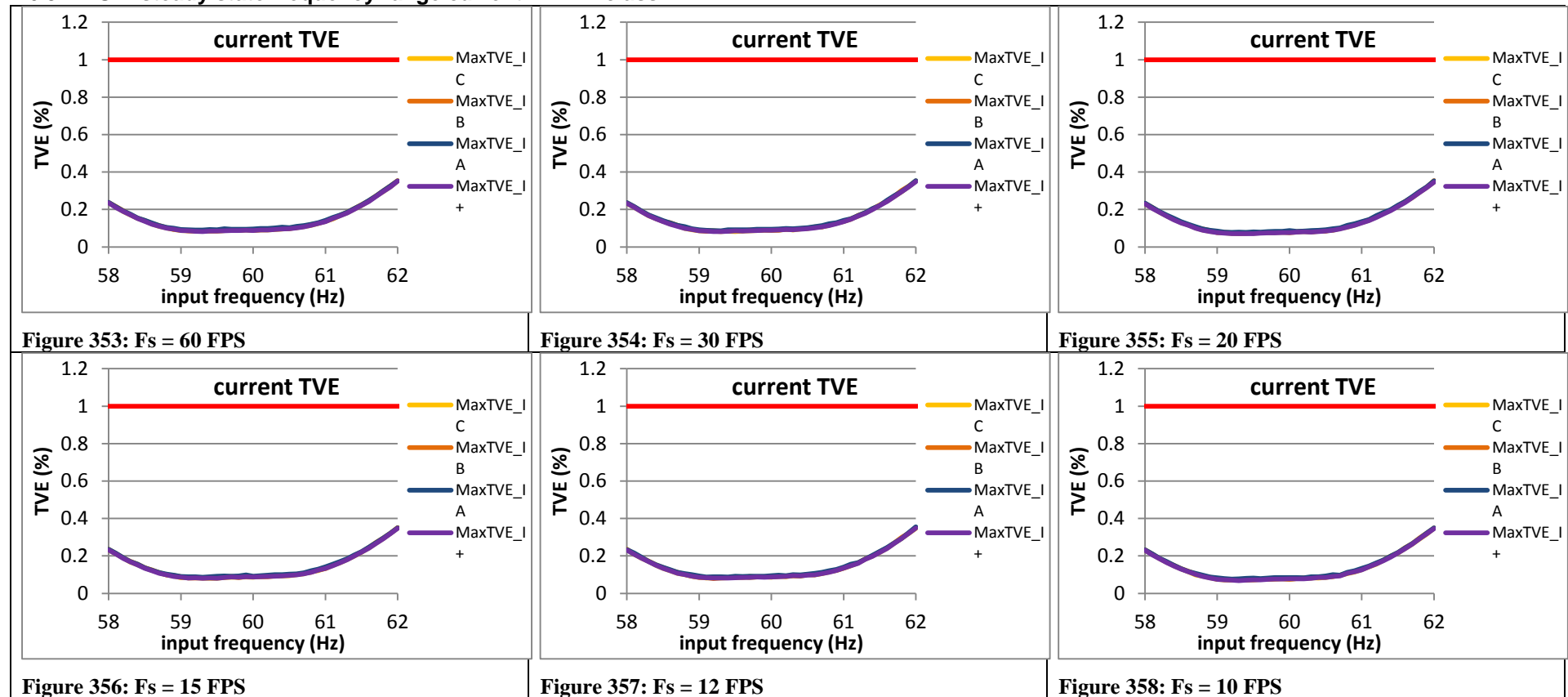
### 2.6.7 PMU F steady state frequency range current TVE: P class



### 2.6.8 PMU G steady state frequency range current TVE: P class

This PMU does not support P class

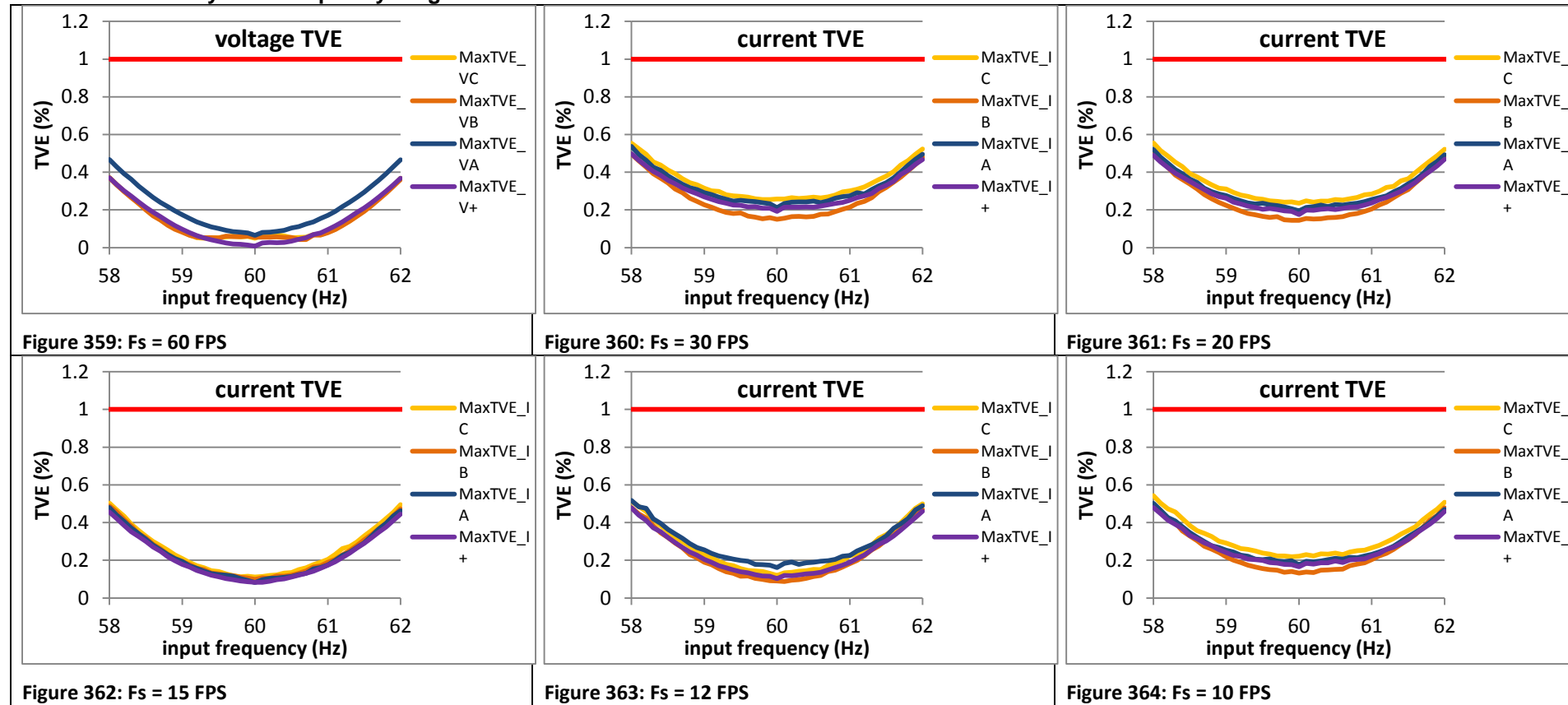
### 2.6.9 PMU H steady state frequency range current TVE: P class



### 2.6.10 PMU I steady state frequency range current TVE: P class

PMU I does not support P class

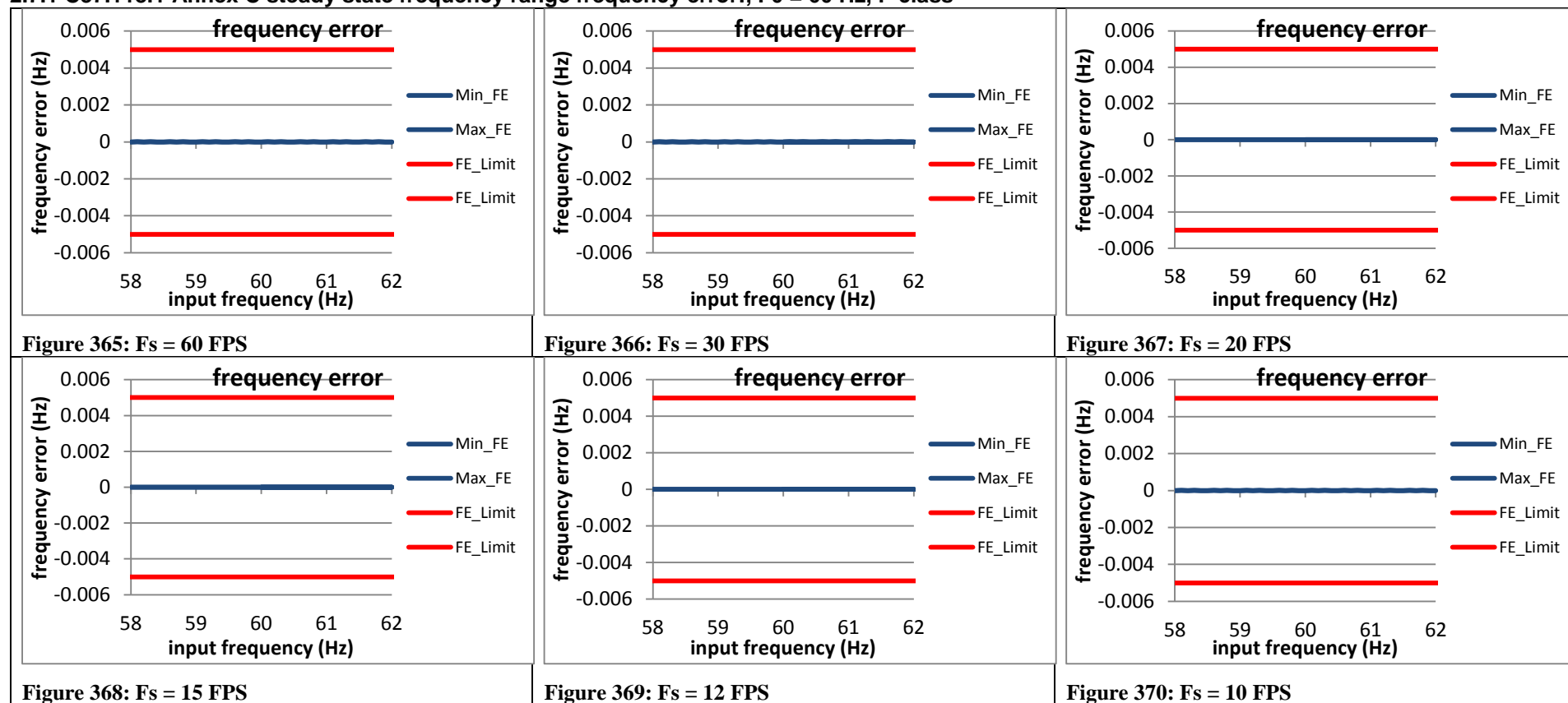
## 2.6.11 PMU J steady state frequency range current TVE: P class



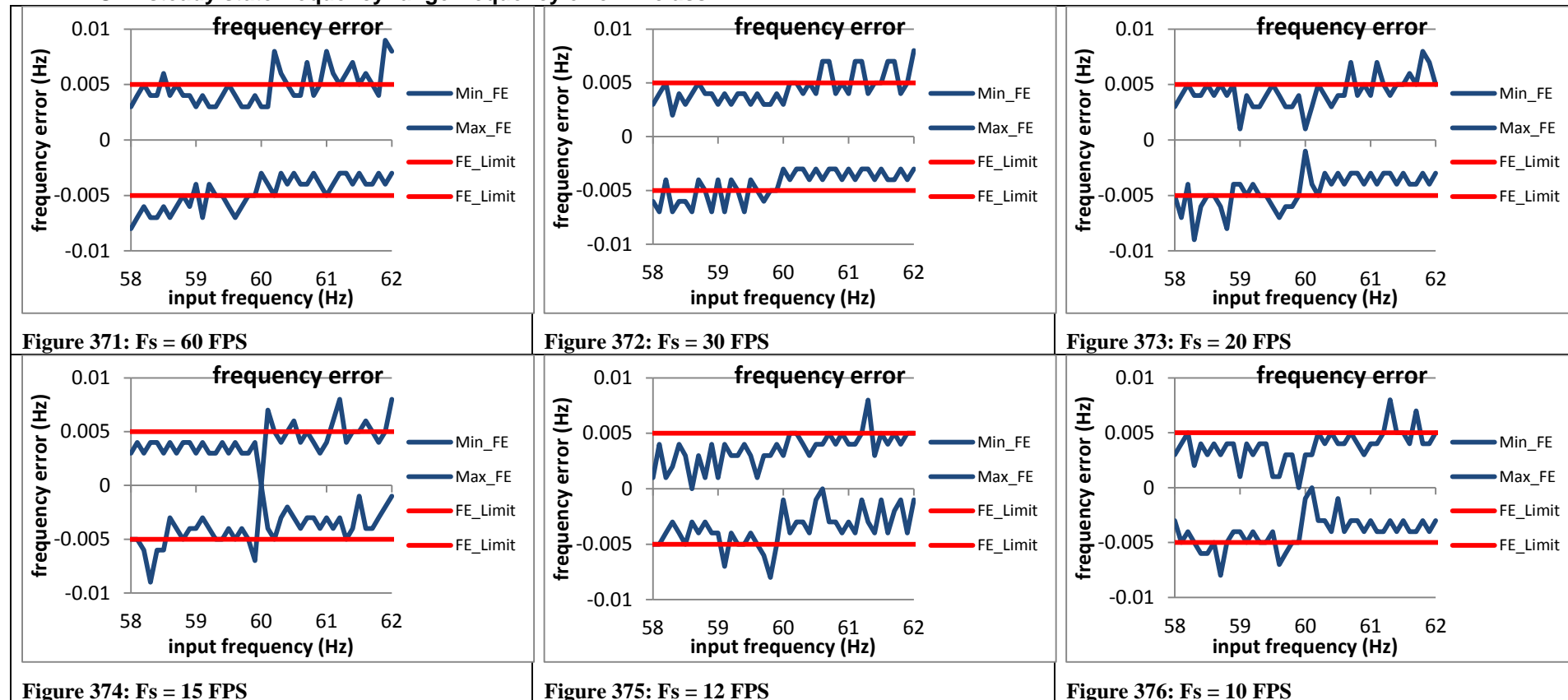


## 2.7 Steady state frequency range frequency error: P class

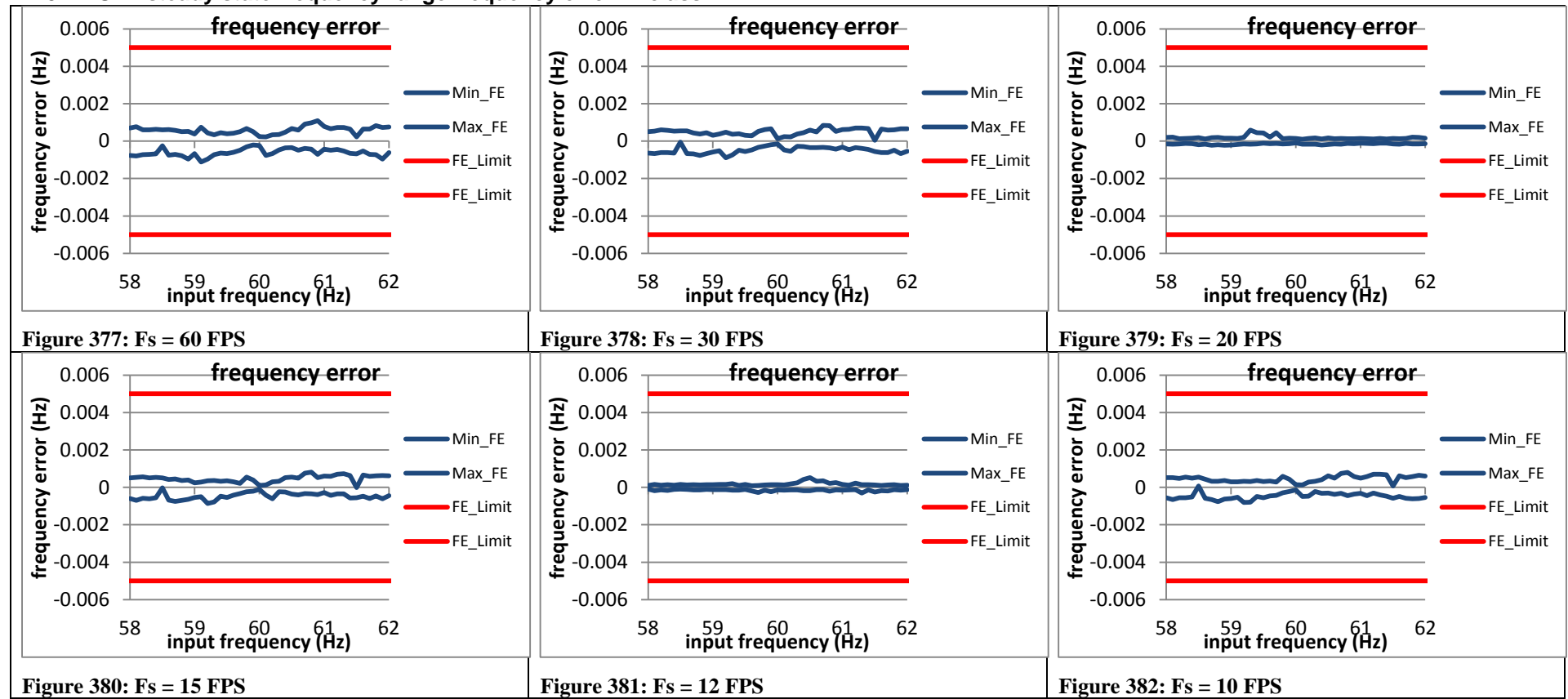
### 2.7.1 C37.118.1 Annex C steady state frequency range frequency error:, F0 = 60 Hz, P class



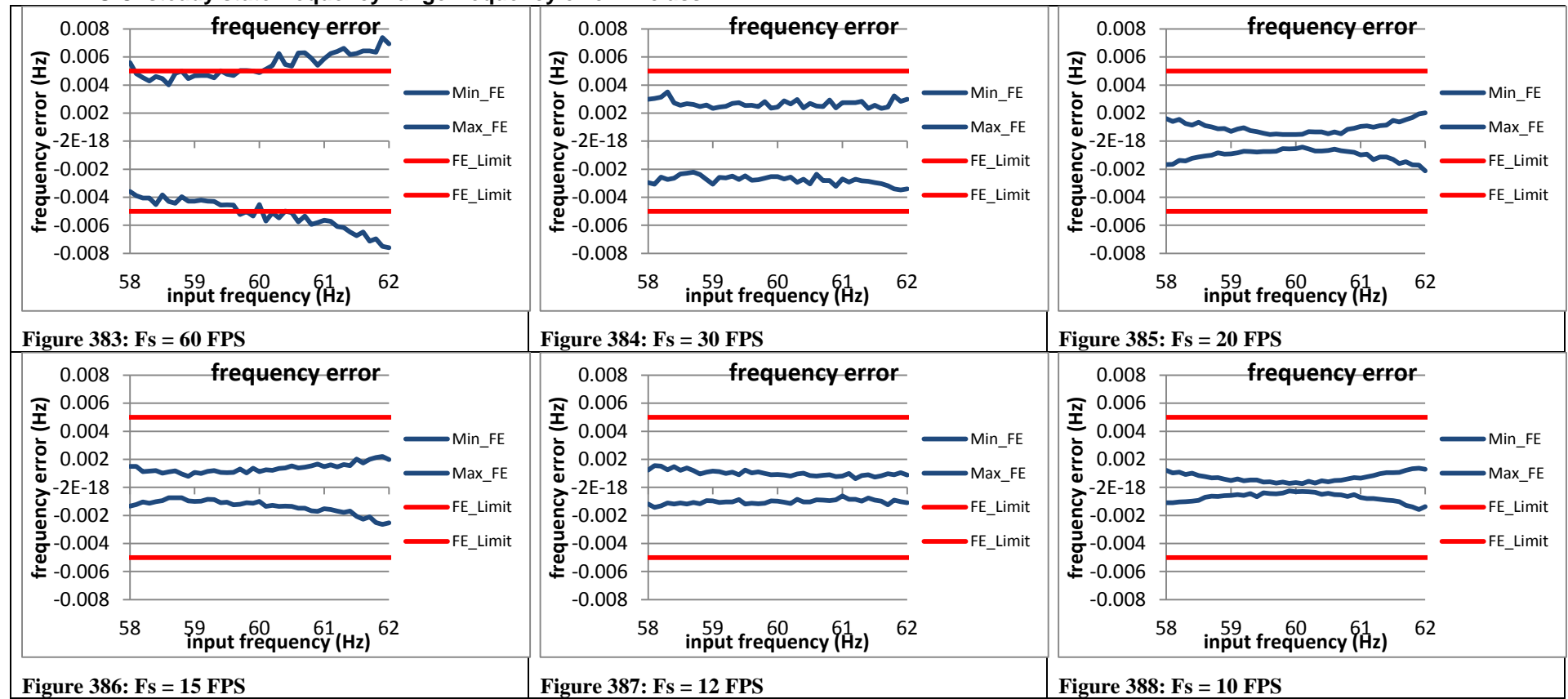
## 2.7.2 PMU A steady state frequency range frequency error: P class



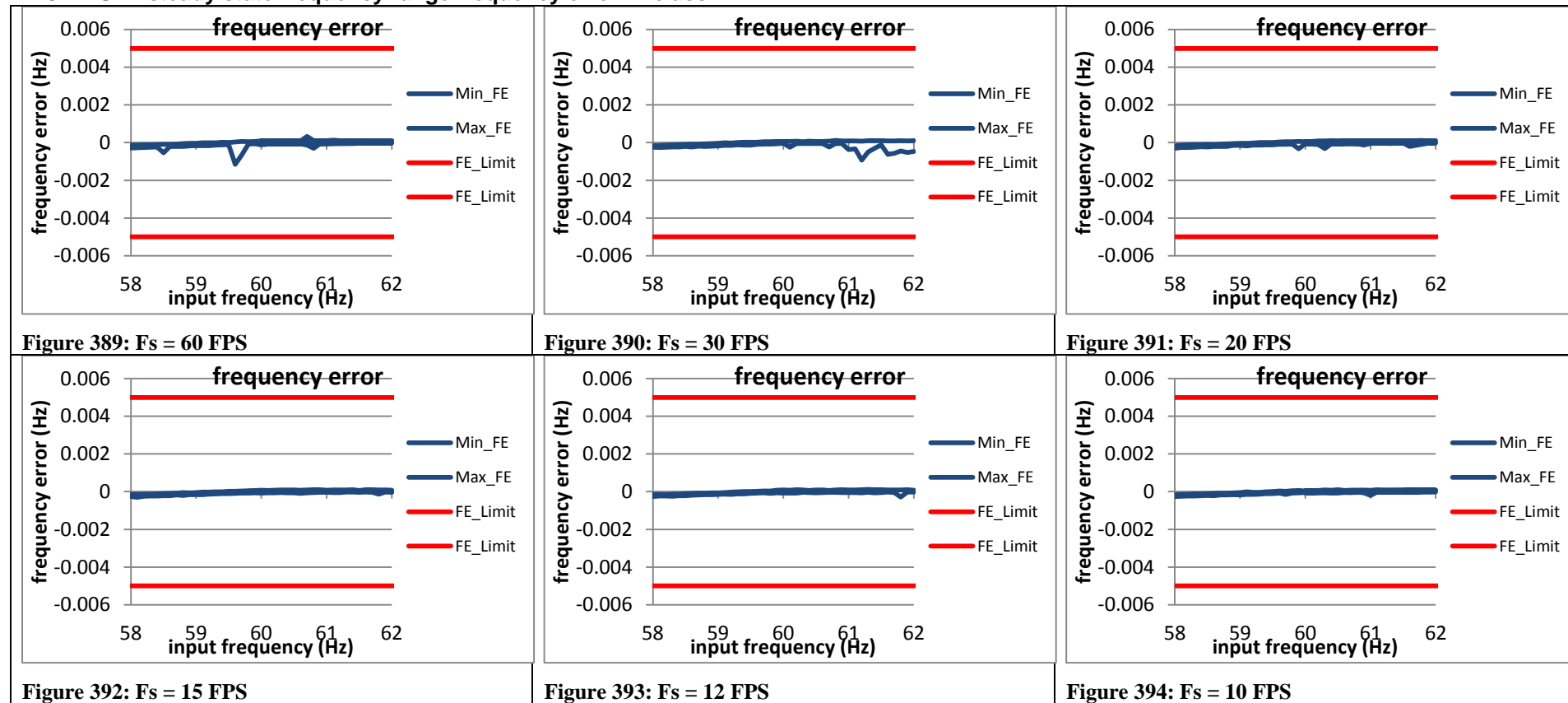
### 2.7.3 PMU B steady state frequency range frequency error: P class



## 2.7.4 PMU C steady state frequency range frequency error: P class



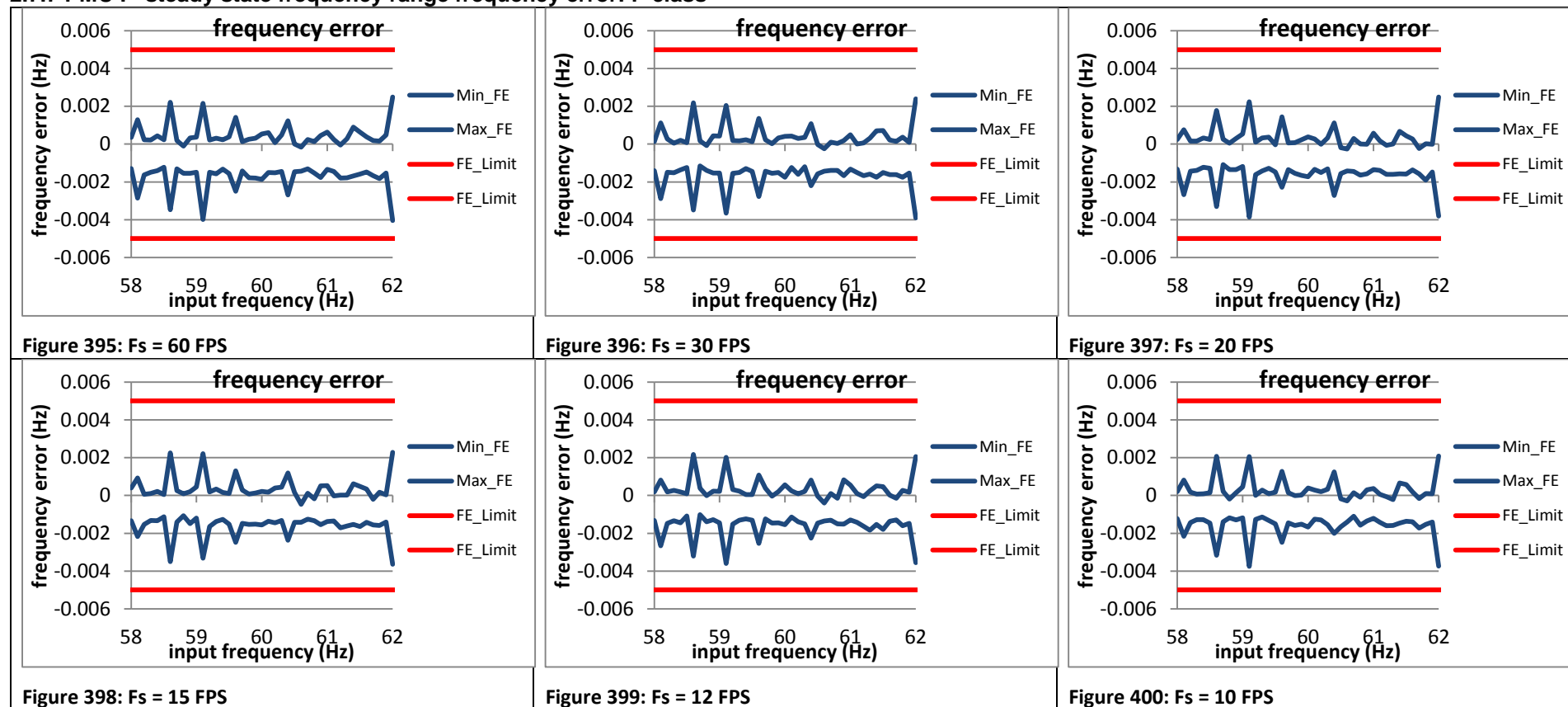
### 2.7.5 PMU D steady state frequency range frequency error: P class



### 2.7.6 PMU E steady state frequency range frequency error: P class

This PMU does not support P class

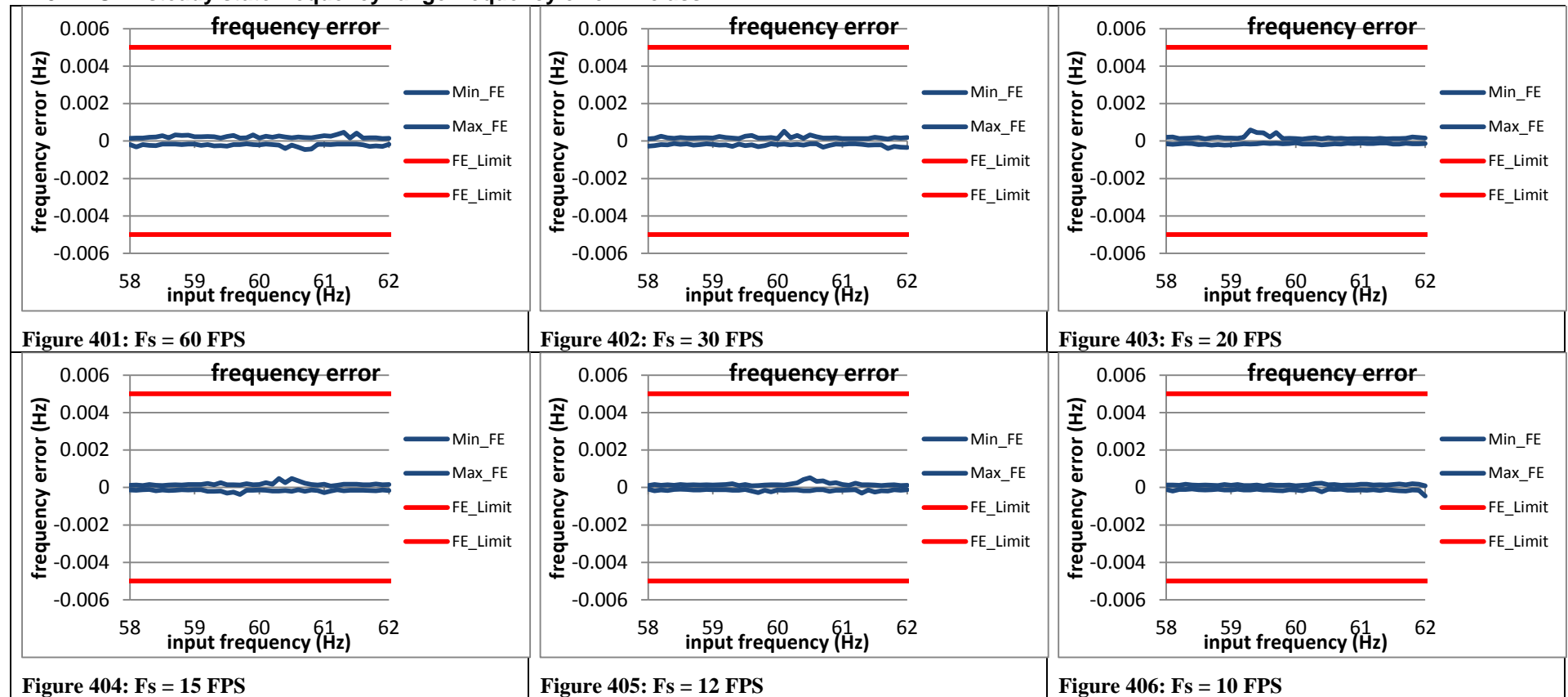
### 2.7.7 PMU F steady state frequency range frequency error: P class



### 2.7.8 PMU G steady state frequency range frequency error: P class

This PMU does not support P class

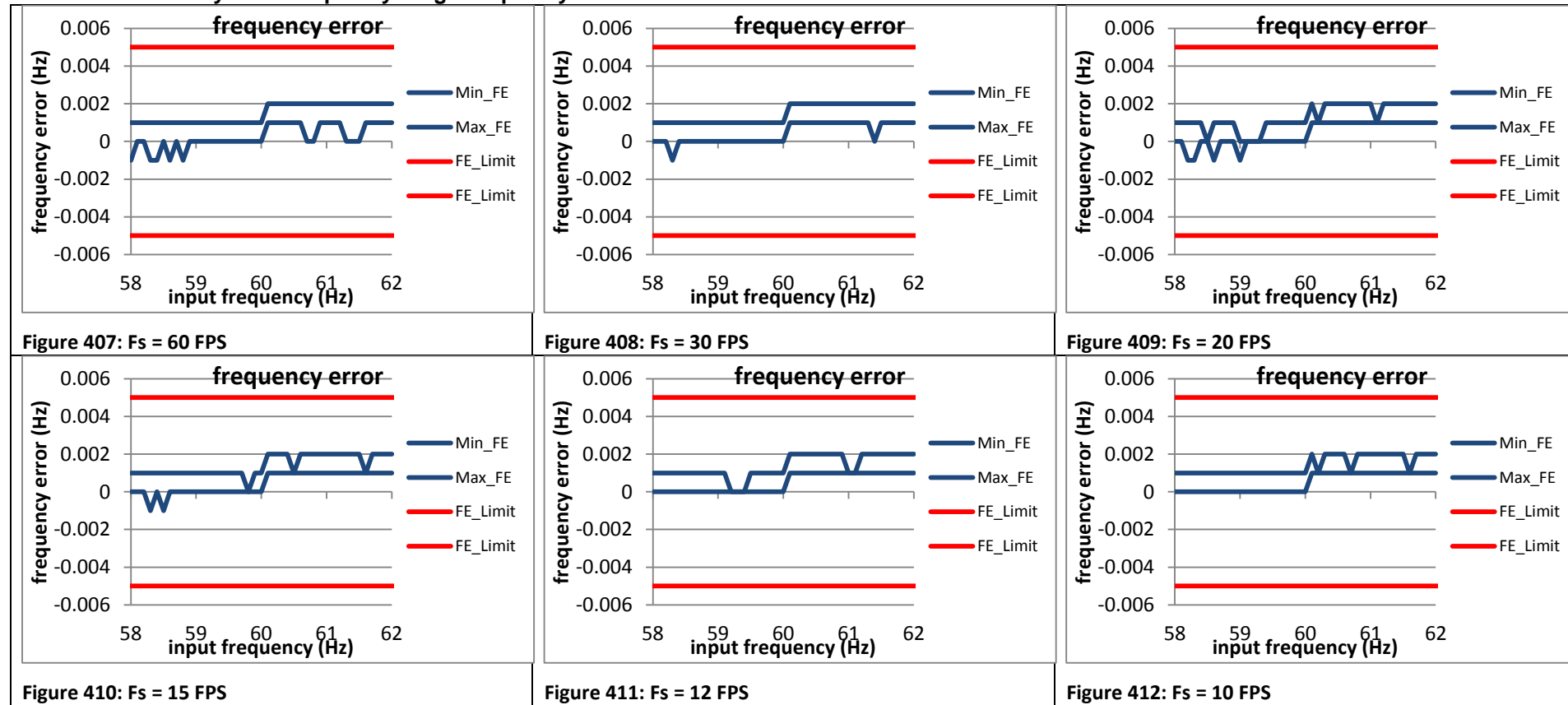
### 2.7.9 PMU H steady state frequency range frequency error: P class



### 2.7.10 PMU I steady state frequency range frequency error: P class

PMU I does not support P class

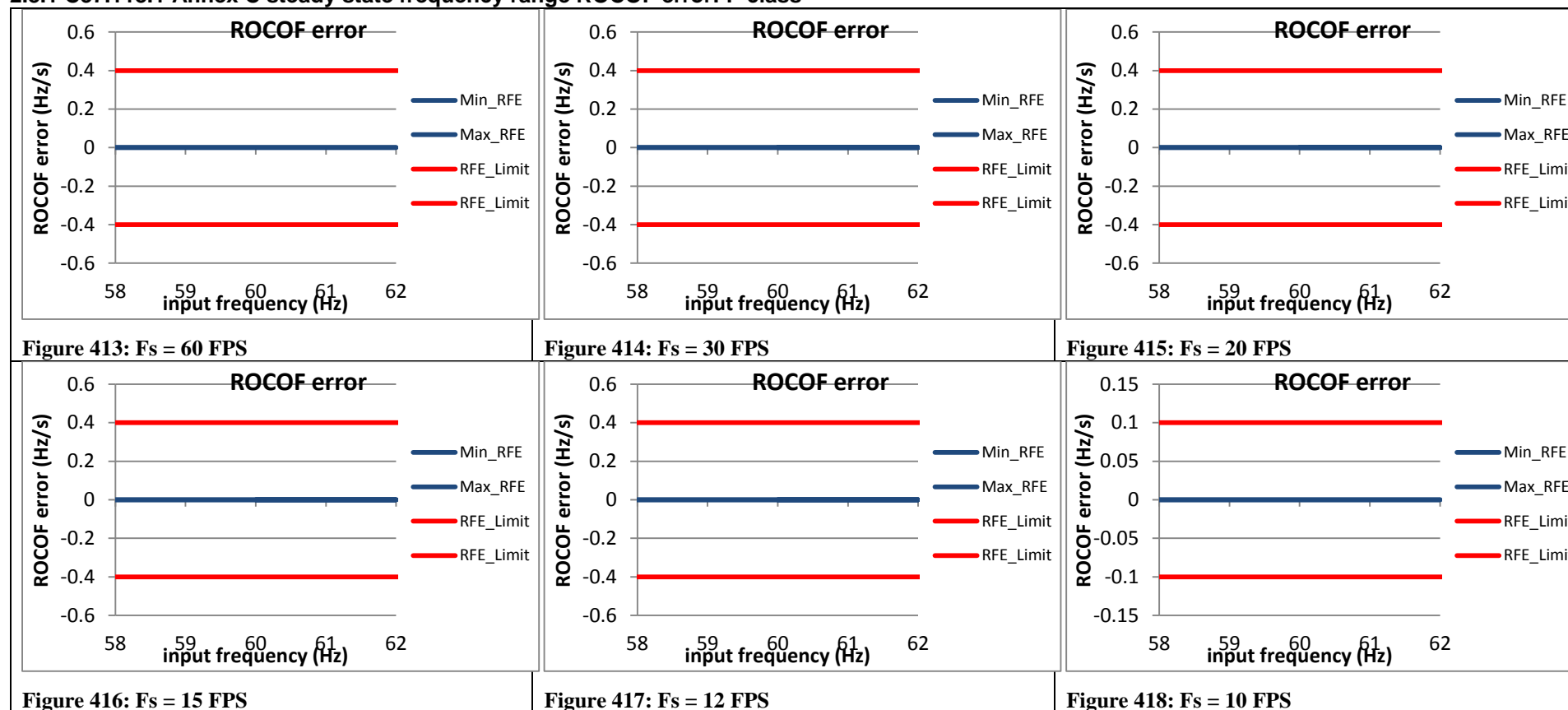
## 2.7.11 PMU J steady state frequency range frequency error: P class



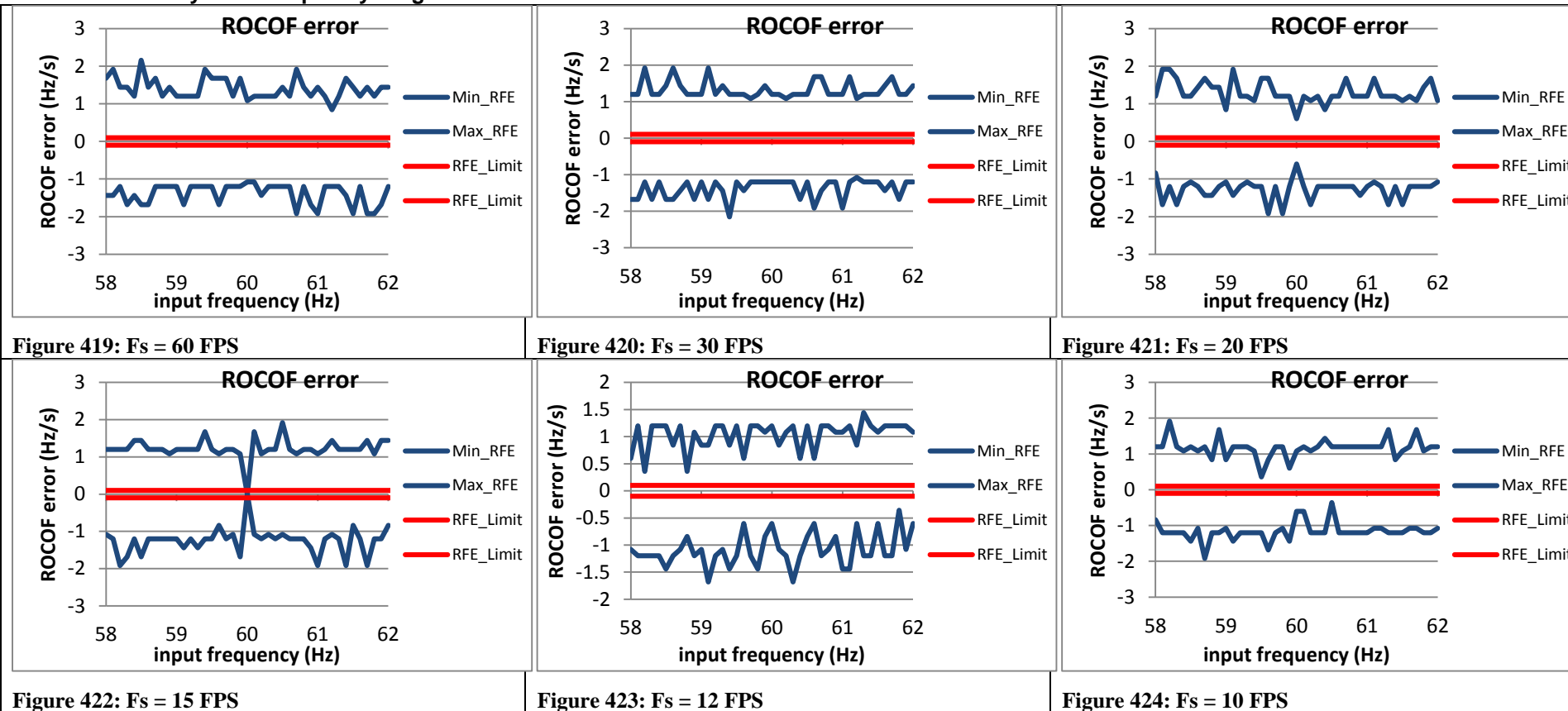


## 2.8 Steady state frequency range ROCOF error: P class

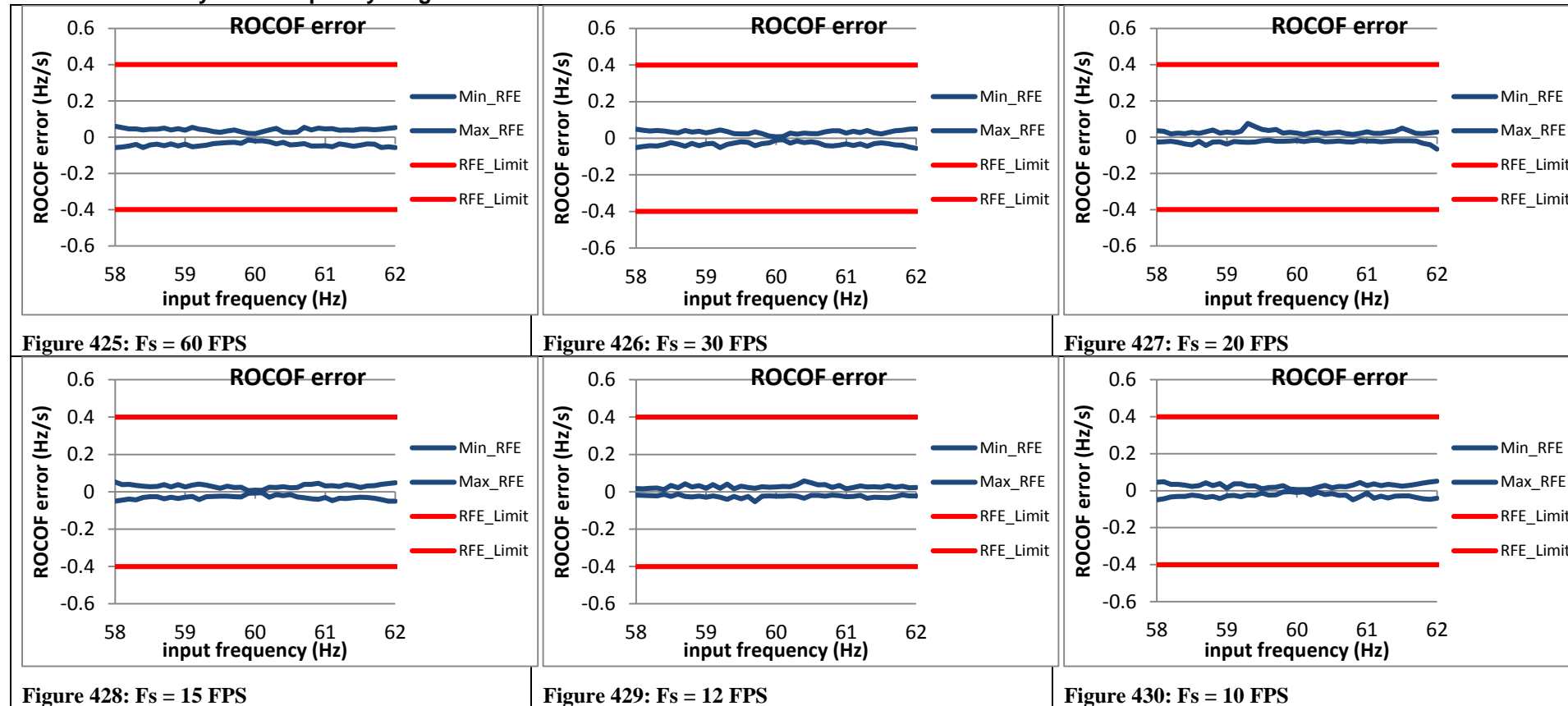
### 2.8.1 C37.118.1 Annex C steady state frequency range ROCOF error: P class



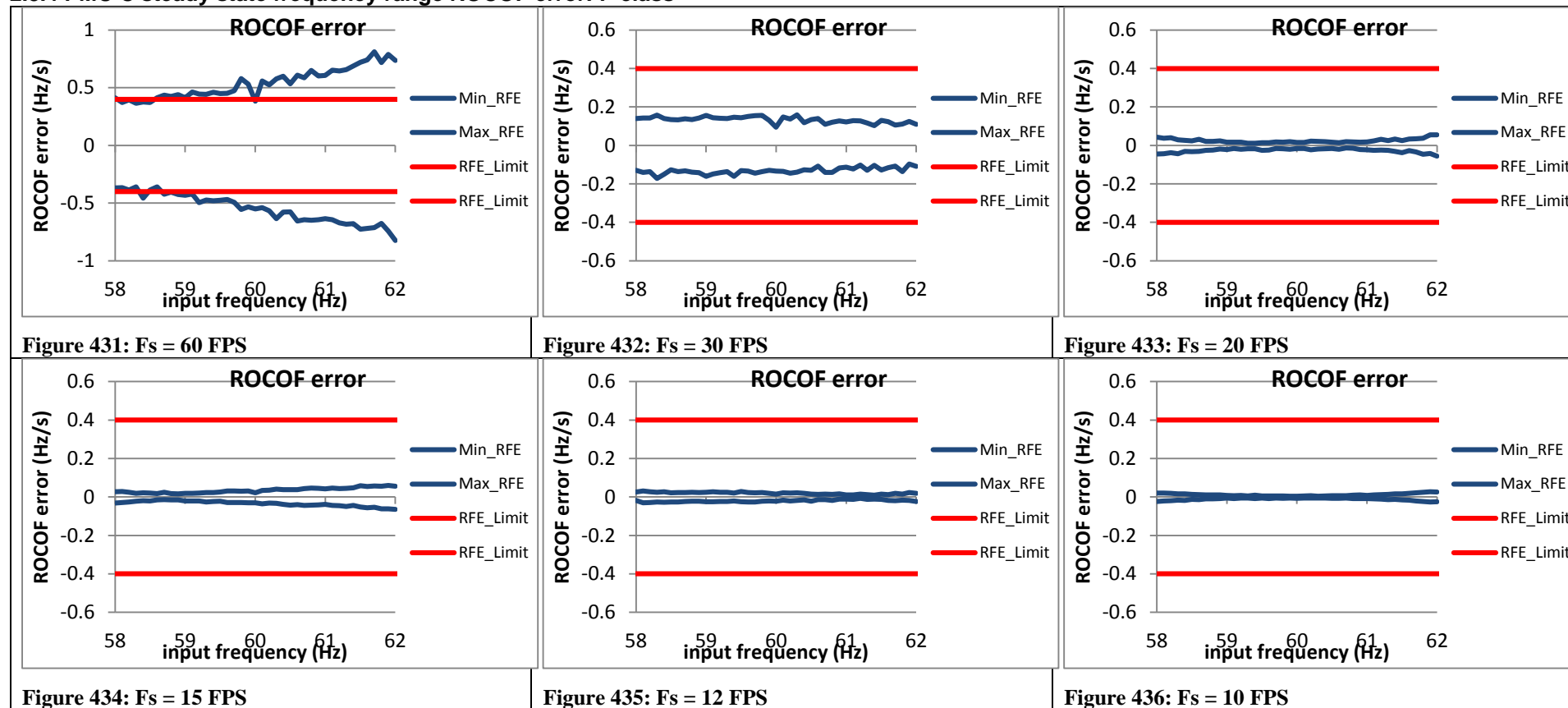
## 2.8.2 PMU A steady state frequency range ROCOF error: P class



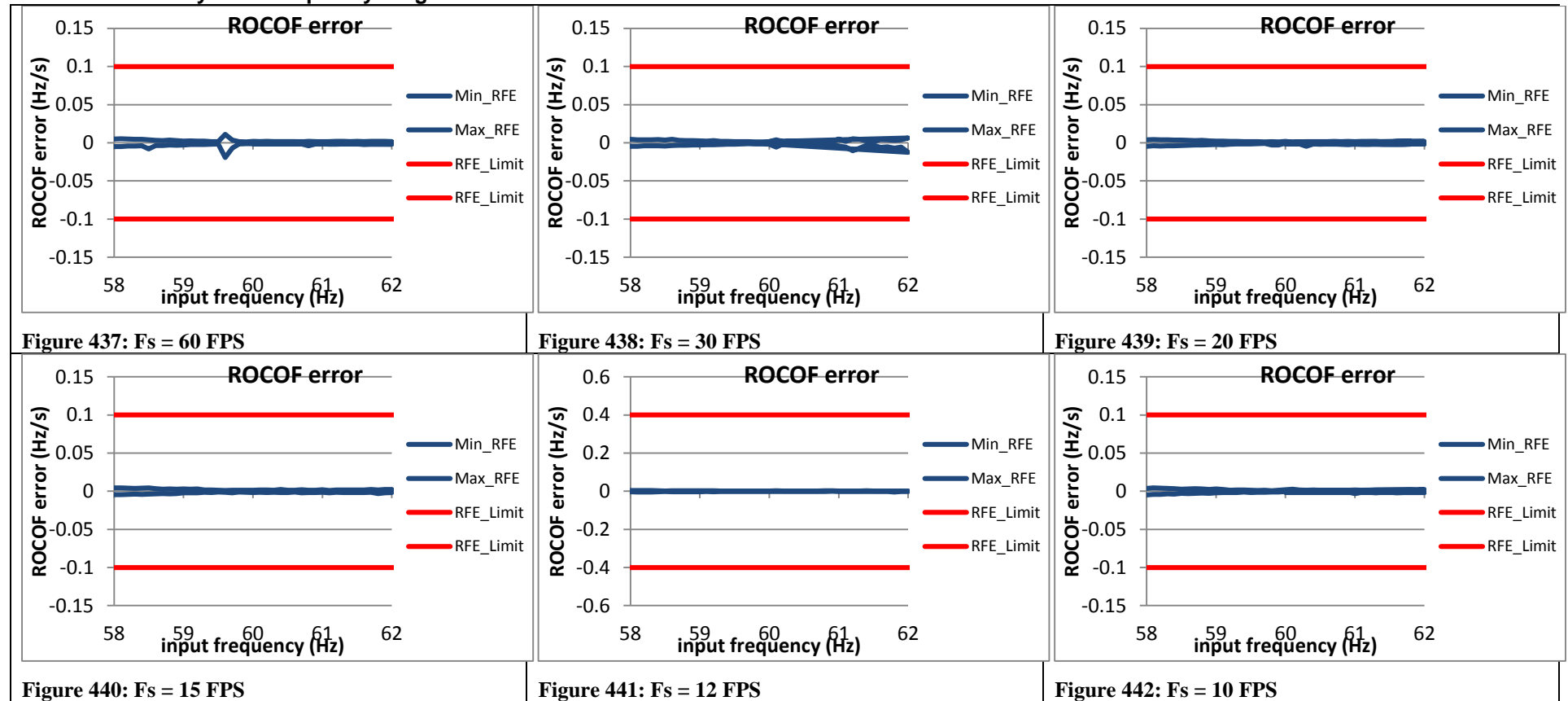
### 2.8.3 PMU B steady state frequency range ROCOF error: P class



## 2.8.4 PMU C steady state frequency range ROCOF error: P class



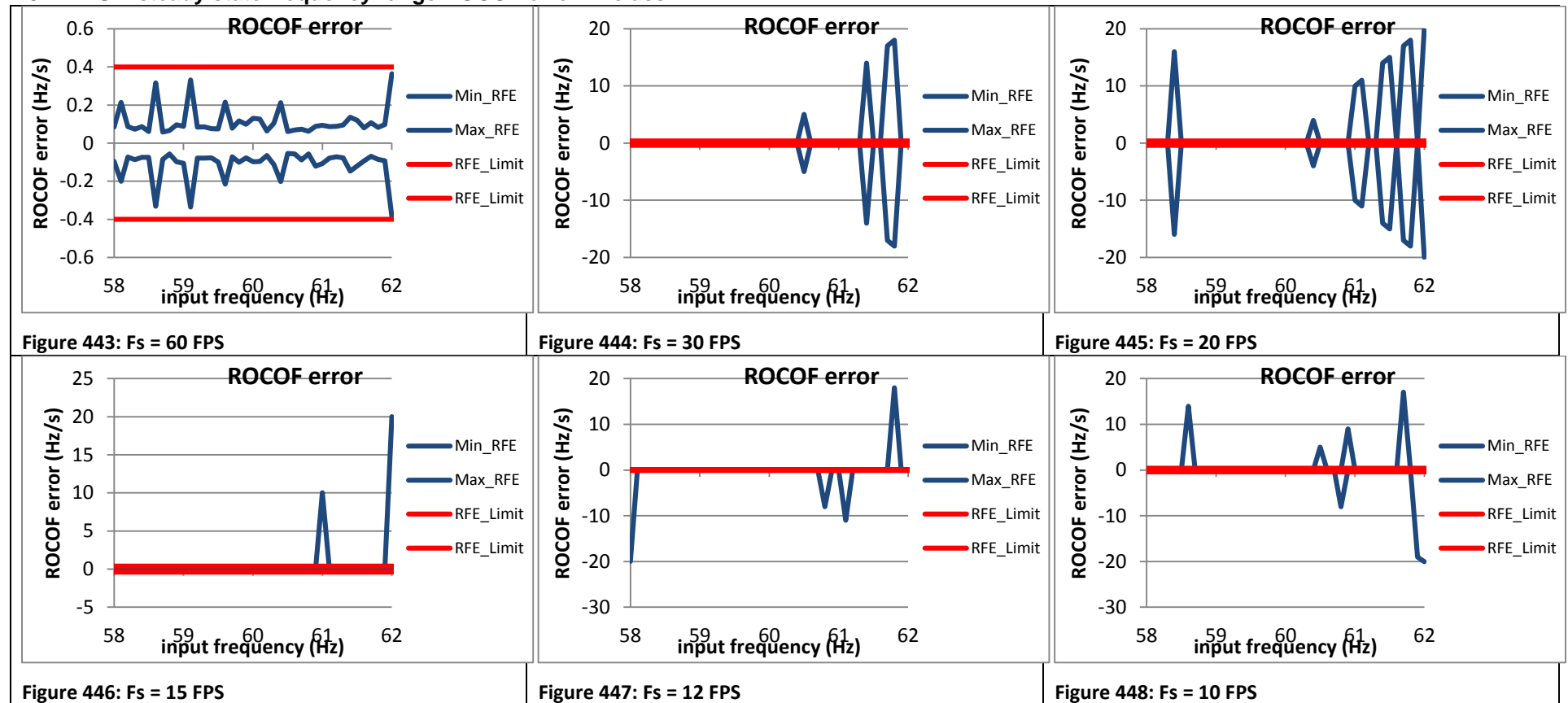
### 2.8.5 PMU D steady state frequency range ROCOF error: P class



### 2.8.6 PMU E steady state frequency range ROCOF error: P class

PMU E does not support P class

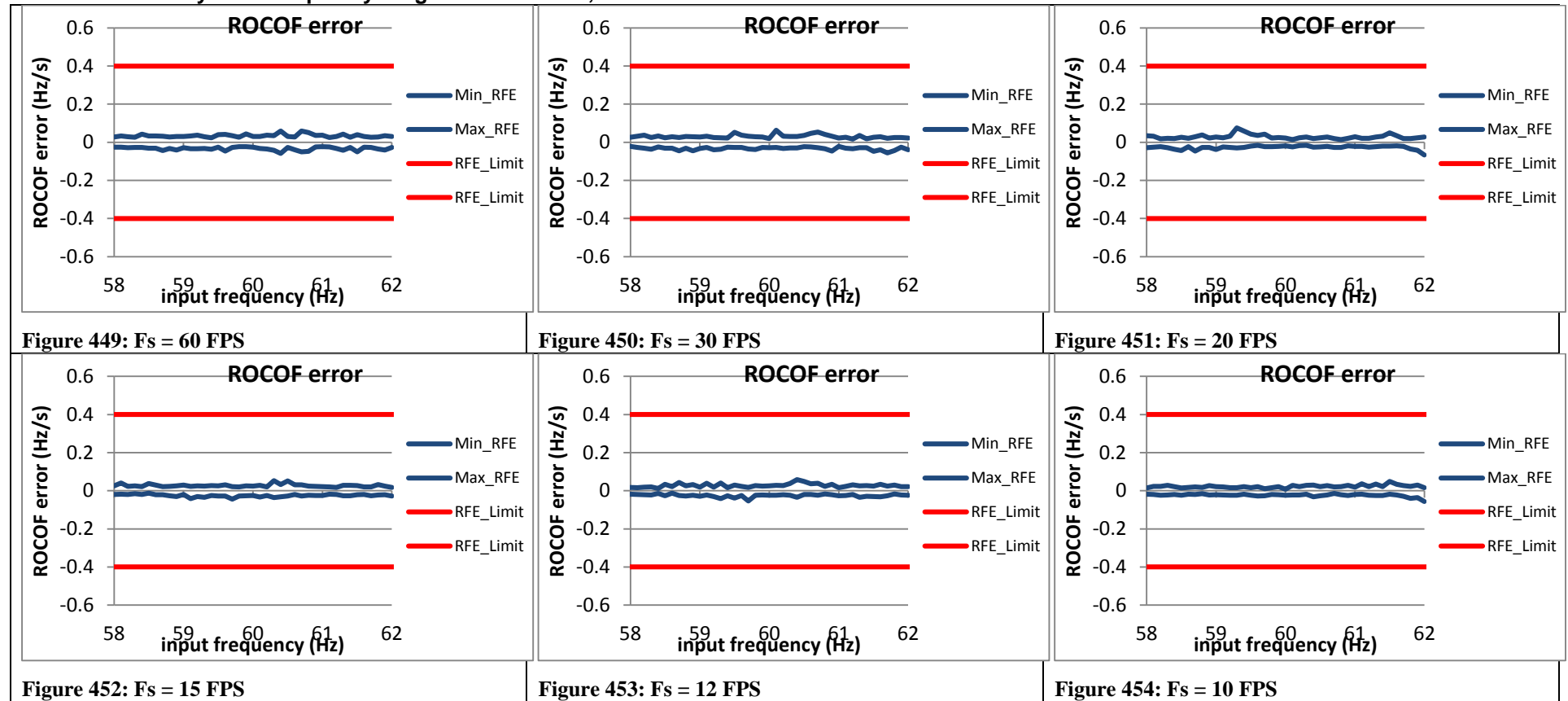
### 2.8.7 PMU F steady state frequency range ROCOF error: P class



### 2.8.8 PMU G steady state frequency range ROCOF error: P class

PMU G does not support P class

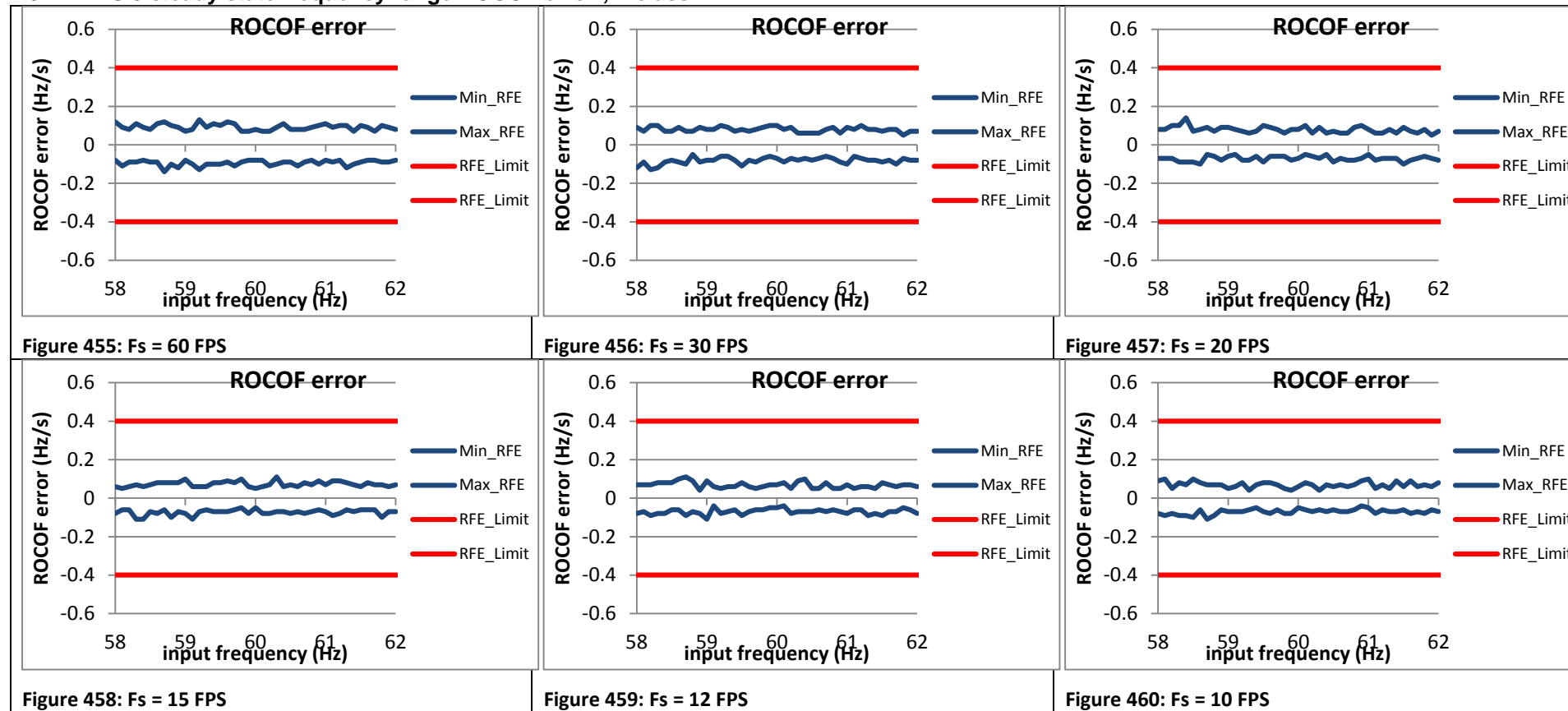
### 2.8.9 PMU H steady state frequency range ROCOF error:, P class



### 2.8.10 PMU I steady state frequency range ROCOF error:, P class

PMU I does not support P class

## 2.8.11 PMU J steady state frequency range ROCOF error:, P class





### 3. Steady state signal magnitude

3. Steady state signal magnitude.....	96
3.1 Steady state signal magnitude voltage TVE M class.....	101
3.1.1 C37.118.1 Annex C steady state signal magnitude voltage TVE: M class.....	101
3.1.2 PMU A steady state signal magnitude voltage TVE: M class.....	102
3.1.3 PMU B steady state signal magnitude voltage TVE: M class.....	103
3.1.4 PMU C steady state signal magnitude voltage TVE: M class.....	104
3.1.5 PMU D steady state signal magnitude voltage TVE: M class.....	105
3.1.6 PMU E steady state signal magnitude voltage TVE: M class.....	106
3.1.7 PMU F steady state signal magnitude voltage TVE: M class.....	107
3.1.8 PMU G steady state signal magnitude voltage TVE: M class.....	108
3.1.9 PMU H steady state signal magnitude voltage TVE: M class.....	109
3.1.10 PMU I steady state signal magnitude voltage TVE: M class.....	110
3.1.11 PMU J steady state signal magnitude voltage TVE: M class.....	111
3.2 Steady state signal magnitude current TVE M class.....	112
3.2.1 C37.118.1 Annex C steady state signal magnitude current TVE: M class.....	112
3.2.2 PMU A steady state signal magnitude current TVE: M class.....	113
3.2.3 PMU B steady state signal magnitude current TVE: M class.....	114
3.2.4 PMU C steady state signal magnitude current TVE: M class.....	115
3.2.5 PMU D steady state signal magnitude current TVE: M class.....	116
3.2.6 PMU E steady state signal magnitude current TVE: M class.....	117
3.2.7 PMU F steady state signal magnitude current TVE: M class.....	118
3.2.8 PMU G steady state signal magnitude current TVE: M class.....	119
3.2.9 PMU H steady state signal magnitude current TVE: M class.....	120
3.2.10 PMU I steady state signal magnitude current TVE: M class.....	121
3.2.11 PMU J steady state signal magnitude current TVE: M class.....	122
3.3 Steady state signal magnitude frequency error M class.....	123
3.3.1 C37.118.1 Annex C steady state signal magnitude frequency error: M class.....	123
3.3.2 PMU A steady state signal magnitude frequency error: M class.....	124
3.3.3 PMU B steady state signal magnitude frequency error: M class.....	125
3.3.4 PMU C steady state signal magnitude frequency error: M class.....	126
3.3.5 PMU D steady state signal magnitude frequency error: M class.....	127
3.3.6 PMU E steady state signal magnitude frequency error: M class.....	128
3.3.7 PMU F steady state signal magnitude frequency error: M class.....	129
3.3.8 PMU G steady state signal magnitude frequency error: M class.....	130

3.3.9 PMU H steady state signal magnitude frequency error: M class .....	131
3.3.10 PMU I steady state signal magnitude frequency error: M class.....	132
3.3.11 PMU J steady state signal magnitude frequency error: M class .....	133
3.4 Steady state signal magnitude ROCOF error M class .....	134
3.4.1 C37.118.1 Annex C steady state signal magnitude ROCOF error: M class .....	134
3.4.2 PMU A steady state signal magnitude ROCOF error: M class .....	135
3.4.3 PMU B steady state signal magnitude ROCOF error: M class.....	136
3.4.4 PMU C steady state signal magnitude ROCOF error: M class .....	137
3.4.5 PMU D steady state signal magnitude ROCOF error: M class .....	138
3.4.6 PMU E steady state signal magnitude ROCOF error: M class.....	139
3.4.7 PMU F steady state signal magnitude ROCOF error: M class .....	140
3.4.8 PMU G* steady state signal magnitude ROCOF error: M class .....	141
3.4.9 PMU H steady state signal magnitude ROCOF error: M class .....	142
3.4.10 PMU I steady state signal magnitude ROCOF error: M class.....	143
3.4.11 PMU I steady state signal magnitude ROCOF error: M class.....	144
3.5 Steady state signal magnitude voltage TVE: P class .....	145
3.5.1 C37.118.1 Annex C steady state signal magnitude voltage TVE: P class .....	145
3.5.2 PMU A steady state signal magnitude voltage TVE: P class .....	146
3.5.3 PMU B steady state signal magnitude voltage TVE: P class .....	147
3.5.4 PMU C steady state signal magnitude voltage TVE: P class .....	148
3.5.5 PMU D steady state signal magnitude voltage TVE: P class .....	149
3.5.6 PMU E steady state signal magnitude voltage TVE: P class.....	149
3.5.7 PMU F steady state signal magnitude voltage TVE P class .....	150
3.5.8 PMU G steady state signal magnitude voltage TVE: P class.....	150
3.5.9 PMU H steady state signal magnitude voltage TVE: P class .....	151
3.5.10 PMU I steady state signal magnitude voltage TVE: P class .....	151
3.5.11 PMU J steady state signal magnitude voltage TVE: P class .....	152
3.6 Steady state signal magnitude current TVE: P class .....	153
3.6.1 C37.118.1 Annex C steady state signal magnitude current TVE: P class .....	153
3.6.2 PMU A steady state signal magnitude current TVE: P class .....	154
3.6.3 PMU B steady state signal magnitude current TVE: P class .....	155
3.6.4 PMU C steady state signal magnitude current TVE: P class .....	156
3.6.5 PMU D steady state signal magnitude current TVE: P class .....	157
3.6.6 PMU E steady state signal magnitude current TVE: P class.....	157
3.6.7 PMU F steady state signal magnitude current TVE: P class.....	158
3.6.8 PMU G steady state signal magnitude current TVE: P class .....	158
3.6.9 PMU H steady state signal magnitude current TVE: P class .....	159
3.6.10 PMU I steady state signal magnitude current TVE: P class .....	159

3.6.11 PMU J steady state signal magnitude current TVE: P class .....	160
3.7 Steady state signal magnitude frequency error: P class .....	161
3.7.1 C37.118.1 Annex C steady state signal magnitude frequency error: F0 = 60 Hz, P class .....	161
3.7.2 PMU A steady state signal magnitude frequency error: P class .....	162
3.7.3 PMU B steady state signal magnitude frequency error: P class .....	163
3.7.4 PMU C steady state signal magnitude frequency error: P class .....	164
3.7.5 PMU D steady state signal magnitude frequency error: P class .....	165
3.7.6 PMU E steady state signal magnitude frequency error: P class .....	165
3.7.7 PMU F steady state signal magnitude frequency error: P class .....	166
3.7.8 PMU G steady state signal magnitude frequency error: P class .....	166
3.7.9 PMU H steady state signal magnitude frequency error: P class .....	167
3.7.10 PMU I steady state signal magnitude frequency error: P class .....	167
3.7.11 PMU I steady state signal magnitude frequency error: P class .....	168
3.8 Steady state signal magnitude ROCOF error: P class .....	169
3.8.1 C37.118.1 Annex C steady state signal magnitude ROCOF error: F0 = 60 Hz, P class .....	169
3.8.2 PMU A steady state signal magnitude ROCOF error: P class .....	170
3.8.3 PMU B steady state signal magnitude ROCOF error: P class .....	171
3.8.4 PMU C steady state signal magnitude ROCOF error: P class .....	172
3.8.5 PMU D steady state signal magnitude ROCOF error: P class .....	173
3.8.6 PMU E steady state signal magnitude ROCOF error: P class .....	173
3.8.7 PMU F steady state signal magnitude ROCOF error: P class .....	174
3.8.8 PMU G steady state signal magnitude ROCOF error: P class .....	174
3.8.9 PMU H steady state signal magnitude ROCOF error: P class .....	175
3.8.10 PMU I steady state signal magnitude ROCOF error: P class .....	175
3.8.11 PMU J steady state signal magnitude ROCOF error: P class .....	176

Reference 5.5.5 of IEEE Std C37.118.1-2011 and C37.118.1a-2014

The steady state signal magnitude is tested by a series of individual steady state tests where the input signal magnitude and frequency is fixed for duration of 5 seconds. Total Vector Error (TVE), Frequency Error (FE) and Rate of Change of Frequency Error (RFE) are measured.

A series of individual tests are run at 10% signal magnitude increments across the C37.118.1-2011 required magnitude ranges determined by the PMU class:

- The magnitude range for M class begins at 10% of nominal input magnitude and ends at 120% nominal voltage magnitude and 200% nominal current magnitude.
- The magnitude range for P class begins at 80% of nominal input magnitude and ends at 120% nominal voltage magnitude and 200% nominal current magnitude.

The maximum TVE of all the test runs is shown along with the limit for TVE to determine if the unit passes or fails the test. There is no limit for FE or RFE but the results are plotted in this report.

Test plan:

For both current and voltage input ranges, apply steady state, nominal frequency, balanced three-phase inputs.

- a) Begin at the low magnitude limits:
  - P class: voltage = 80% of nominal, current = 10% of nominal.
  - M class: voltage = 10% of nominal, current = 10% of nominal.
- b) Wait for the system to settle.
- c) Capture the PMU output for 5 seconds.
- d) Calculate the errors: TVE, FE, RFE for each report.
- e) Calculate the Max TVE.
- f) Increase the input magnitudes by 10% of the nominal value (not a percentage of the actual value).
- g) Repeat step b) through step f) until the upper magnitude limits are reached: 120% of nominal voltage, 200% of nominal current (P and M class).

### Steady state signal magnitude test results

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R			
	V	E		V	E		V	E		V	E		V	E		V	E		V	E		V	E		V	E		V	E		V	E				
	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E					
C37.118.1 Annex C	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-			
PMU A	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-			
PMU B	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-			
PMU C	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-			
PMU D	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-			
PMU E	P	-	-	-	-	-	P	-	-	-	-	-	P	-	-	-	-	-	P	-	-	-	-	-	P	-	-	-	-	-	-	-	-			
PMU F	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-			
PMU G	F	-	-	-	-	-	F	-	-	-	-	-	F	-	-	-	-	-	F	-	-	-	-	F	-	-	-	-	-	-	-	-	-			
PMU H	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-			
PMU I	P	-	-	-	-	-	P	-	-	-	-	-	P	-	-	-	-	-	P	-	-	-	-	-	P	-	-	-	-	-	P	-	-			
PMI J	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-	P	-	-			

P = pass (results are within the limits), F = fail (results are outside the limits), I = indeterminate (results are within the test instrument's uncertainty of the limits)

Dash (-) indicates that there is no performance limit for frequency and ROCOF tests.

The PMU standard does not specify performance limits for frequency and ROCOF error. In the table above, this is specified as a dash (-). Frequency and ROCOF is plotted below for information purposes. There are no limit lines shown.

### 3.1 Steady state signal magnitude voltage TVE M class

#### 3.1.1 C37.118.1 Annex C steady state signal magnitude voltage TVE: M class

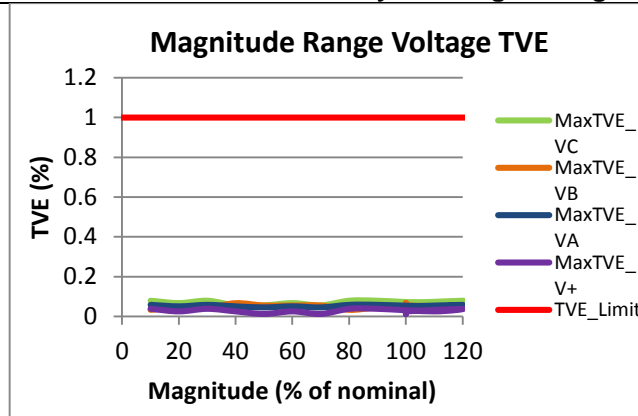


Figure 461:  $F_s = 60$  FPS

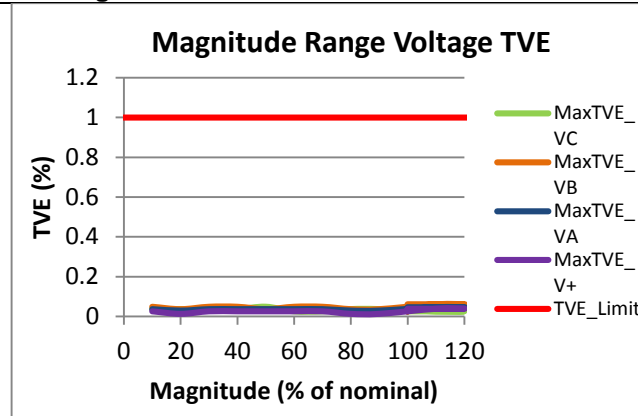


Figure 462:  $F_s = 30$  FPS

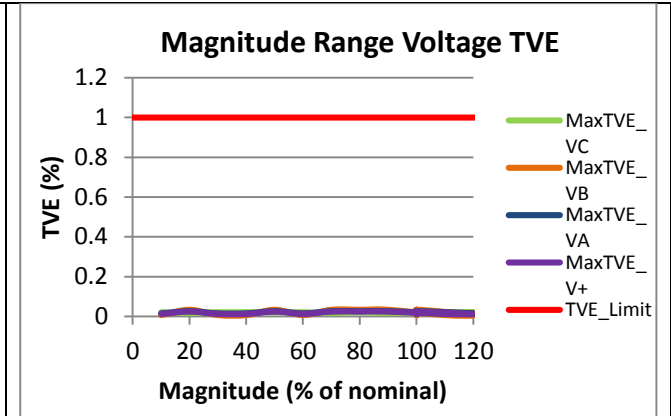


Figure 463:  $F_s = 20$  FPS

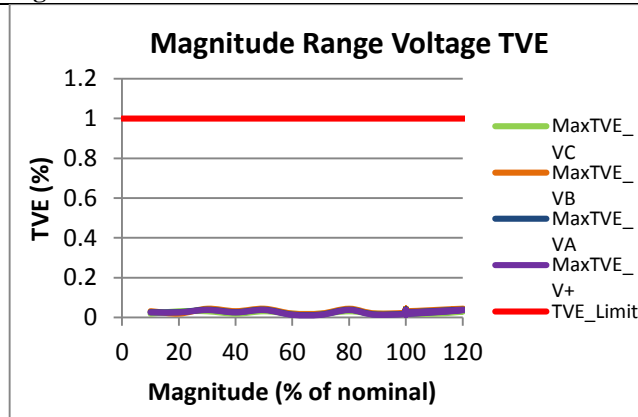


Figure 464:  $F_s = 15$  FPS

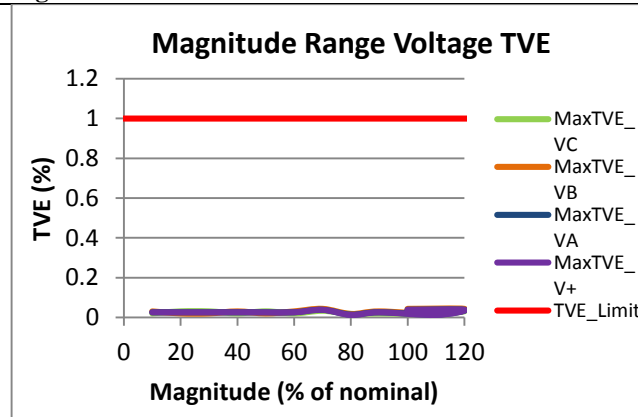


Figure 465:  $F_s = 12$  FPS

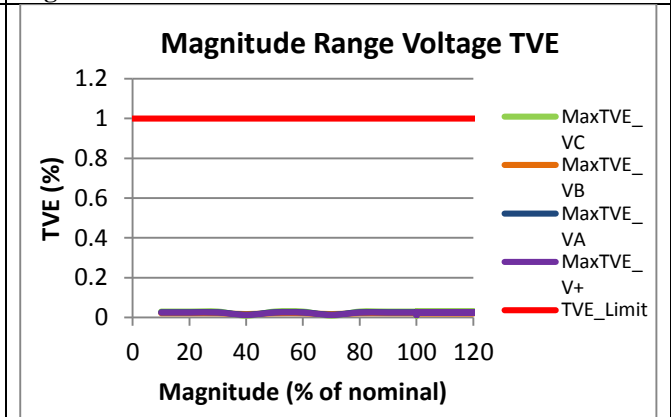


Figure 466:  $F_s = 10$  FPS

### 3.1.2 PMU A steady state signal magnitude voltage TVE: M class

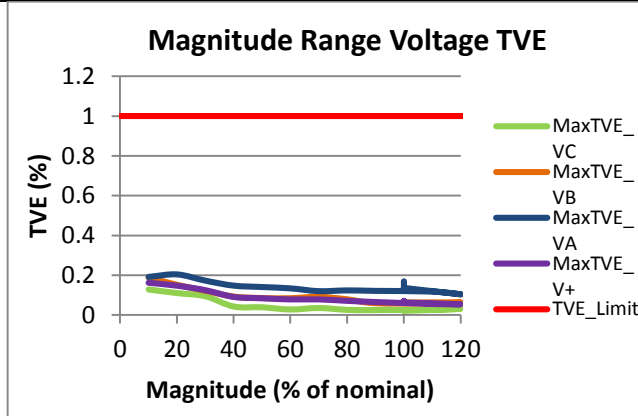


Figure 467: Fs = 60 FPS

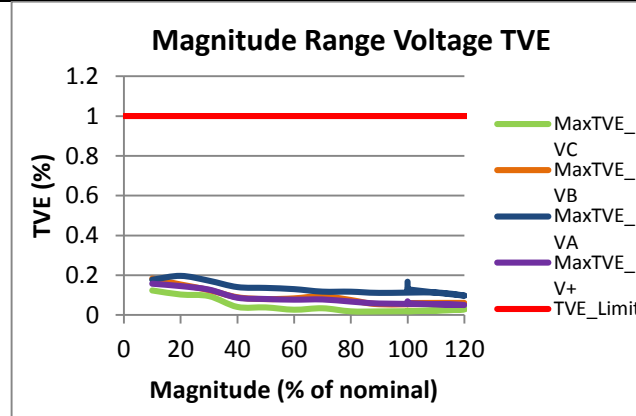


Figure 468: Fs = 30 FPS

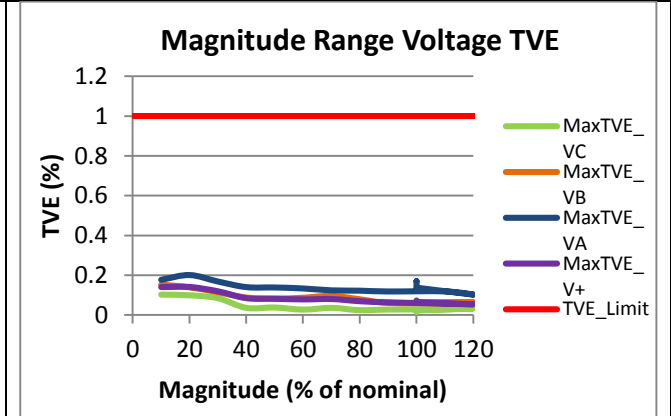


Figure 469: Fs = 20 FPS

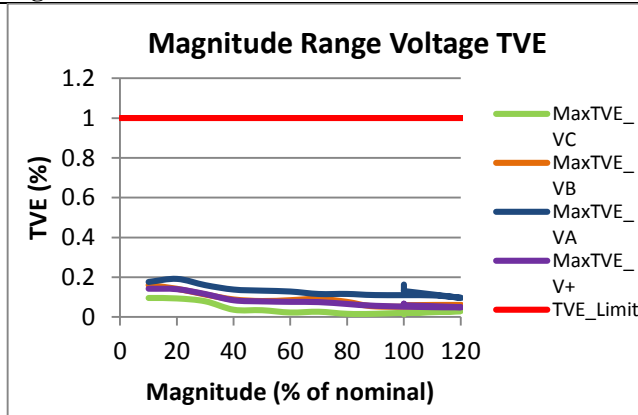


Figure 470: Fs = 15 FPS

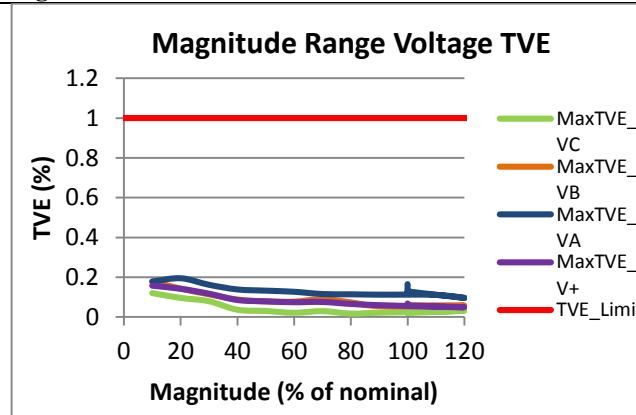


Figure 471: Fs = 12 FPS

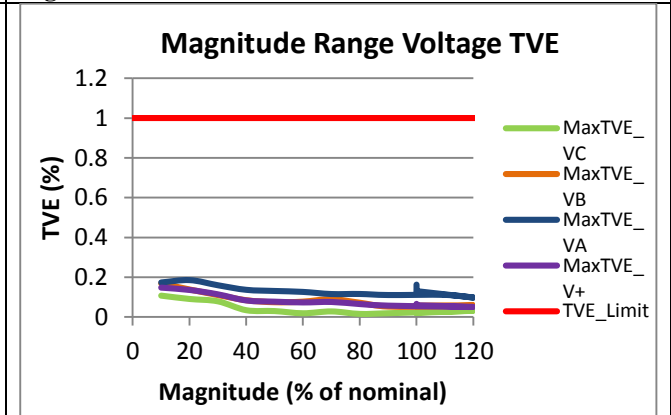


Figure 472: Fs = 10 FPS

### 3.1.3 PMU B steady state signal magnitude voltage TVE: M class

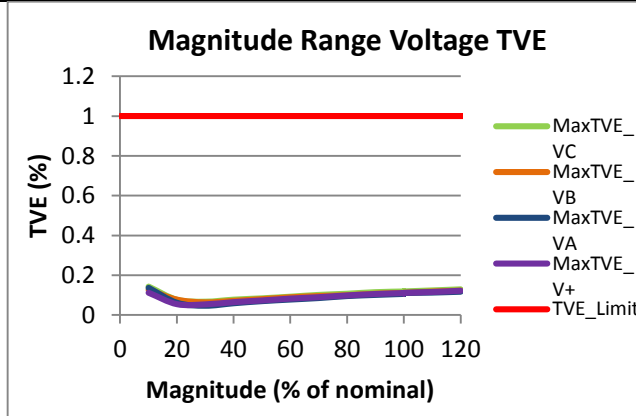


Figure 473: Fs = 60 FPS

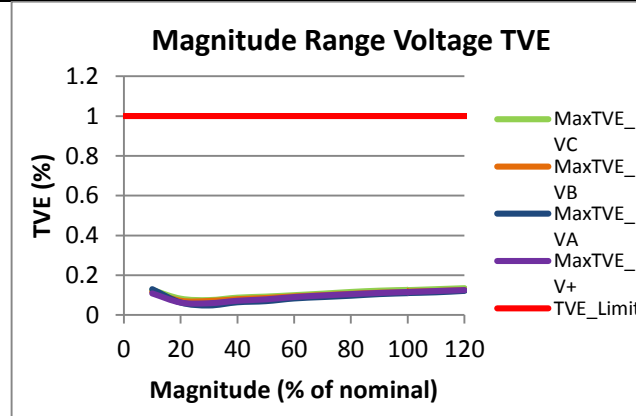


Figure 474: Fs = 30 FPS

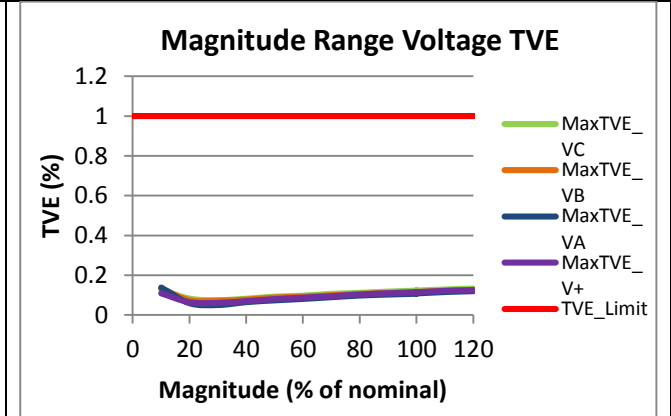


Figure 475: Fs = 20 FPS

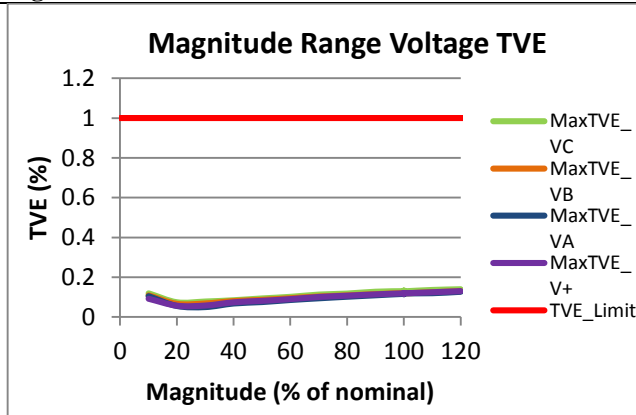


Figure 476: Fs = 15 FPS

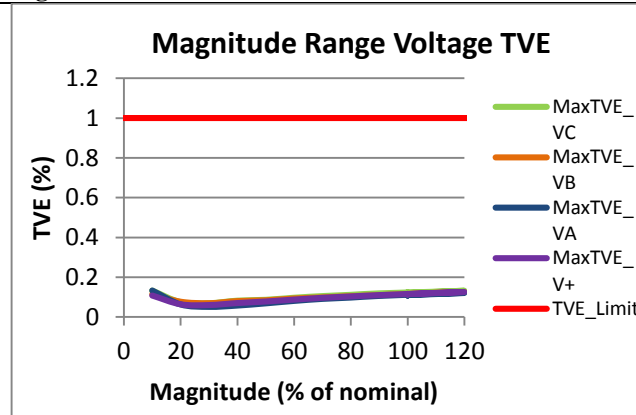


Figure 477: Fs = 12 FPS

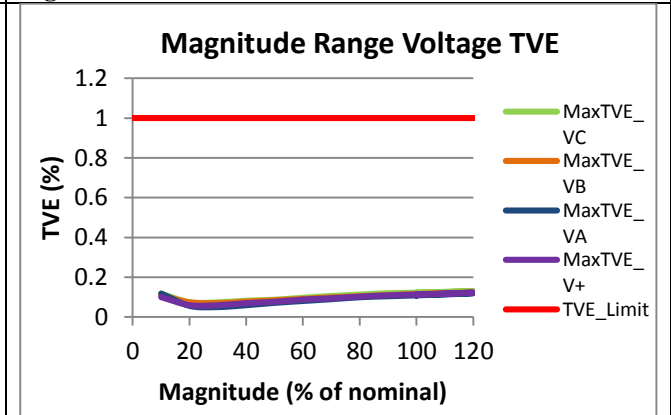


Figure 478: Fs = 10 FPS



### 3.1.4 PMU C steady state signal magnitude voltage TVE: M class

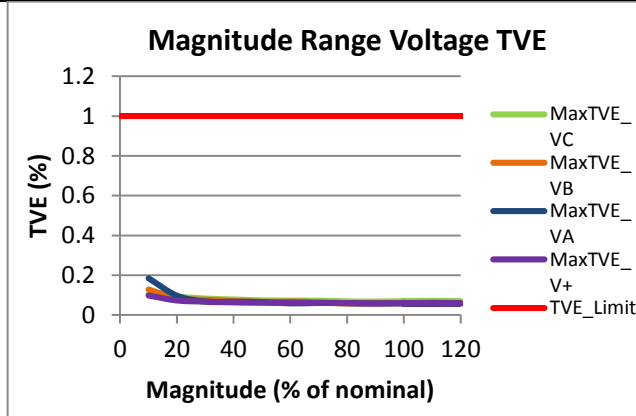


Figure 479:  $F_s = 60$  FPS

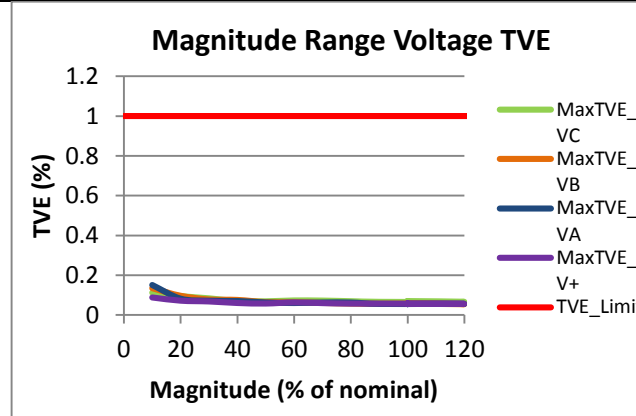


Figure 480:  $F_s = 30$  FPS

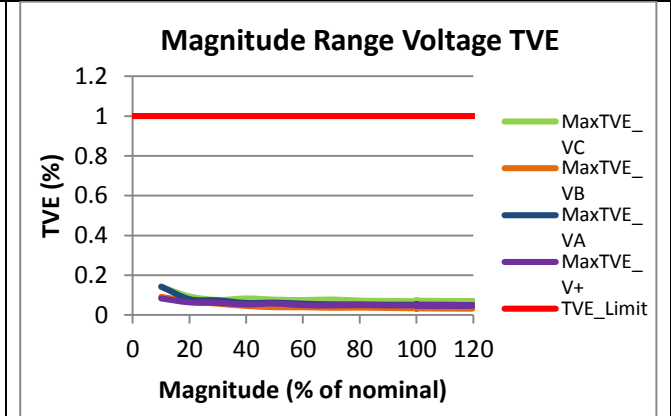


Figure 481:  $F_s = 20$  FPS

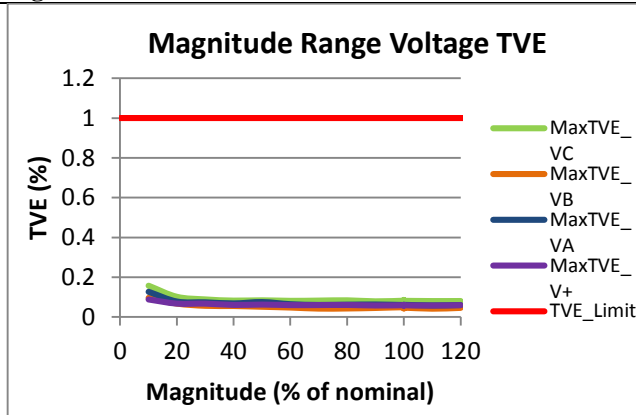


Figure 482:  $F_s = 15$  FPS

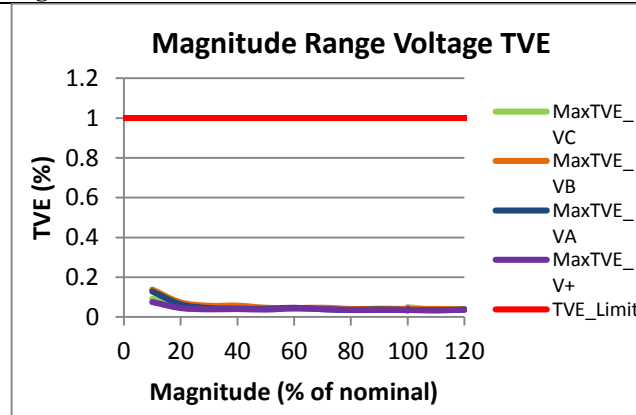


Figure 483:  $F_s = 12$  FPS

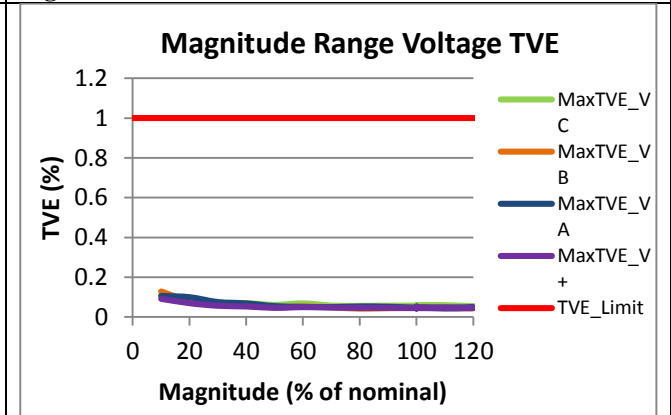


Figure 484:  $F_s = 10$  FPS

### 3.1.5 PMU D steady state signal magnitude voltage TVE: M class

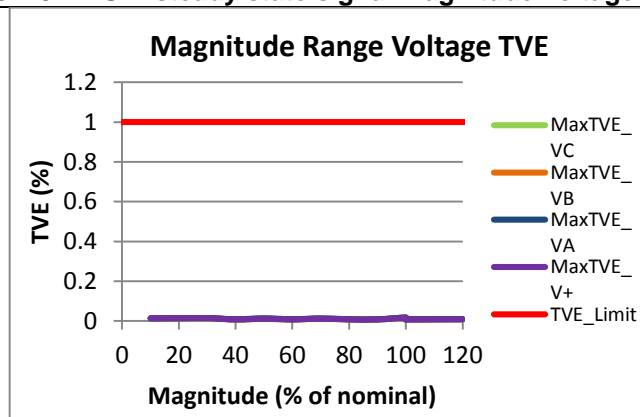


Figure 485:  $F_s = 60$  FPS

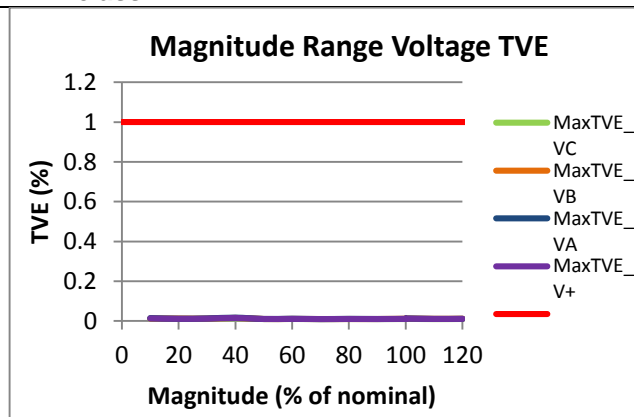


Figure 486:  $F_s = 30$  FPS

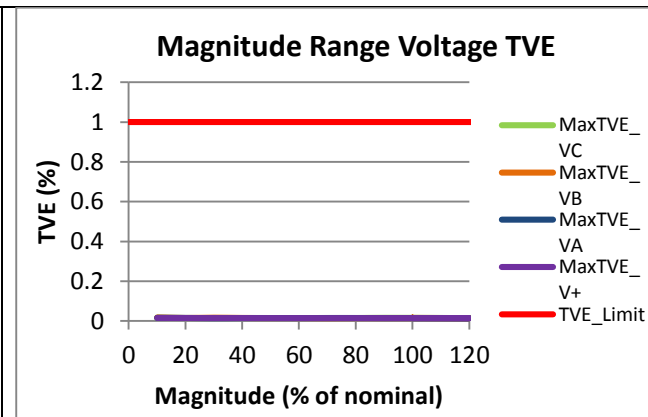


Figure 487:  $F_s = 20$  FPS

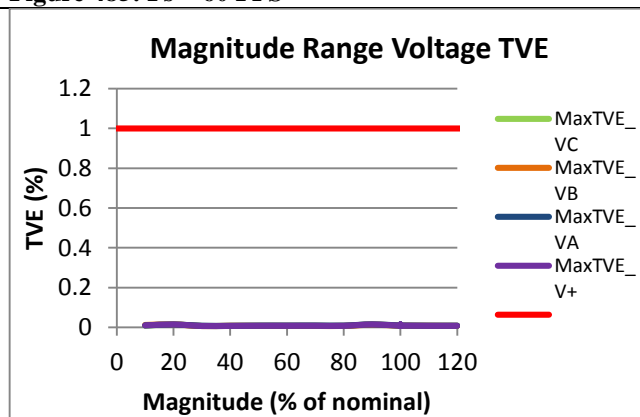


Figure 488:  $F_s = 15$  FPS

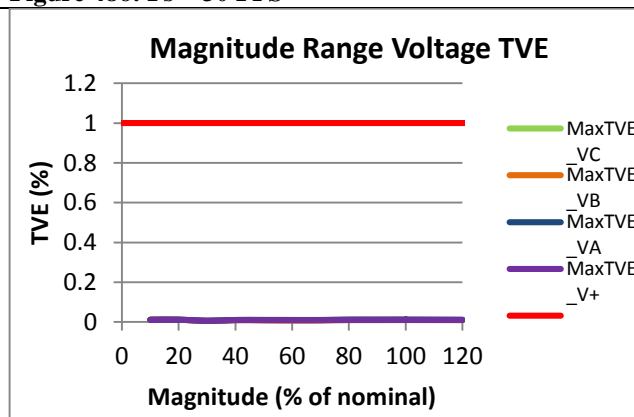


Figure 489:  $F_s = 12$  FPS

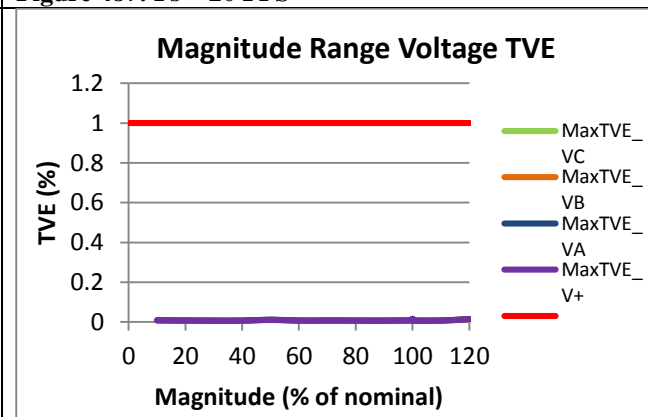


Figure 490:  $F_s = 10$  FPS

### 3.1.6 PMU E steady state signal magnitude voltage TVE: M class

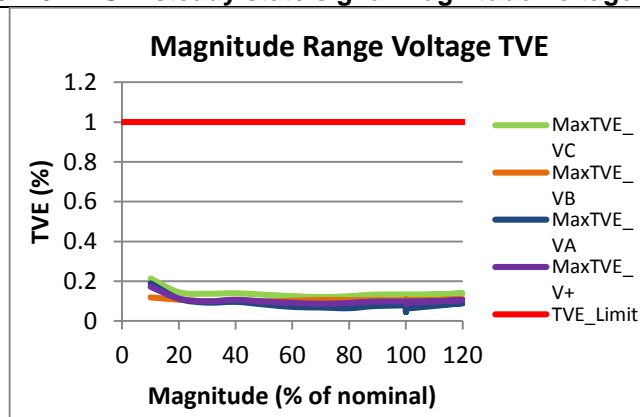


Figure 491: Fs = 60 FPS

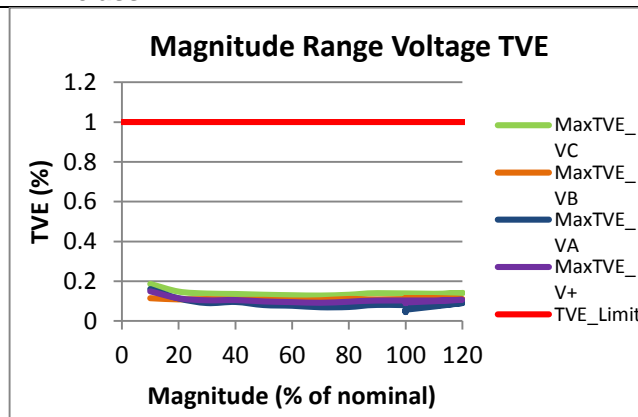


Figure 492: Fs = 30 FPS

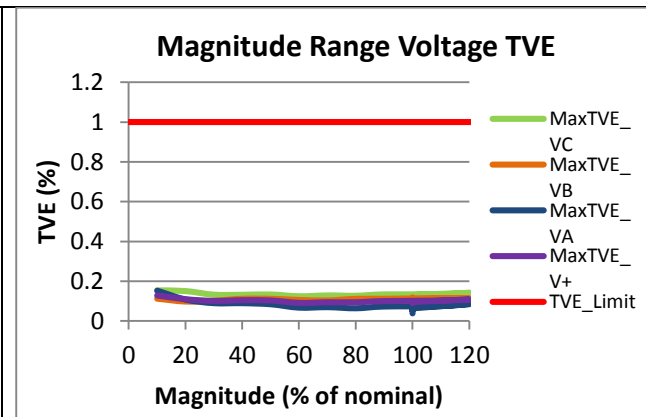


Figure 493: Fs = 20 FPS

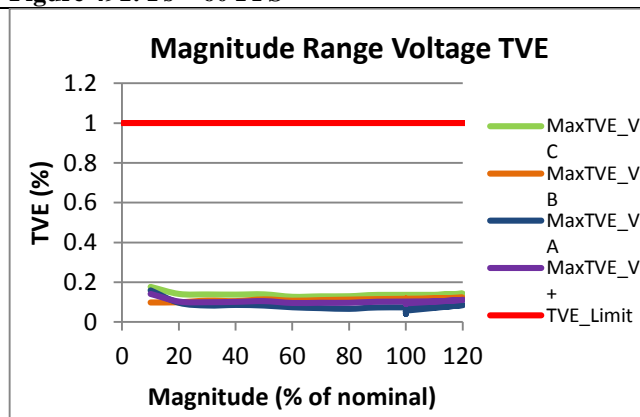


Figure 494: Fs = 15 FPS

MISSING DATA

Figure 495: Fs = 12 FPS

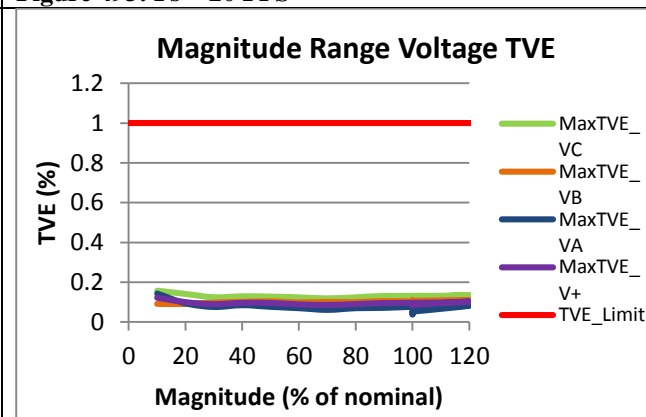


Figure 496: Fs = 10 FPS

### 3.1.7 PMU F steady state signal magnitude voltage TVE: M class

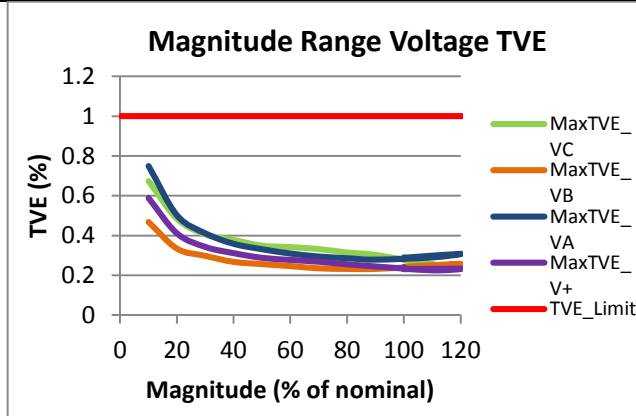


Figure 497:  $F_s = 60$  FPS

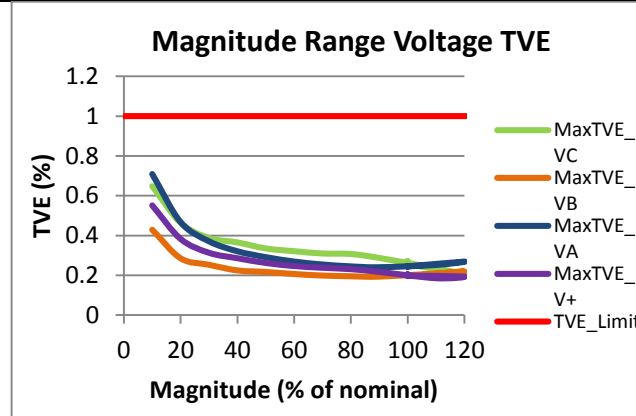


Figure 498:  $F_s = 30$  FPS

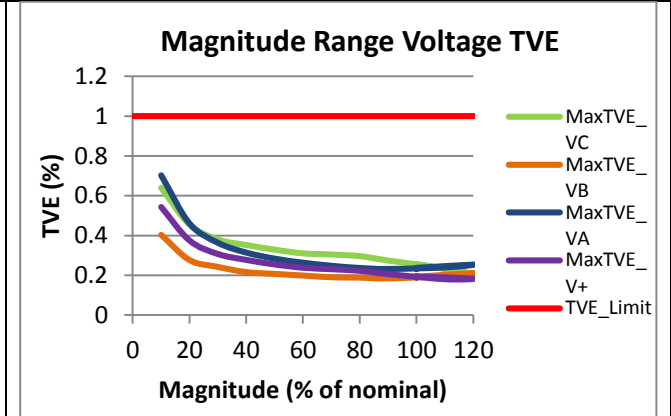


Figure 499:  $F_s = 20$  FPS

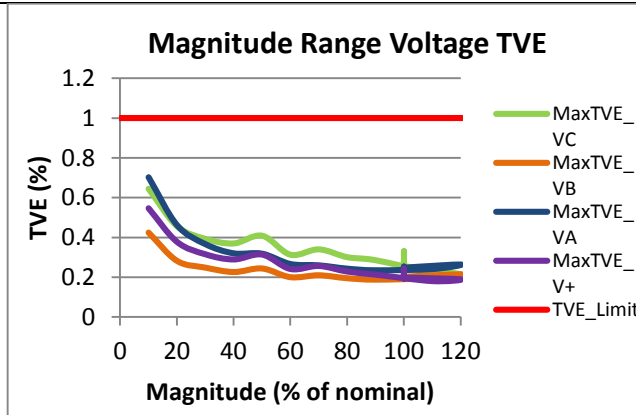


Figure 500:  $F_s = 15$  FPS

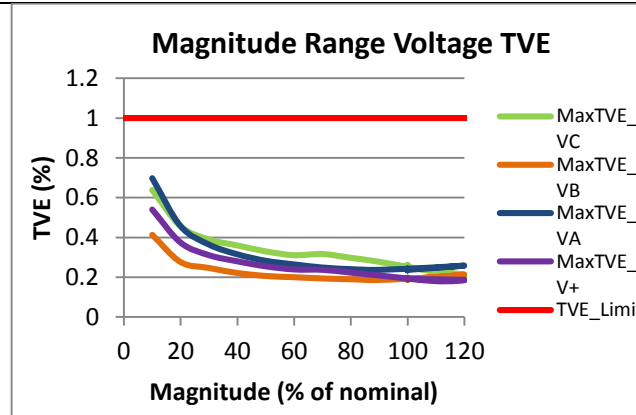


Figure 501:  $F_s = 12$  FPS

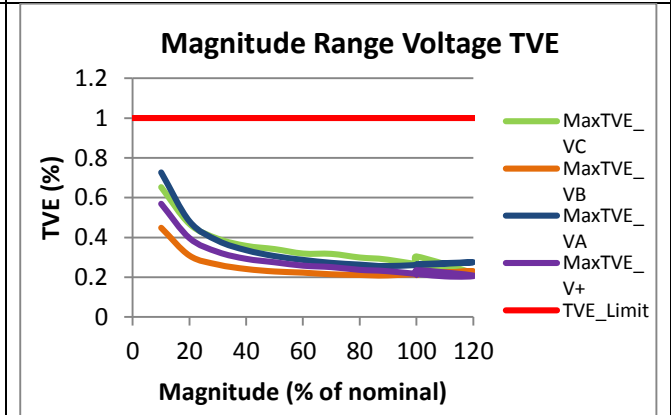


Figure 502:  $F_s = 10$  FPS

### 3.1.8 PMU G steady state signal magnitude voltage TVE: M class

Figure 503:  $F_s = 60$  FPS is not supported by this PMU

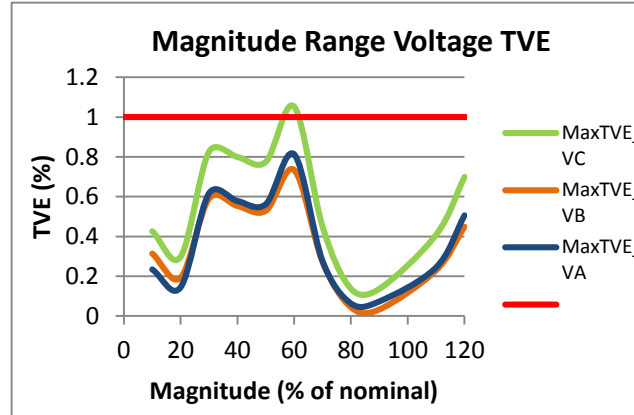


Figure 504:  $F_s = 30$  FPS

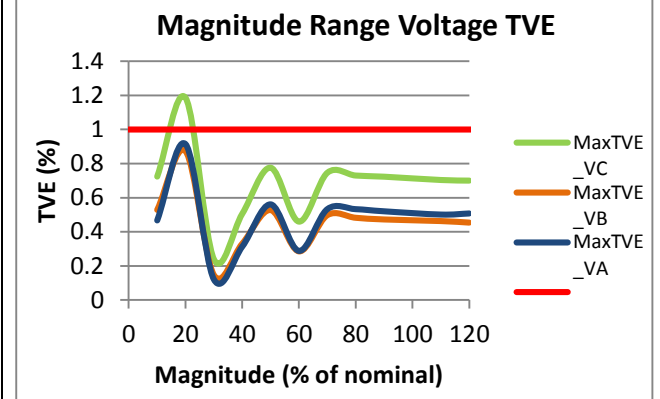


Figure 505:  $F_s = 20$  FPS

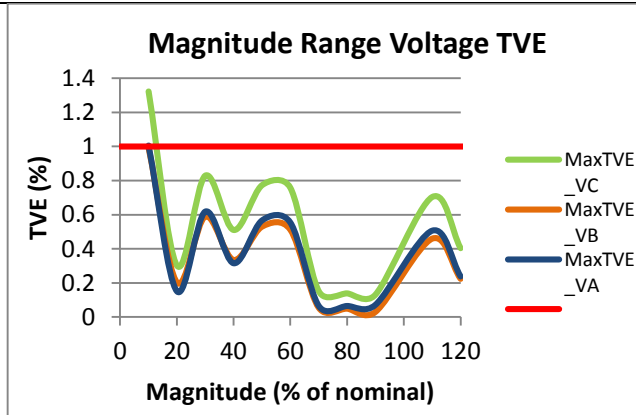


Figure 506:  $F_s = 15$  FPS

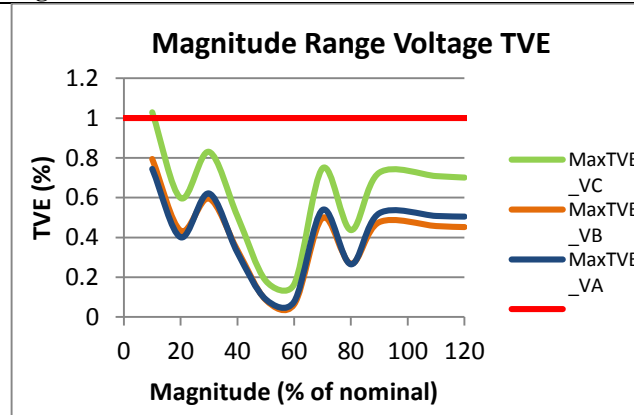


Figure 507:  $F_s = 12$  FPS

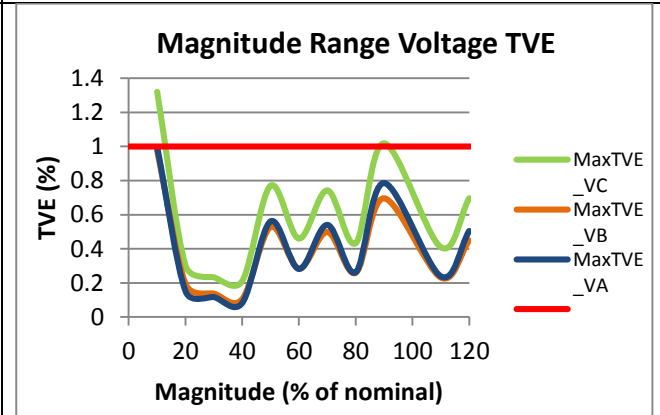


Figure 508:  $F_s = 10$  FPS

### 3.1.9 PMU H steady state signal magnitude voltage TVE: M class

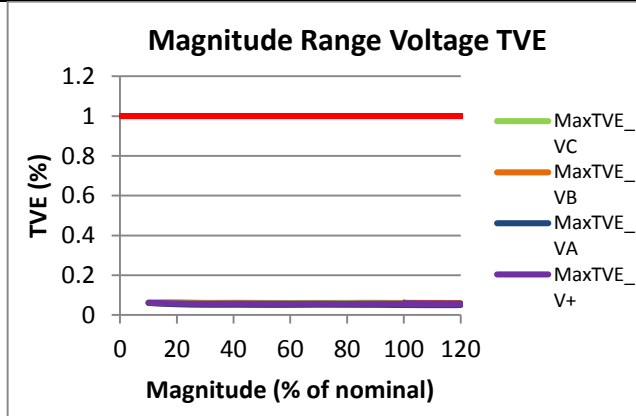


Figure 509: Fs = 60 FPS

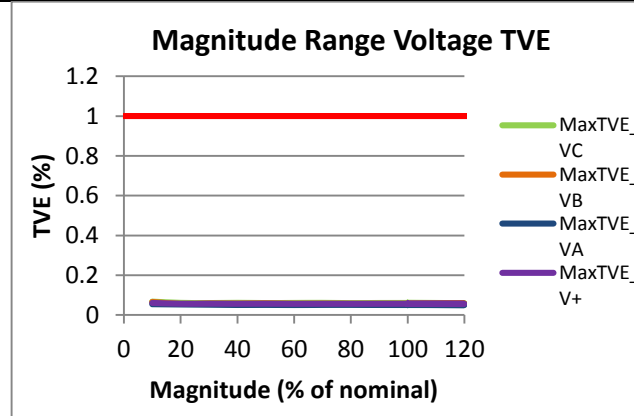


Figure 510: Fs = 30 FPS

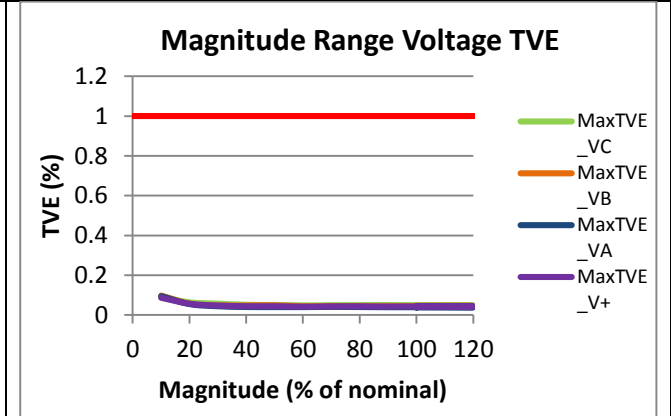


Figure 511: Fs = 20 FPS

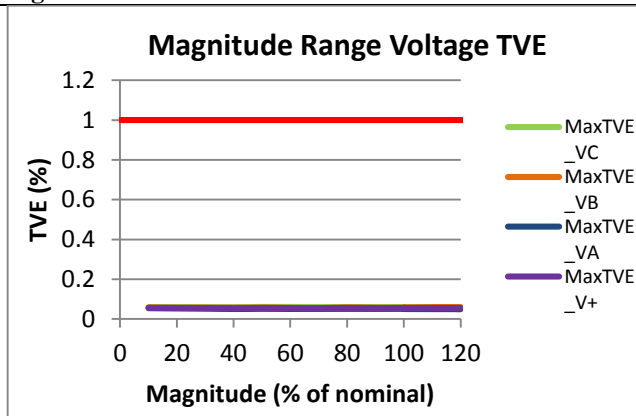


Figure 512: Fs = 15 FPS

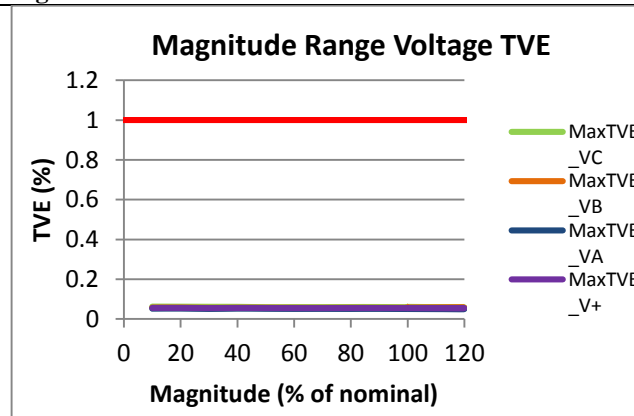


Figure 513: Fs = 12 FPS

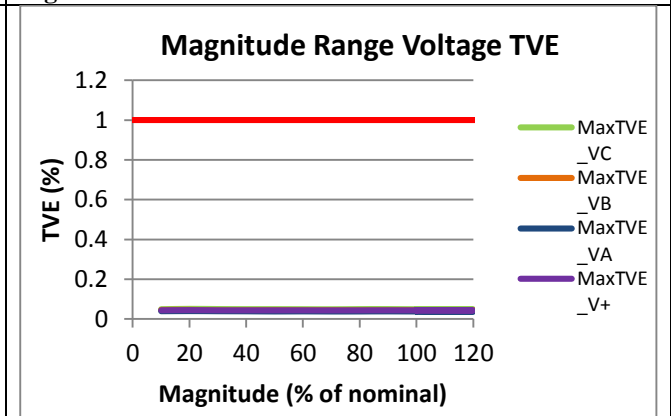


Figure 514: Fs = 10 FPS

### 3.1.10 PMU I steady state signal magnitude voltage TVE: M class

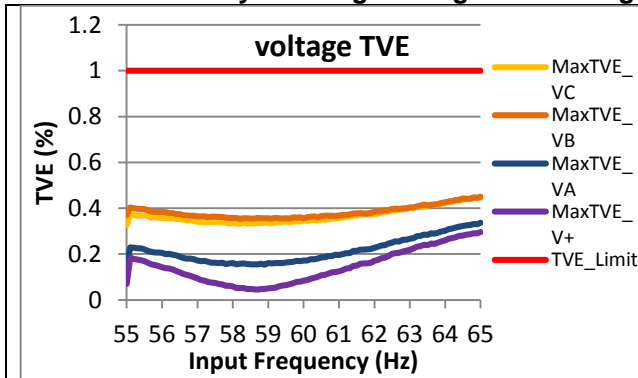


Figure 515:  $F_s = 60$  FPS

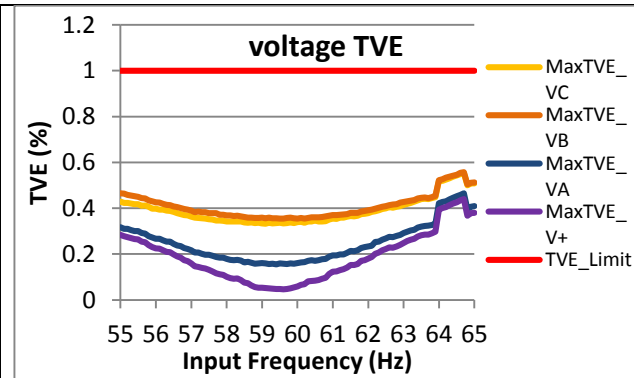


Figure 516:  $F_s = 30$  FPS

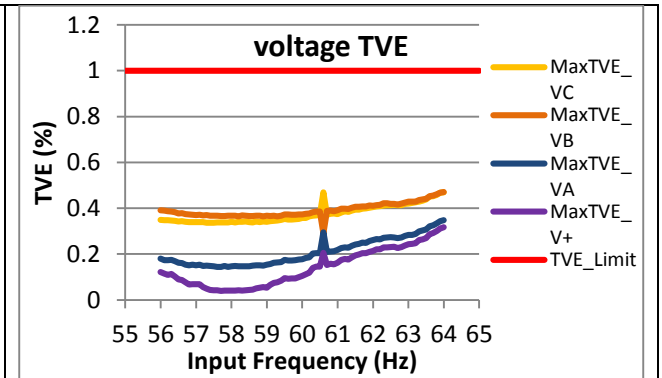


Figure 517:  $F_s = 20$  FPS

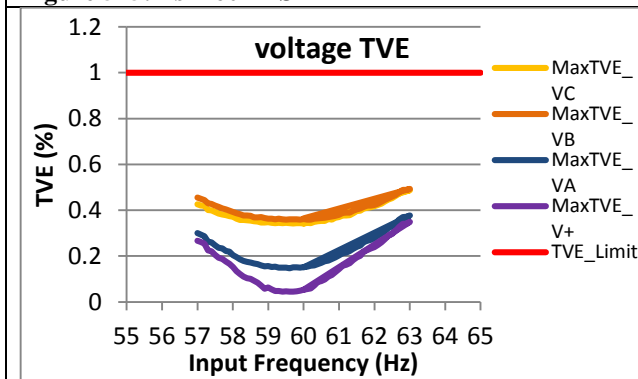


Figure 518:  $F_s = 15$  FPS

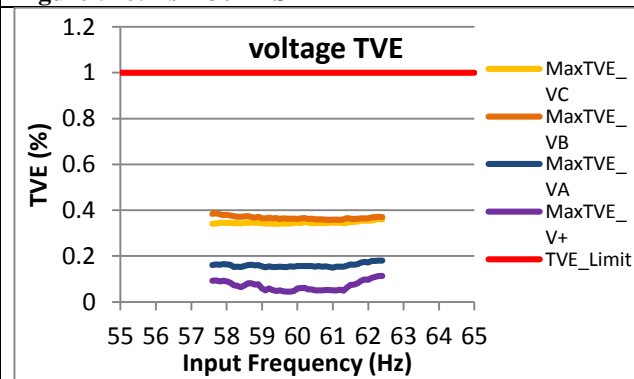


Figure 519:  $F_s = 12$  FPS

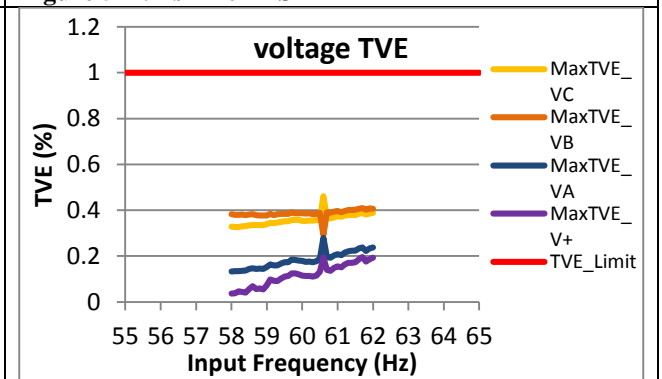


Figure 520:  $F_s = 10$  FPS

### 3.1.11 PMU J steady state signal magnitude voltage TVE: M class

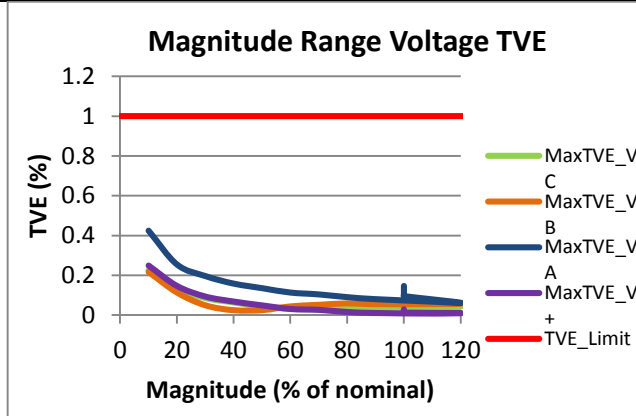


Figure 521: Fs = 60 FPS

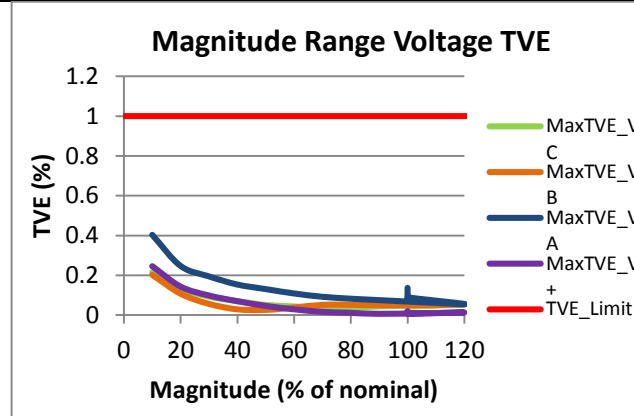


Figure 522: Fs = 30 FPS

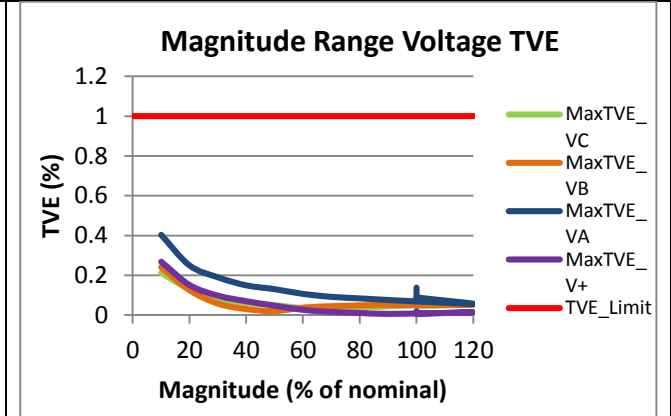


Figure 523: Fs = 20 FPS

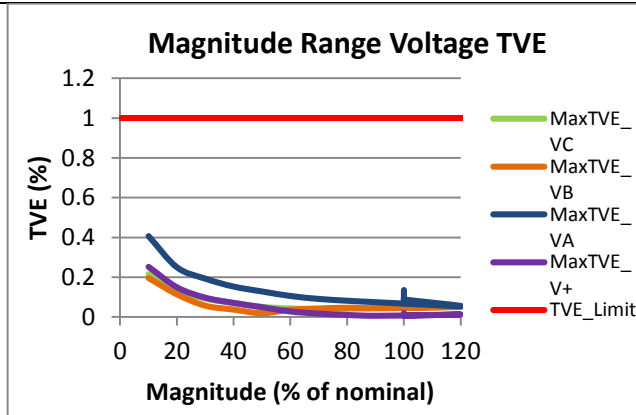


Figure 524: Fs = 15 FPS

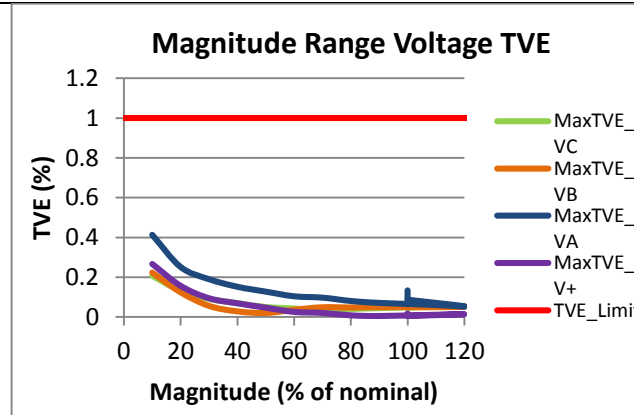


Figure 525: Fs = 12 FPS

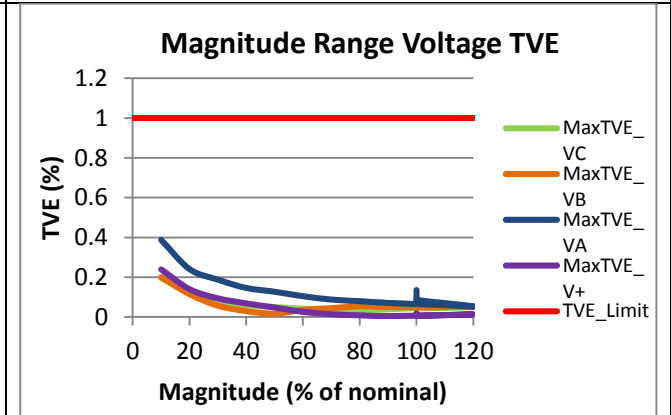
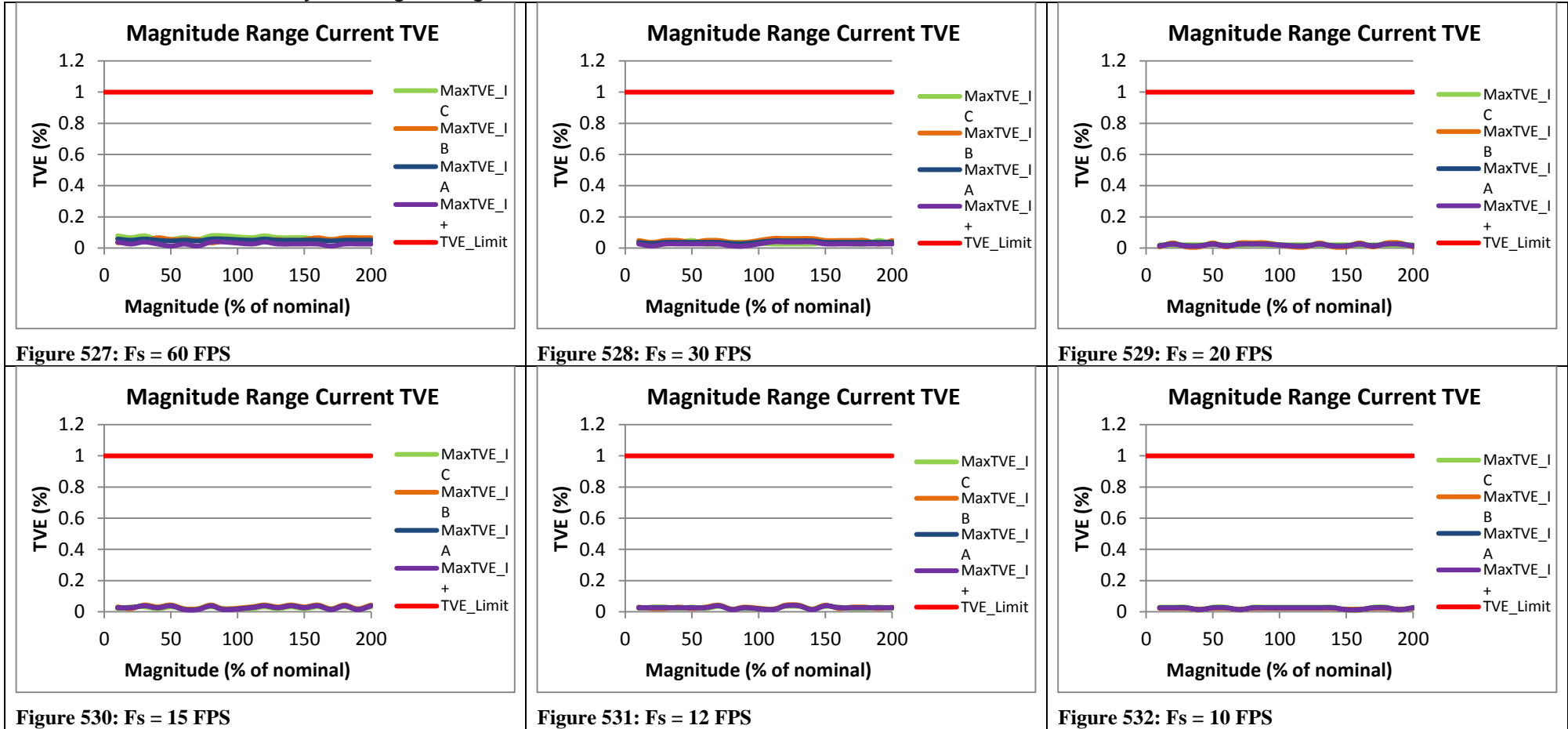


Figure 526: Fs = 10 FPS



### 3.2 Steady state signal magnitude current TVE M class

#### 3.2.1 C37.118.1 Annex C steady state signal magnitude current TVE: M class



### 3.2.2 PMU A steady state signal magnitude current TVE: M class

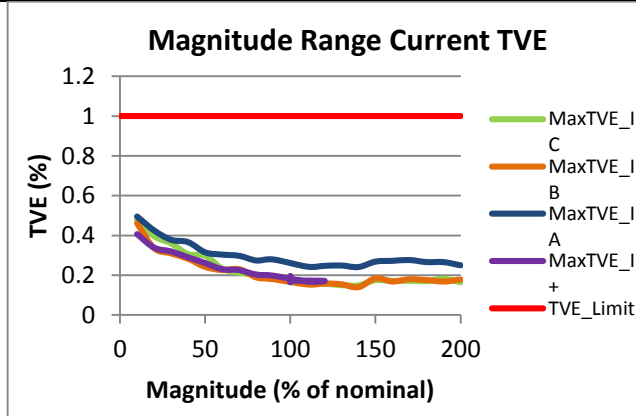


Figure 533:  $F_s = 60$  FPS

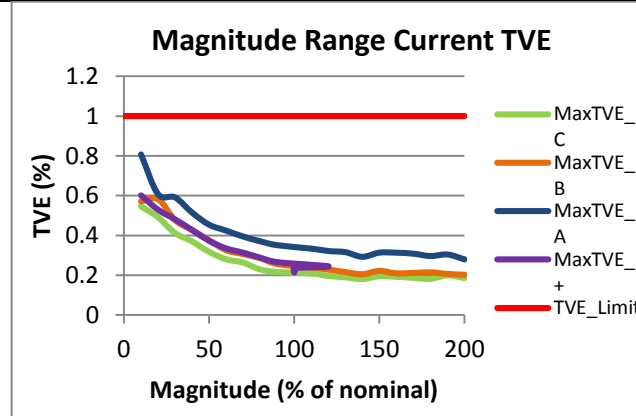


Figure 534:  $F_s = 30$  FPS

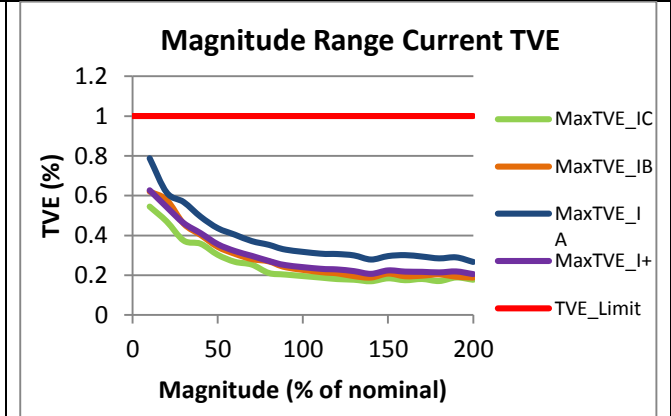


Figure 535:  $F_s = 20$  FPS

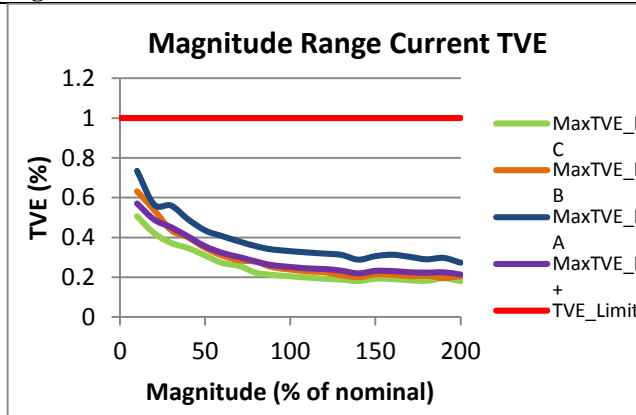


Figure 536:  $F_s = 15$  FPS

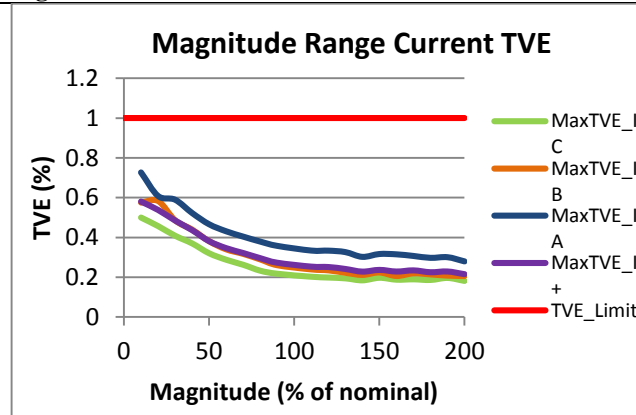


Figure 537:  $F_s = 12$  FPS

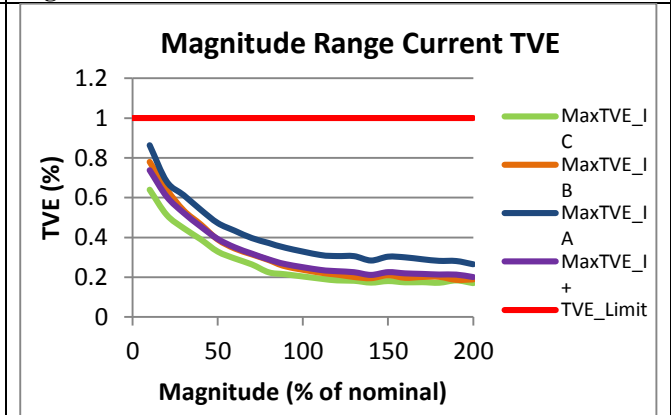


Figure 538:  $F_s = 10$  FPS

### 3.2.3 PMU B steady state signal magnitude current TVE: M class

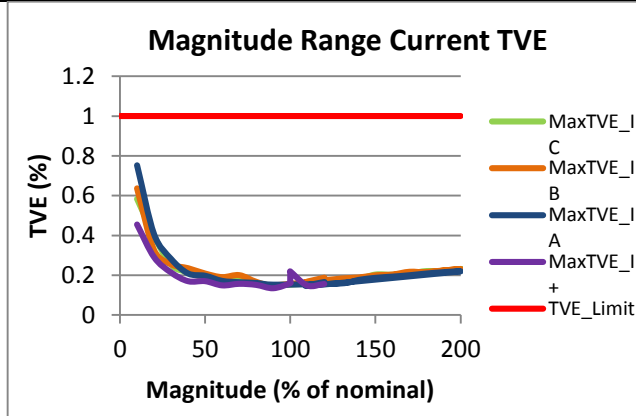


Figure 539: Fs = 60 FPS

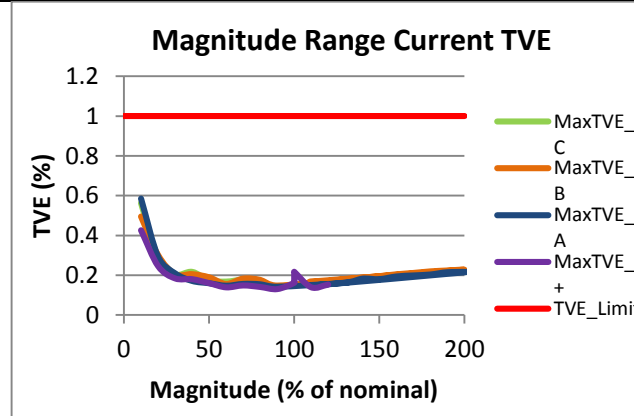


Figure 540: Fs = 30 FPS

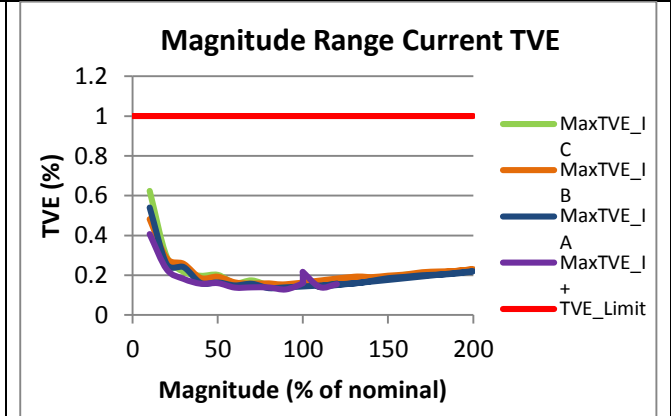


Figure 541: Fs = 20 FPS

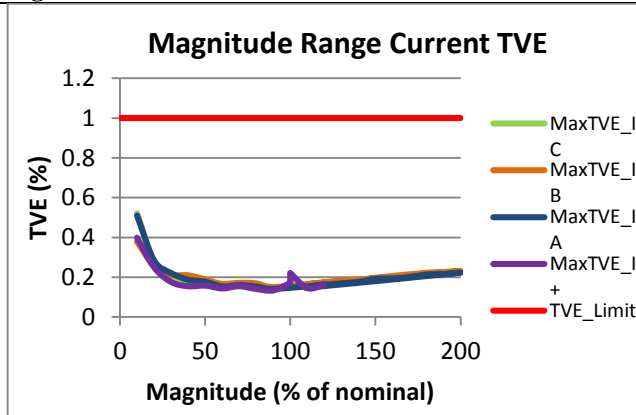


Figure 542: Fs = 15 FPS

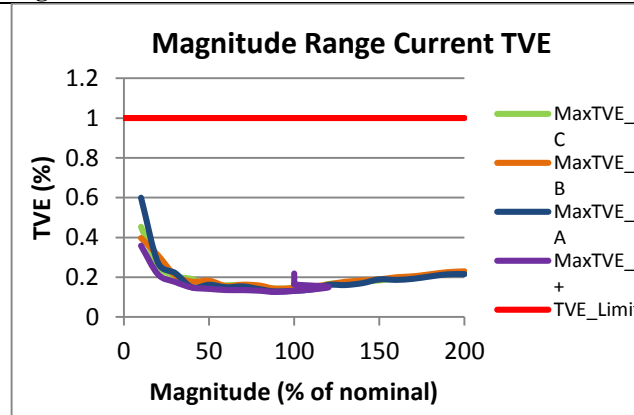


Figure 543: Fs = 12 FPS

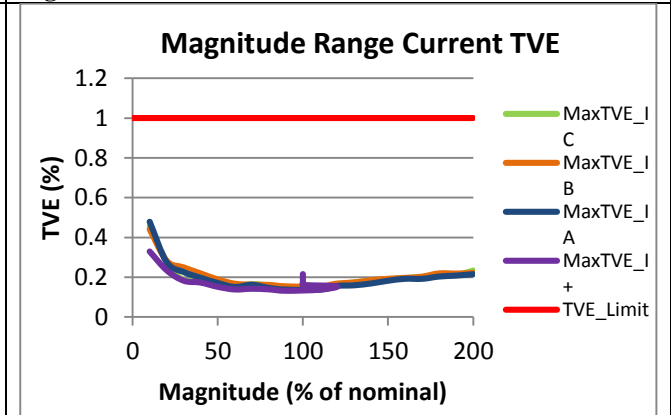


Figure 544: Fs = 10 FPS

### 3.2.4 PMU C steady state signal magnitude current TVE: M class

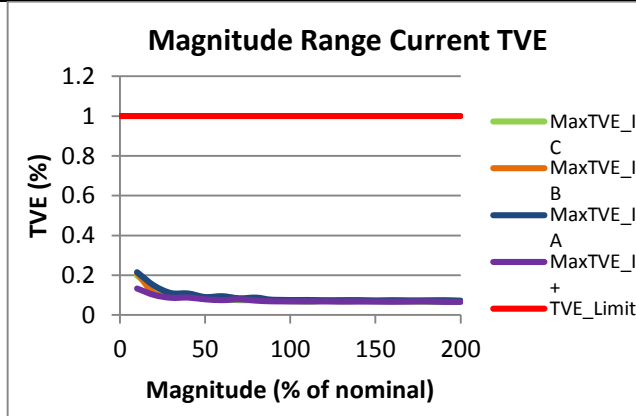


Figure 545: Fs = 60 FPS

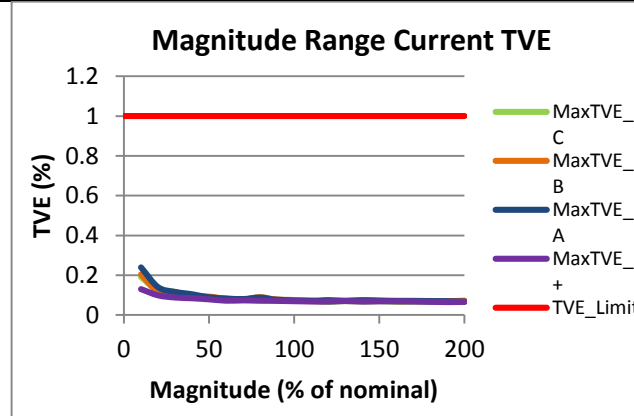


Figure 546: Fs = 30 FPS

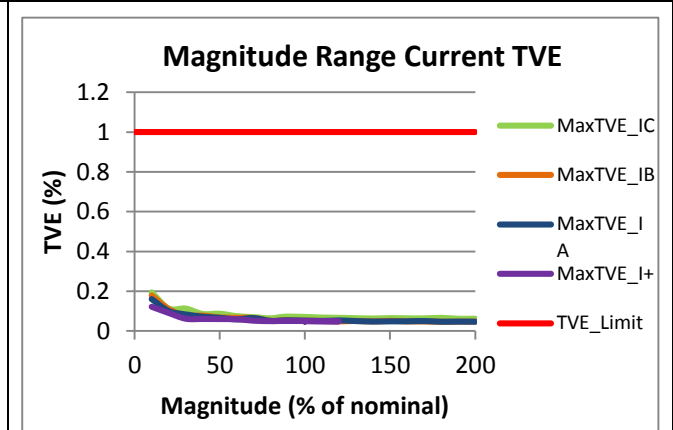


Figure 547: Fs = 20 FPS

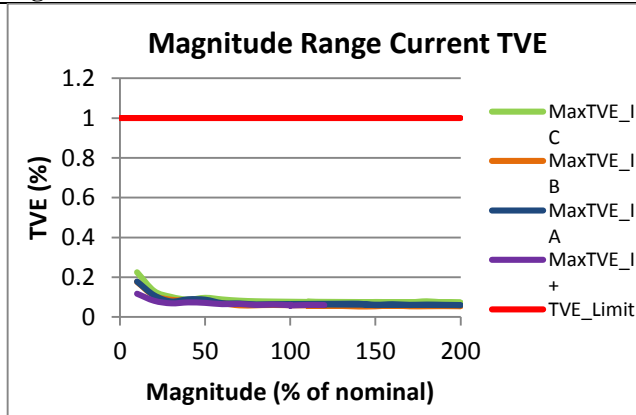


Figure 548: Fs = 15 FPS

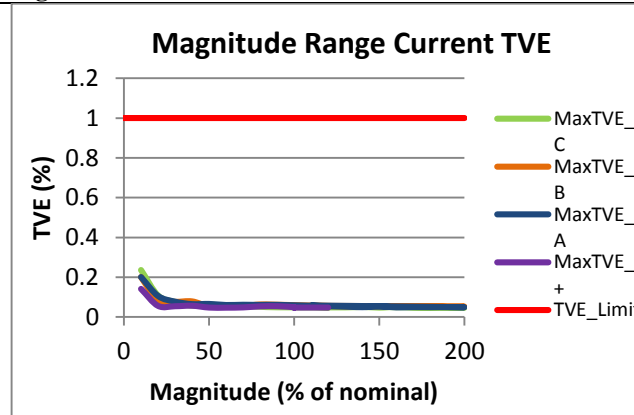


Figure 549: Fs = 12 FPS

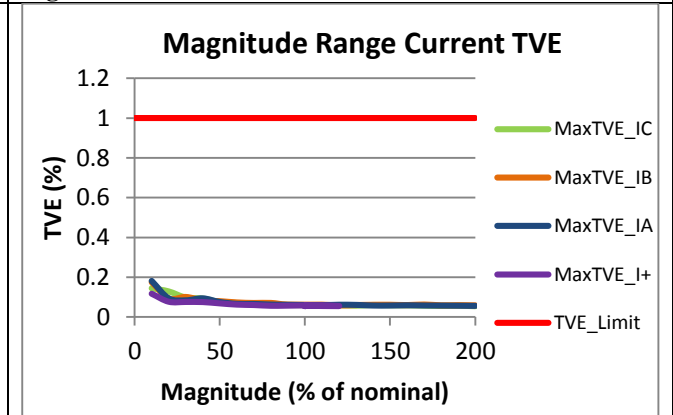


Figure 550: Fs = 10 FPS

### 3.2.5 PMU D steady state signal magnitude current TVE: M class

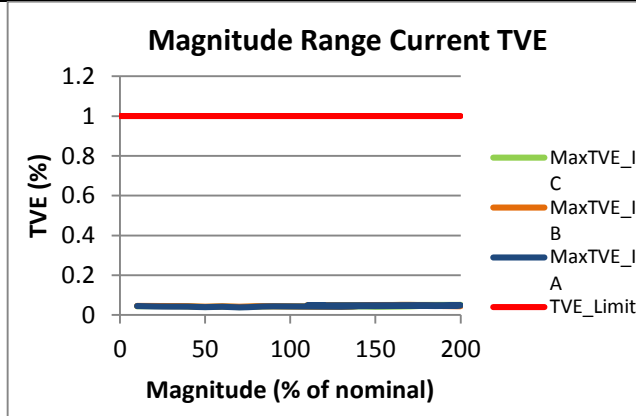


Figure 551:  $F_s = 60$  FPS

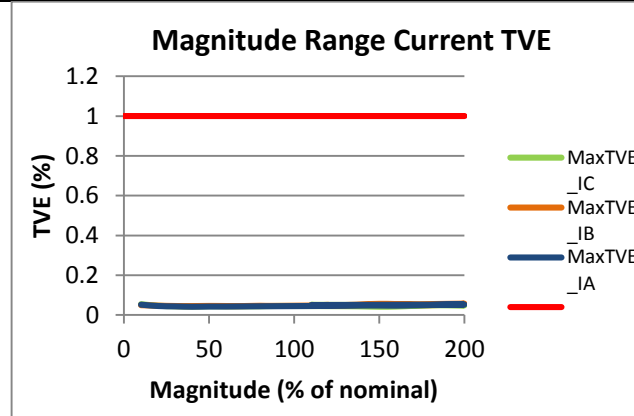


Figure 552:  $F_s = 30$  FPS

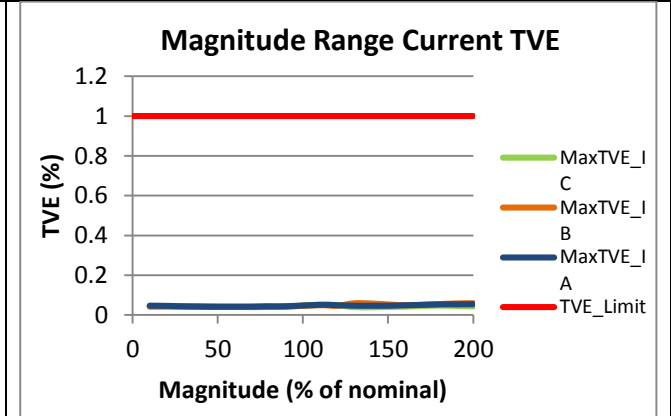


Figure 553:  $F_s = 20$  FPS

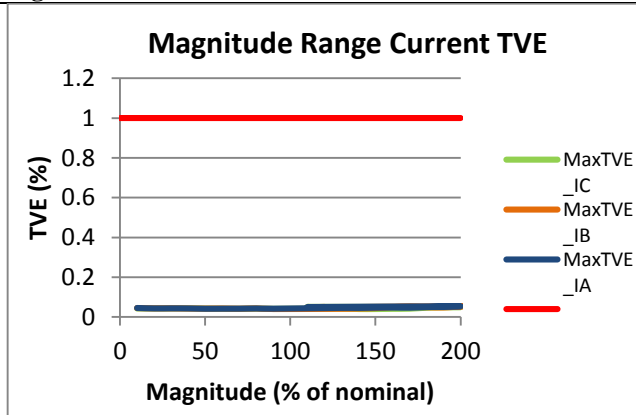


Figure 554:  $F_s = 15$  FPS

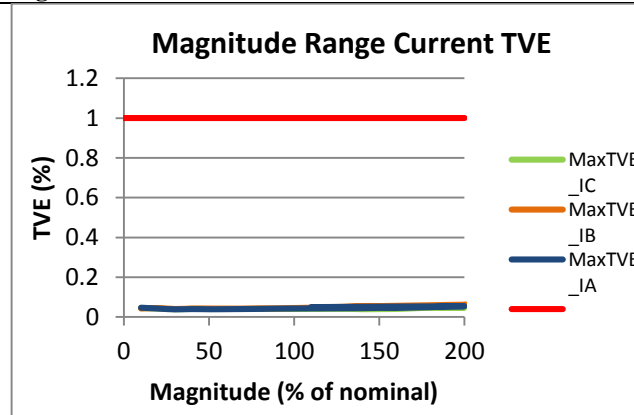


Figure 555:  $F_s = 12$  FPS

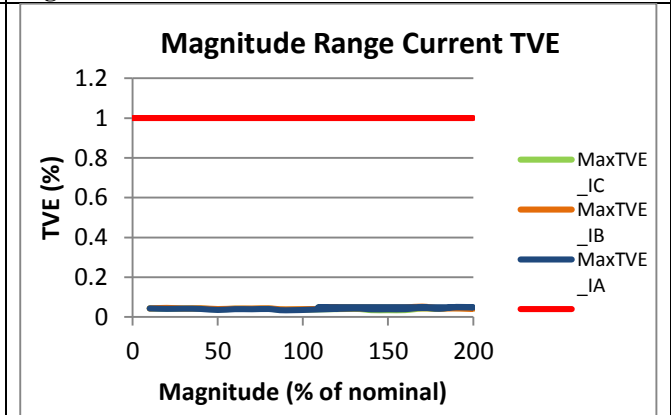


Figure 556:  $F_s = 10$  FPS

3.2.6 PMU E steady state signal magnitude current TVE: M class

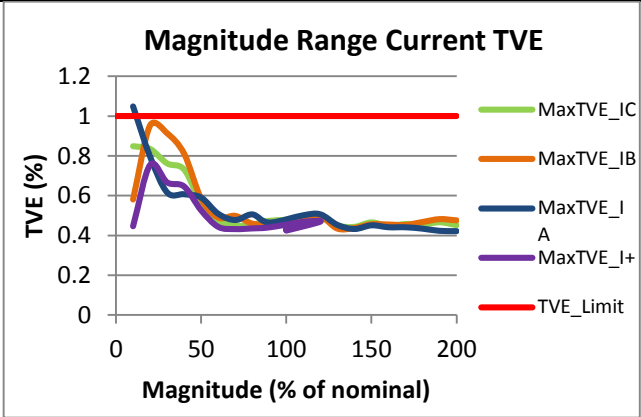


Figure 557: Fs = 60 FPS

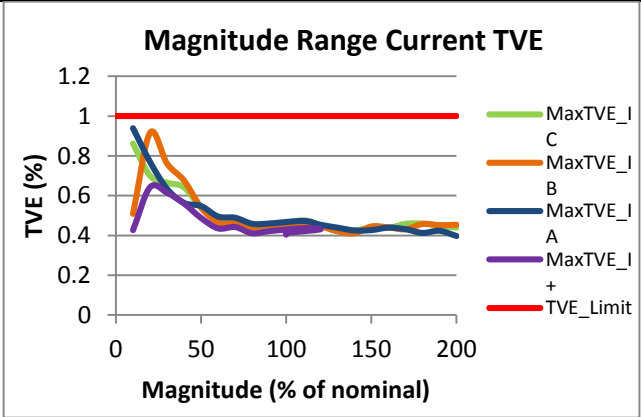


Figure 558: Fs = 30 FPS

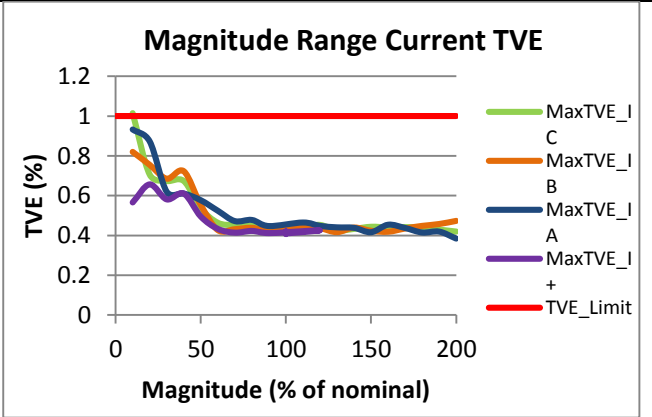


Figure 559: Fs = 20 FPS

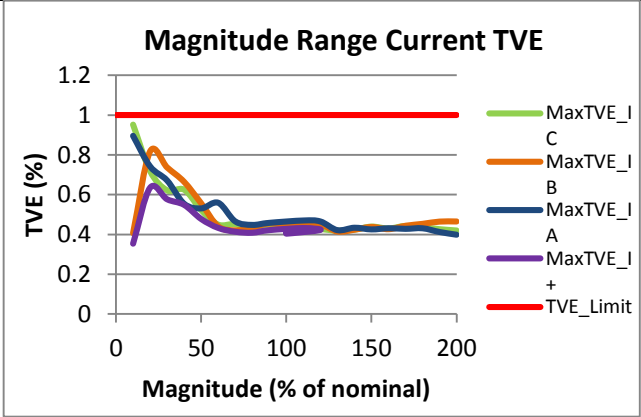


Figure 560: Fs = 15 FPS

MISSING DATA

Figure 561: Fs = 12 FPS

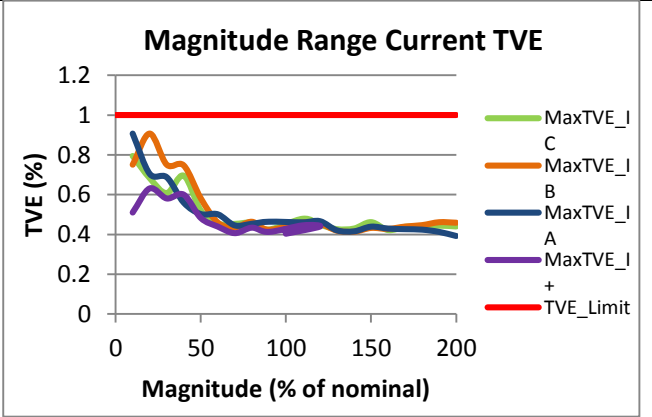


Figure 562: Fs = 10 FPS

### 3.2.7 PMU F steady state signal magnitude current TVE: M class

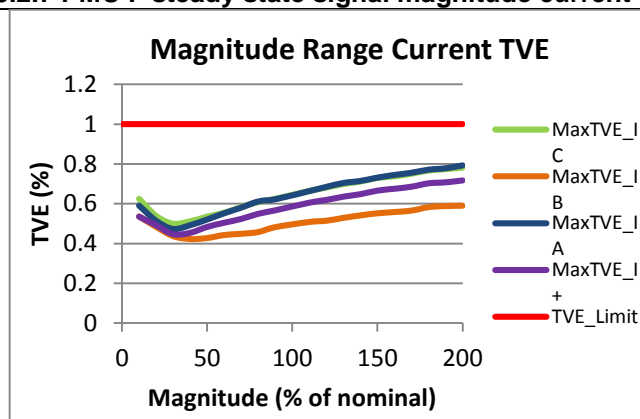


Figure 563: Fs = 60 FPS

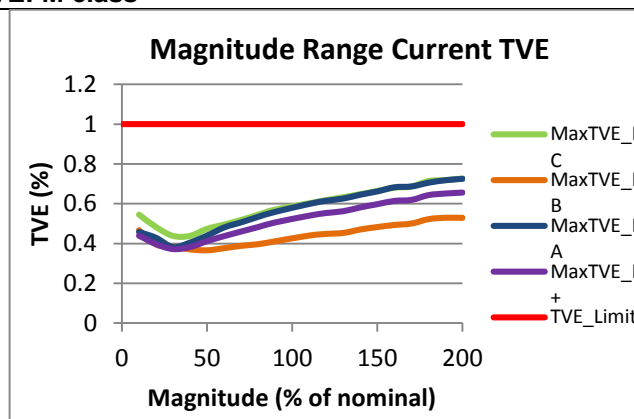


Figure 564: Fs = 30 FPS

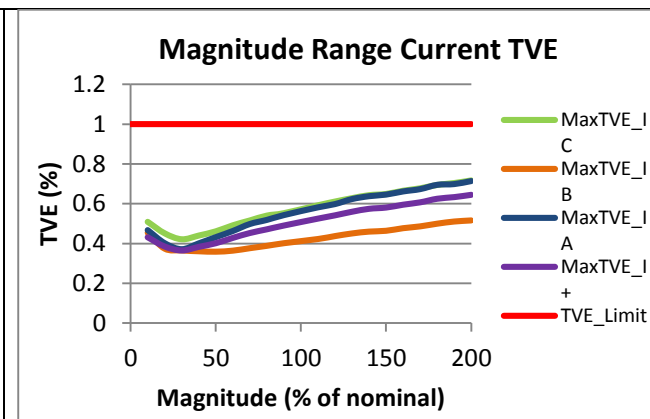


Figure 565: Fs = 20 FPS

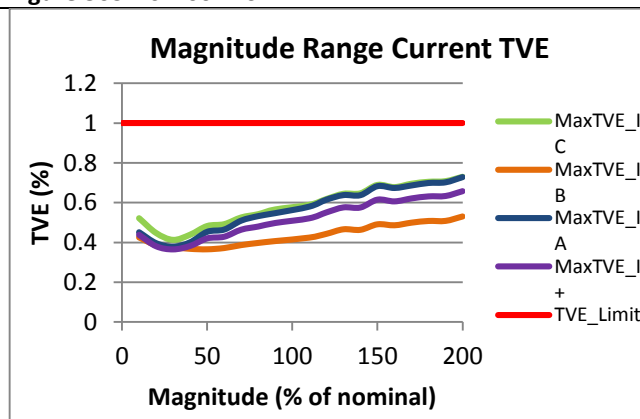


Figure 566: Fs = 15 FPS

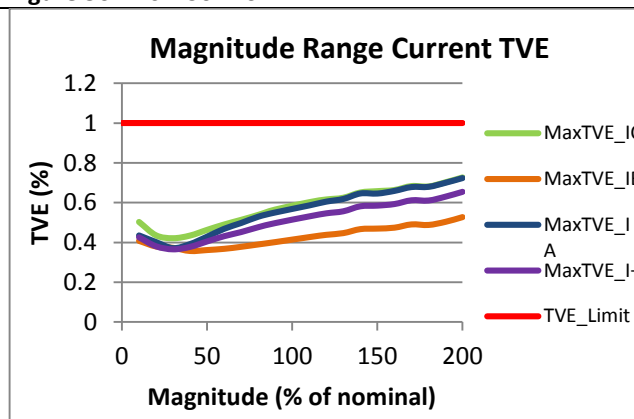


Figure 567: Fs = 12 FPS

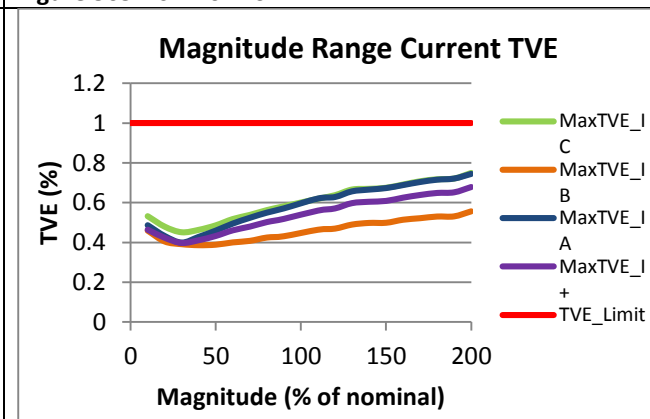


Figure 568: Fs = 10 FPS

### 3.2.8 PMU G steady state signal magnitude current TVE: M class

Figure 569:  $F_s = 60$  FPS is not supported by this PMU

Magnitude Range Current TVE

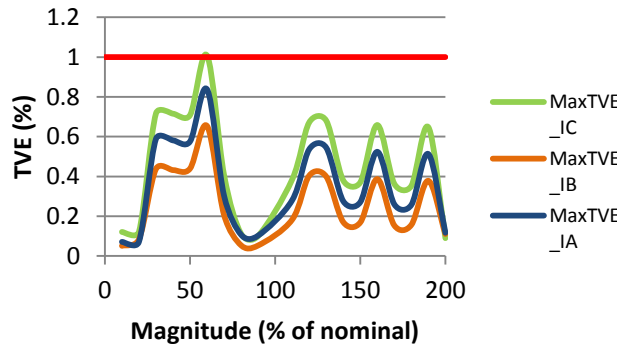


Figure 570:  $F_s = 30$  FPS

Magnitude Range Current TVE

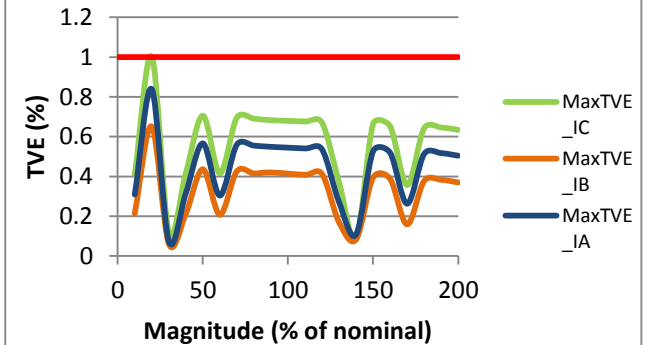


Figure 571:  $F_s = 20$  FPS

Magnitude Range Current TVE

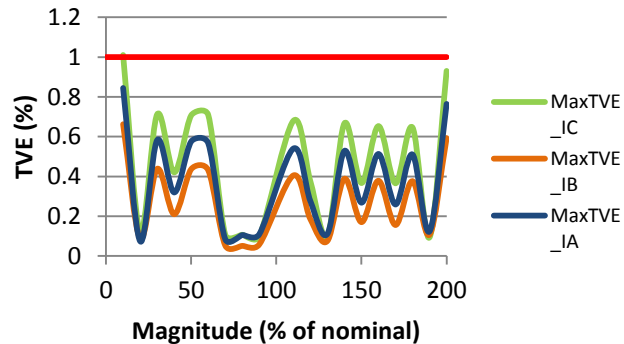


Figure 572:  $F_s = 15$  FPS

Magnitude Range Current TVE

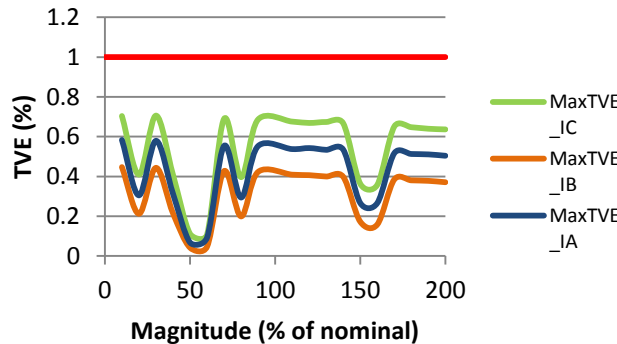


Figure 573:  $F_s = 12$  FPS

Magnitude Range Current TVE

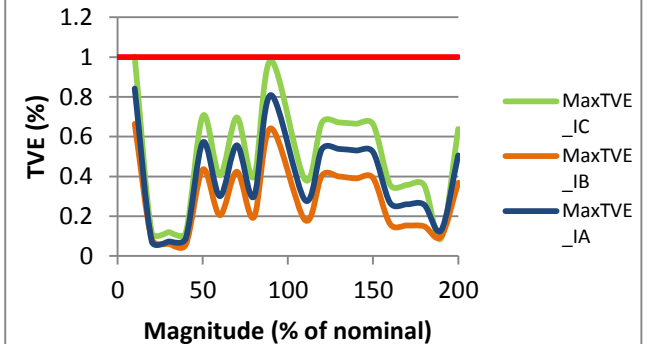


Figure 574:  $F_s = 10$  FPS



### 3.2.9 PMU H steady state signal magnitude current TVE: M class

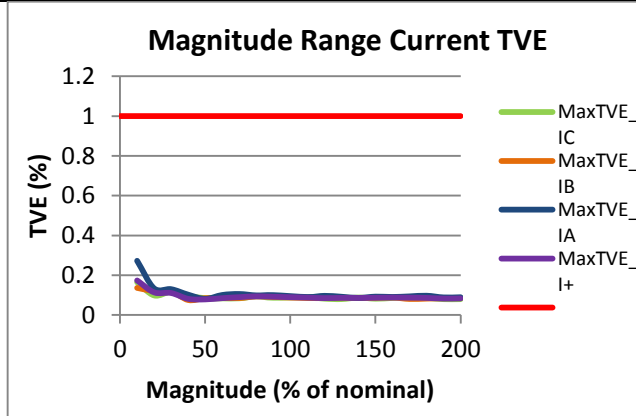


Figure 575:  $F_s = 60$  FPS

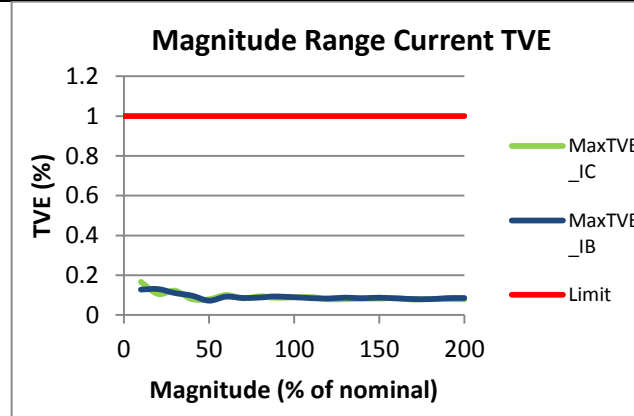


Figure 576:  $F_s = 30$  FPS

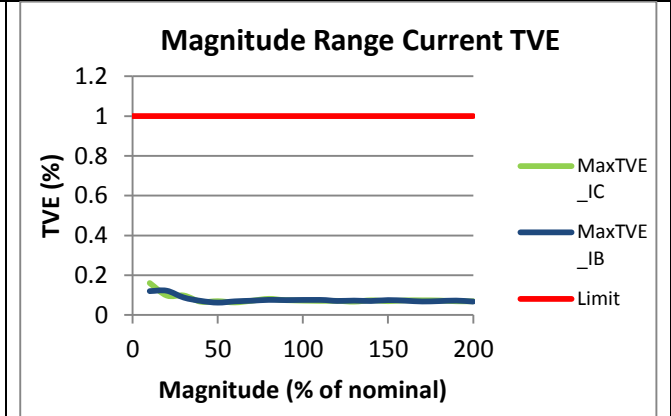


Figure 577:  $F_s = 20$  FPS

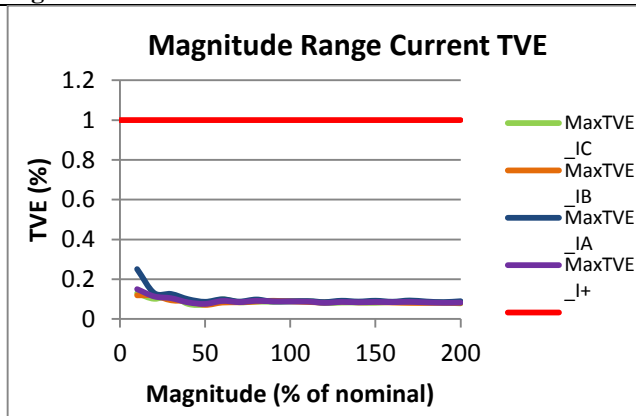


Figure 578:  $F_s = 15$  FPS

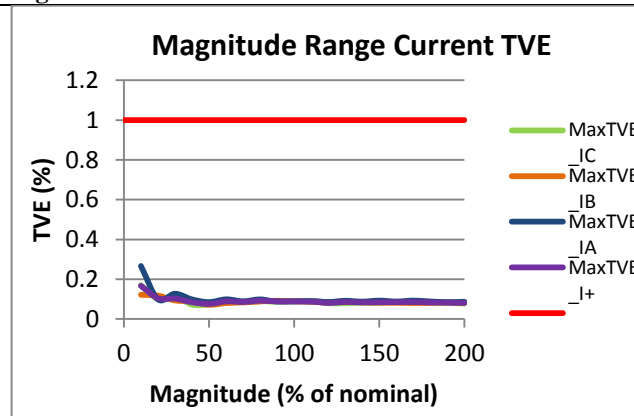


Figure 579:  $F_s = 12$  FPS

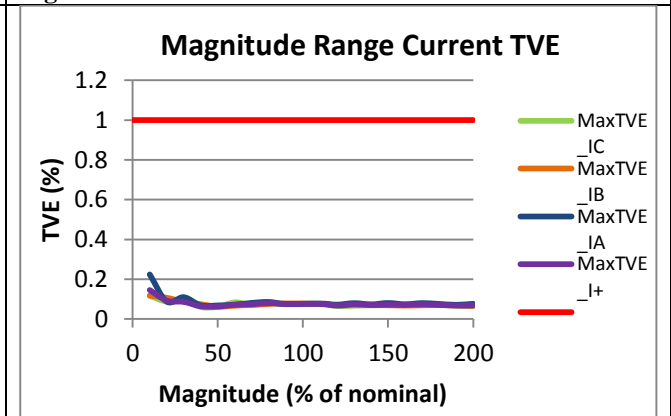


Figure 580:  $F_s = 10$  FPS

### 3.2.10 PMU I steady state signal magnitude current TVE: M class

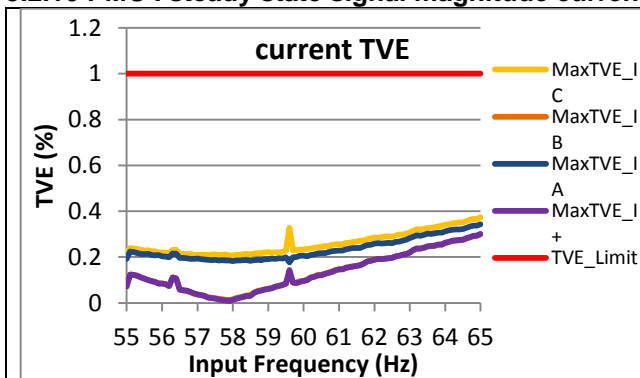


Figure 581:  $F_s = 60$  FPS

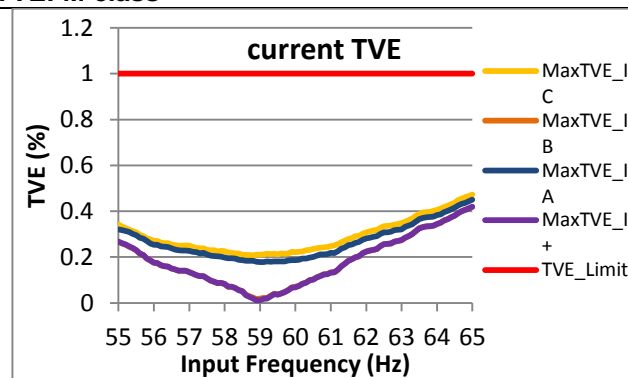


Figure 582:  $F_s = 30$  FPS

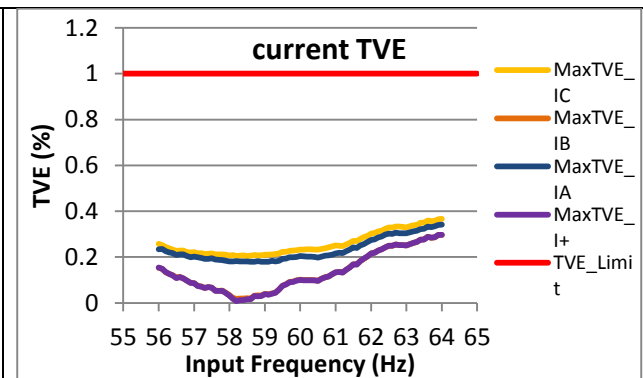


Figure 583:  $F_s = 20$  FPS

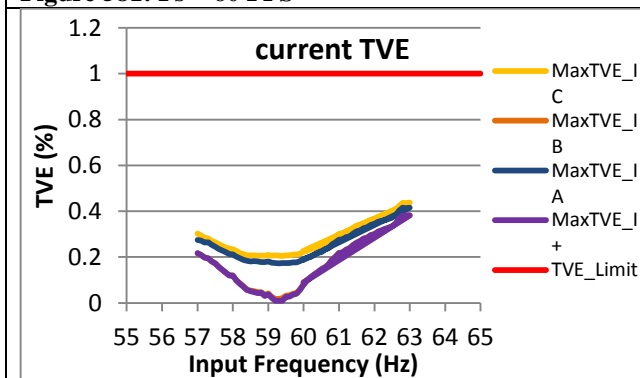


Figure 584:  $F_s = 15$  FPS

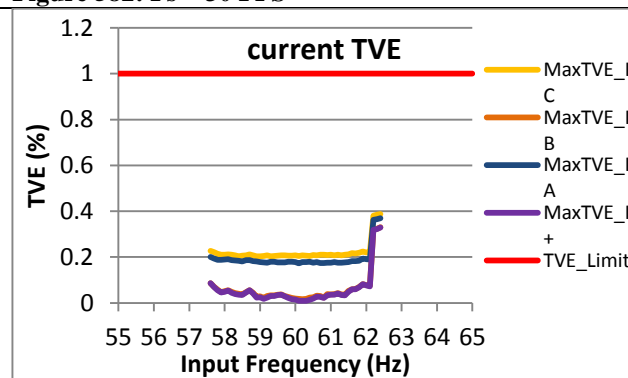


Figure 585:  $F_s = 12$  FPS

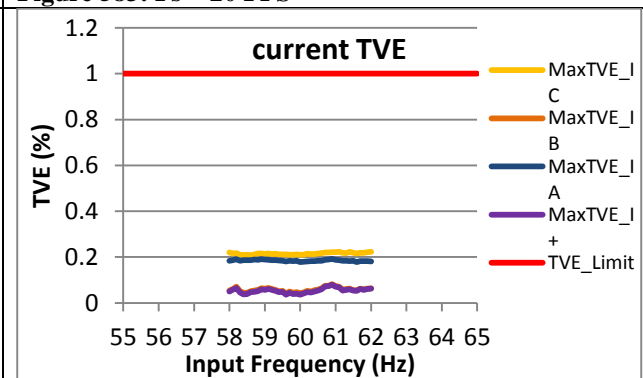


Figure 586:  $F_s = 10$  FPS

### 3.2.11 PMU J steady state signal magnitude current TVE: M class

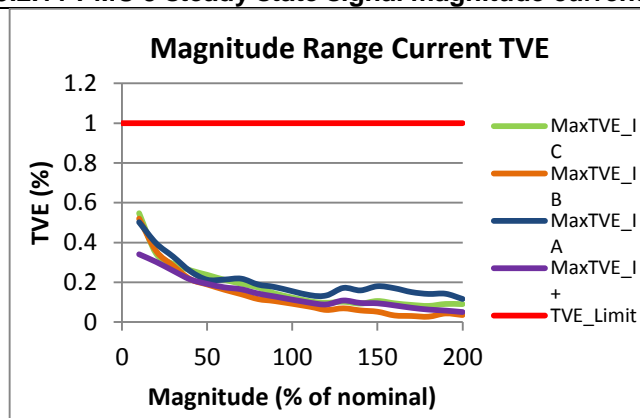


Figure 587: Fs = 60 FPS

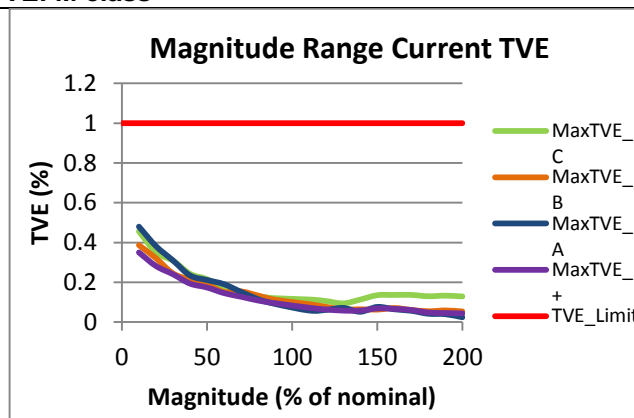


Figure 588: Fs = 30 FPS

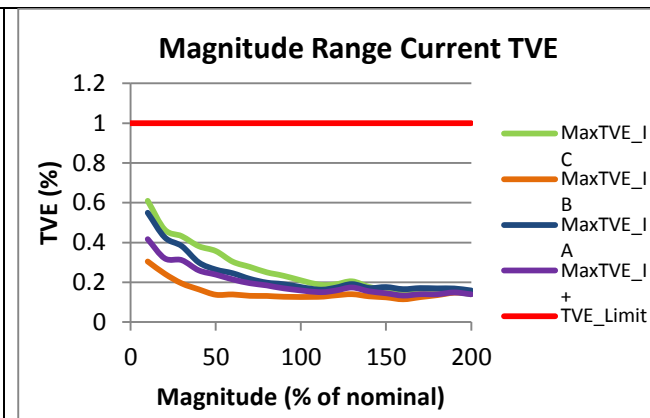


Figure 589: Fs = 20 FPS

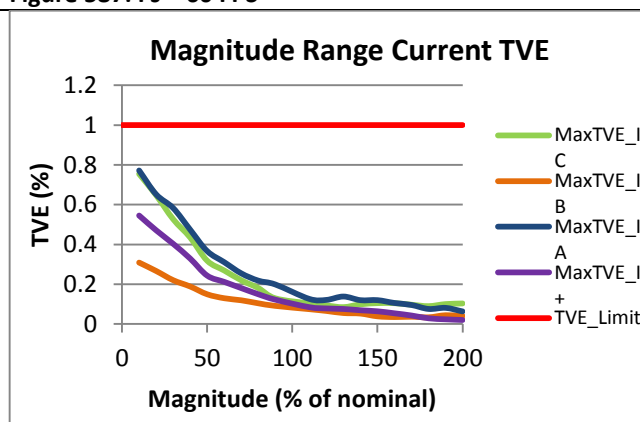


Figure 590: Fs = 15 FPS

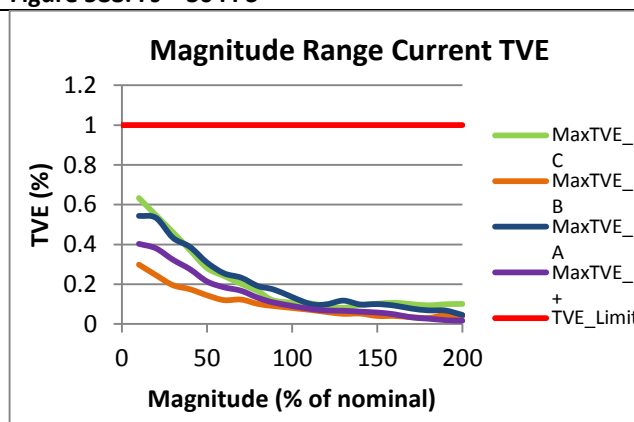


Figure 591: Fs = 12 FPS

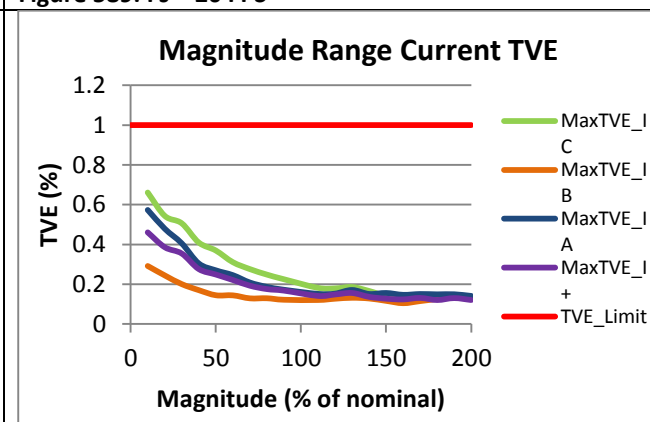
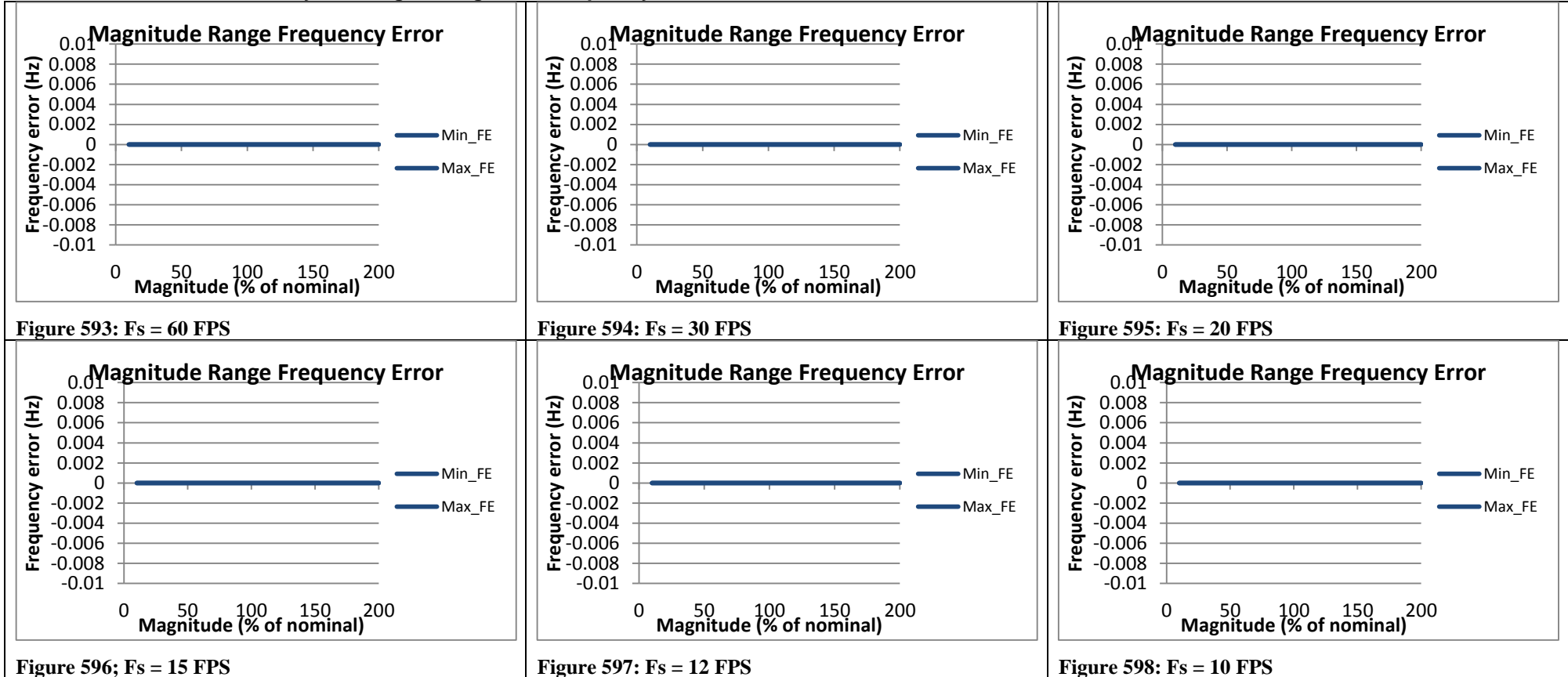


Figure 592: Fs = 10 FPS

### 3.3 Steady state signal magnitude frequency error M class

No performance limits are shown in the plots below because the steady state magnitude range tests do not require frequency error to meet performance limits

#### 3.3.1 C37.118.1 Annex C steady state signal magnitude frequency error: M class



### 3.3.2 PMU A steady state signal magnitude frequency error: M class

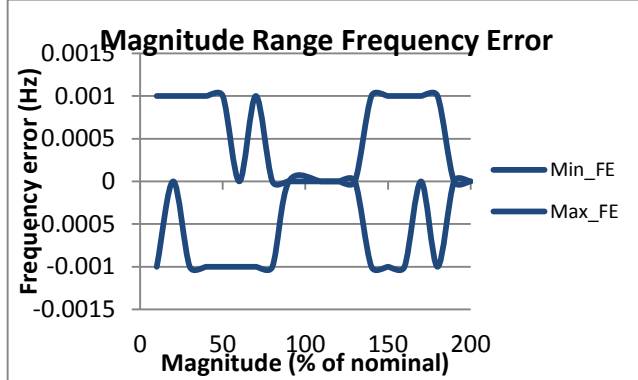


Figure 599:  $F_s = 60$  FPS

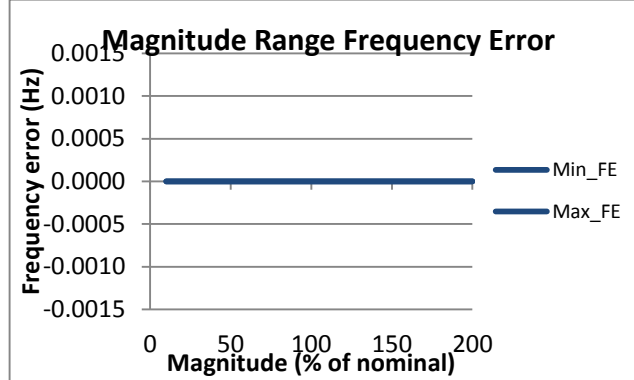


Figure 600:  $F_s = 30$  FPS

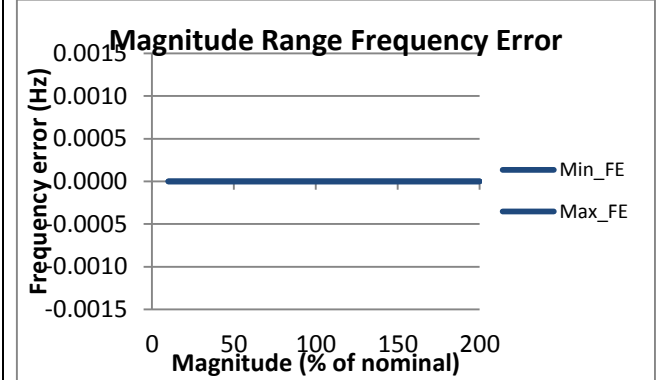


Figure 601:  $F_s = 20$  FPS

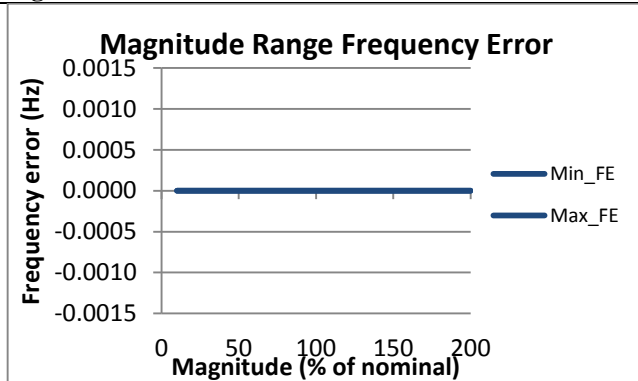


Figure 602:  $F_s = 15$  FPS

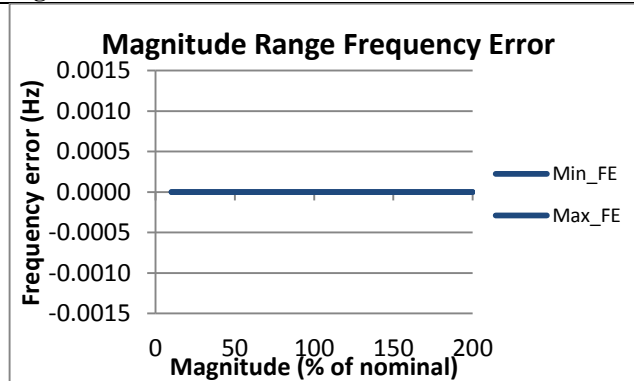


Figure 603:  $F_s = 12$  FPS

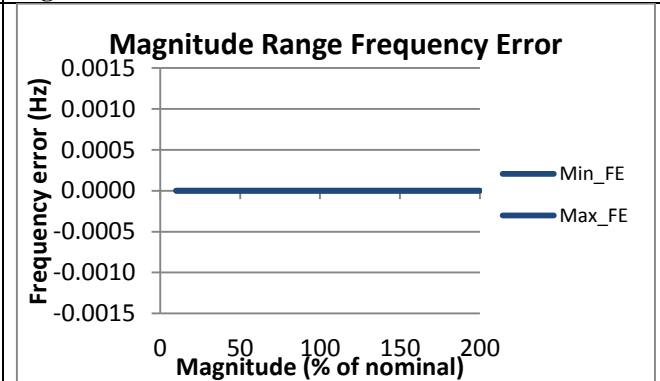


Figure 604:  $F_s = 10$  FPS

### 3.3.3 PMU B steady state signal magnitude frequency error: M class

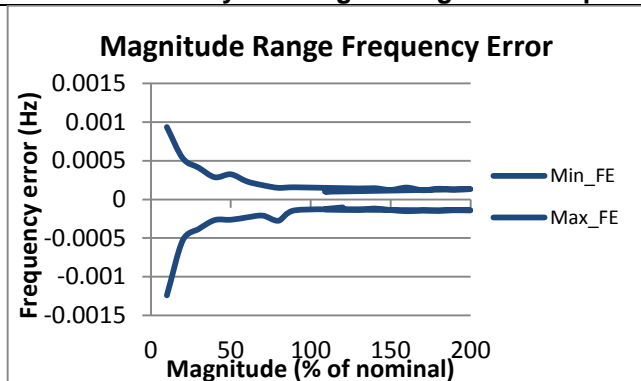


Figure 605:  $F_s = 60$  FPS

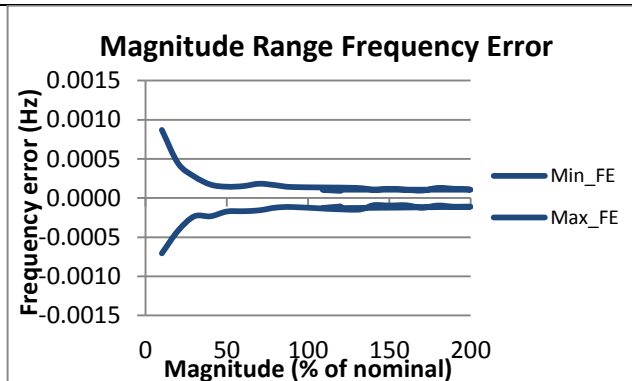


Figure 606:  $F_s = 30$  FPS

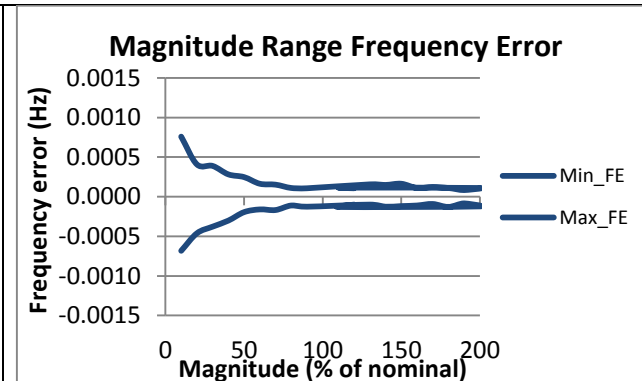


Figure 607:  $F_s = 20$  FPS

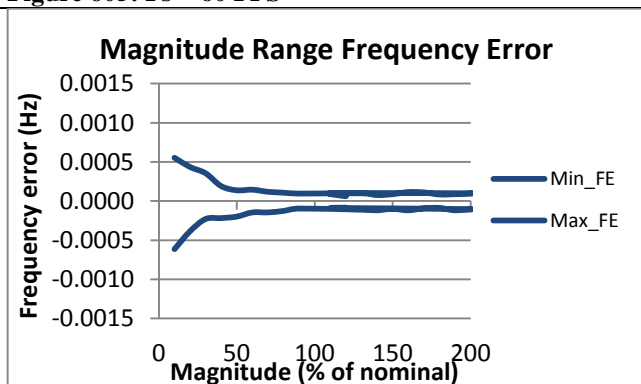


Figure 608:  $F_s = 15$  FPS

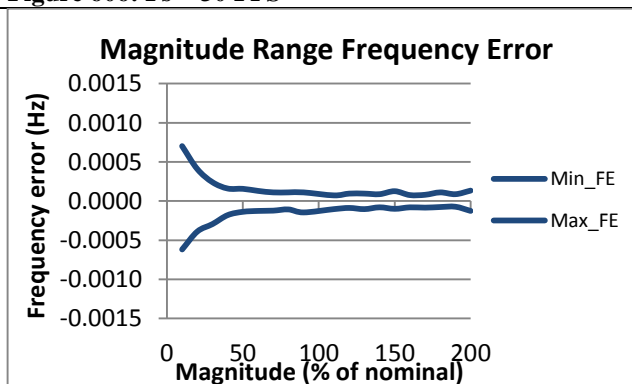


Figure 609:  $F_s = 12$  FPS

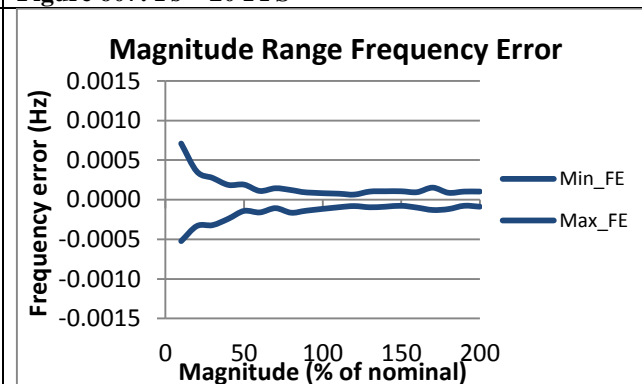


Figure 610:  $F_s = 10$  FPS

### 3.3.4 PMU C steady state signal magnitude frequency error: M class

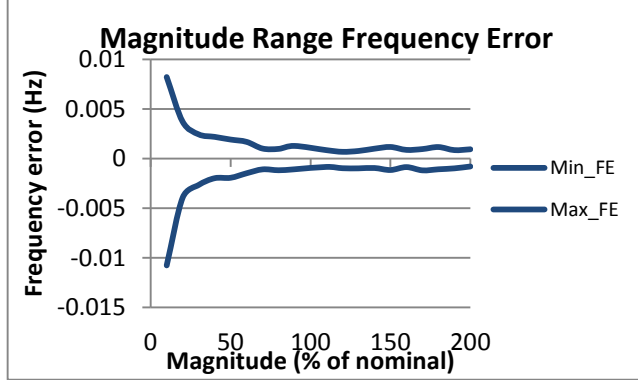


Figure 611:  $F_s = 60$  FPS

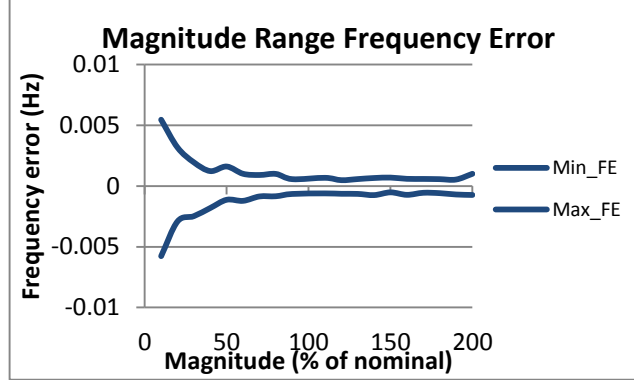


Figure 612:  $F_s = 30$  FPS

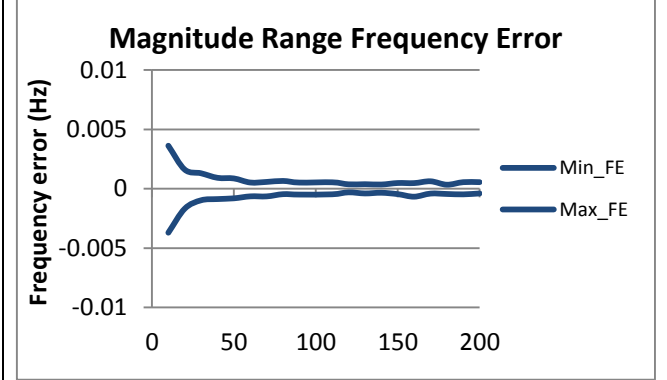


Figure 613:  $F_s = 20$  FPS

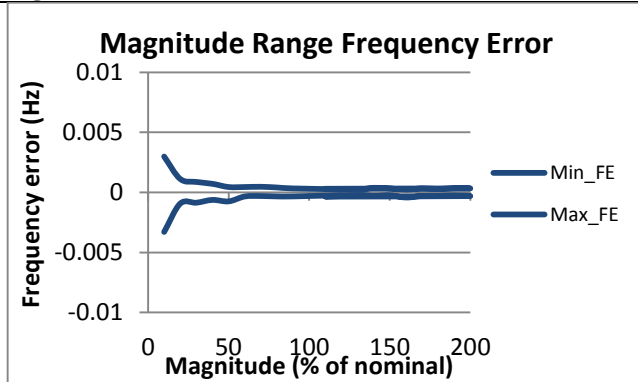


Figure 614:  $F_s = 15$  FPS

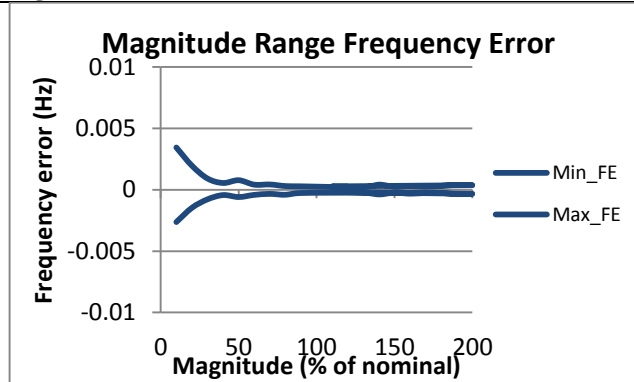


Figure 615:  $F_s = 12$  FPS

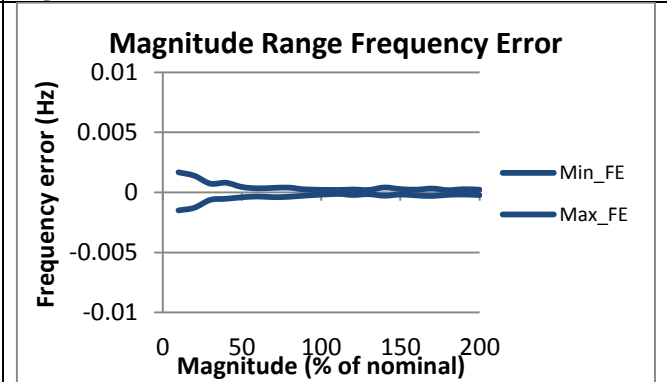


Figure 616:  $F_s = 10$  FPS

### 3.3.5 PMU D steady state signal magnitude frequency error: M class

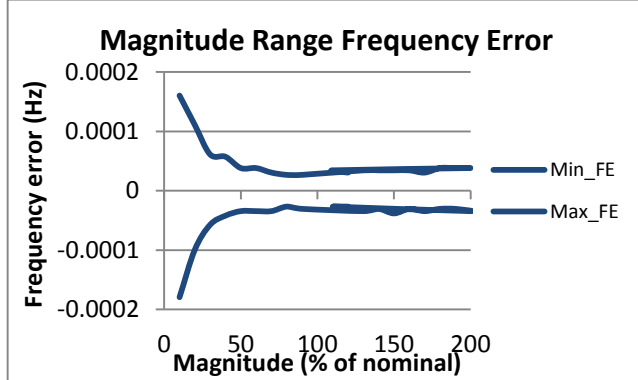


Figure 617:  $F_s = 60$  FPS

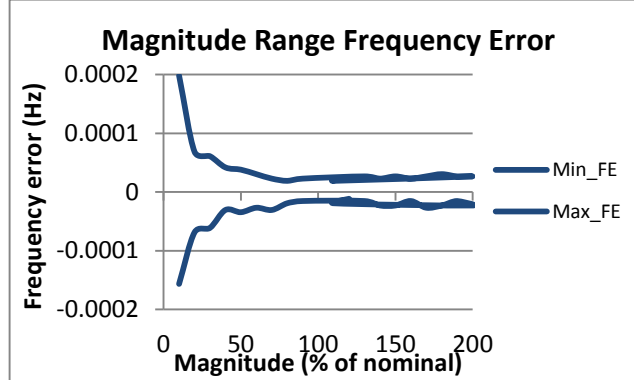


Figure 618:  $F_s = 30$  FPS

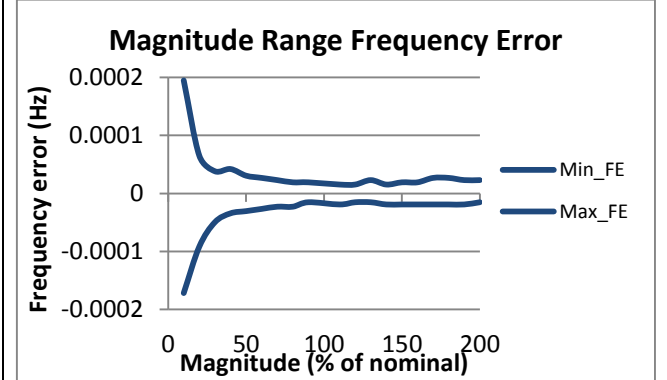


Figure 619:  $F_s = 20$  FPS

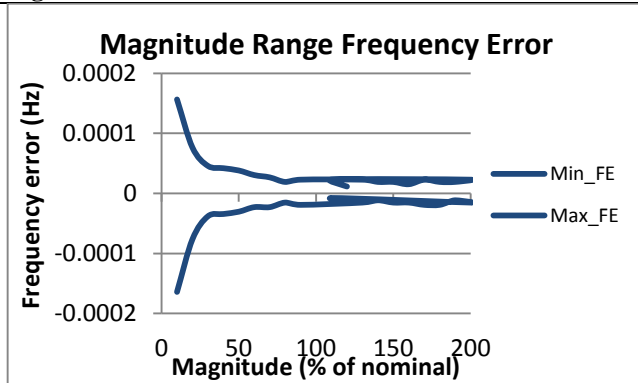


Figure 620:  $F_s = 15$  FPS

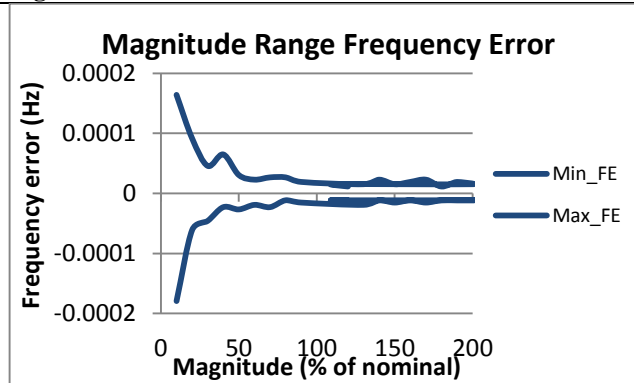


Figure 621:  $F_s = 12$  FPS

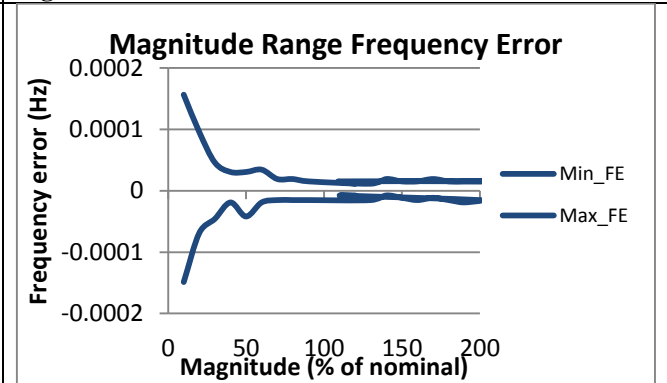


Figure 622:  $F_s = 10$  FPS



### 3.3.6 PMU E steady state signal magnitude frequency error: M class

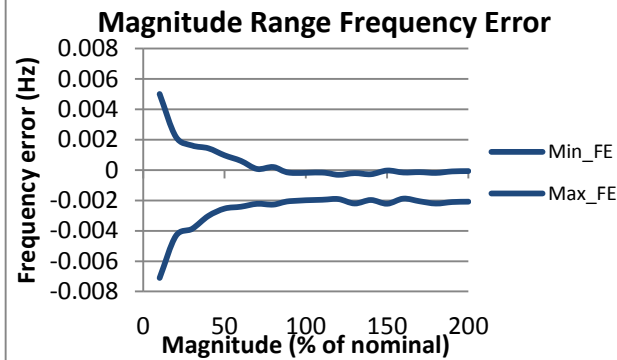


Figure 623:  $F_s = 60$  FPS

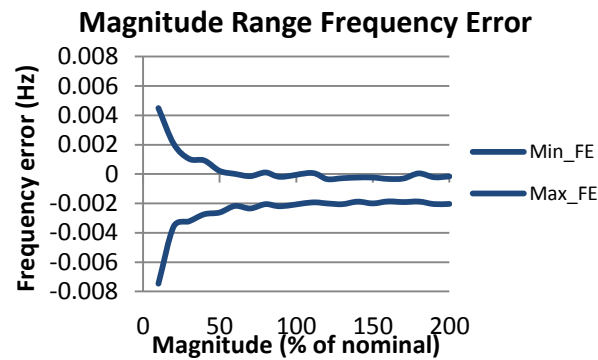


Figure 624:  $F_s = 30$  FPS

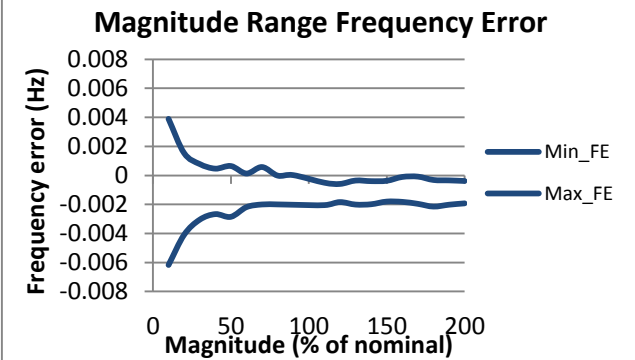


Figure 625:  $F_s = 20$  FPS

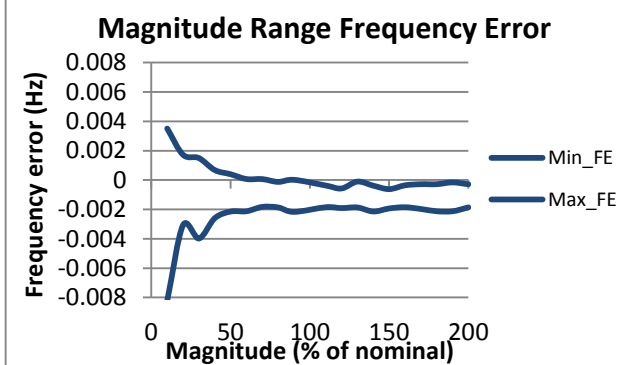


Figure 626:  $F_s = 15$  FPS

MISSING DATA

Figure 627:  $F_s = 12$  FPS

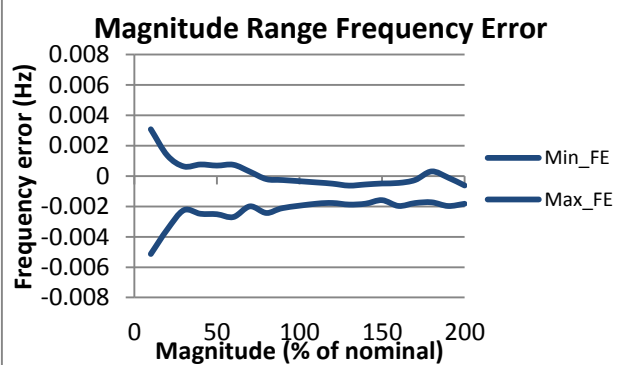


Figure 628:  $F_s = 10$  FPS

### 3.3.7 PMU F steady state signal magnitude frequency error: M class

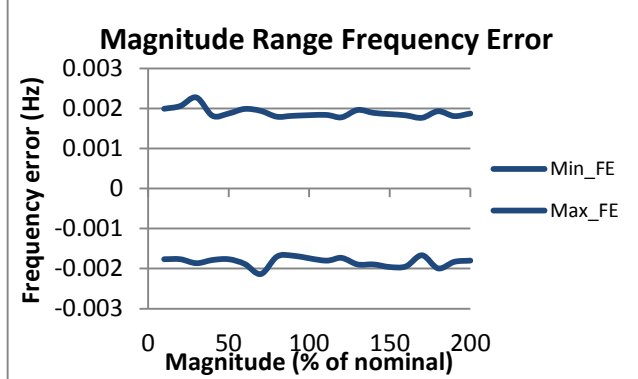


Figure 629:  $F_s = 60$  FPS

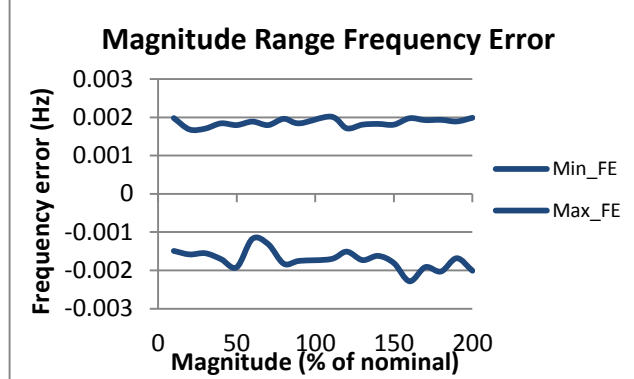


Figure 630:  $F_s = 30$  FPS

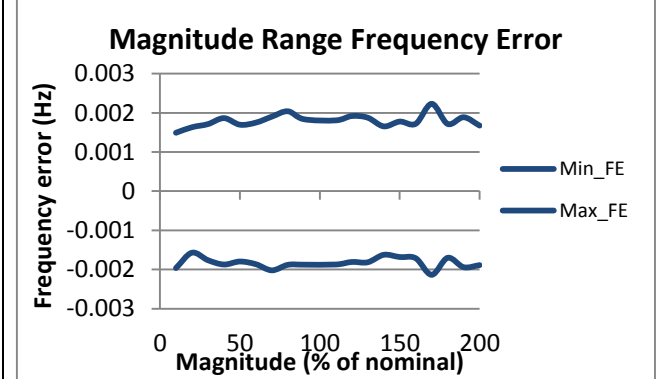


Figure 631:  $F_s = 20$  FPS

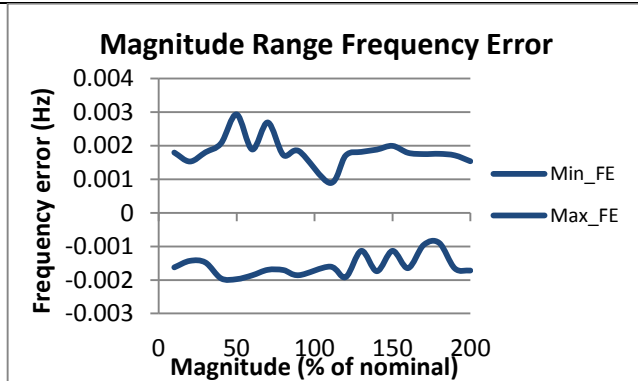


Figure 632:  $F_s = 15$  FPS

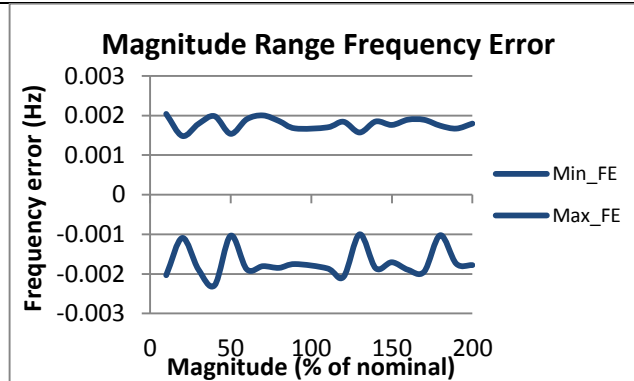


Figure 633:  $F_s = 12$  FPS

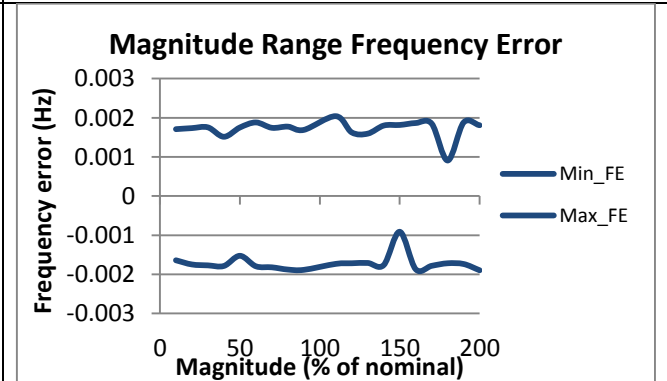


Figure 634:  $F_s = 10$  FPS

### 3.3.8 PMU G steady state signal magnitude frequency error: M class

Figure 635:  $F_s = 60$  FPS is not supported by this PMU

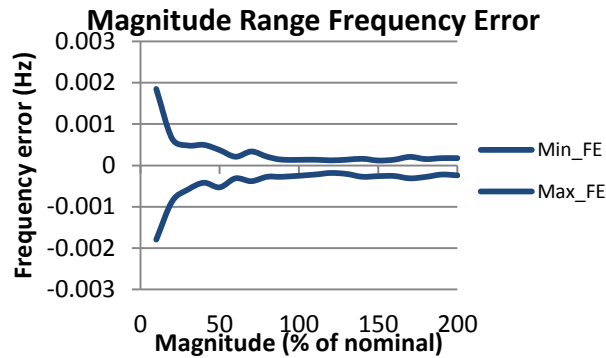


Figure 636:  $F_s = 30$  FPS

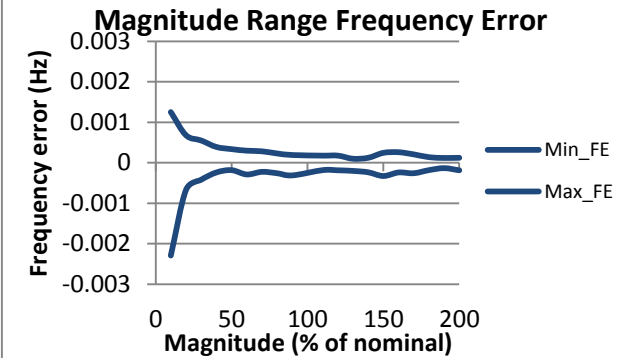


Figure 637:  $F_s = 20$  FPS

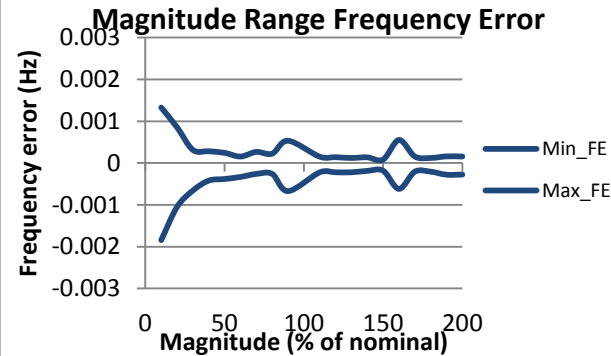


Figure 638:  $F_s = 15$  FPS

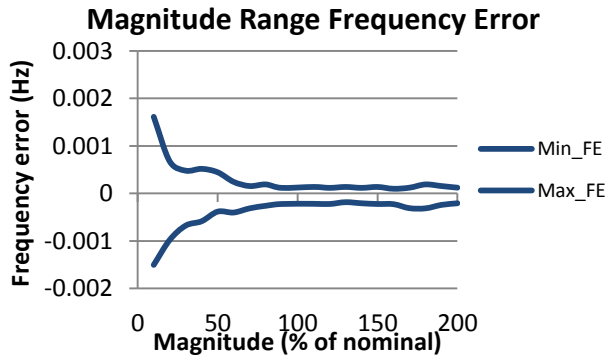


Figure 639:  $F_s = 12$  FPS

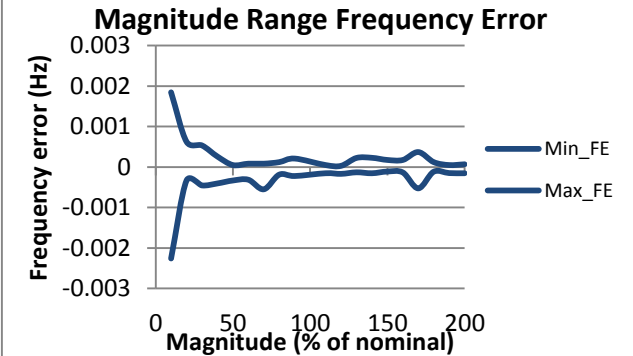


Figure 640:  $F_s = 10$  FPS

### 3.3.9 PMU H steady state signal magnitude frequency error: M class

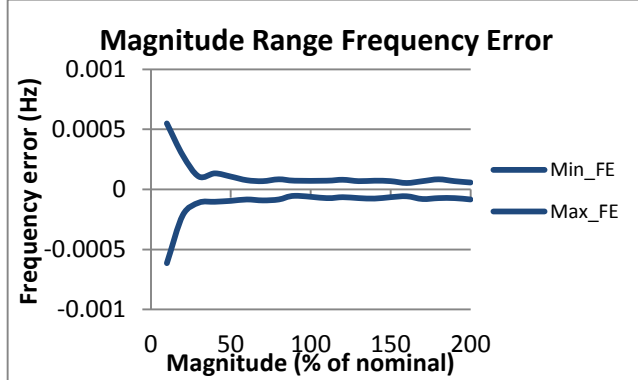


Figure 641:  $F_s = 60$  FPS

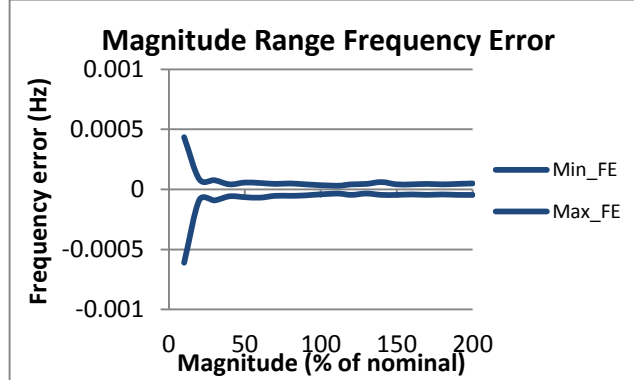


Figure 642:  $F_s = 30$  FPS

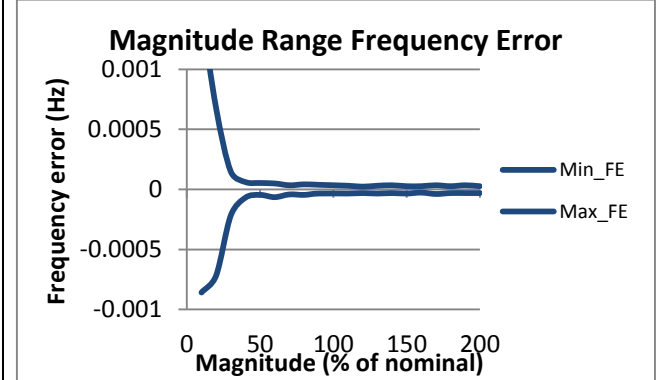


Figure 643:  $F_s = 20$  FPS

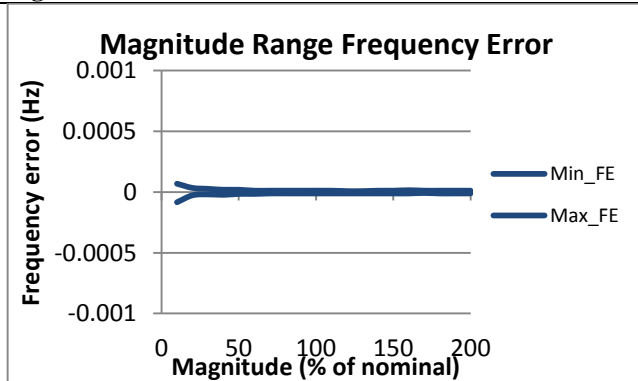


Figure 644:  $F_s = 15$  FPS

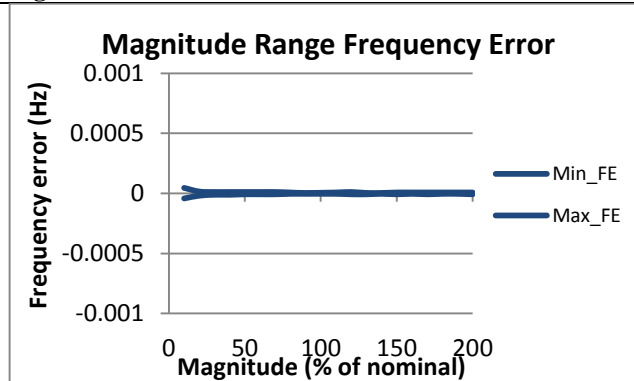


Figure 645:  $F_s = 12$  FPS

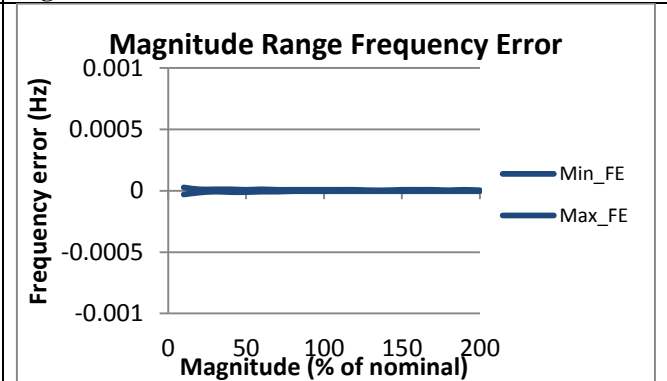


Figure 646:  $F_s = 10$  FPS

### 3.3.10 PMU I steady state signal magnitude frequency error: M class

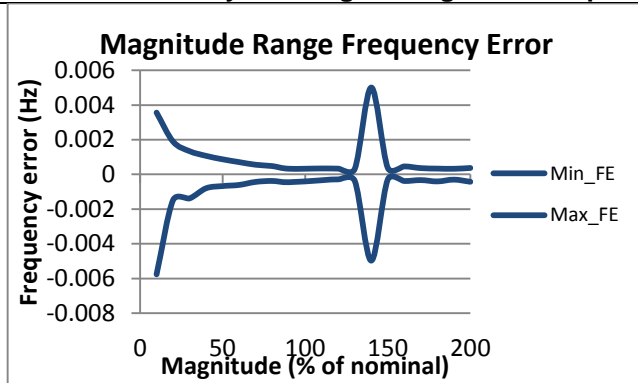


Figure 647:  $F_s = 60$  FPS

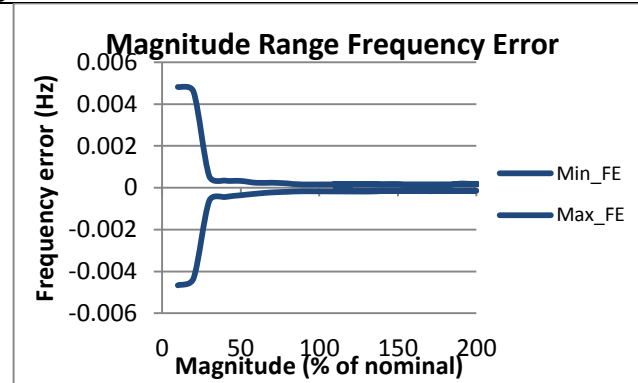


Figure 648:  $F_s = 30$  FPS

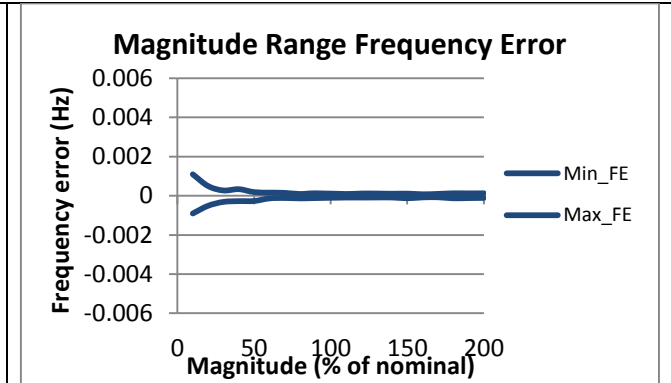


Figure 649:  $F_s = 20$  FPS

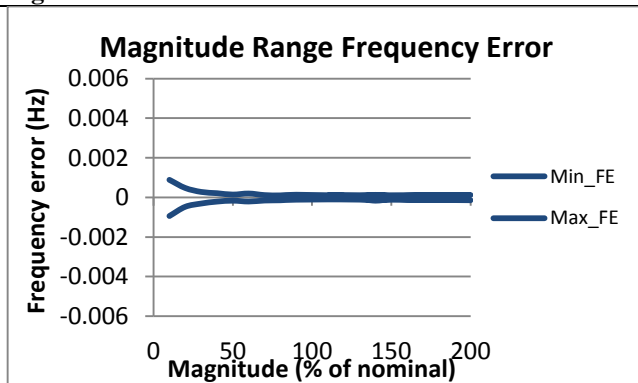


Figure 650:  $F_s = 15$  FPS

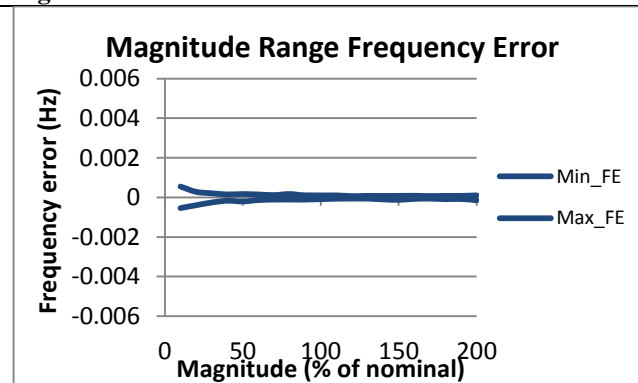


Figure 651:  $F_s = 12$  FPS

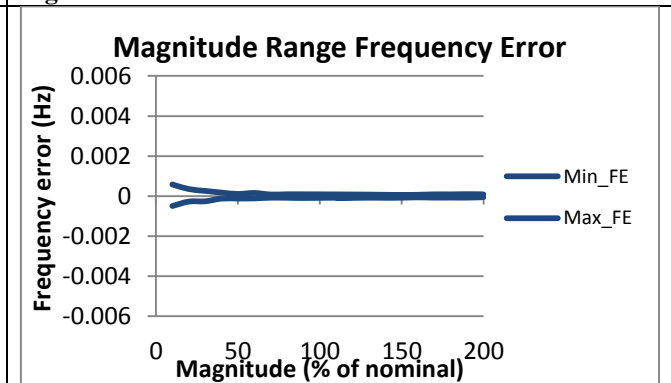


Figure 652:  $F_s = 10$  FPS

### 3.3.11 PMU J steady state signal magnitude frequency error: M class

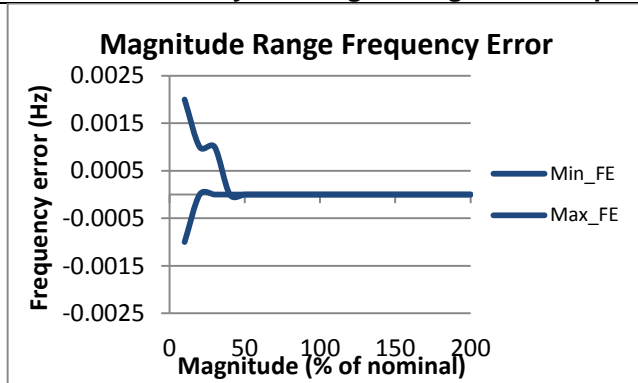


Figure 653:  $F_s = 60$  FPS

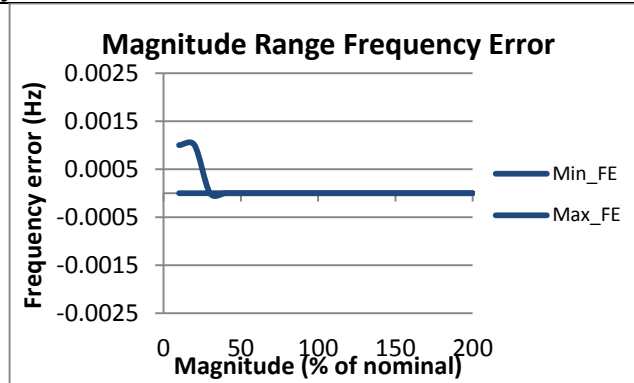


Figure 654:  $F_s = 30$  FPS

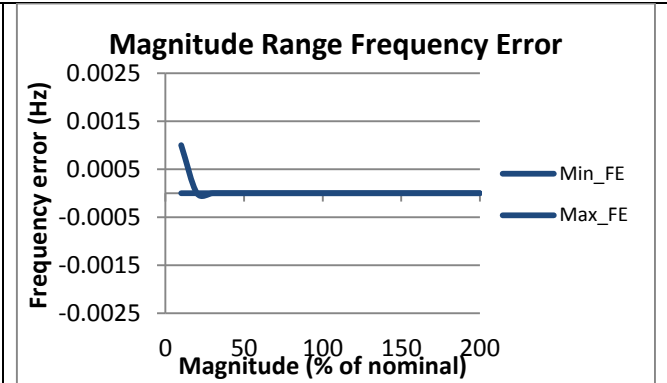


Figure 655:  $F_s = 20$  FPS

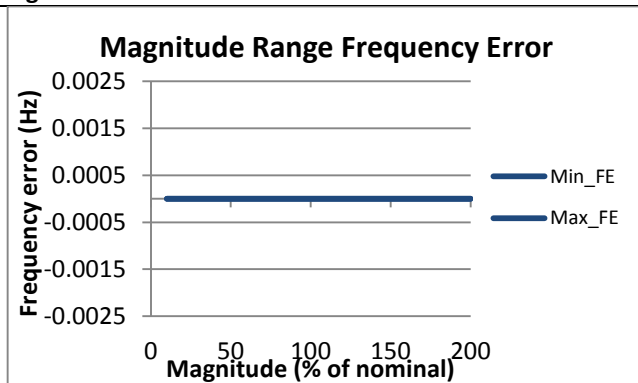


Figure 656:  $F_s = 15$  FPS

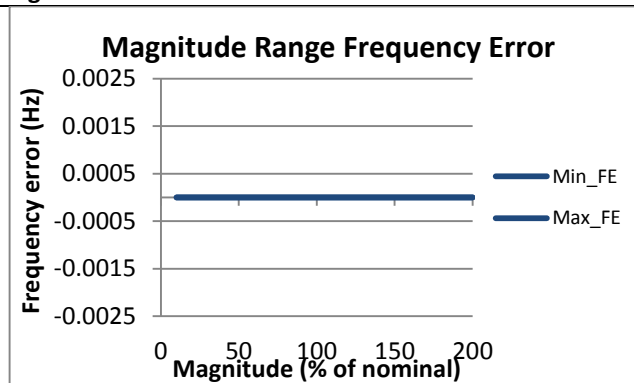


Figure 657:  $F_s = 12$  FPS

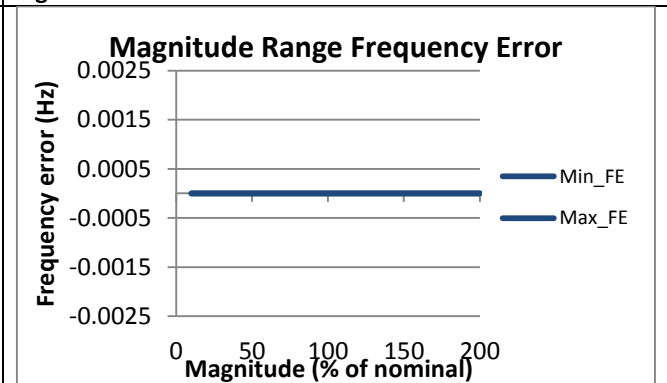
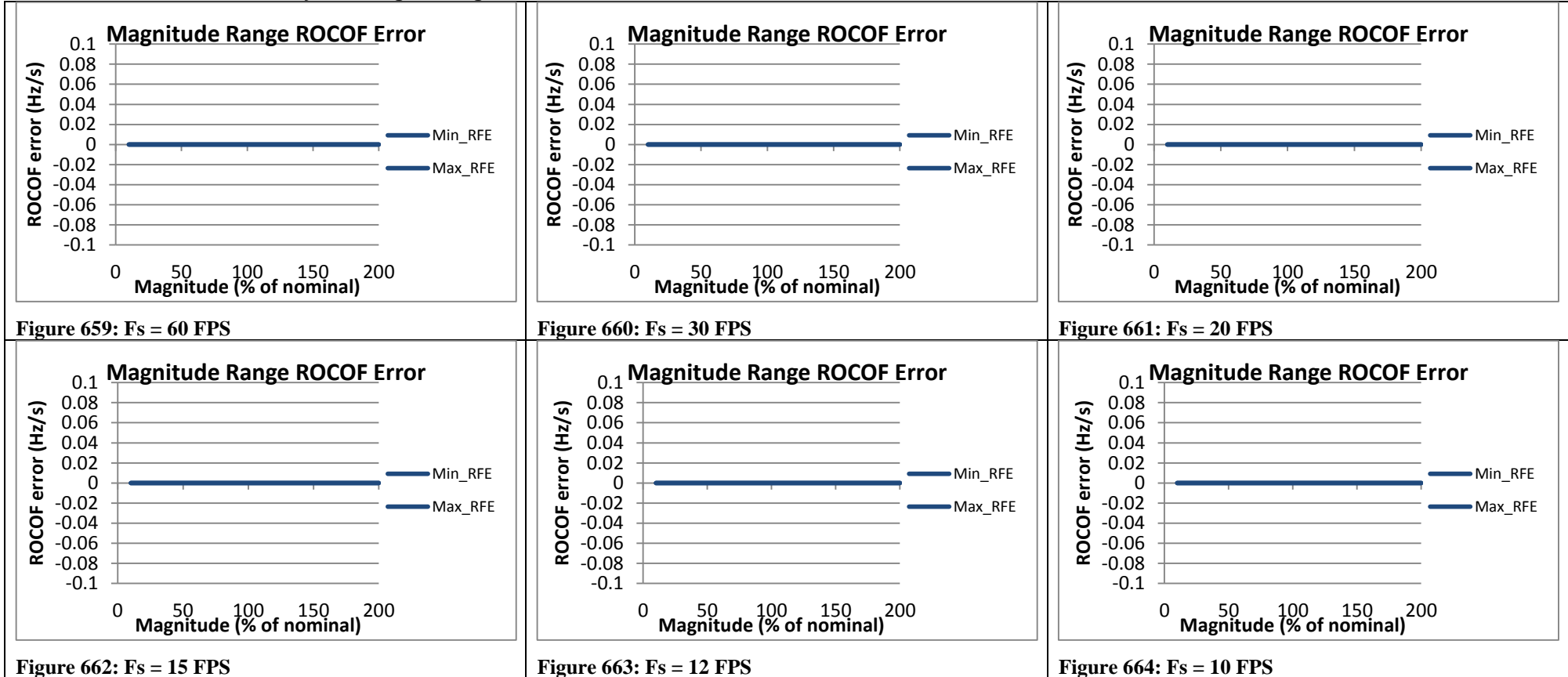


Figure 658:  $F_s = 10$  FPS

### 3.4 Steady state signal magnitude ROCOF error M class

No limits are shown in the plots below because the steady state magnitude range tests do not require ROCOF error to meet performance limits

#### 3.4.1 C37.118.1 Annex C steady state signal magnitude ROCOF error: M class



### 3.4.2 PMU A steady state signal magnitude ROCOF error: M class

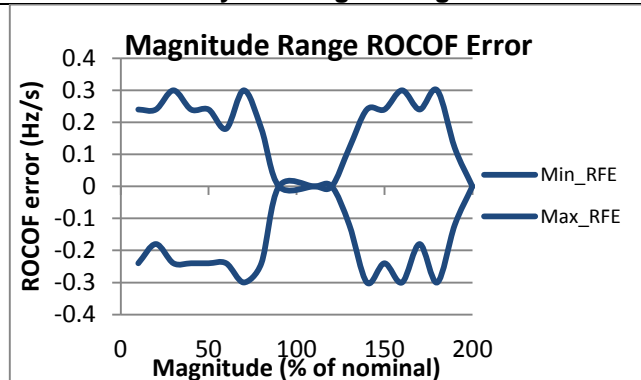


Figure 665:  $F_s = 60$  FPS

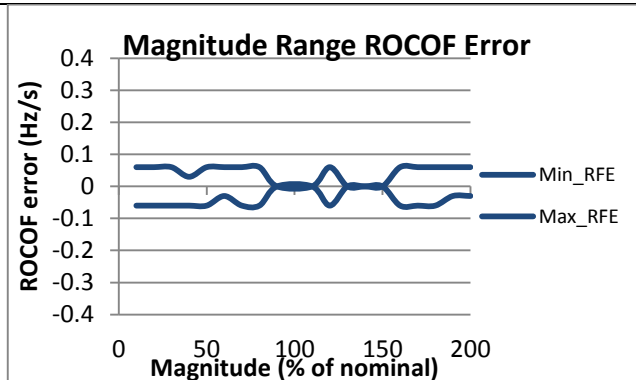


Figure 666:  $F_s = 30$  FPS

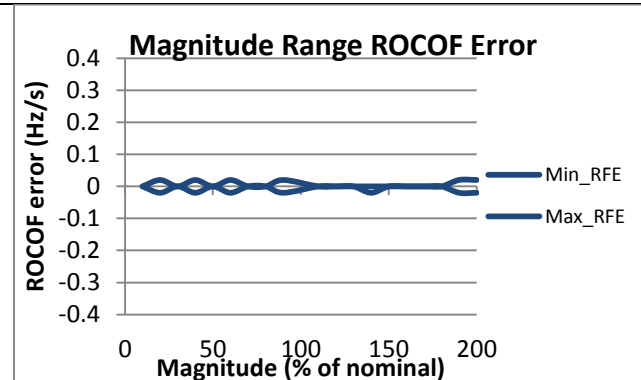


Figure 667:  $F_s = 20$  FPS

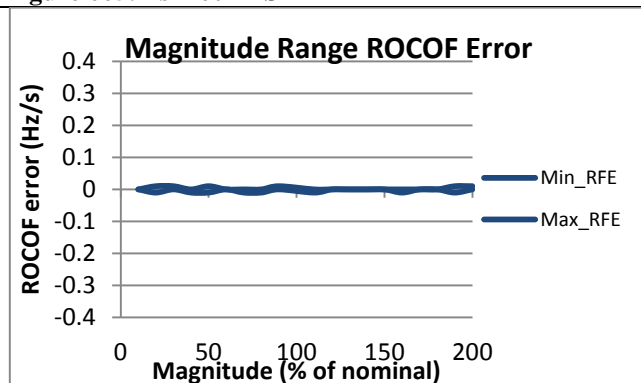


Figure 668:  $F_s = 15$  FPS

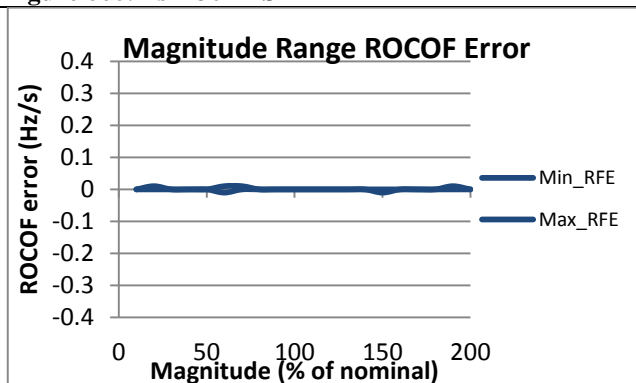


Figure 669:  $F_s = 12$  FPS

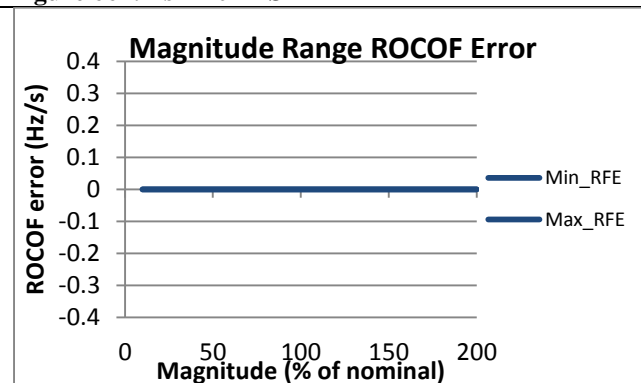


Figure 670:  $F_s = 10$  FPS



### 3.4.3 PMU B steady state signal magnitude ROCOF error: M class

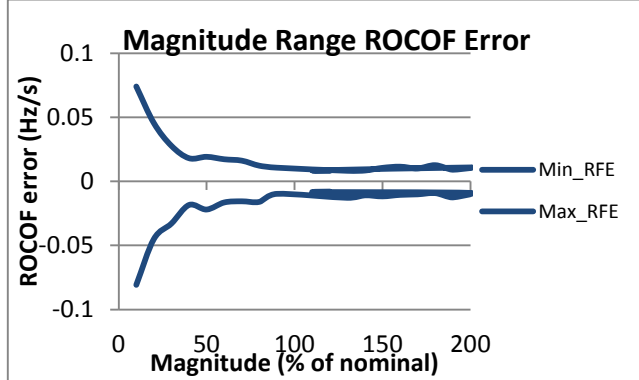


Figure 671:  $F_s = 60$  FPS

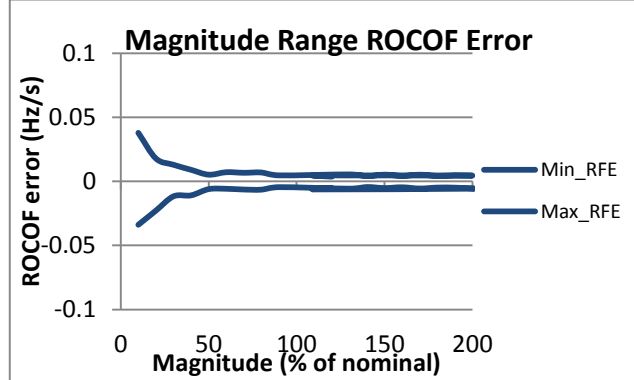


Figure 672:  $F_s = 30$  FPS

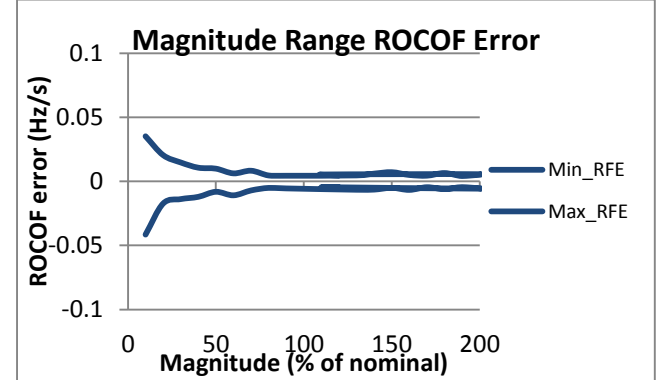


Figure 673:  $F_s = 20$  FPS

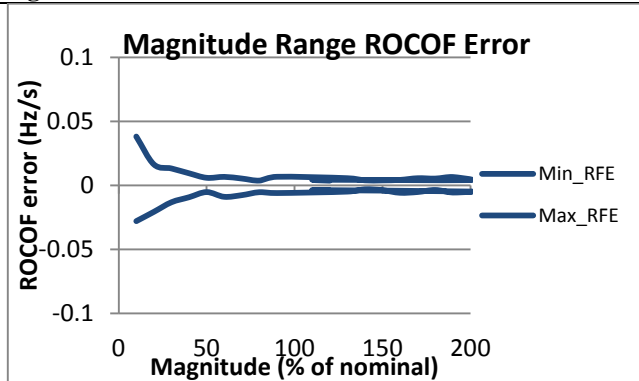


Figure 674:  $F_s = 15$  FPS

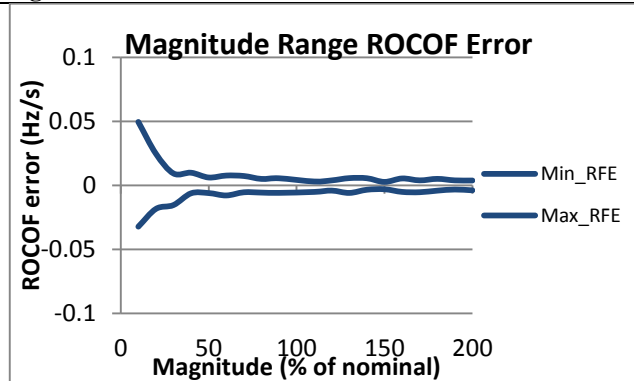


Figure 675:  $F_s = 12$  FPS

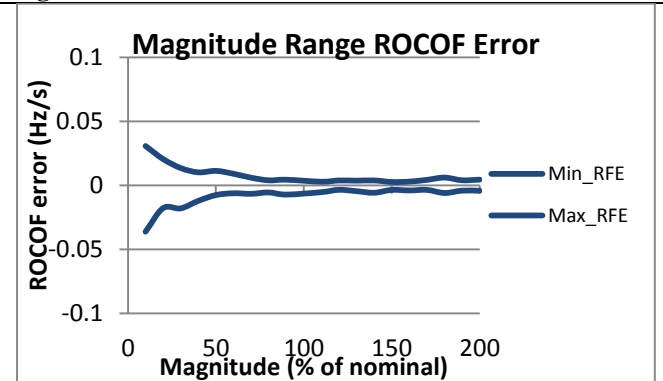


Figure 676:  $F_s = 10$  FPS

#### 3.4.4 PMU C steady state signal magnitude ROCOF error: M class

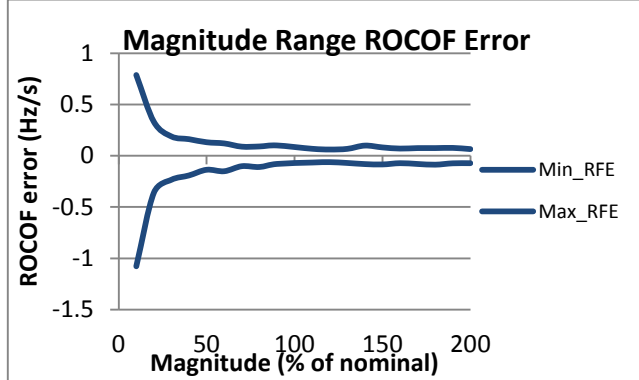


Figure 677:  $F_s = 60$  FPS

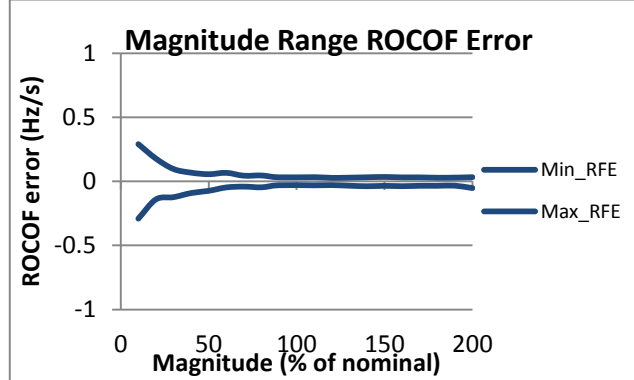


Figure 678:  $F_s = 30$  FPS

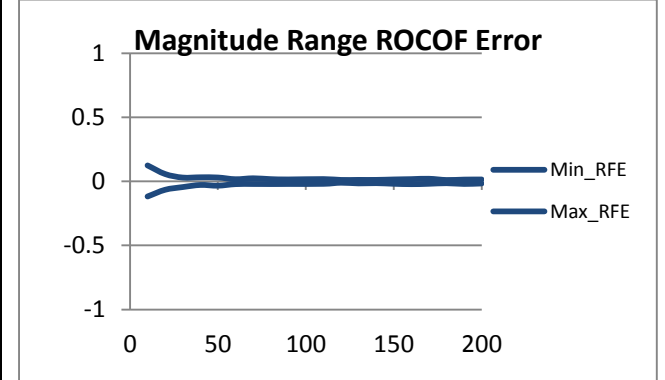


Figure 679:  $F_s = 20$  FPS

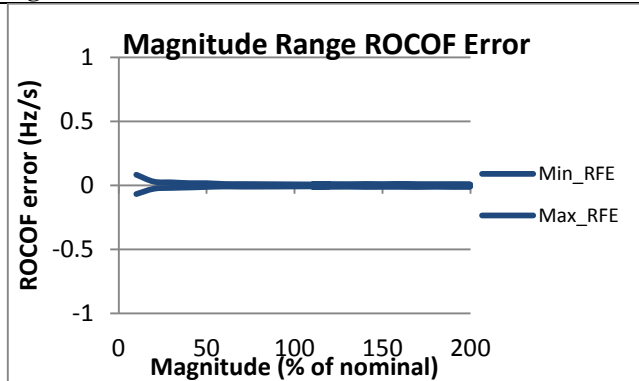


Figure 680:  $F_s = 15$  FPS

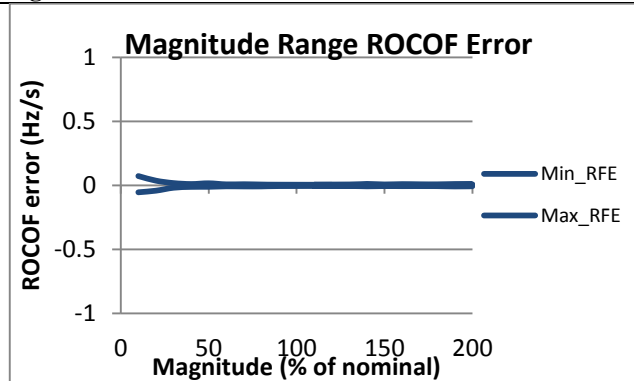


Figure 681:  $F_s = 12$  FPS

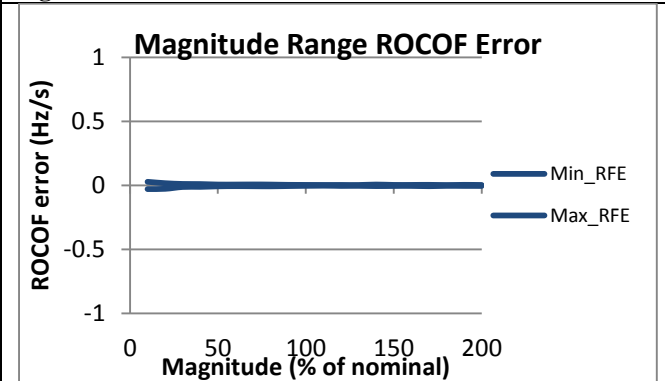


Figure 682:  $F_s = 10$  FPS

### 3.4.5 PMU D steady state signal magnitude ROCOF error: M class

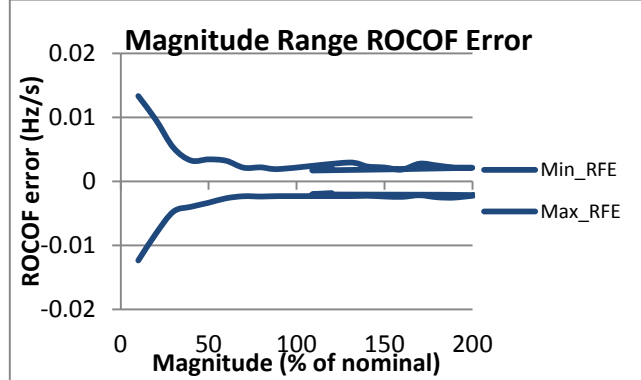


Figure 683:  $F_s = 60$  FPS

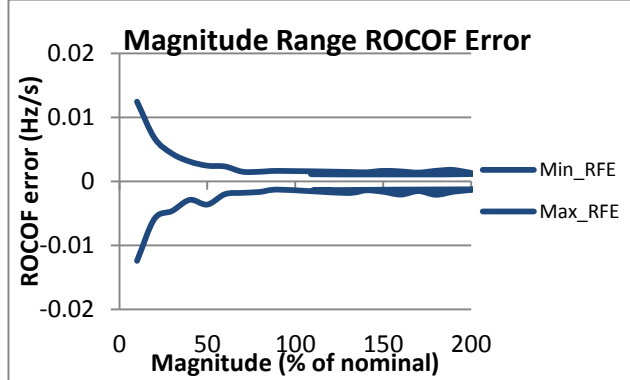


Figure 684:  $F_s = 30$  FPS

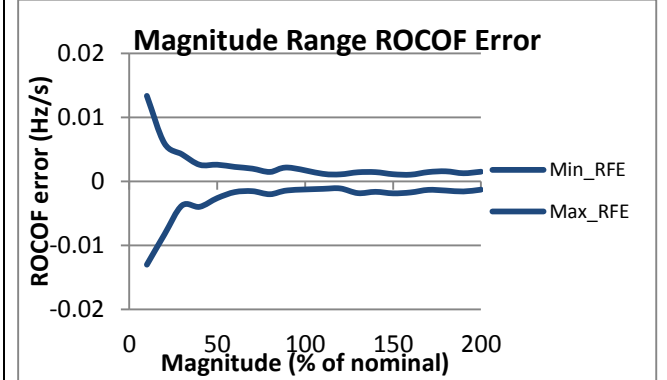


Figure 685:  $F_s = 20$  FPS

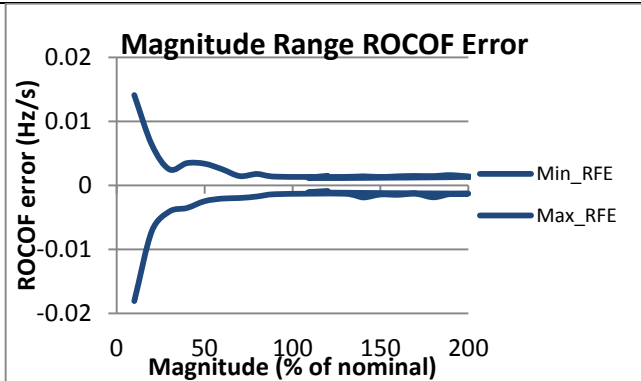


Figure 686:  $F_s = 15$  FPS

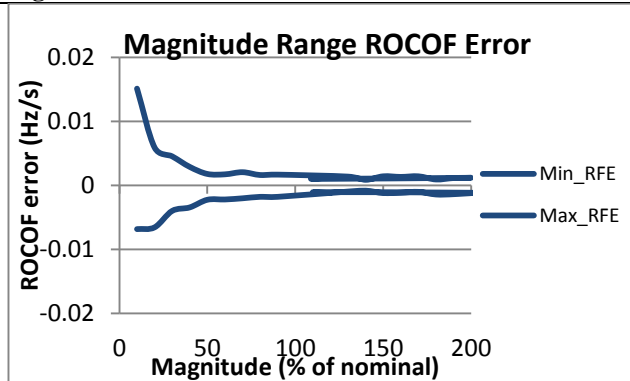


Figure 687:  $F_s = 12$  FPS

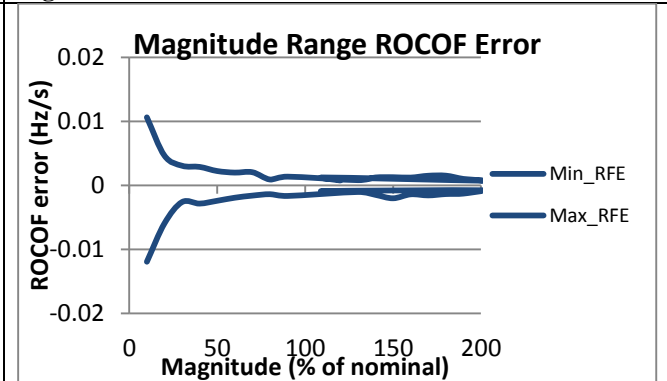


Figure 688:  $F_s = 10$  FPS

### 3.4.6 PMU E steady state signal magnitude ROCOF error: M class

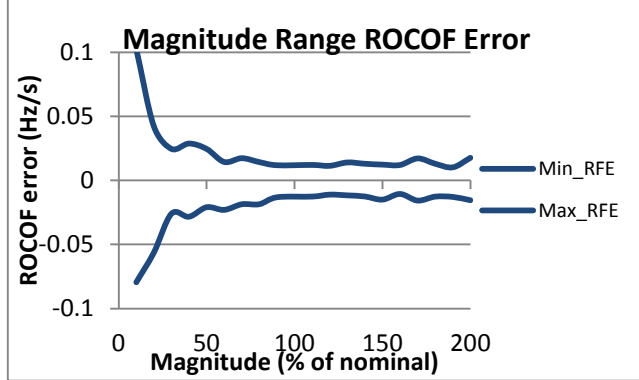


Figure 689:  $F_s = 60$  FPS

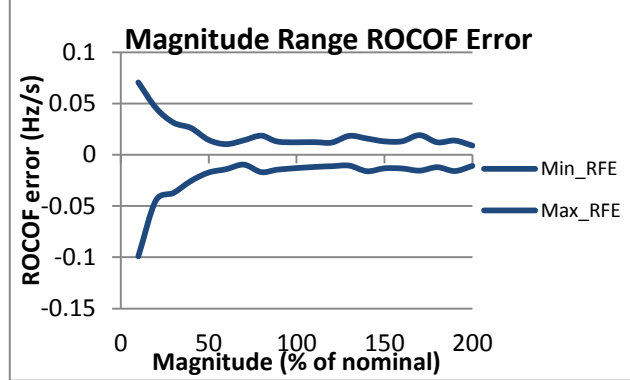


Figure 690:  $F_s = 30$  FPS

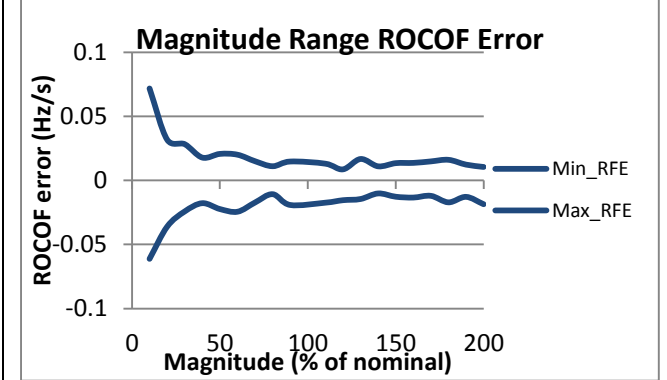


Figure 691:  $F_s = 20$  FPS

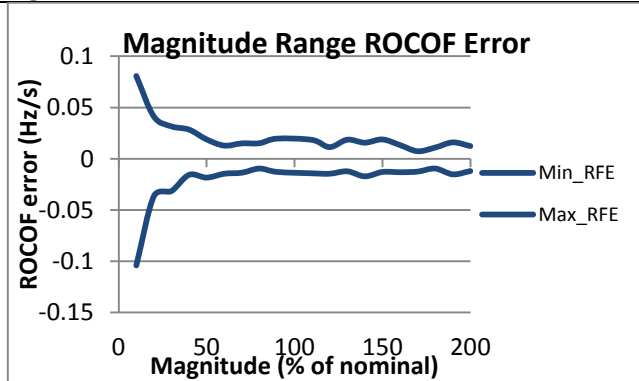


Figure 692:  $F_s = 15$  FPS

MISSING DATA

Figure 693:  $F_s = 12$  FPS

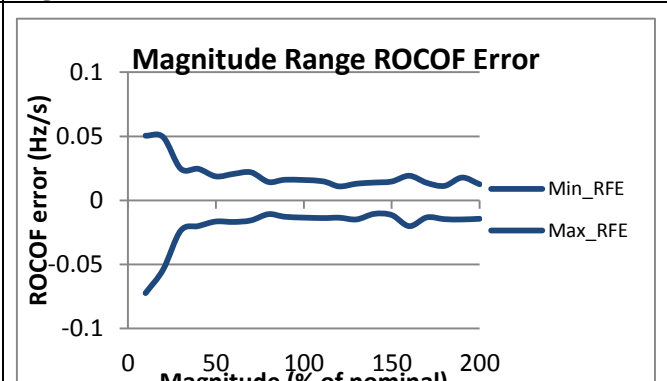


Figure 694:  $F_s = 10$  FPS

### 3.4.7 PMU F steady state signal magnitude ROCOF error: M class

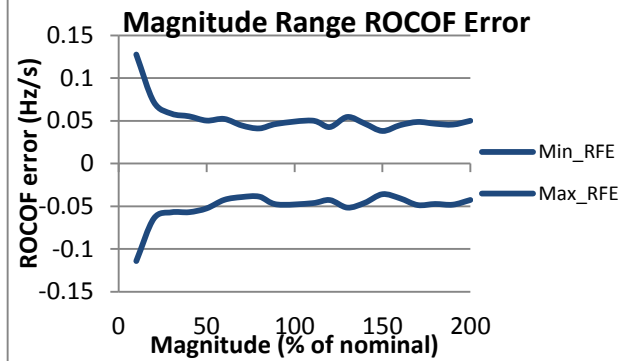


Figure 695:  $F_s = 60$  FPS

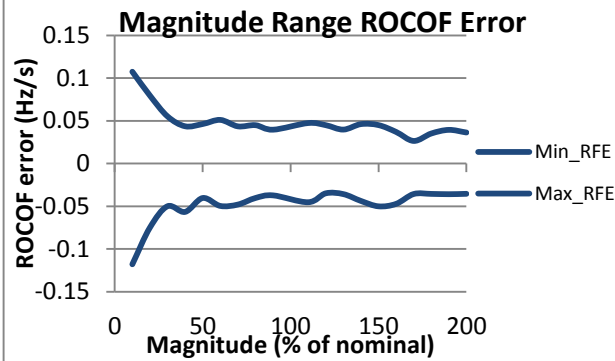


Figure 696:  $F_s = 30$  FPS

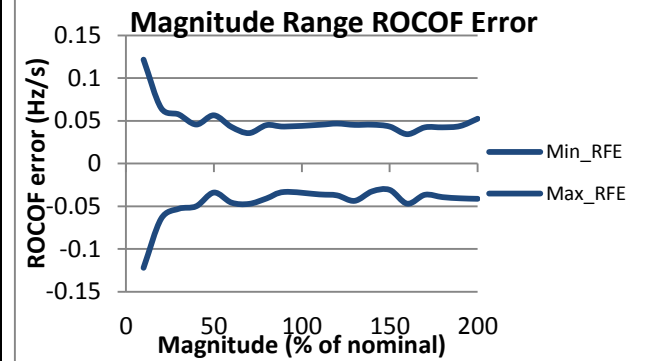


Figure 697:  $F_s = 20$  FPS

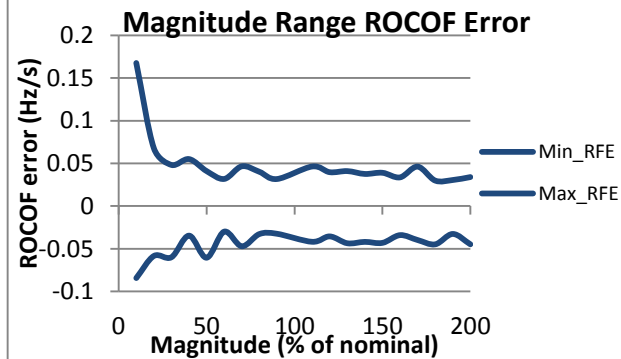


Figure 698:  $F_s = 15$  FPS

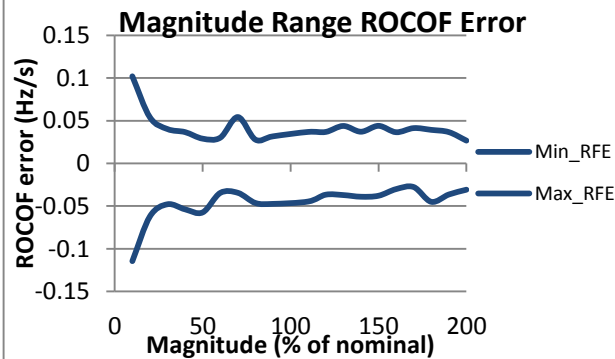


Figure 699:  $F_s = 12$  FPS

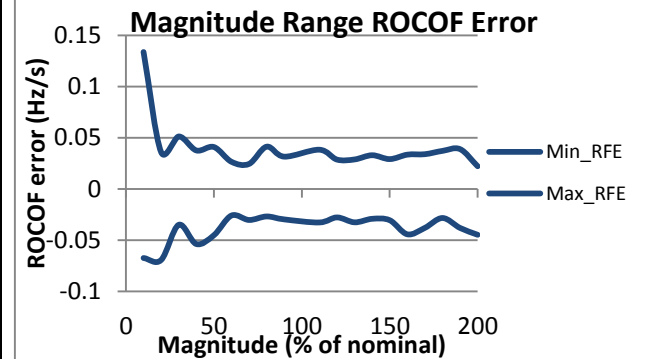


Figure 700:  $F_s = 10$  FPS

### 3.4.8 PMU G\* steady state signal magnitude ROCOF error: M class

Figure 701:  $F_s = 60$  FPS is not supported by this PMU

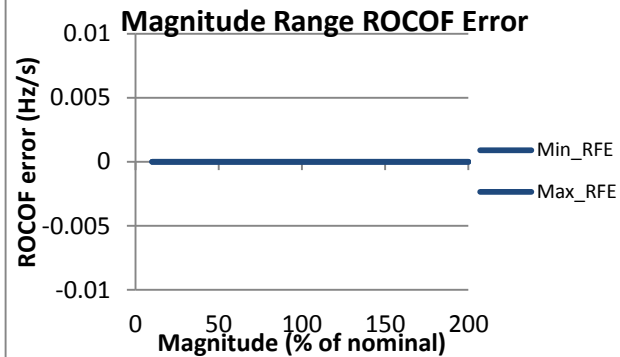


Figure 702:  $F_s = 30$  FPS

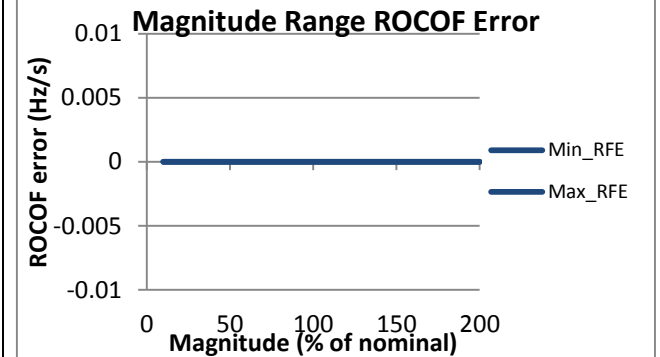


Figure 703:  $F_s = 20$  FPS

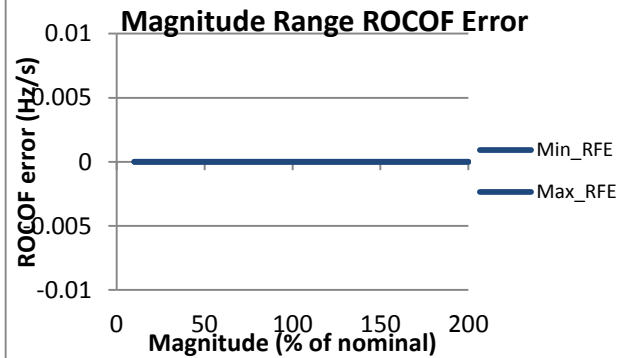


Figure 704:  $F_s = 15$  FPS

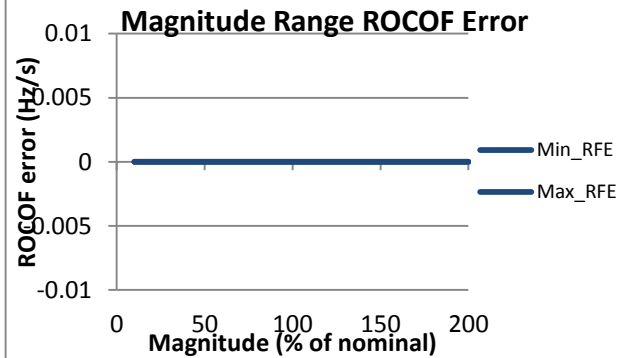


Figure 705:  $F_s = 12$  FPS

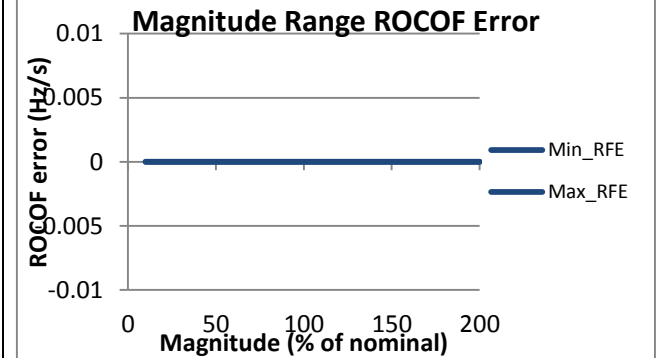


Figure 706:  $F_s = 10$  FPS

\* PMU G always outputs ROCOF = 0

### 3.4.9 PMU H steady state signal magnitude ROCOF error: M class

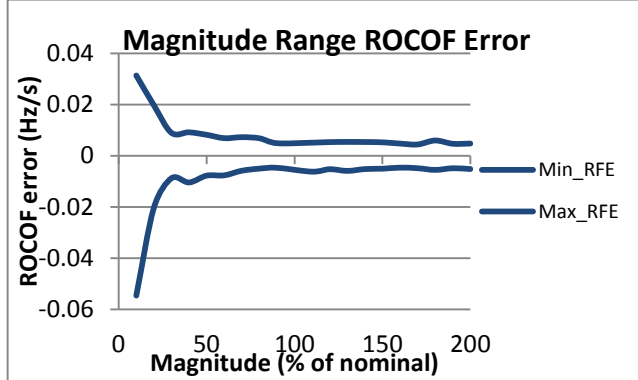


Figure 707:  $F_s = 60$  FPS

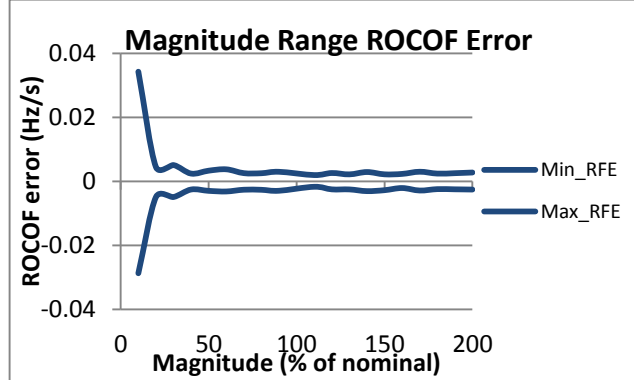


Figure 708:  $F_s = 30$  FPS

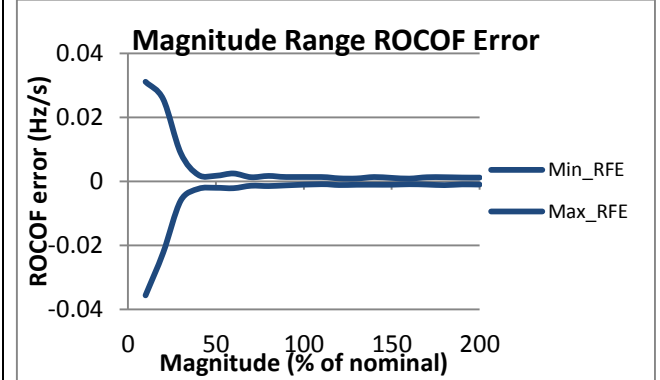


Figure 709:  $F_s = 20$  FPS

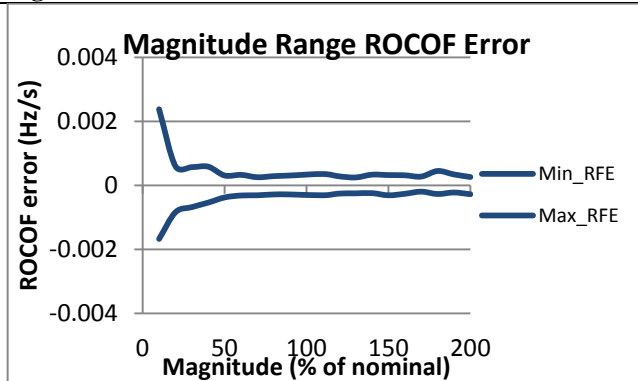


Figure 710:  $F_s = 15$  FPS

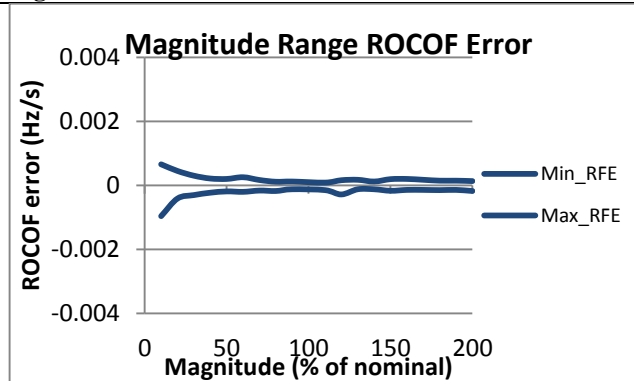


Figure 711:  $F_s = 12$  FPS

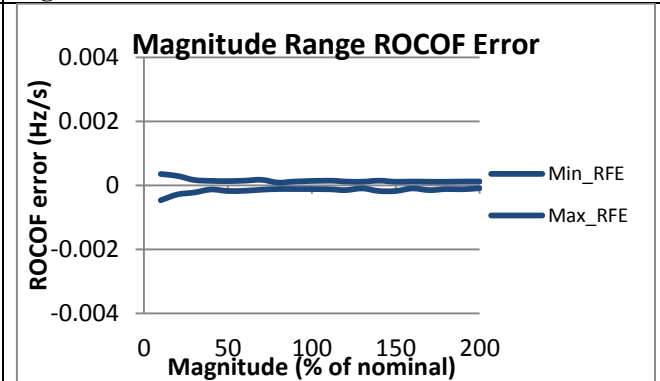


Figure 712:  $F_s = 10$  FPS

### 3.4.10 PMU I steady state signal magnitude ROCOF error: M class

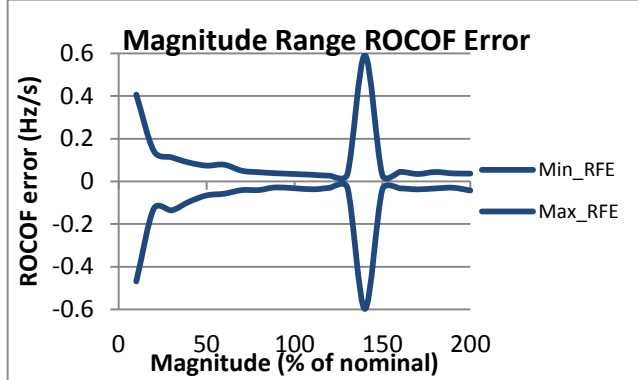


Figure 713:  $F_s = 60$  FPS

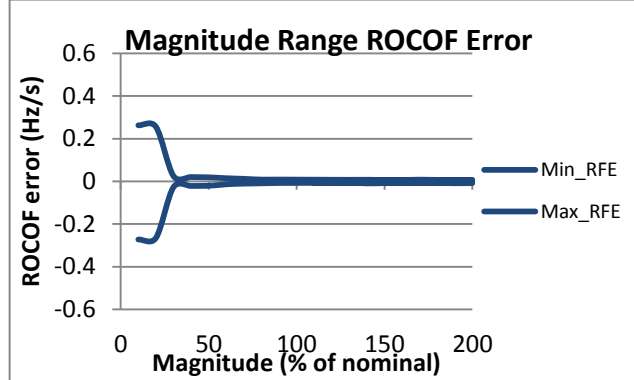


Figure 714:  $F_s = 30$  FPS

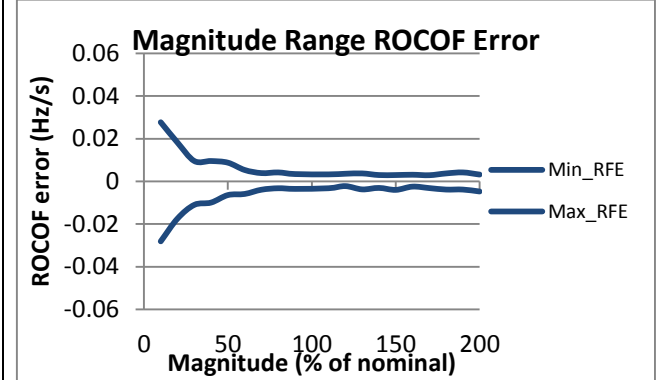


Figure 715:  $F_s = 20$  FPS

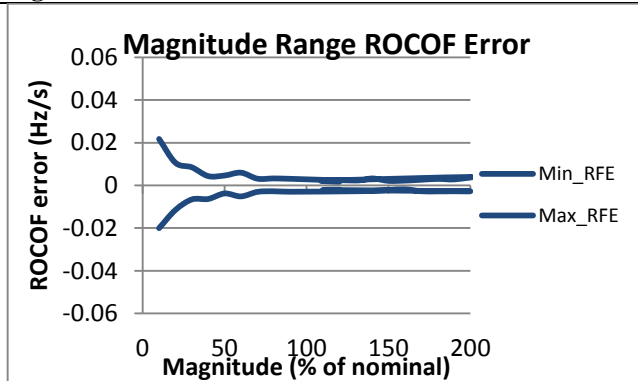


Figure 716:  $F_s = 15$  FPS

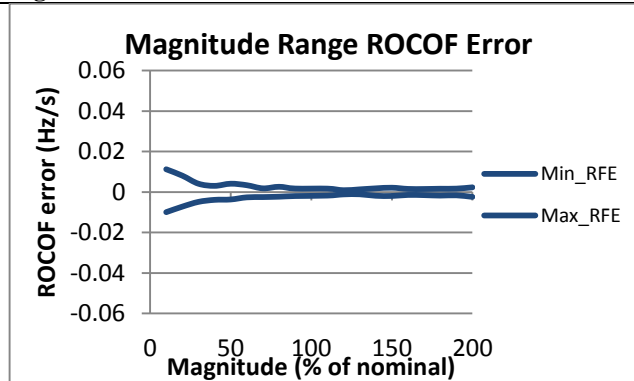


Figure 717:  $F_s = 12$  FPS

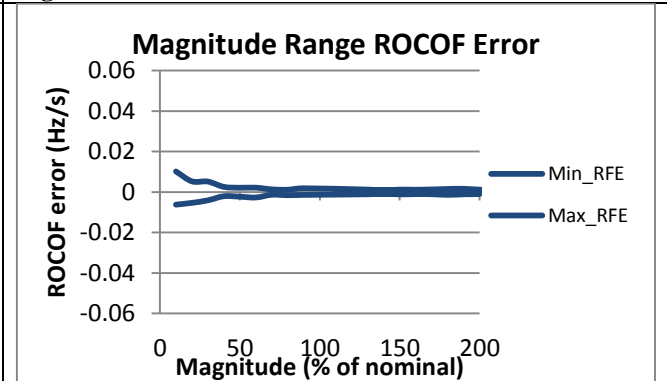


Figure 718:  $F_s = 10$  FPS



### 3.4.11 PMU I steady state signal magnitude ROCOF error: M class

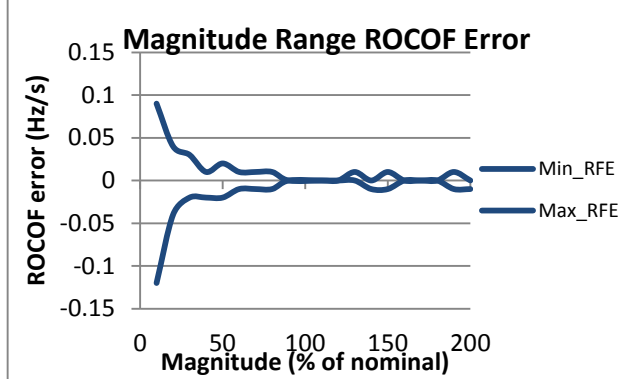


Figure 719:  $F_s = 60$  FPS

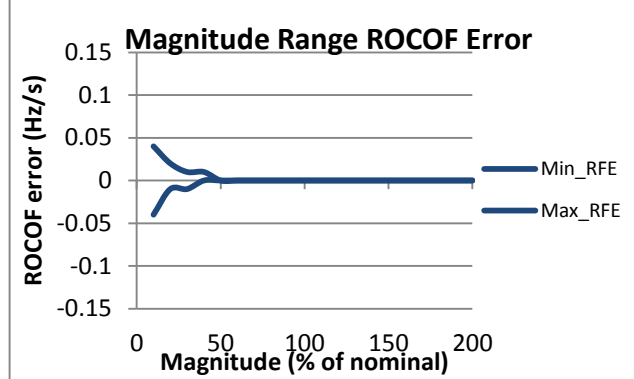


Figure 720:  $F_s = 30$  FPS

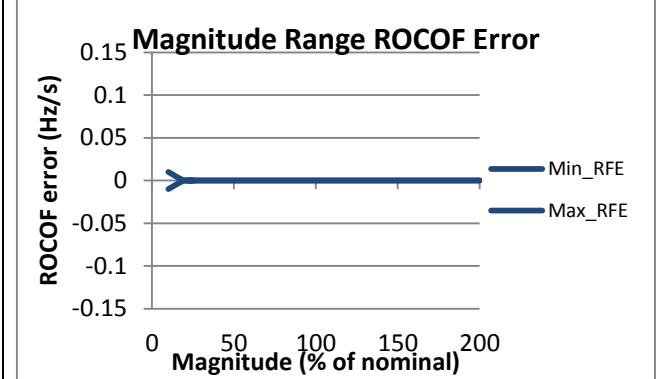


Figure 721:  $F_s = 20$  FPS

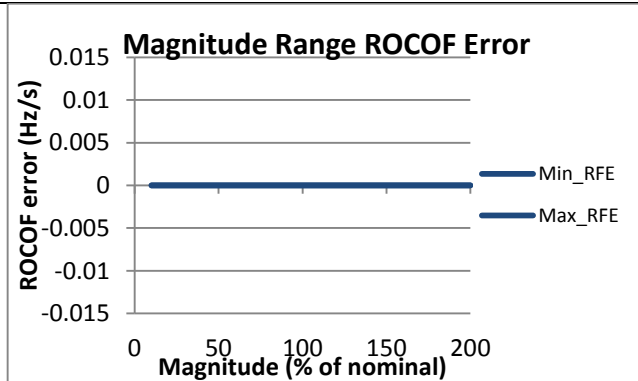


Figure 722:  $F_s = 15$  FPS

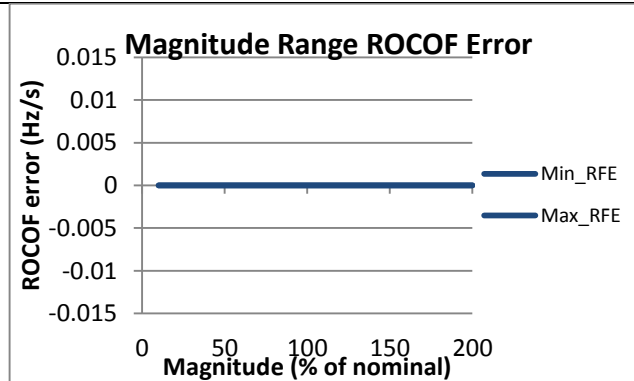


Figure 723:  $F_s = 12$  FPS

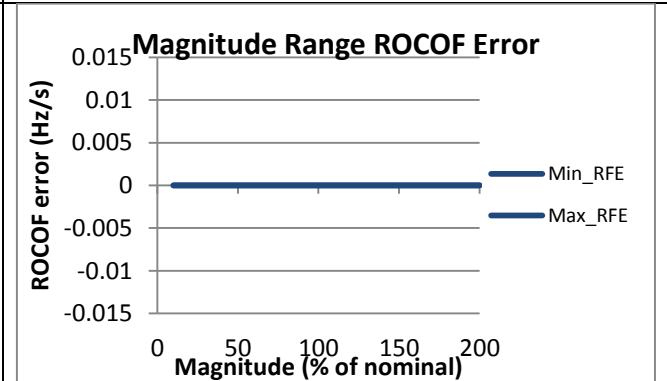


Figure 724:  $F_s = 10$  FPS

### 3.5 Steady state signal magnitude voltage TVE: P class

#### 3.5.1 C37.118.1 Annex C steady state signal magnitude voltage TVE: P class

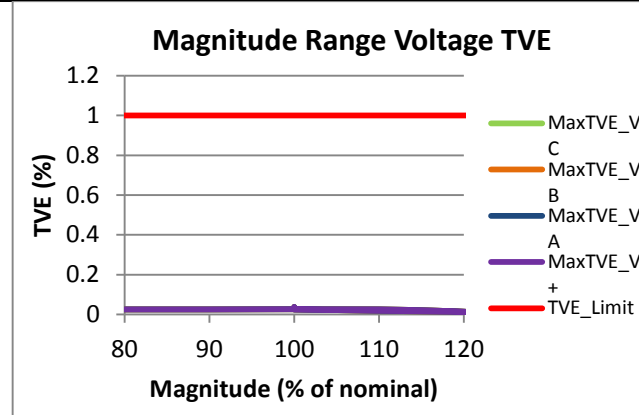


Figure 725:  $F_s = 60$  FPS

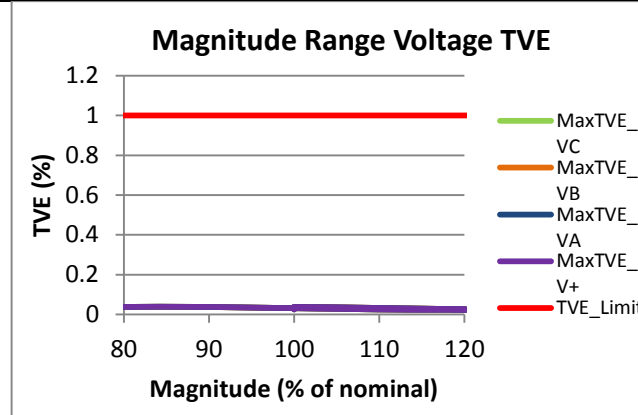


Figure 726:  $F_s = 30$  FPS

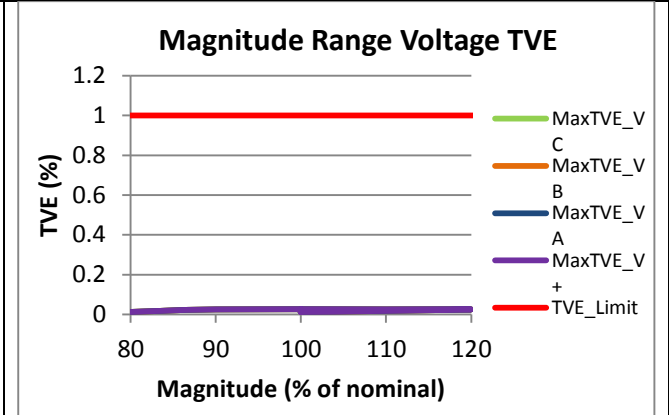


Figure 727:  $F_s = 20$  FPS

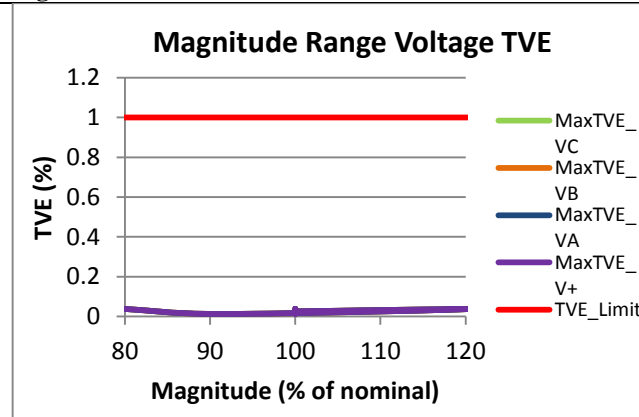


Figure 728:  $F_s = 15$  FPS

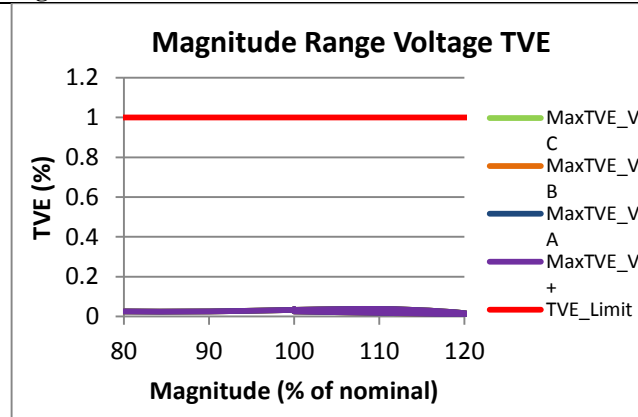


Figure 729:  $F_s = 12$  FPS

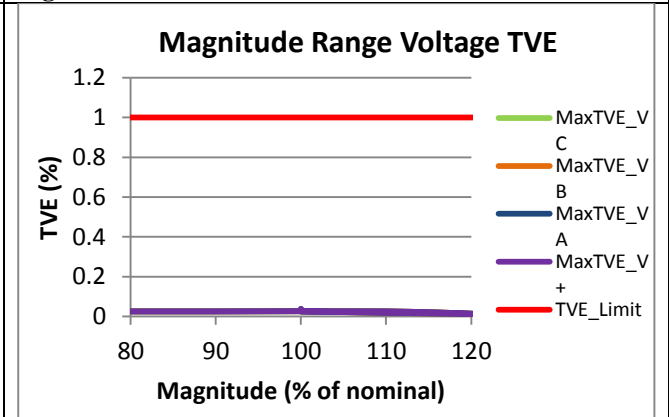


Figure 730:  $F_s = 10$  FPS

### 3.5.2 PMU A steady state signal magnitude voltage TVE: P class

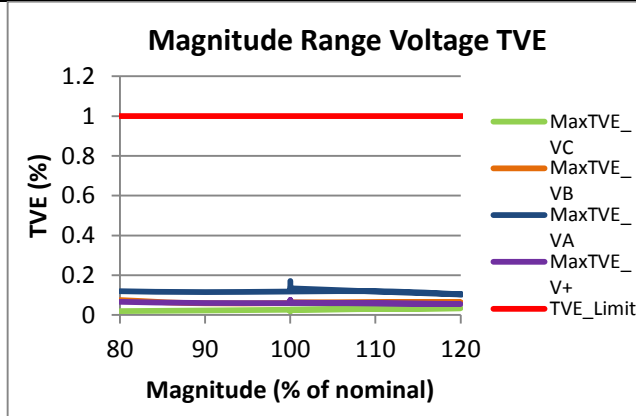


Figure 731: Fs = 60 FPS

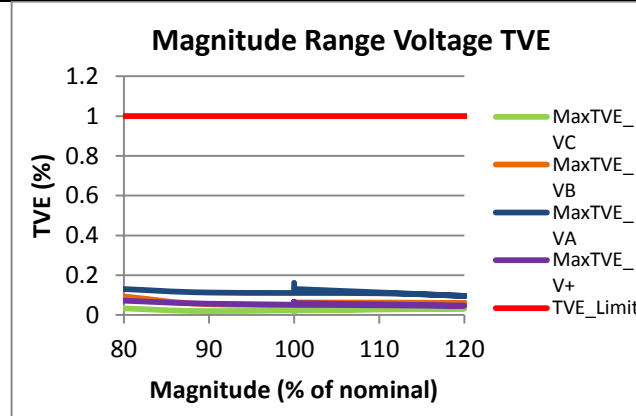


Figure 732: Fs = 30 FPS

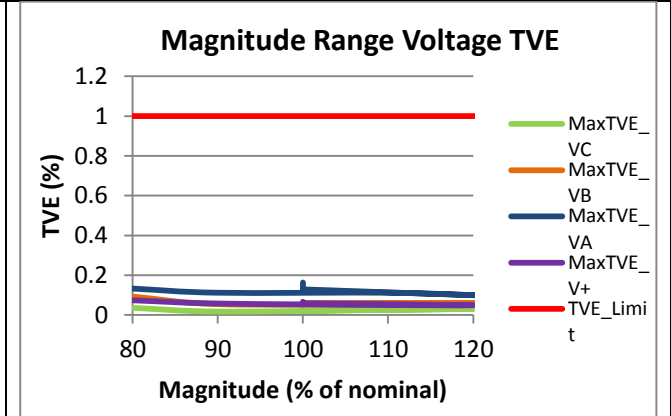


Figure 733: Fs = 20 FPS

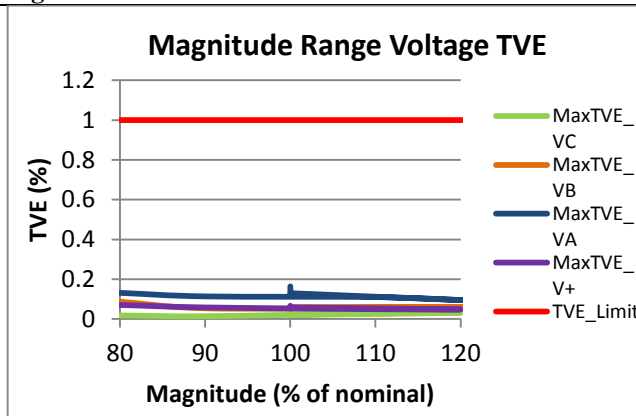


Figure 734: Fs = 15 FPS

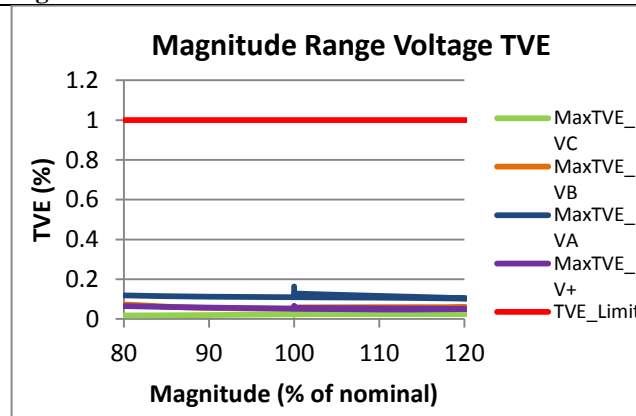


Figure 735: Fs = 12 FPS

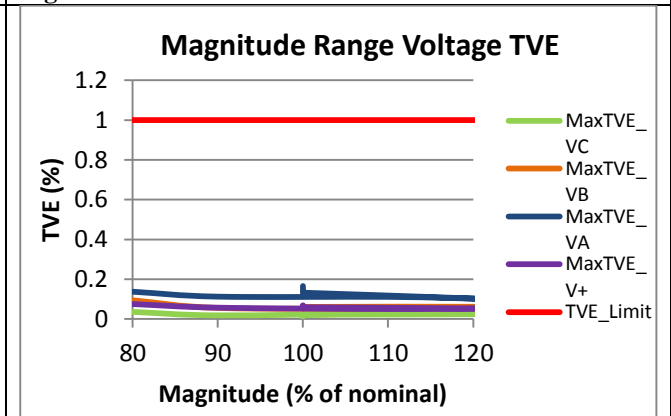


Figure 736: Fs = 10 FPS

### 3.5.3 PMU B steady state signal magnitude voltage TVE: P class

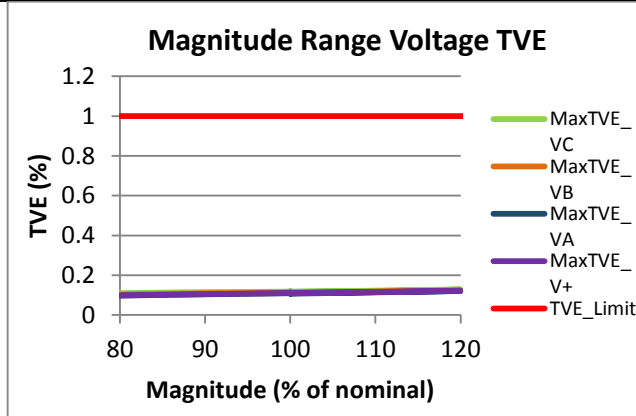


Figure 737: Fs = 60 FPS

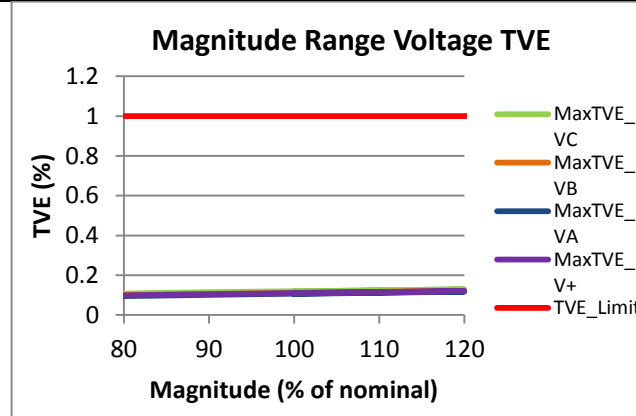


Figure 738: Fs = 30 FPS

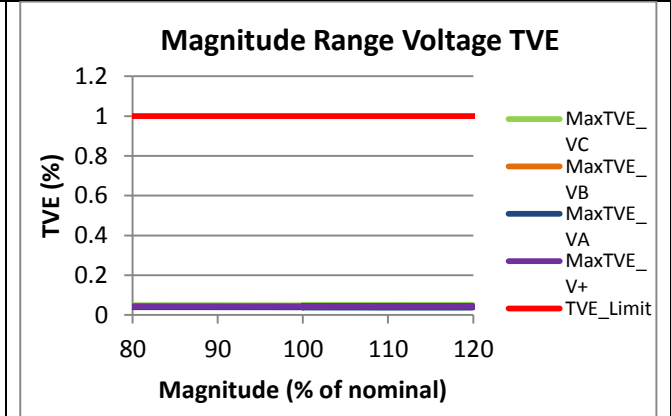


Figure 739: Fs = 20 FPS

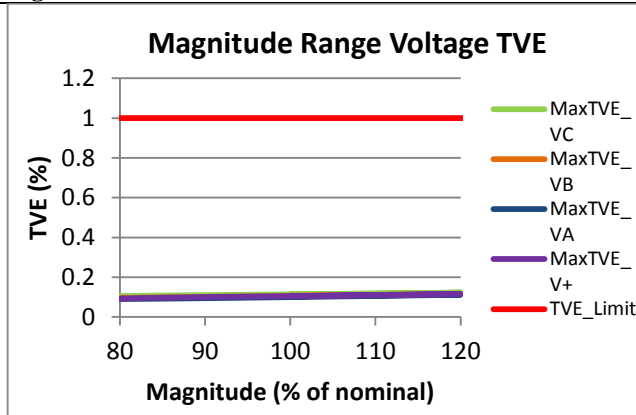


Figure 740: Fs = 15 FPS

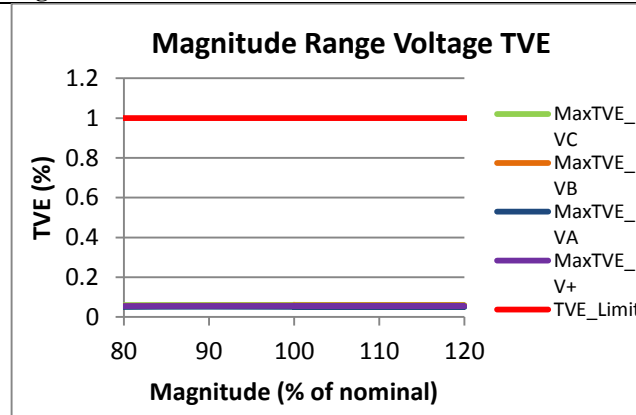


Figure 741: Fs = 12 FPS

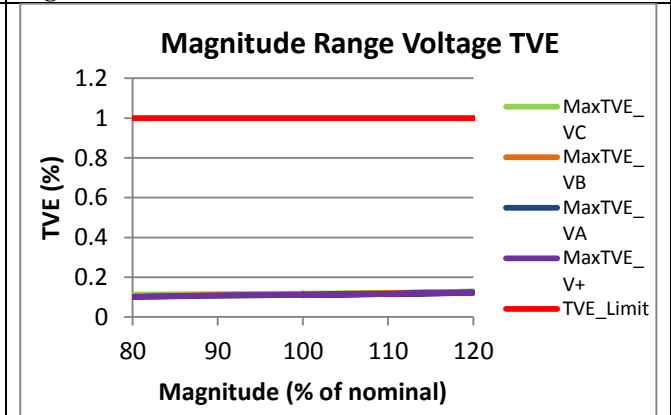


Figure 742: Fs = 10 FPS

### 3.5.4 PMU C steady state signal magnitude voltage TVE: P class

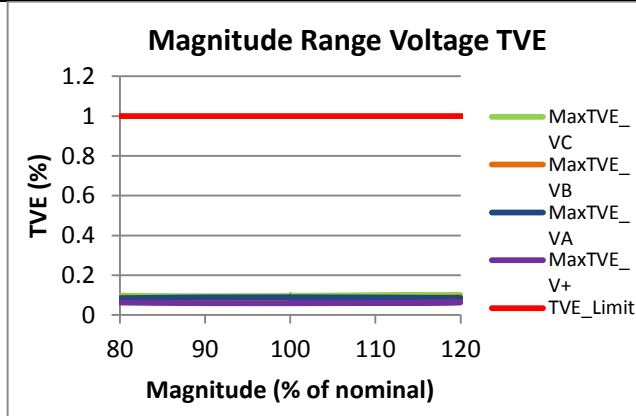


Figure 743: Fs = 60 FPS

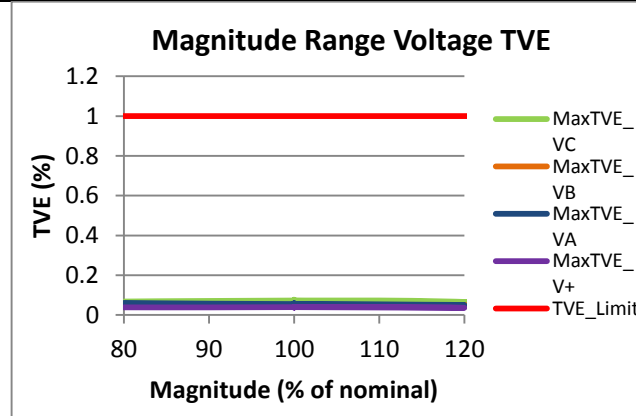


Figure 744: Fs = 30 FPS

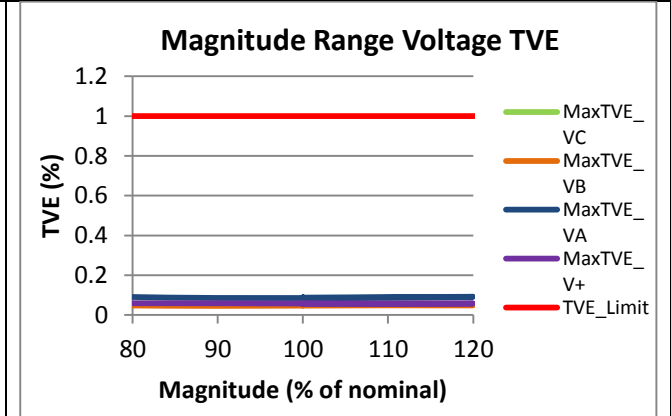


Figure 745: Fs = 20 FPS

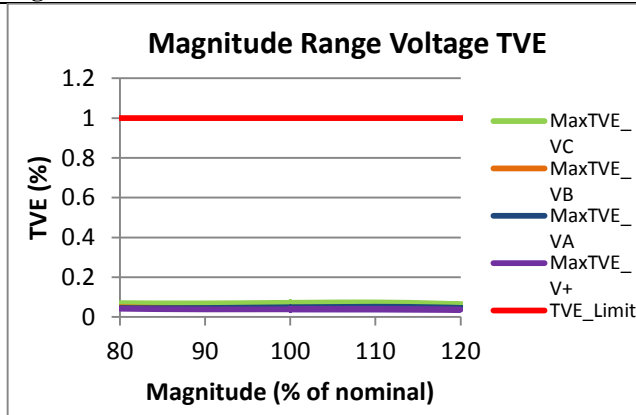


Figure 746: Fs = 15 FPS

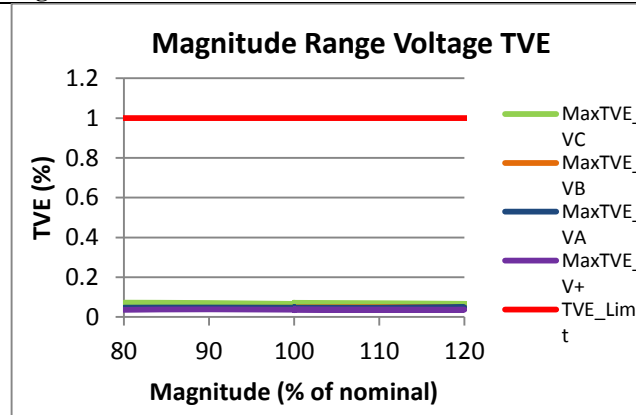


Figure 747: Fs = 12 FPS

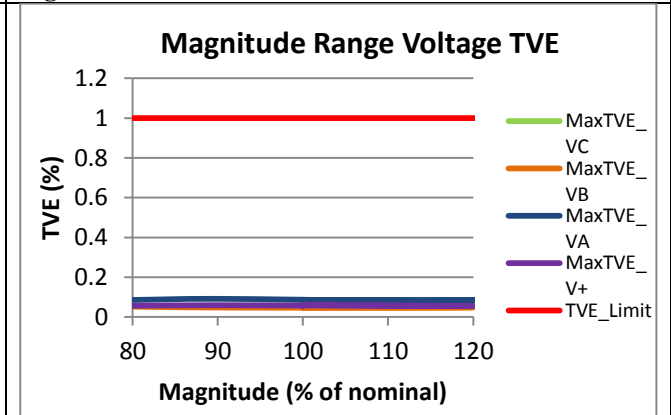
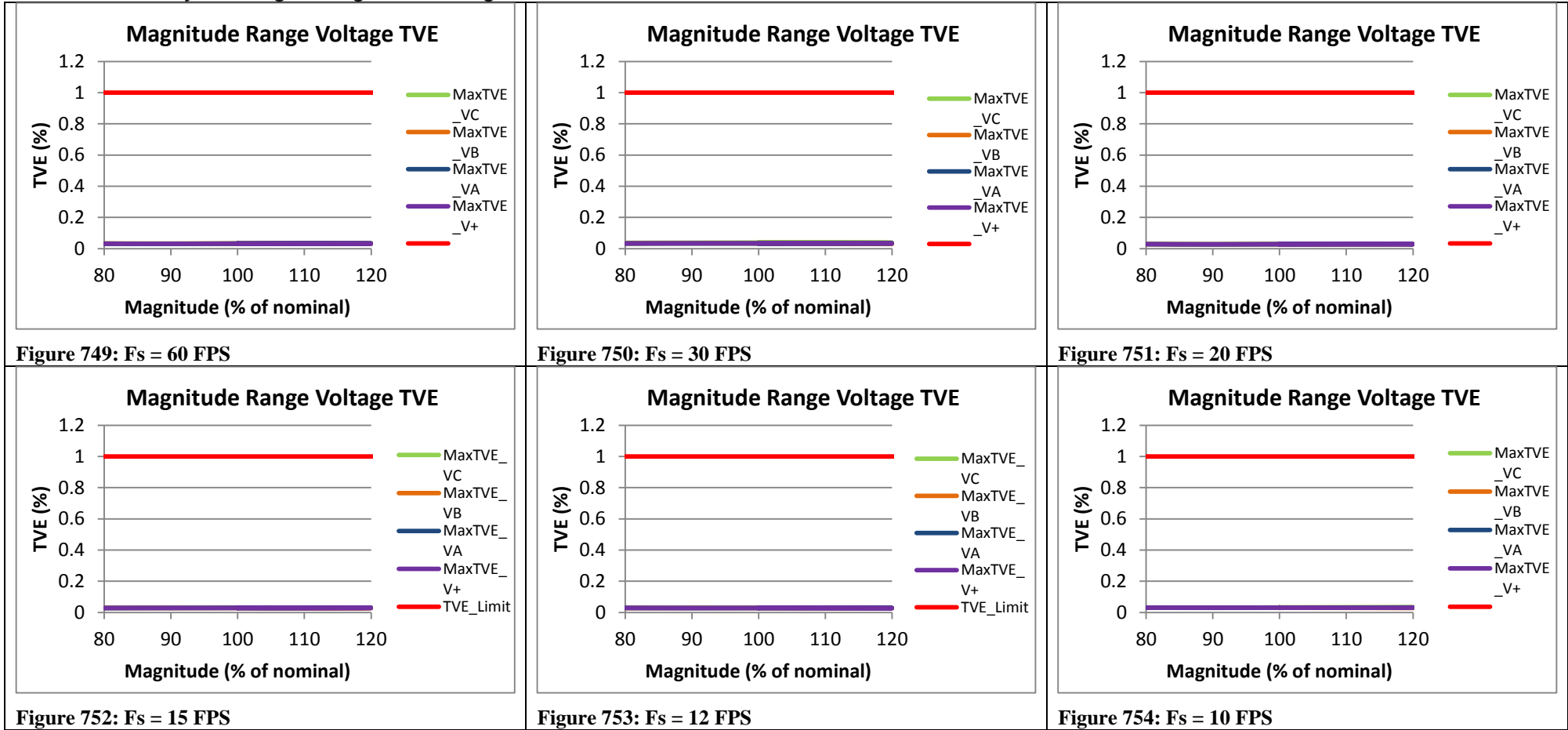


Figure 748: Fs = 10 FPS

### 3.5.5 PMU D steady state signal magnitude voltage TVE: P class



### 3.5.6 PMU E steady state signal magnitude voltage TVE: P class

PMU E does not support P class

### 3.5.7 PMU F steady state signal magnitude voltage TVE P class

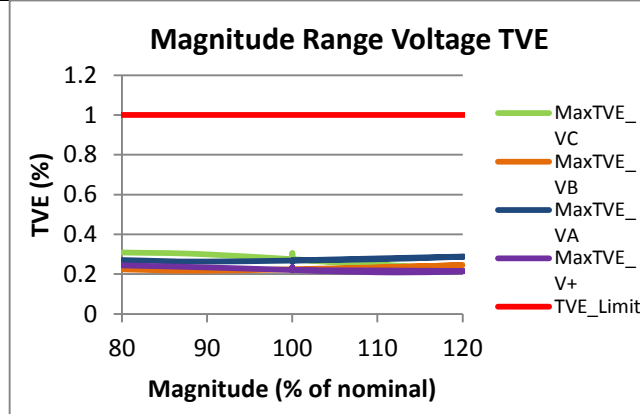


Figure 755: Fs = 60 FPS

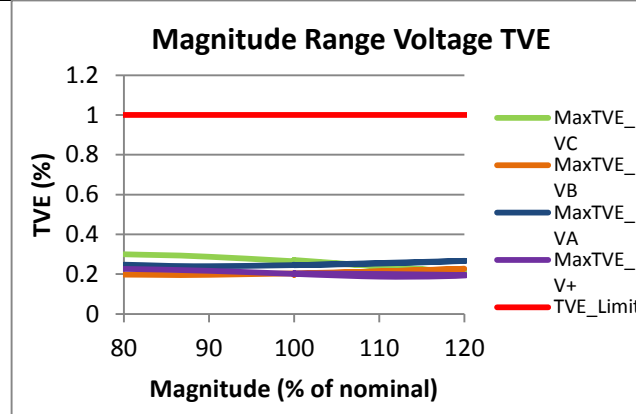


Figure 756: Fs = 30 FPS

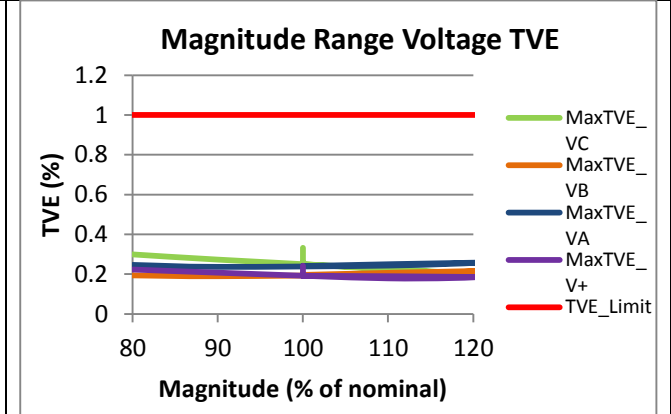


Figure 757: Fs = 20 FPS

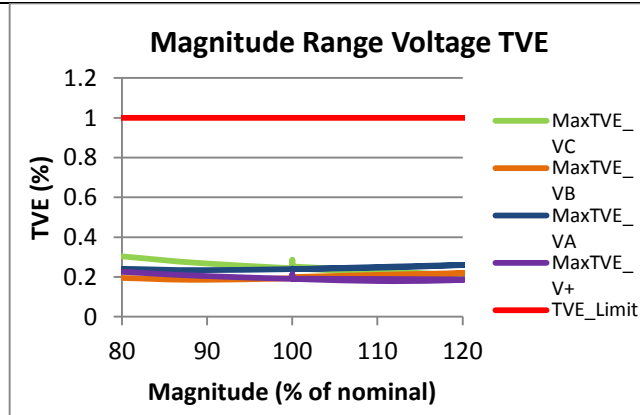


Figure 758: Fs = 15 FPS

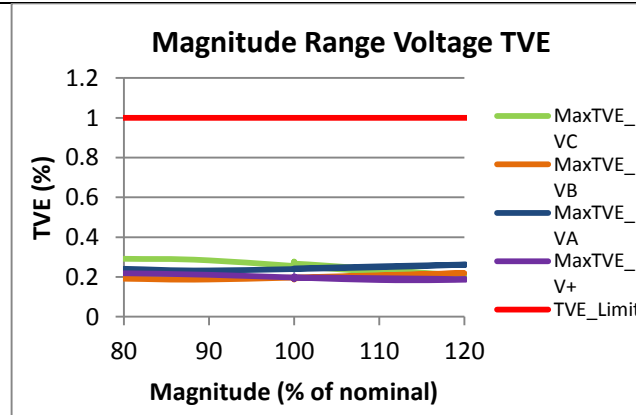


Figure 759: Fs = 12 FPS

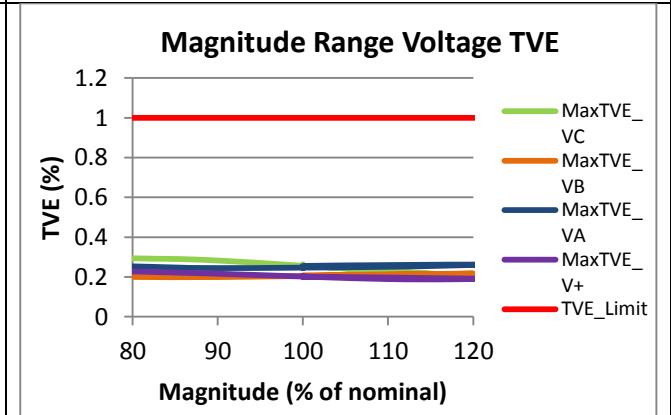
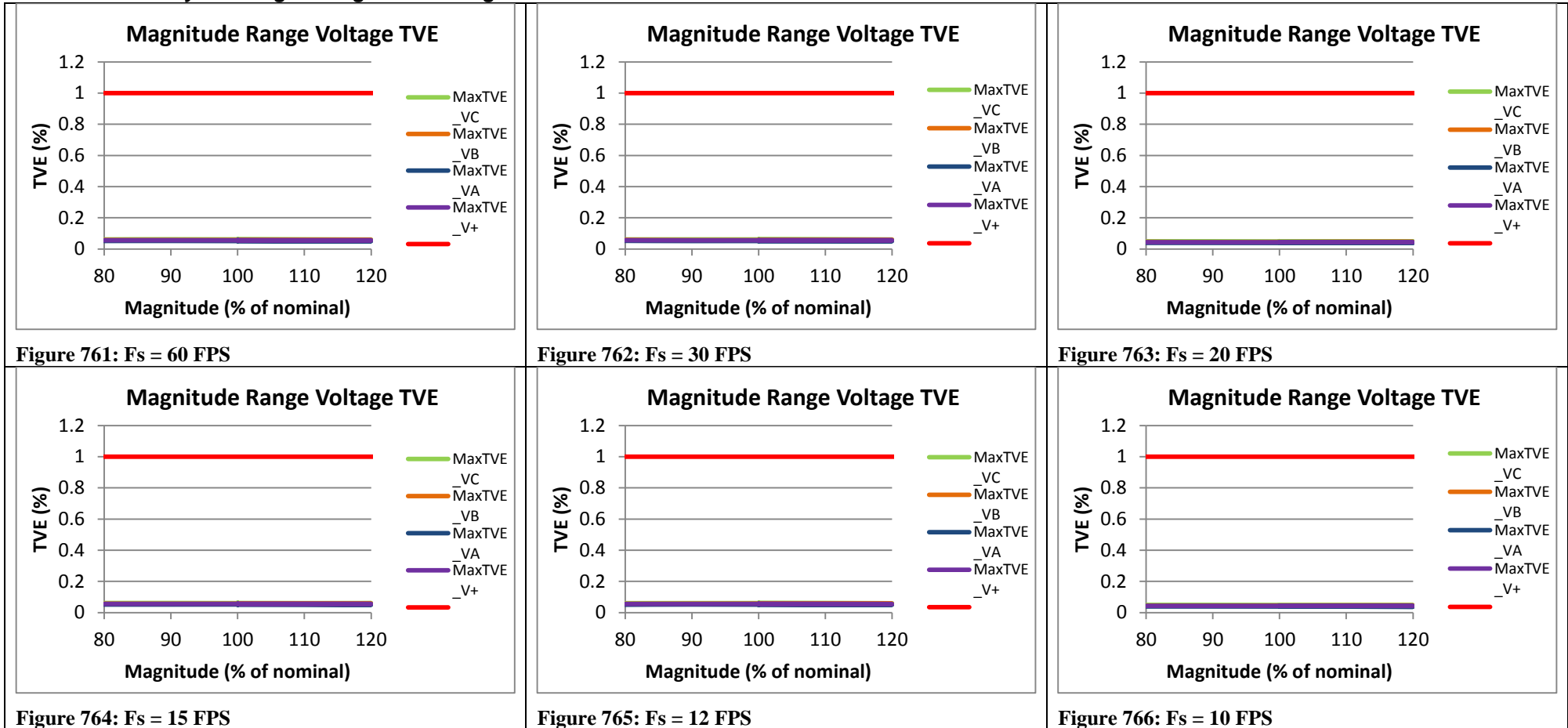


Figure 760: Fs = 10 FPS

### 3.5.8 PMU G steady state signal magnitude voltage TVE: P class

PMU G does not support P class

### 3.5.9 PMU H steady state signal magnitude voltage TVE: P class



### 3.5.10 PMU I steady state signal magnitude voltage TVE: P class

PMU I does not support P Class



### 3.5.11 PMU J steady state signal magnitude voltage TVE: P class

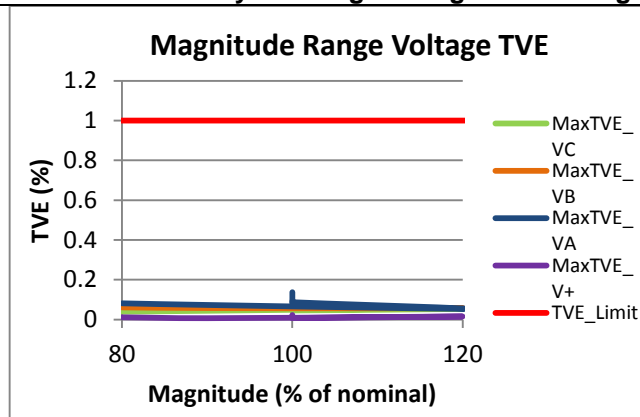


Figure 767: Fs = 60 FPS

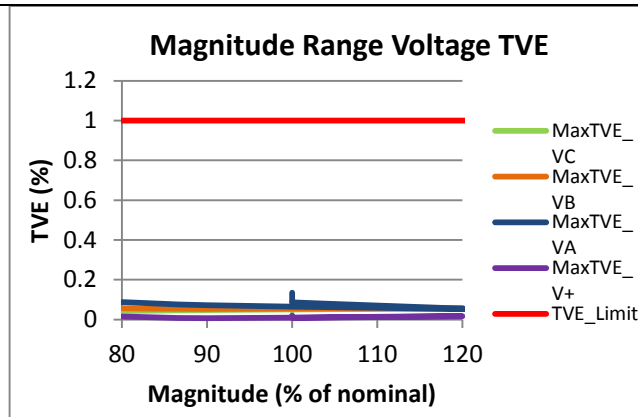


Figure 768: Fs = 30 FPS

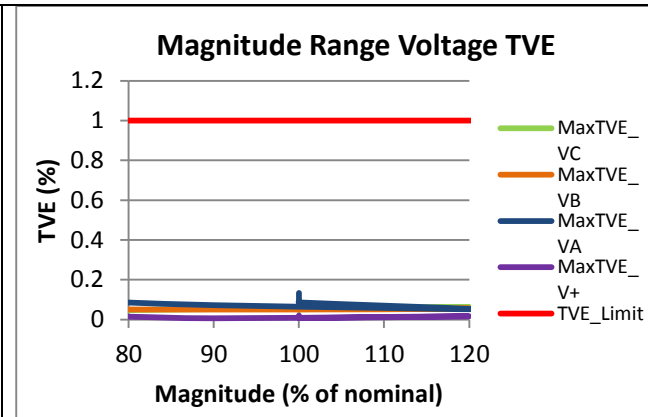


Figure 769: Fs = 20 FPS

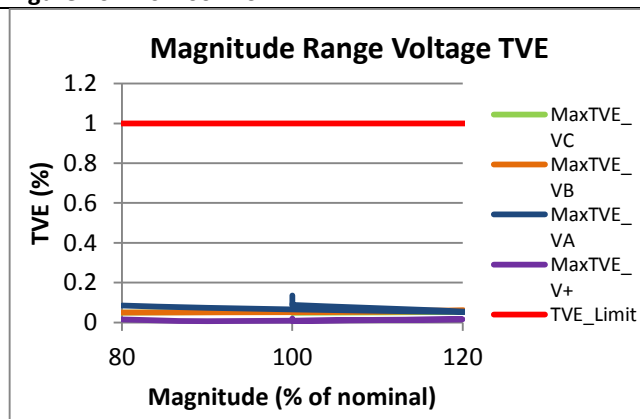


Figure 770: Fs = 15 FPS

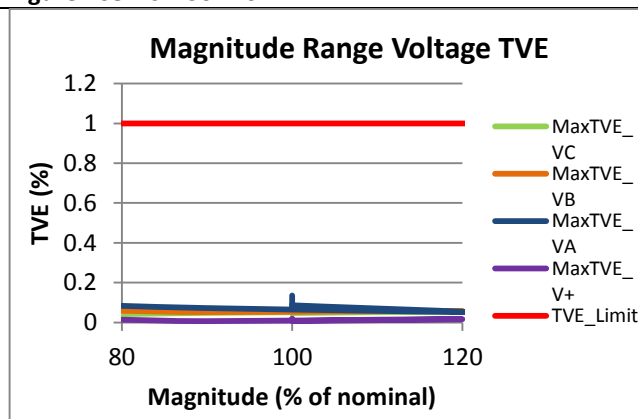


Figure 771: Fs = 12 FPS

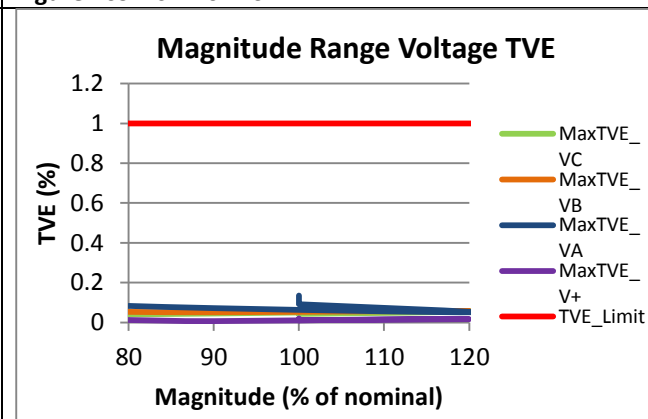


Figure 772: Fs = 10 FPS

### 3.6 Steady state signal magnitude current TVE: P class

#### 3.6.1 C37.118.1 Annex C steady state signal magnitude current TVE: P class

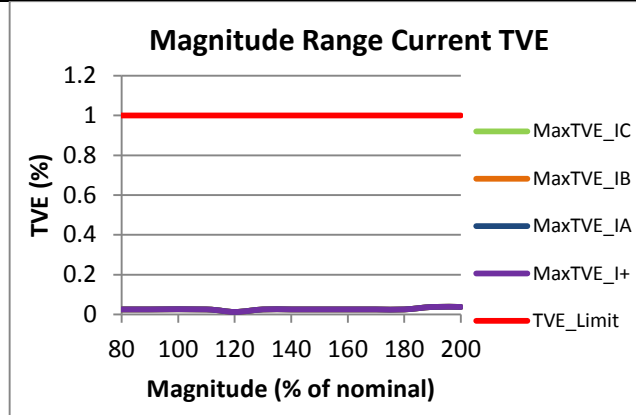


Figure 773:  $F_s = 60$  FPS

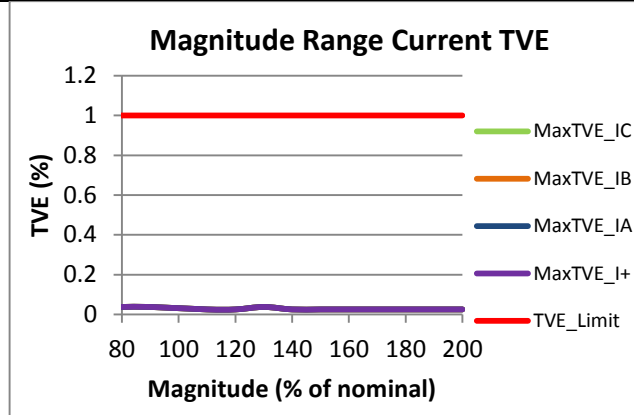


Figure 774:  $F_s = 30$  FPS

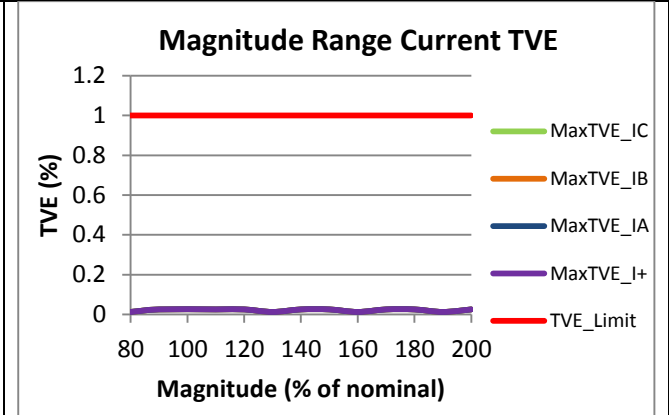


Figure 775:  $F_s = 20$  FPS

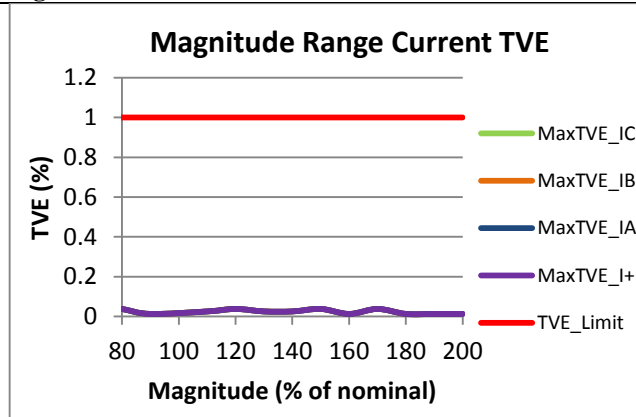


Figure 776:  $F_s = 15$  FPS

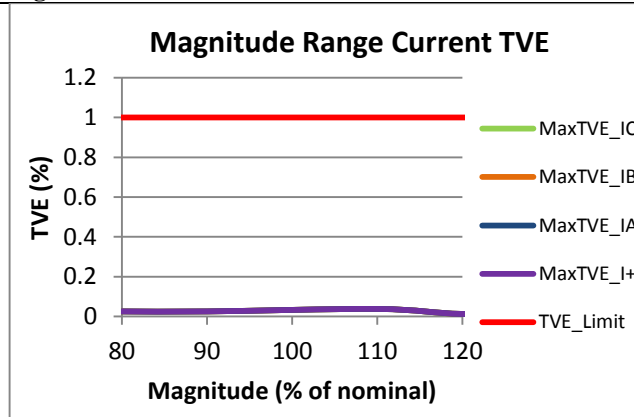


Figure 777:  $F_s = 12$  FPS

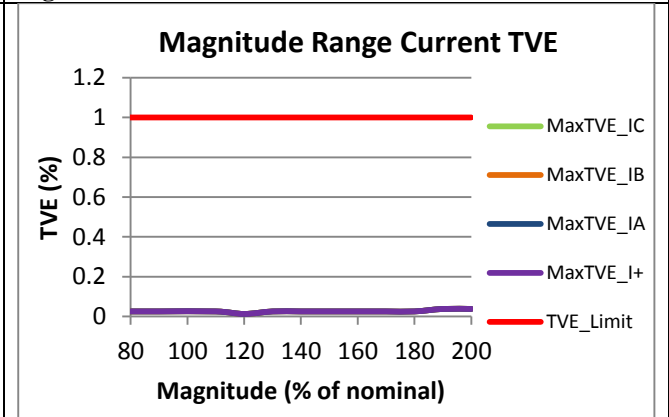


Figure 778:  $F_s = 10$  FPS

### 3.6.2 PMU A steady state signal magnitude current TVE: P class

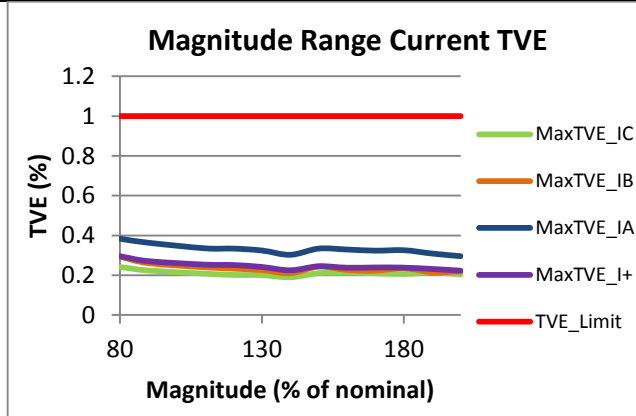


Figure 779:  $F_s = 60$  FPS

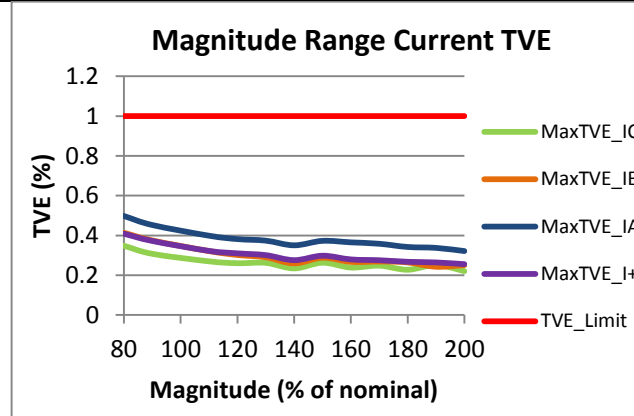


Figure 780:  $F_s = 30$  FPS

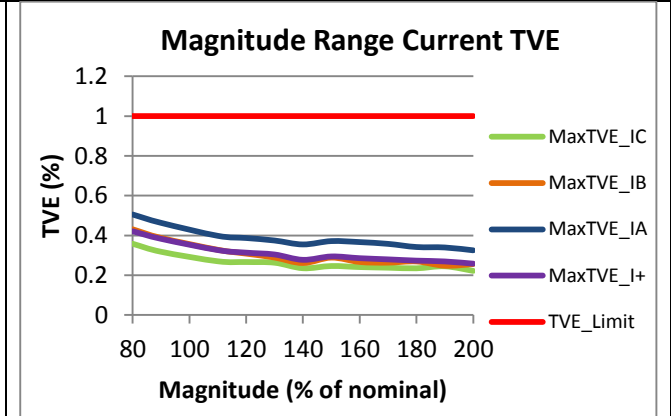


Figure 781:  $F_s = 20$  FPS

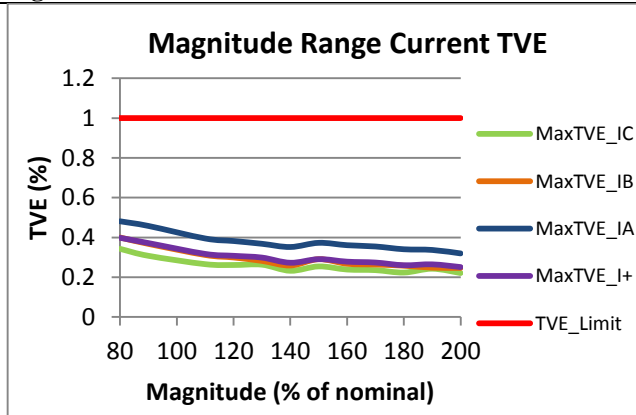


Figure 782:  $F_s = 15$  FPS

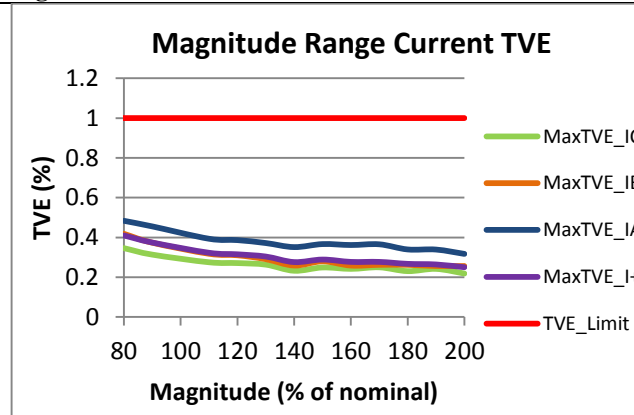


Figure 783:  $F_s = 12$  FPS

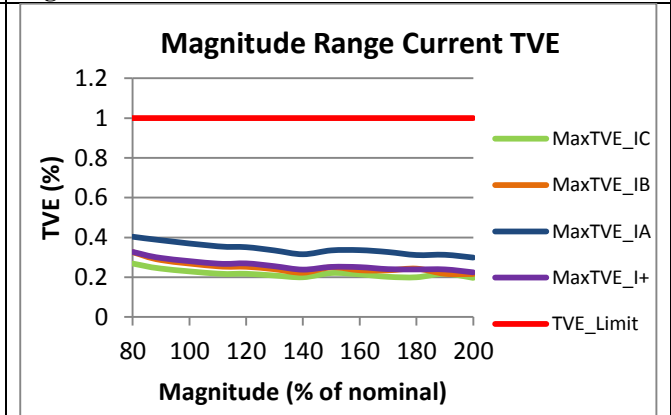


Figure 784:  $F_s = 10$  FPS

### 3.6.3 PMU B steady state signal magnitude current TVE: P class

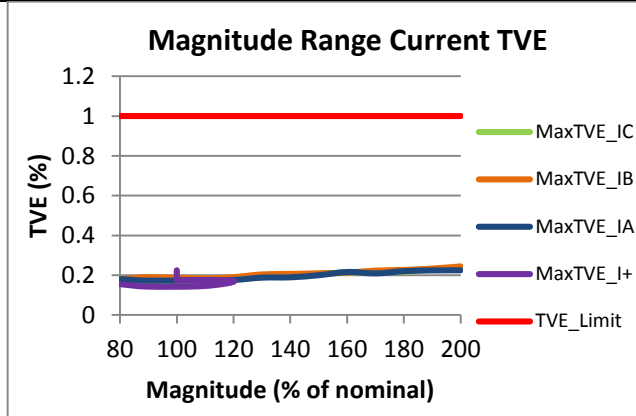


Figure 785:  $F_s = 60$  FPS

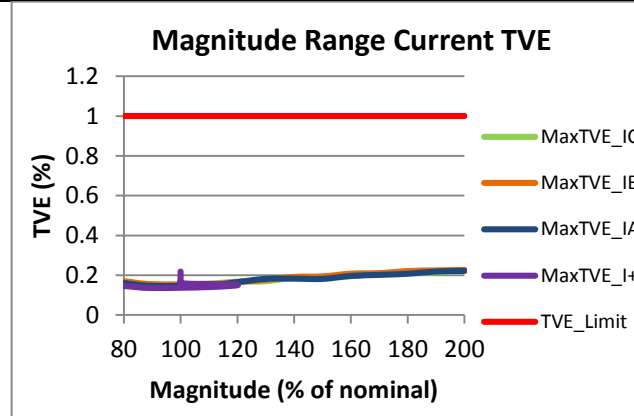


Figure 786:  $F_s = 30$  FPS

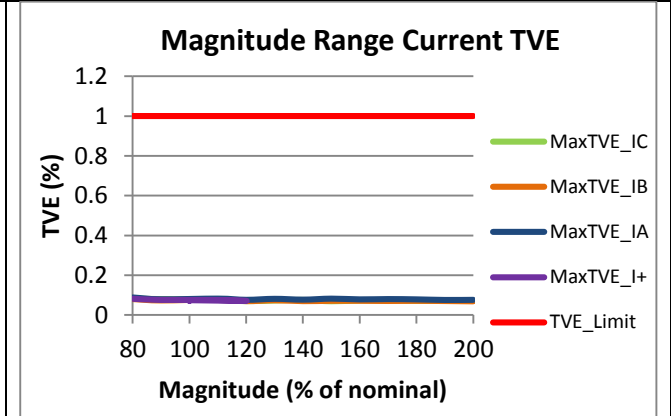


Figure 787:  $F_s = 20$  FPS

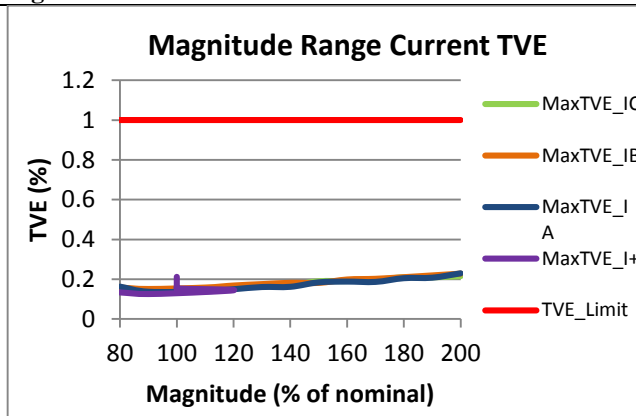


Figure 788:  $F_s = 15$  FPS

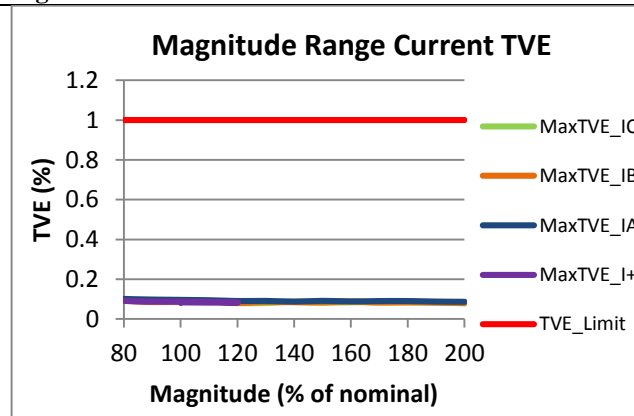


Figure 789:  $F_s = 12$  FPS

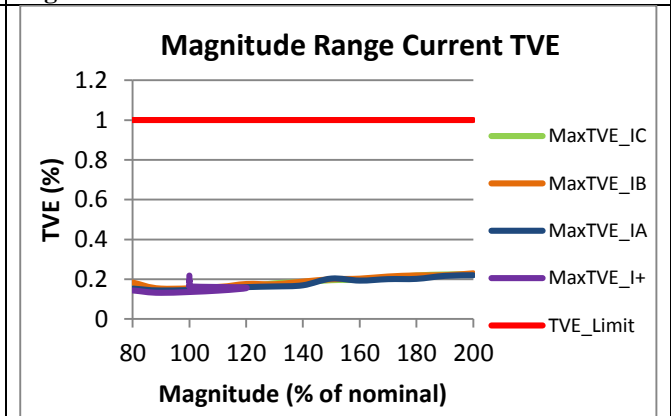


Figure 790:  $F_s = 10$  FPS

### 3.6.4 PMU C steady state signal magnitude current TVE: P class

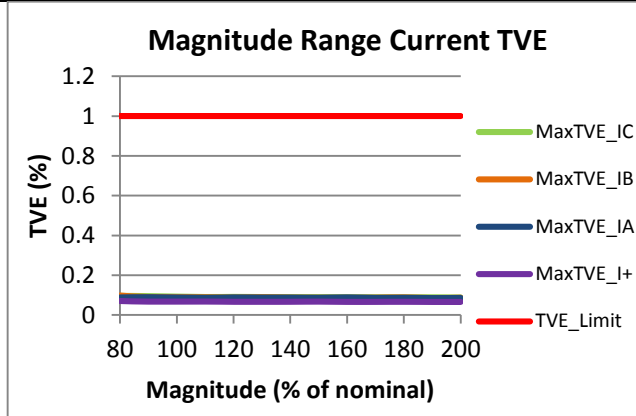


Figure 791: Fs = 60 FPS

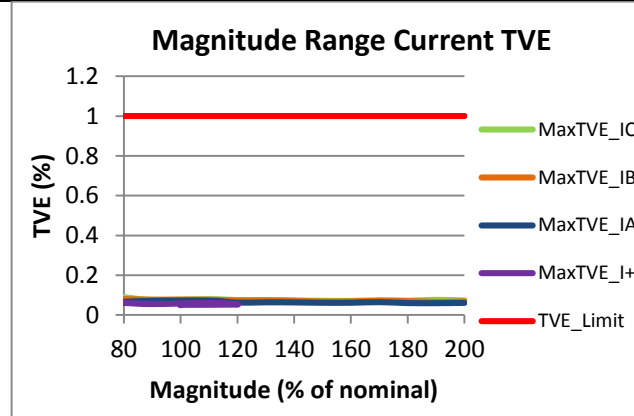


Figure 792: Fs = 30 FPS

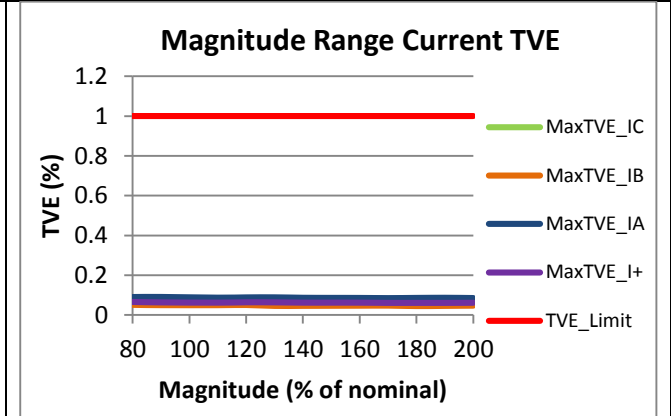


Figure 793: Fs = 20 FPS

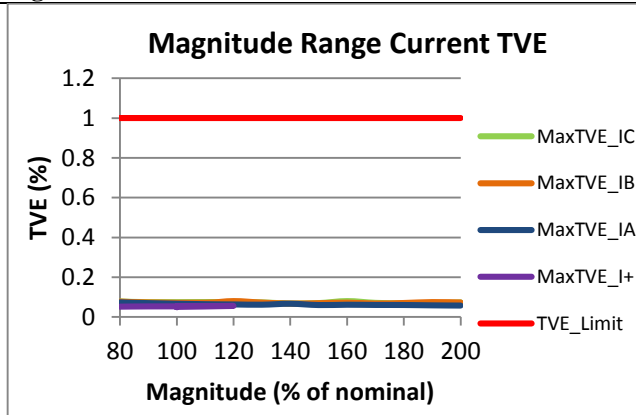


Figure 794: Fs = 15 FPS

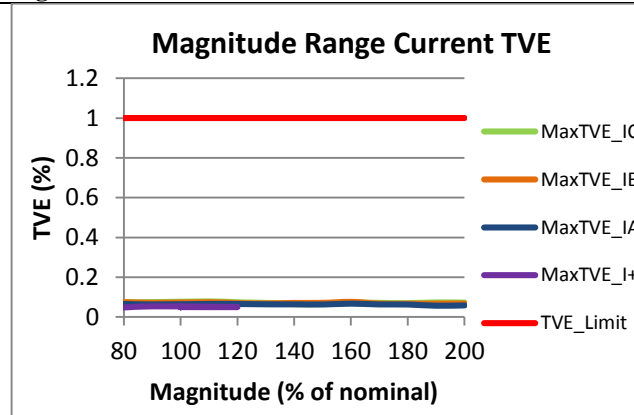


Figure 795: Fs = 12 FPS

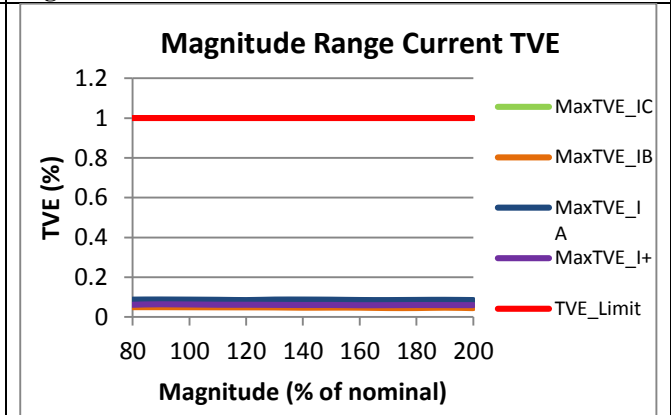


Figure 796: Fs = 10 FPS

### 3.6.5 PMU D steady state signal magnitude current TVE: P class

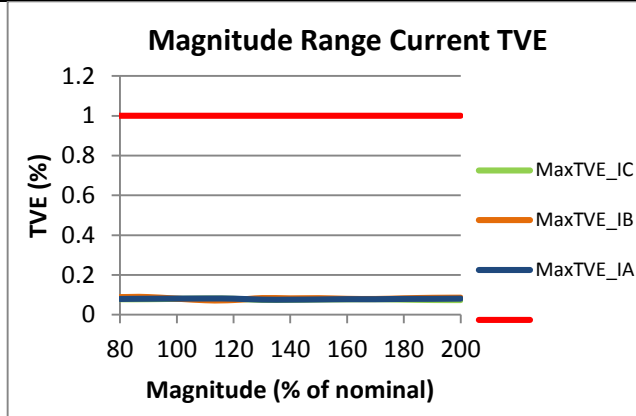


Figure 797:  $F_s = 60$  FPS

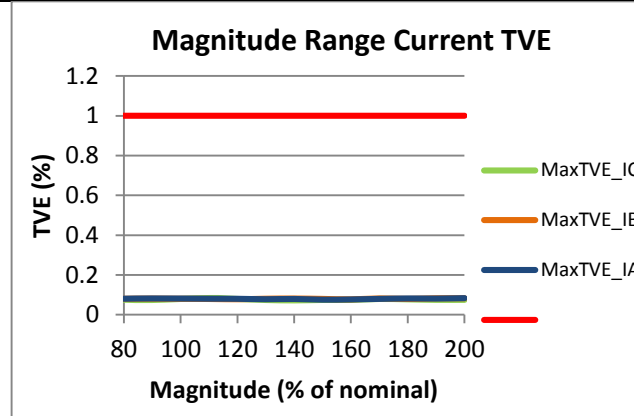


Figure 798:  $F_s = 30$  FPS

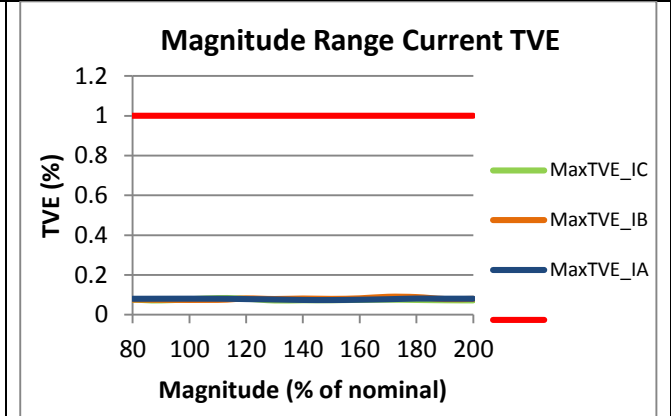


Figure 799:  $F_s = 20$  FPS

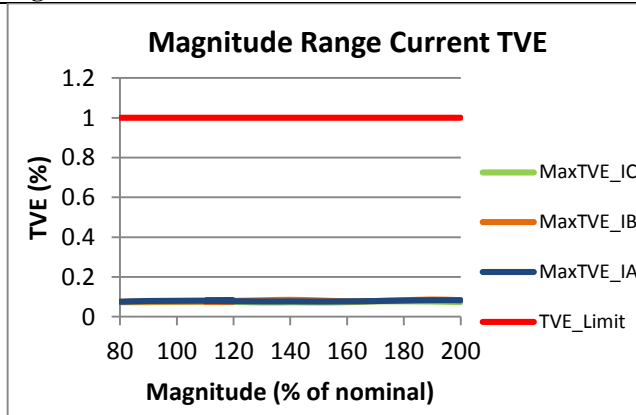


Figure 800:  $F_s = 15$  FPS

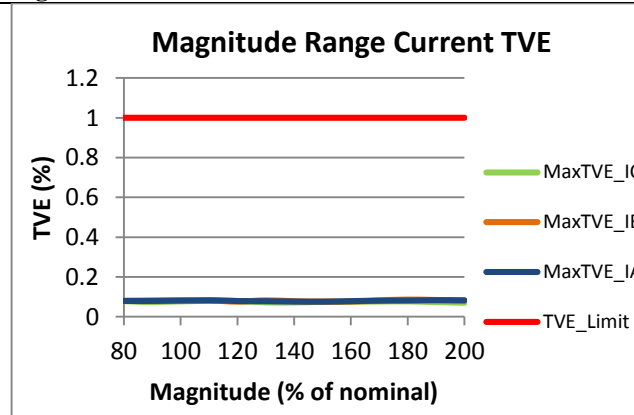


Figure 801:  $F_s = 12$  FPS

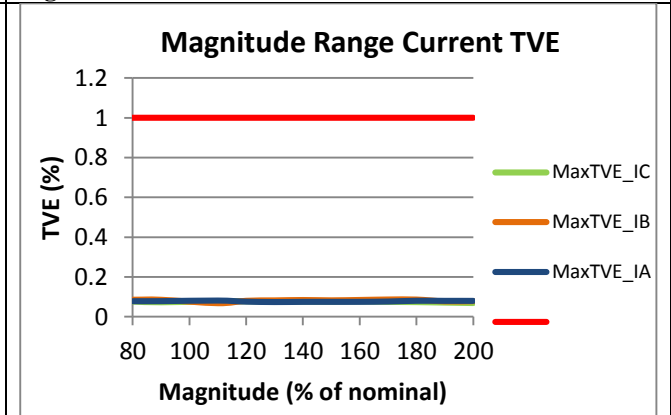


Figure 802:  $F_s = 10$  FPS

### 3.6.6 PMU E steady state signal magnitude current TVE: P class

PMU E does not support P class

### 3.6.7 PMU F steady state signal magnitude current TVE: P class

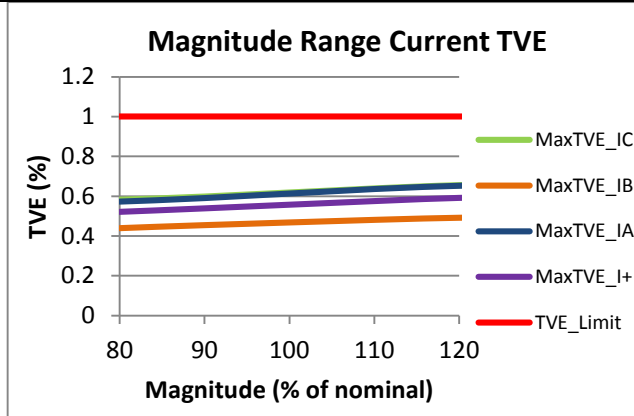


Figure 803: Fs = 60 FPS

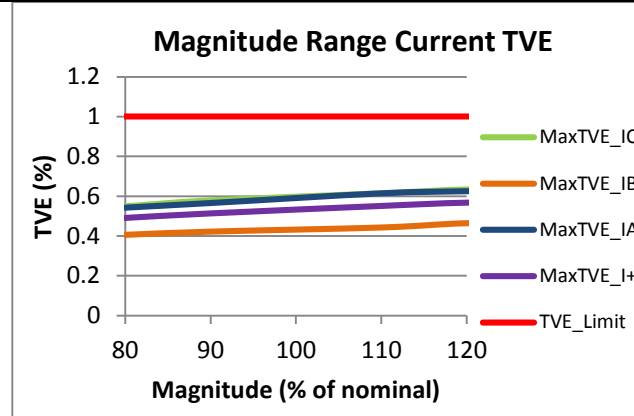


Figure 804: Fs = 30 FPS

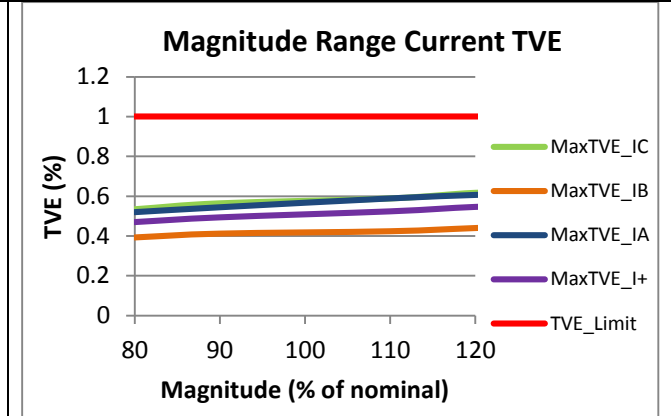


Figure 805: Fs = 20 FPS

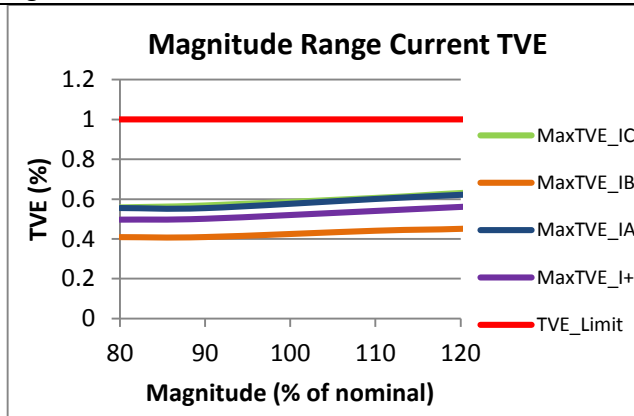


Figure 806: Fs = 15 FPS

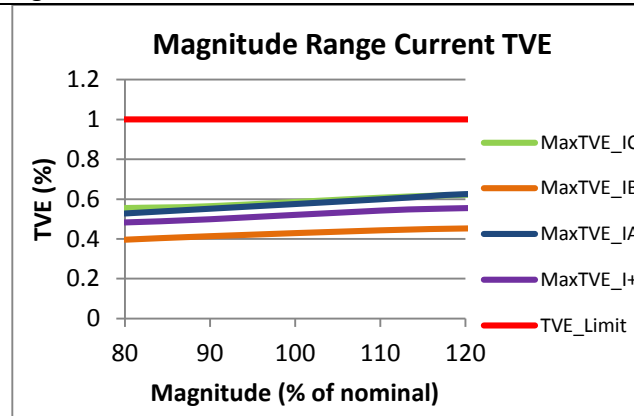


Figure 807: Fs = 12 FPS

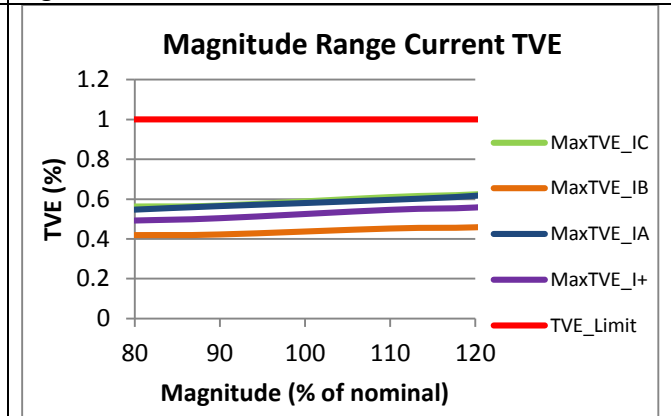


Figure 808: Fs = 10 FPS

### 3.6.8 PMU G steady state signal magnitude current TVE: P class

PMU G does not support P class

### 3.6.9 PMU H steady state signal magnitude current TVE: P class

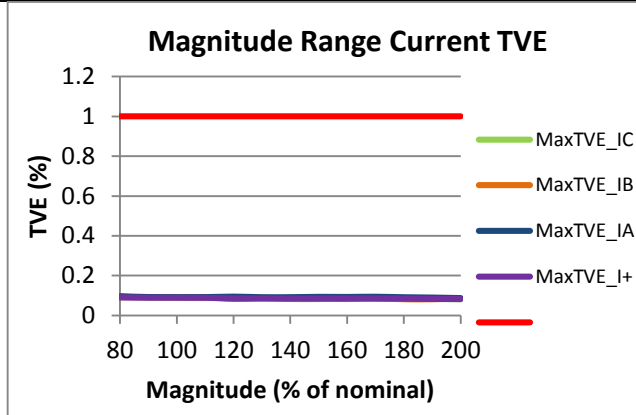


Figure 809:  $F_s = 60$  FPS

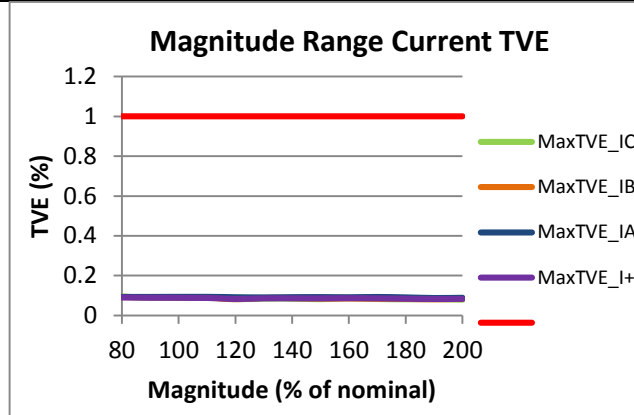


Figure 810:  $F_s = 30$  FPS

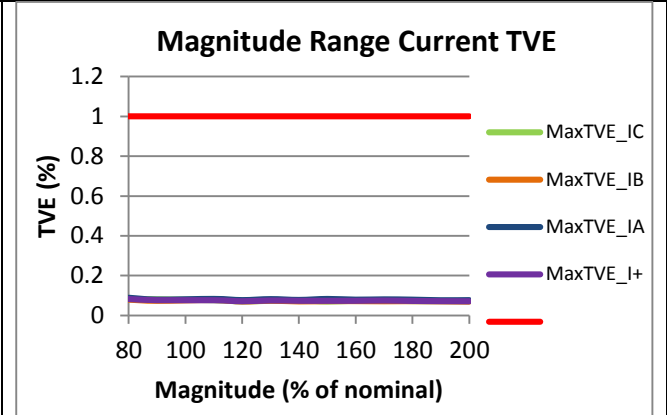


Figure 811:  $F_s = 20$  FPS

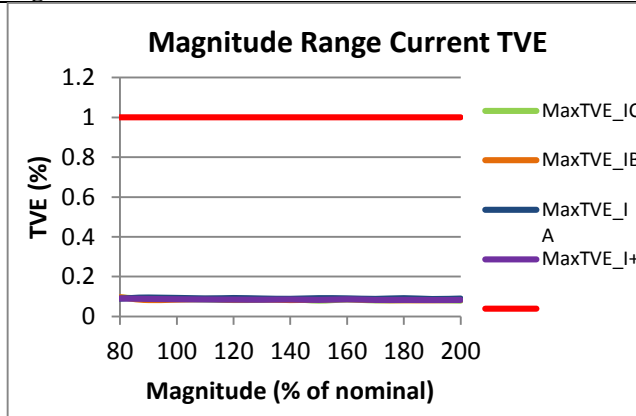


Figure 812:  $F_s = 15$  FPS

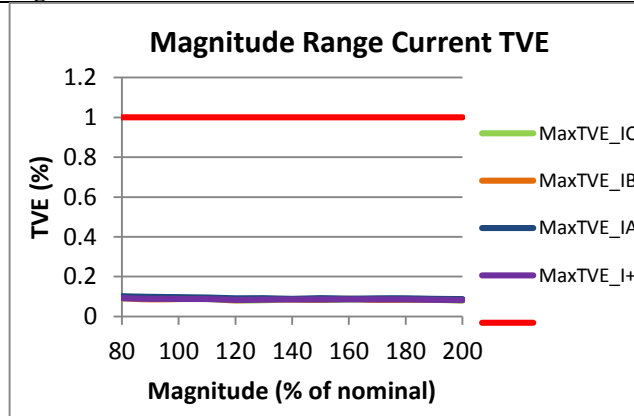


Figure 813:  $F_s = 12$  FPS

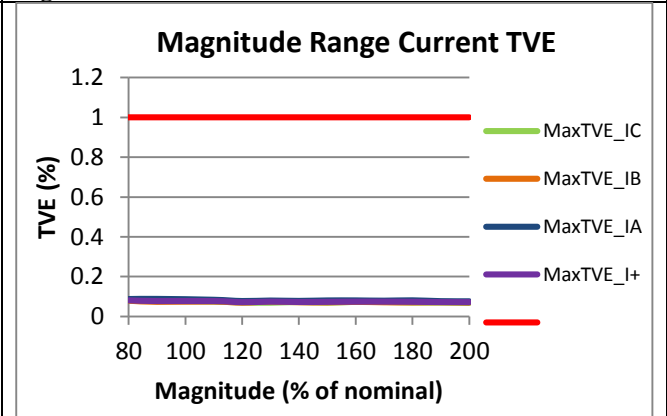


Figure 814:  $F_s = 10$  FPS

### 3.6.10 PMU I steady state signal magnitude current TVE: P class

PMU I does not support P class



### 3.6.11 PMU J steady state signal magnitude current TVE: P class

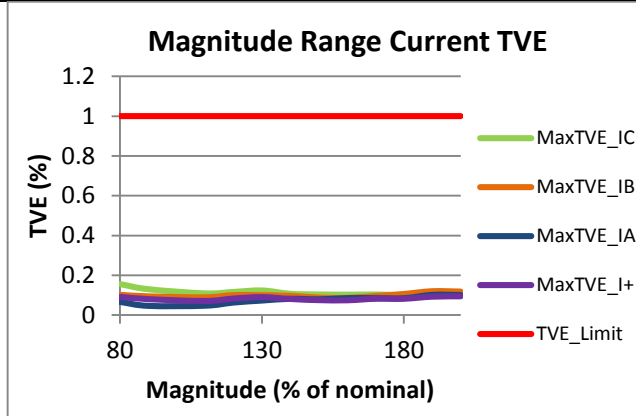


Figure 815: Fs = 60 FPS

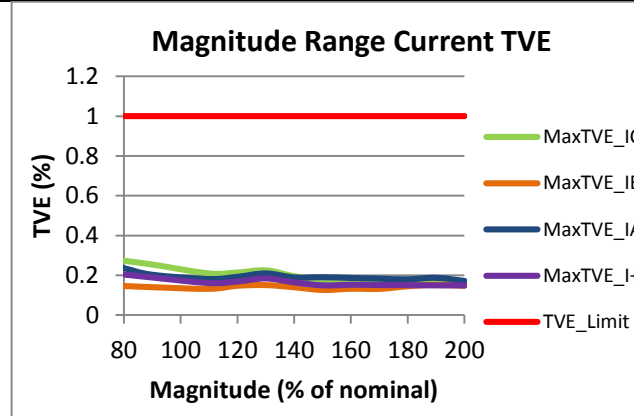


Figure 816: Fs = 30 FPS

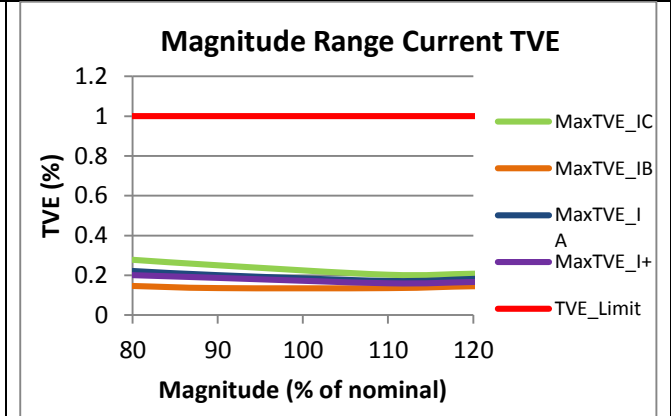


Figure 817: Fs = 20 FPS

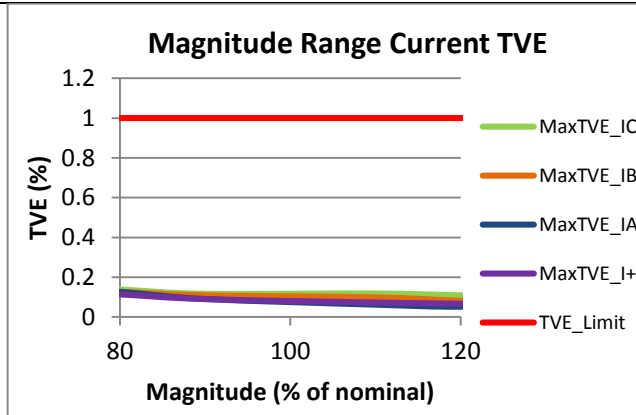


Figure 818: Fs = 15 FPS

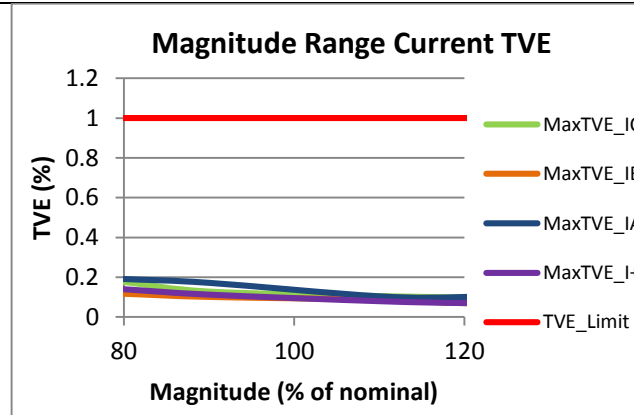


Figure 819: Fs = 12 FPS

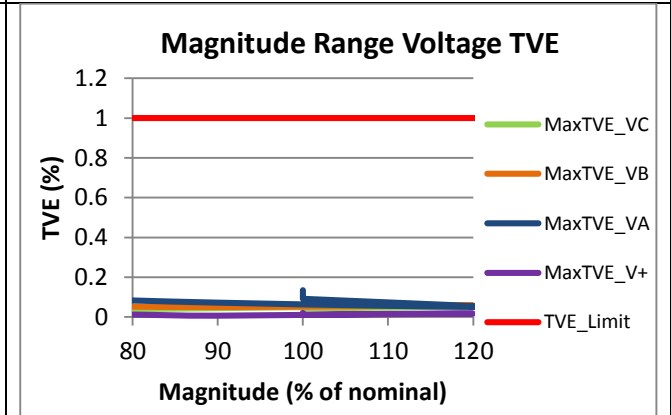
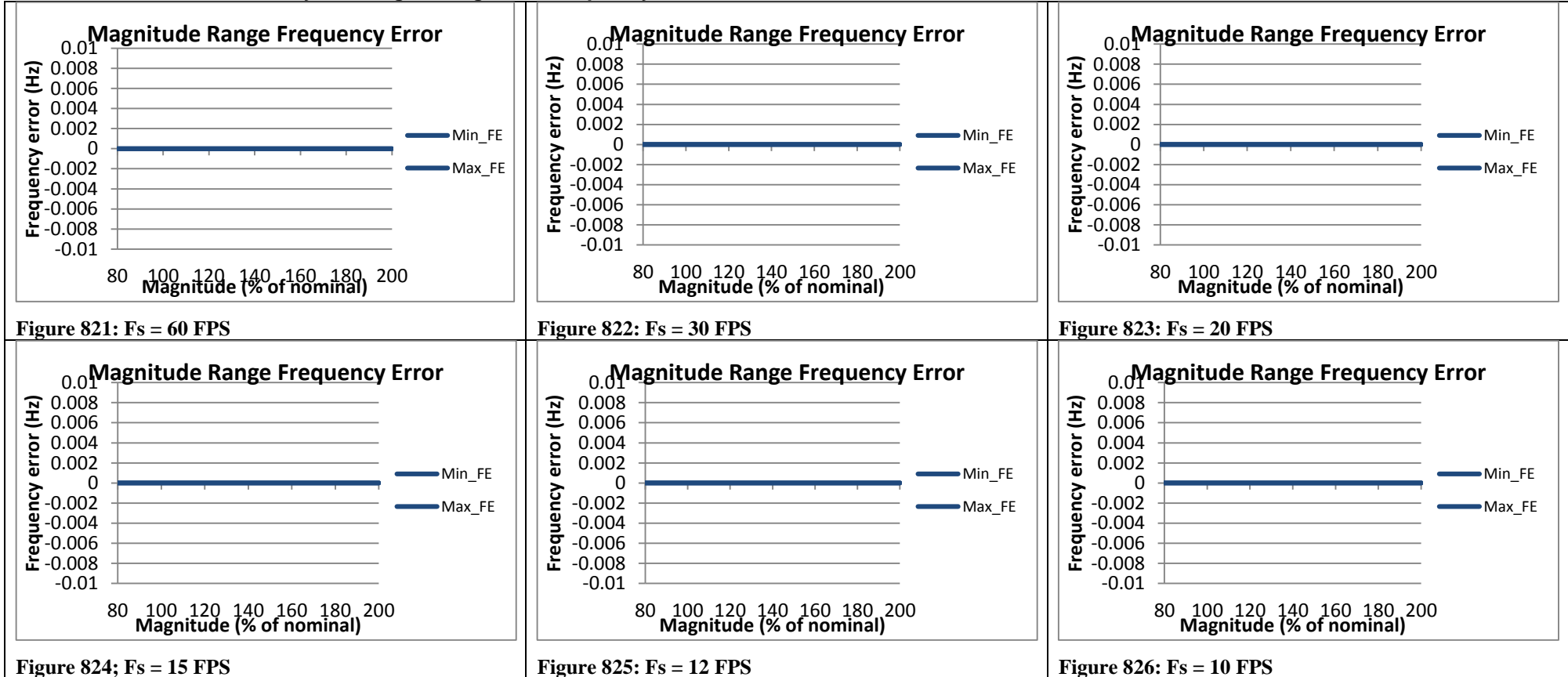


Figure 820: Fs = 10 FPS

### 3.7 Steady state signal magnitude frequency error: P class

No performance limits are shown in the plots below because the steady state magnitude range tests do not require frequency error to meet performance limits

#### 3.7.1 C37.118.1 Annex C steady state signal magnitude frequency error:, F0 = 60 Hz, P class



### 3.7.2 PMU A steady state signal magnitude frequency error: P class

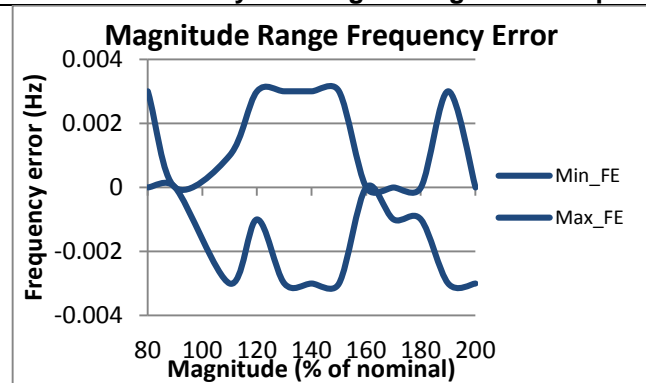


Figure 827:  $F_s = 60$  FPS

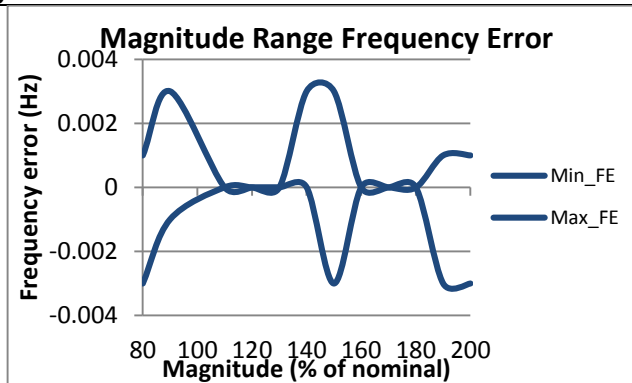


Figure 828:  $F_s = 30$  FPS

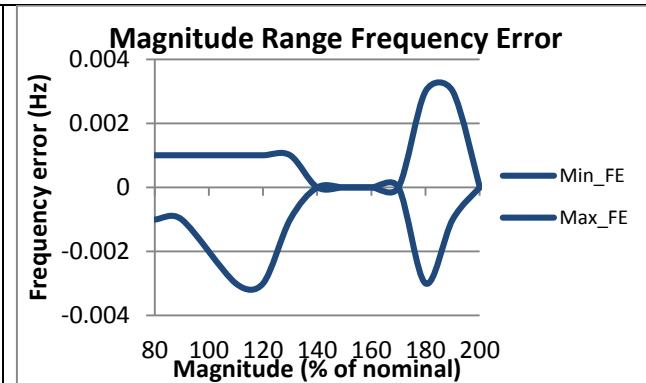


Figure 829:  $F_s = 20$  FPS

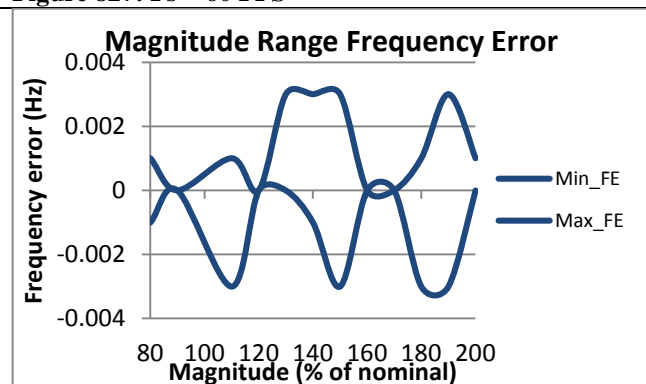


Figure 830:  $F_s = 15$  FPS

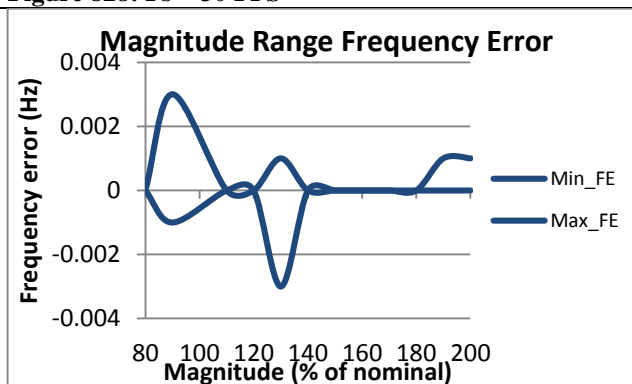


Figure 831:  $F_s = 12$  FPS

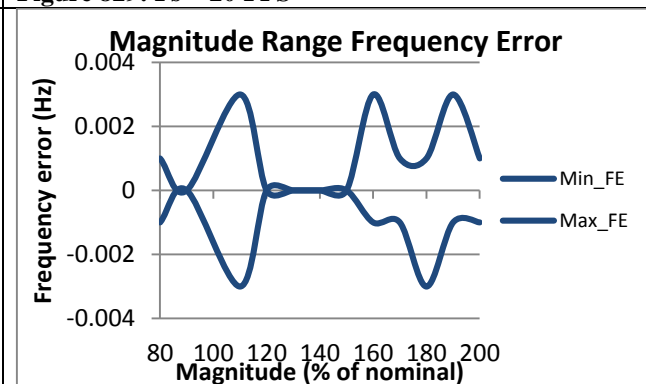


Figure 832:  $F_s = 10$  FPS

### 3.7.3 PMU B steady state signal magnitude frequency error: P class

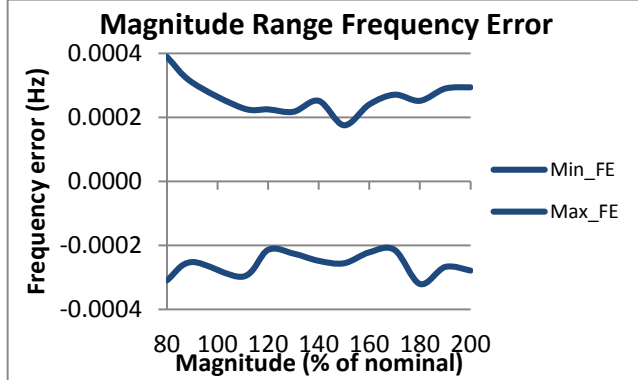


Figure 833:  $F_s = 60$  FPS

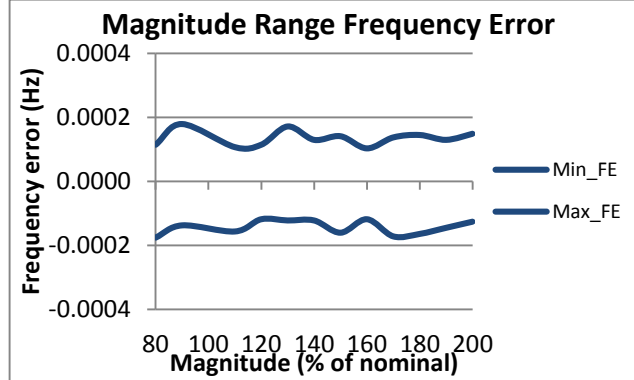


Figure 834:  $F_s = 30$  FPS

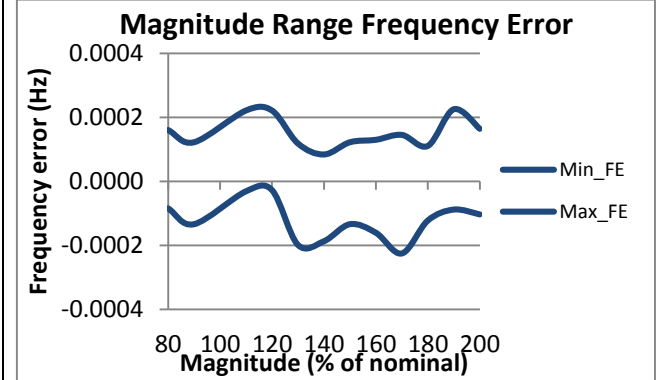


Figure 835:  $F_s = 20$  FPS

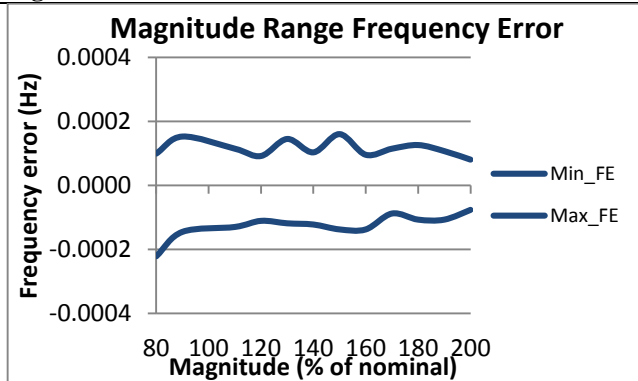


Figure 836:  $F_s = 15$  FPS

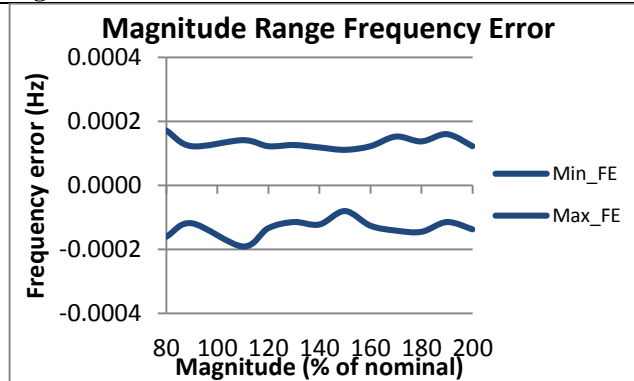


Figure 837:  $F_s = 12$  FPS

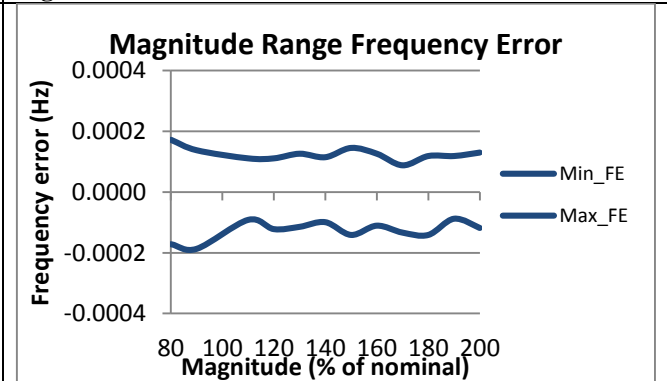


Figure 838:  $F_s = 10$  FPS

### 3.7.4 PMU C steady state signal magnitude frequency error: P class

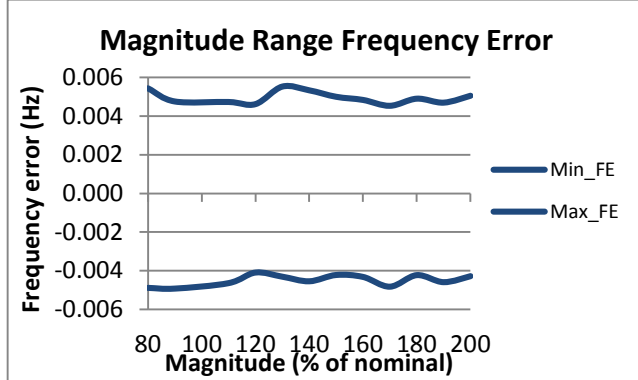


Figure 839:  $F_s = 60$  FPS

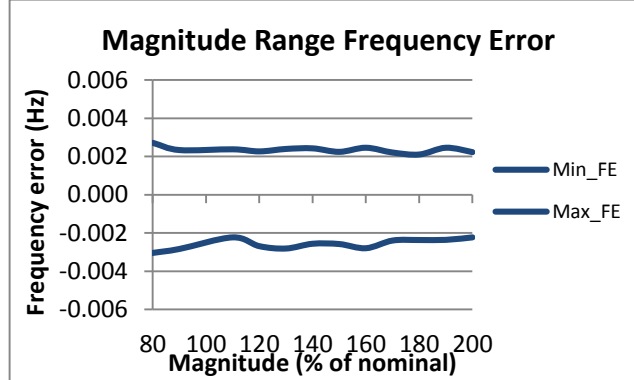


Figure 840:  $F_s = 30$  FPS

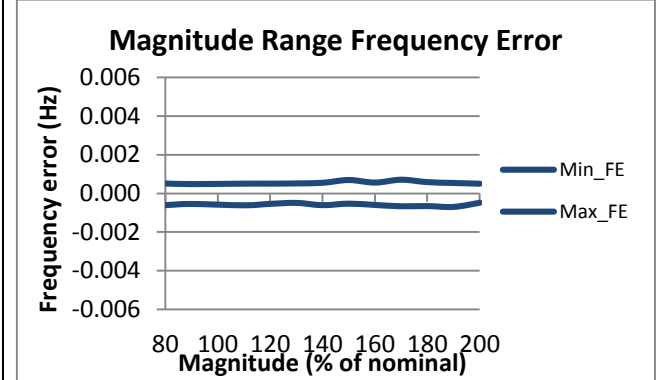


Figure 841:  $F_s = 20$  FPS

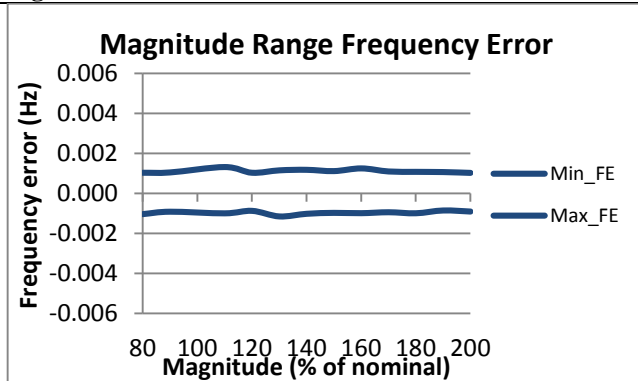


Figure 842:  $F_s = 15$  FPS

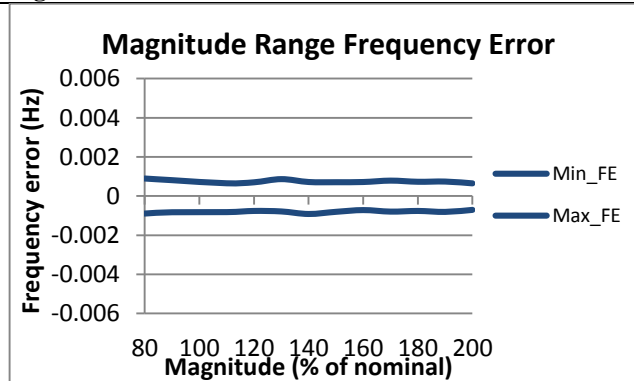


Figure 843:  $F_s = 12$  FPS

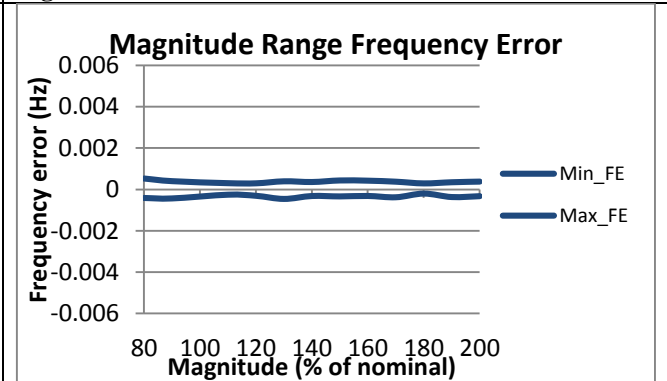


Figure 844:  $F_s = 10$  FPS

### 3.7.5 PMU D steady state signal magnitude frequency error: P class

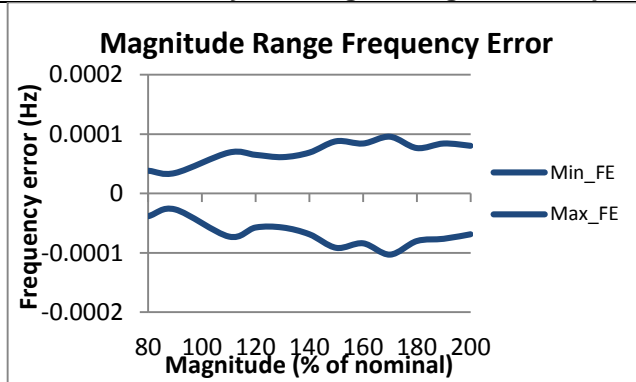


Figure 845:  $F_s = 60$  FPS

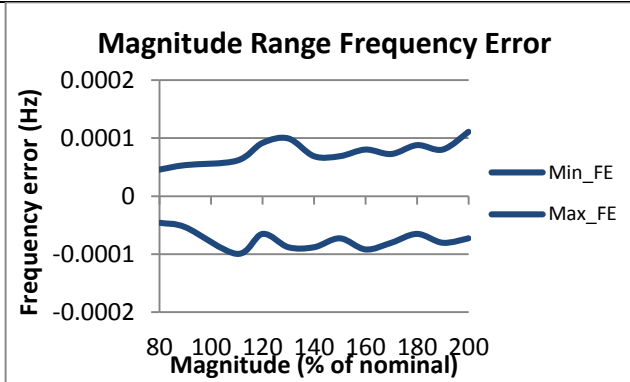


Figure 846:  $F_s = 30$  FPS

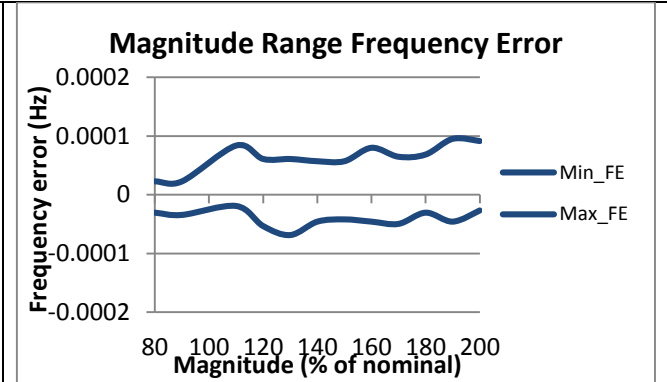


Figure 847:  $F_s = 20$  FPS

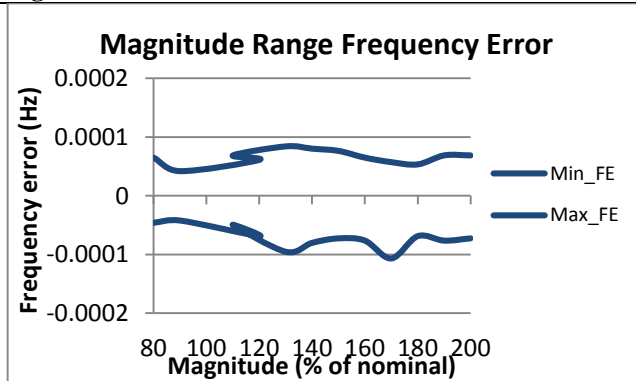


Figure 848:  $F_s = 15$  FPS

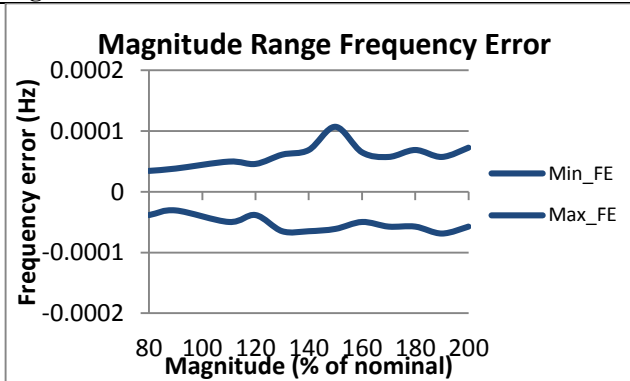


Figure 849:  $F_s = 12$  FPS

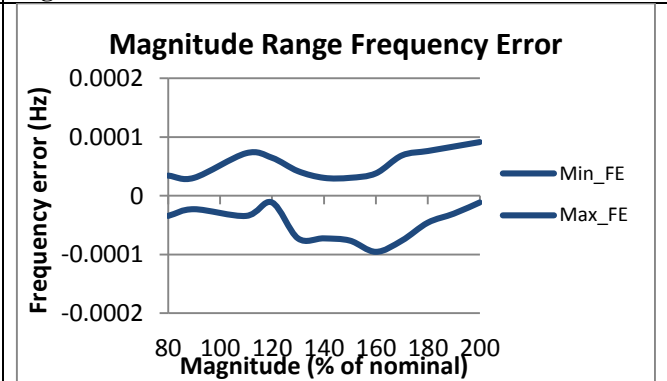


Figure 850:  $F_s = 10$  FPS

### 3.7.6 PMU E steady state signal magnitude frequency error: P class

PMU E does not support P class

### 3.7.7 PMU F steady state signal magnitude frequency error: P class

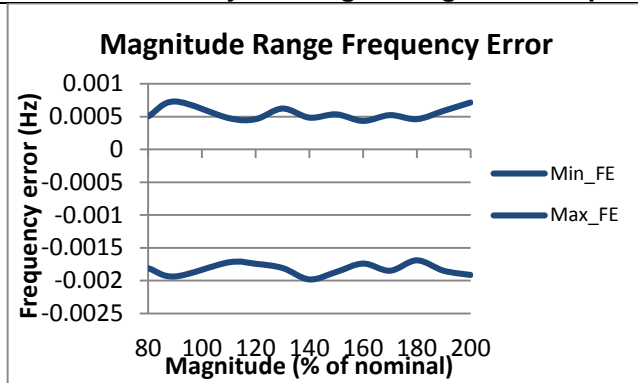


Figure 851:  $F_s = 60$  FPS

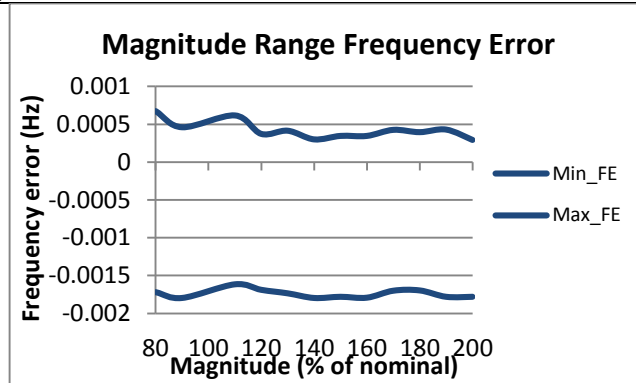


Figure 852:  $F_s = 30$  FPS

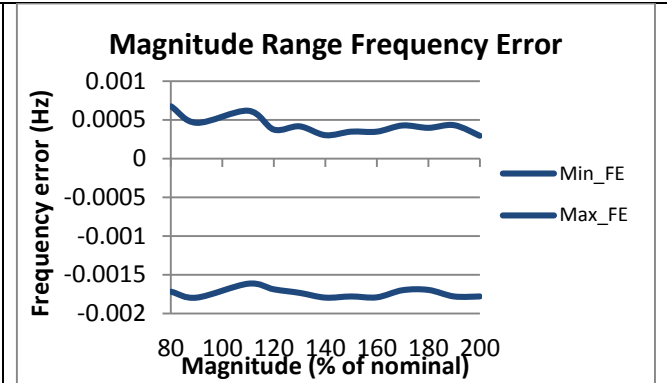


Figure 853:  $F_s = 20$  FPS

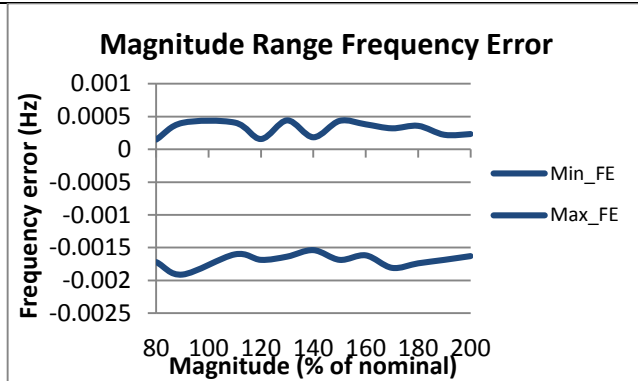


Figure 854:  $F_s = 15$  FPS

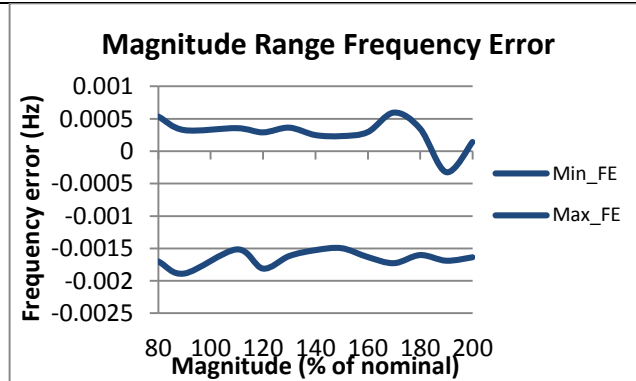


Figure 855:  $F_s = 12$  FPS

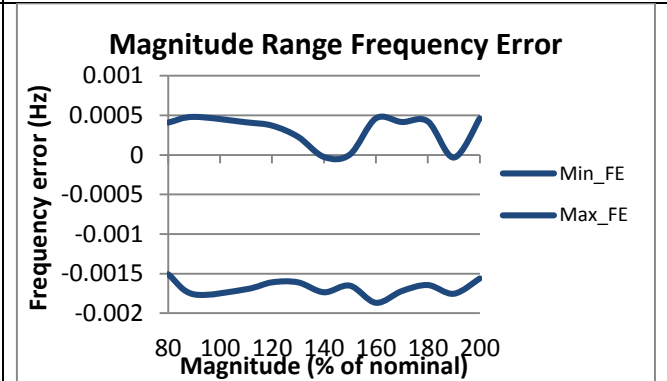


Figure 856:  $F_s = 10$  FPS

### 3.7.8 PMU G steady state signal magnitude frequency error: P class

PMU G does not support P class

### 3.7.9 PMU H steady state signal magnitude frequency error: P class

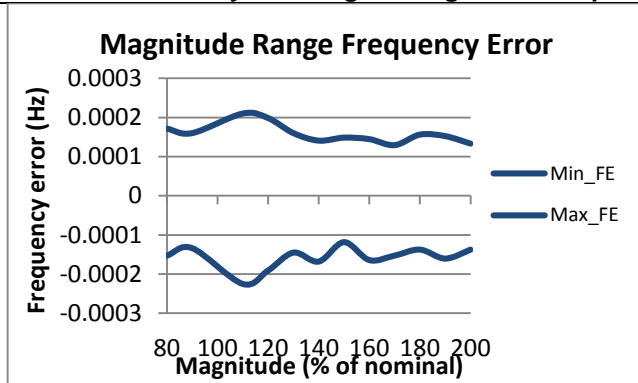


Figure 857:  $F_s = 60$  FPS

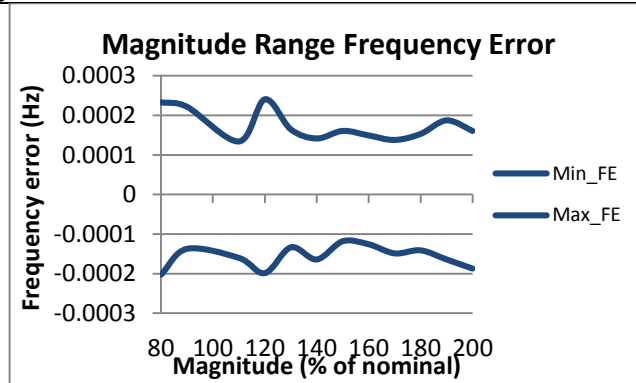


Figure 858:  $F_s = 30$  FPS

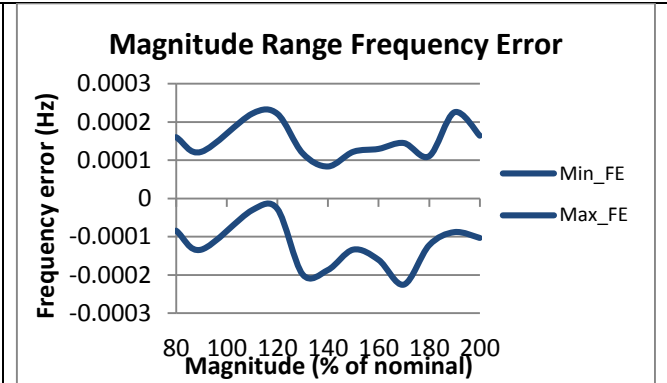


Figure 859:  $F_s = 20$  FPS

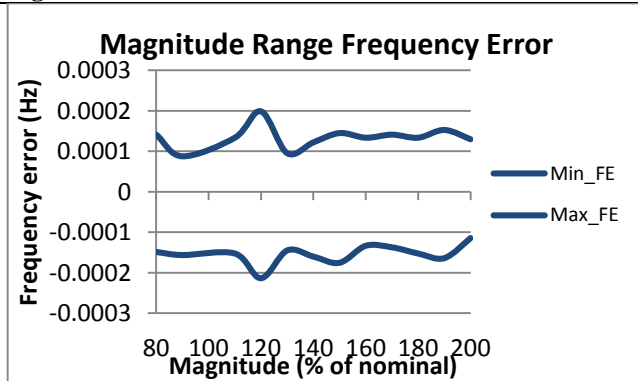


Figure 860:  $F_s = 15$  FPS

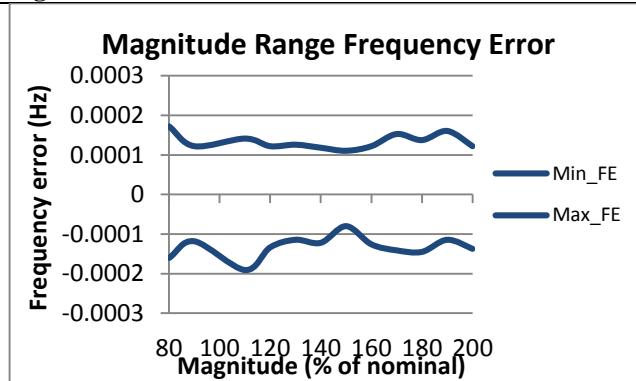


Figure 861:  $F_s = 12$  FPS

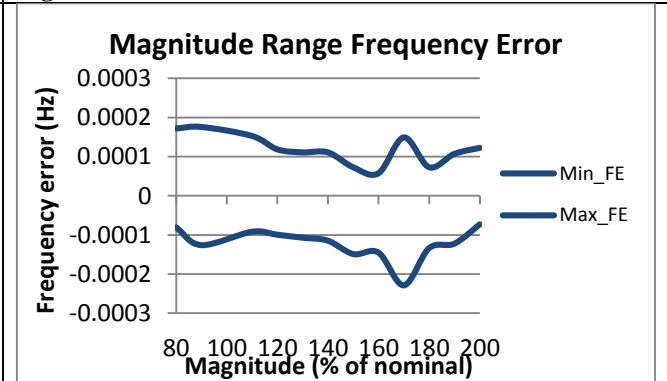


Figure 862:  $F_s = 10$  FPS

### 3.7.10 PMU I steady state signal magnitude frequency error: P class

PMU I does not support P class



### 3.7.11 PMU I steady state signal magnitude frequency error: P class

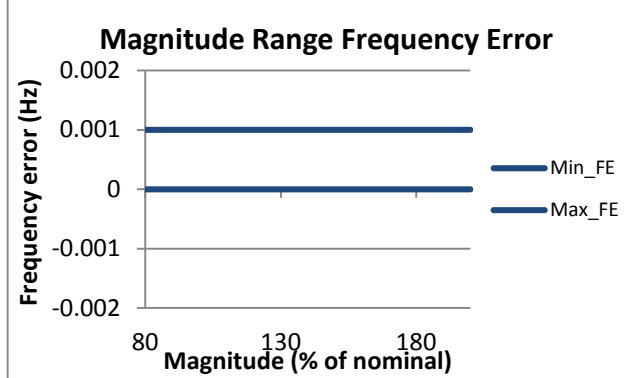


Figure 863:  $F_s = 60$  FPS

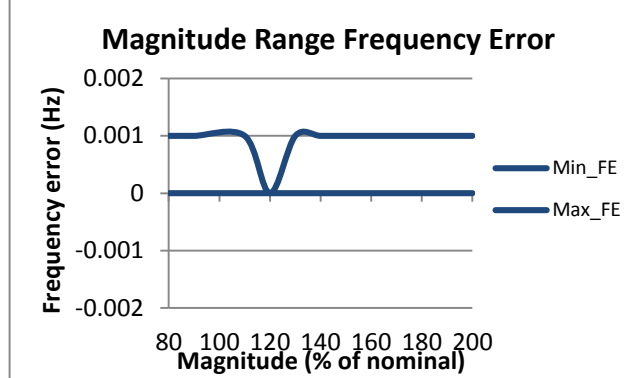


Figure 864:  $F_s = 30$  FPS

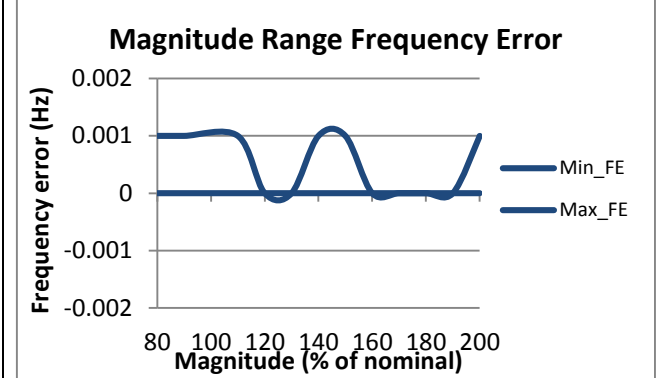


Figure 865:  $F_s = 20$  FPS

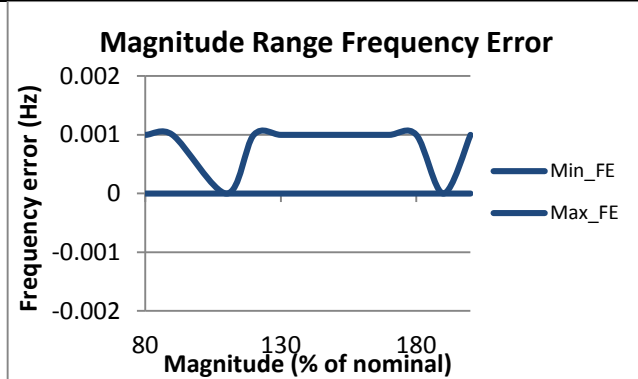


Figure 866:  $F_s = 15$  FPS

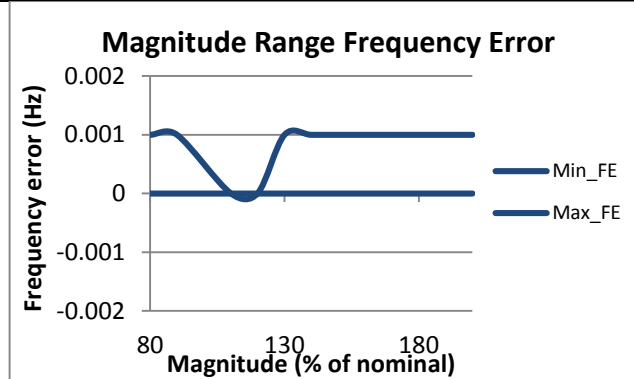


Figure 867:  $F_s = 12$  FPS

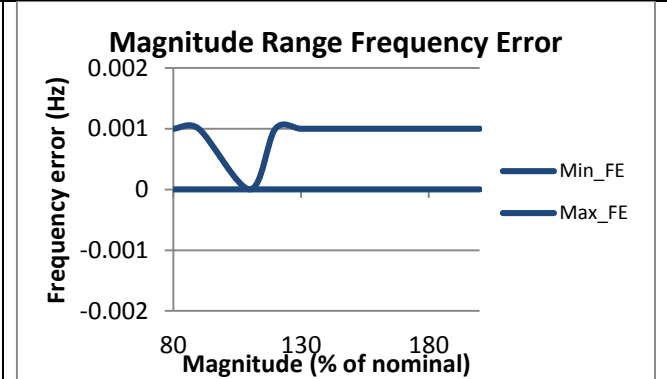
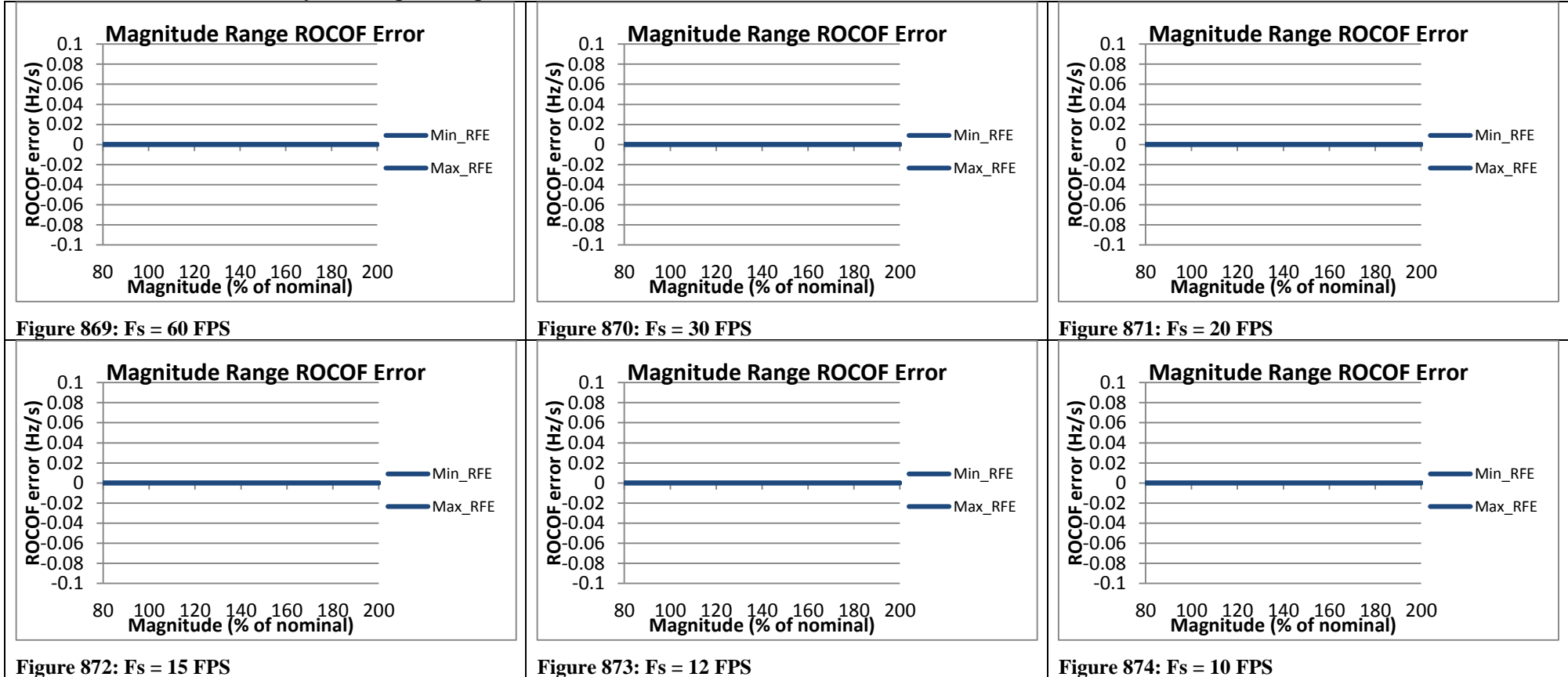


Figure 868:  $F_s = 10$  FPS

### 3.8 Steady state signal magnitude ROCOF error: P class

No performance limits are shown in the plots below because the steady state magnitude range tests do not require frequency error to meet performance limits

#### 3.8.1 C37.118.1 Annex C steady state signal magnitude ROCOF error:, F0 = 60 Hz, P class



### 3.8.2 PMU A steady state signal magnitude ROCOF error: P class

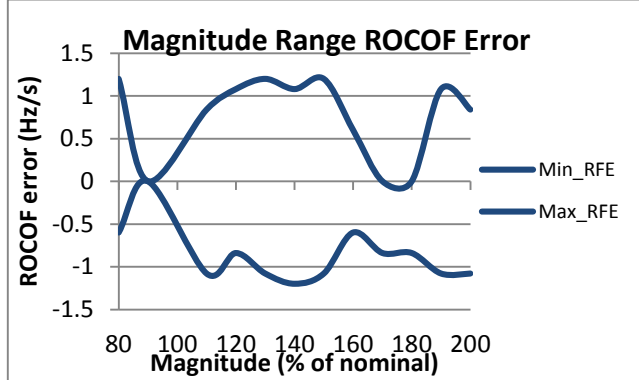


Figure 875:  $F_s = 60$  FPS

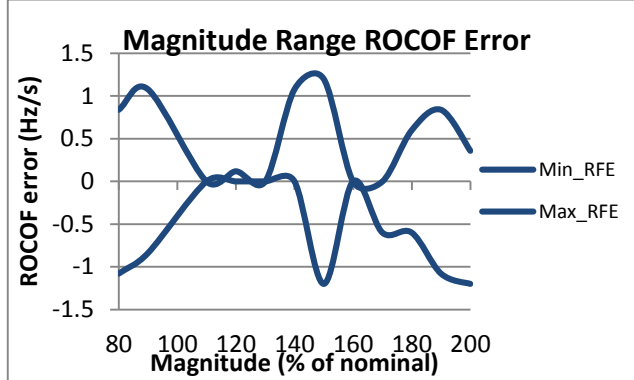


Figure 876:  $F_s = 30$  FPS

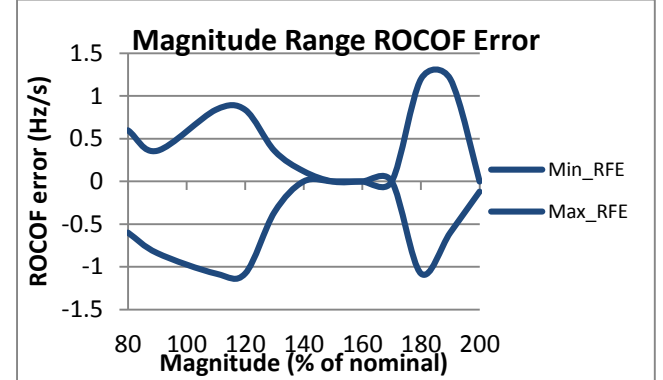


Figure 877:  $F_s = 20$  FPS

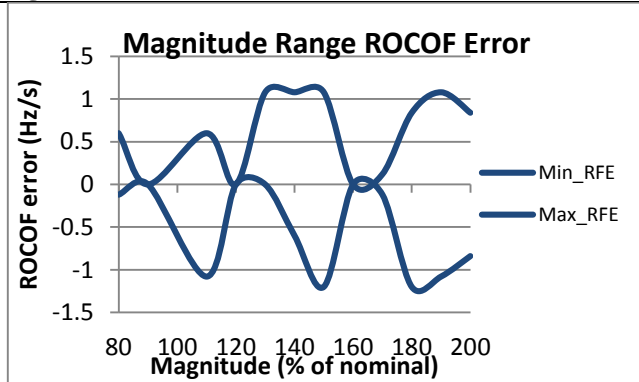


Figure 878:  $F_s = 15$  FPS

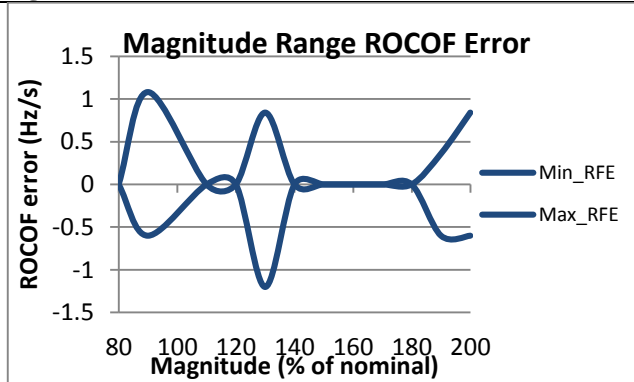


Figure 879:  $F_s = 12$  FPS

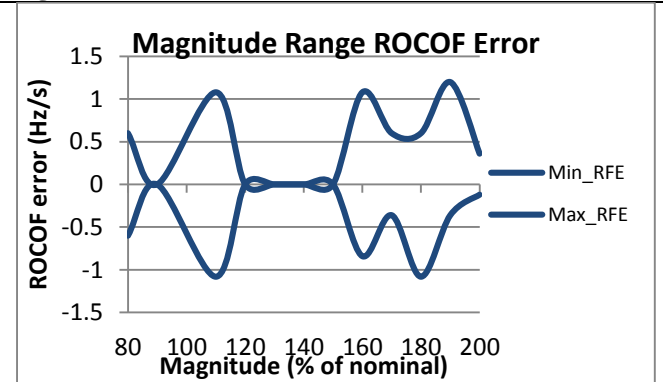


Figure 880:  $F_s = 10$  FPS

### 3.8.3 PMU B steady state signal magnitude ROCOF error: P class

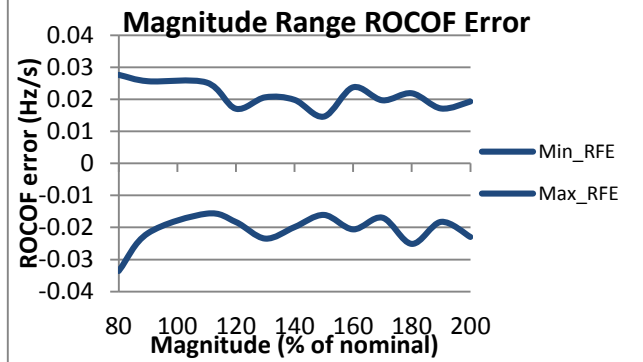


Figure 881:  $F_s = 60$  FPS

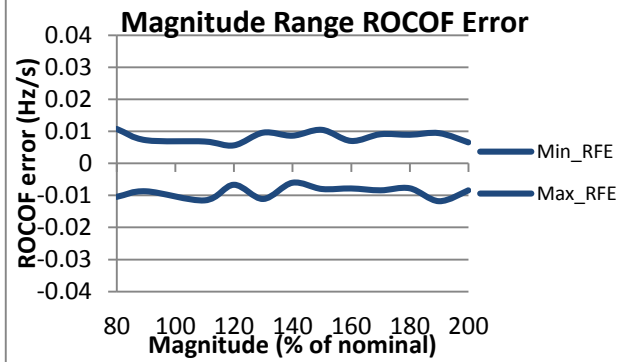


Figure 882:  $F_s = 30$  FPS

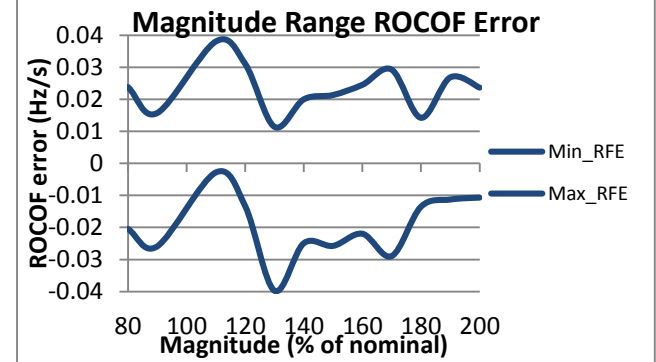


Figure 883:  $F_s = 20$  FPS

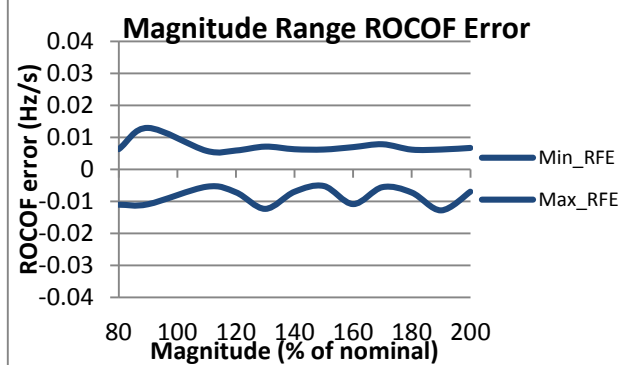


Figure 884:  $F_s = 15$  FPS

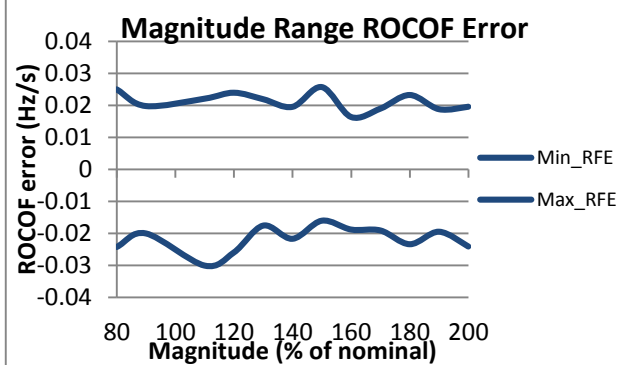


Figure 885:  $F_s = 12$  FPS

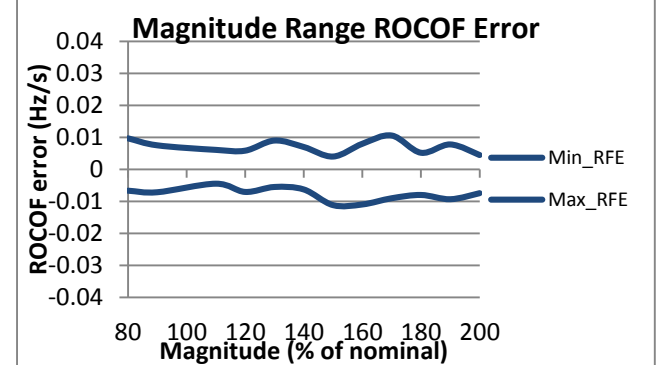


Figure 886:  $F_s = 10$  FPS

### 3.8.4 PMU C steady state signal magnitude ROCOF error: P class

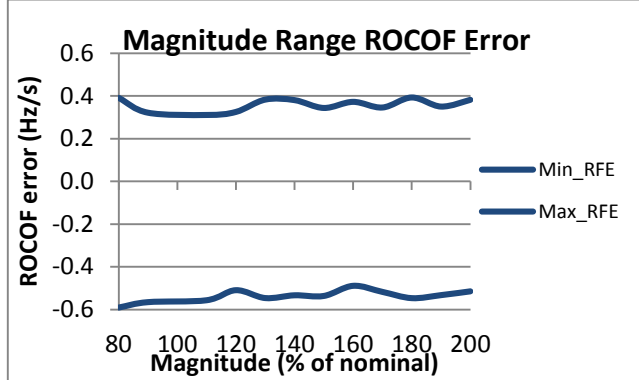


Figure 887:  $F_s = 60$  FPS

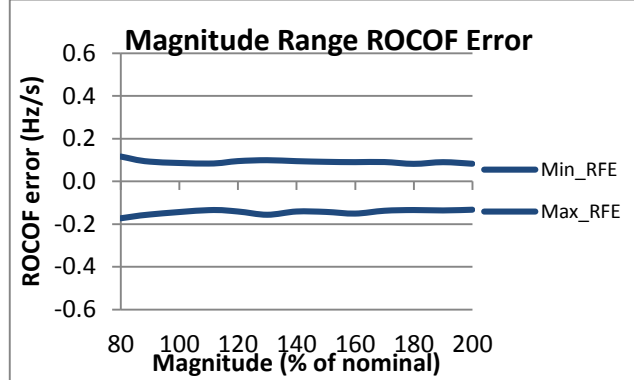


Figure 888:  $F_s = 30$  FPS

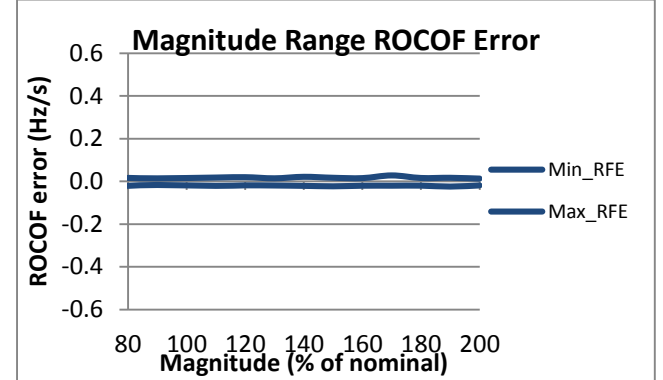


Figure 889:  $F_s = 20$  FPS

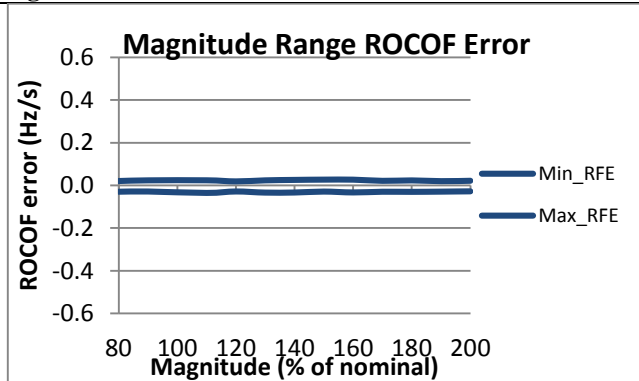


Figure 890:  $F_s = 15$  FPS

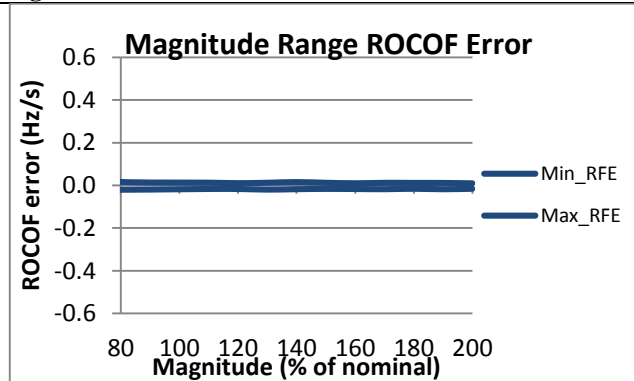


Figure 891:  $F_s = 12$  FPS

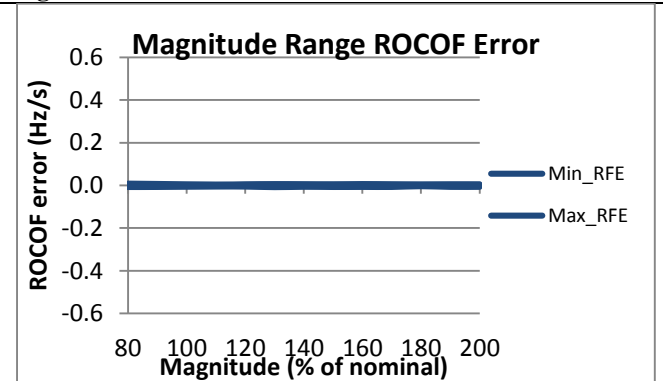


Figure 892:  $F_s = 10$  FPS

### 3.8.5 PMU D steady state signal magnitude ROCOF error: P class

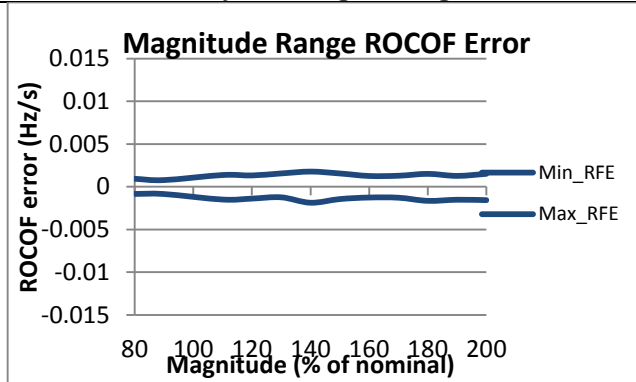


Figure 893:  $F_s = 60$  FPS

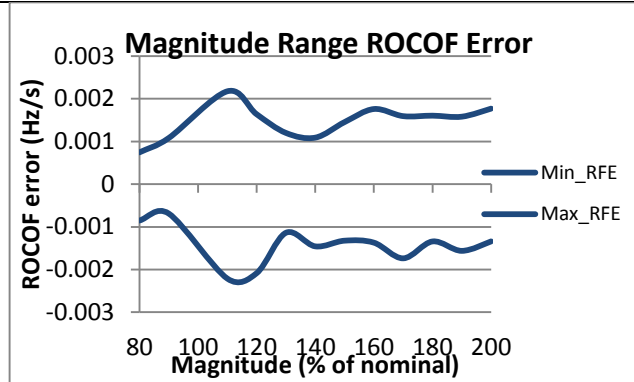


Figure 894:  $F_s = 30$  FPS

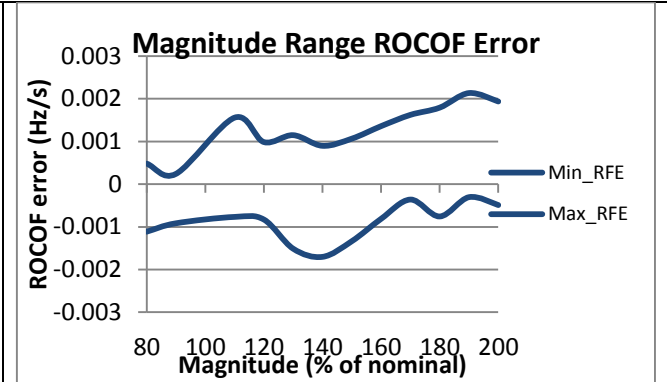


Figure 895:  $F_s = 20$  FPS

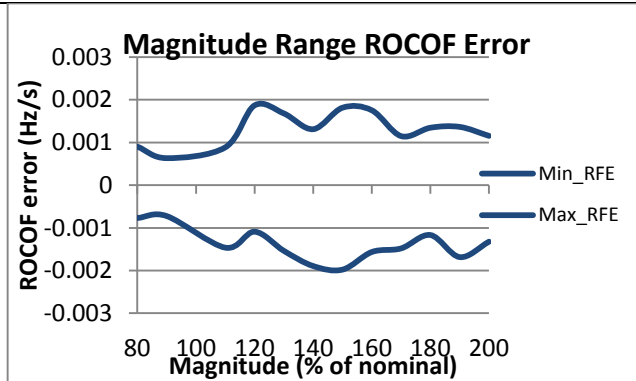


Figure 896:  $F_s = 15$  FPS

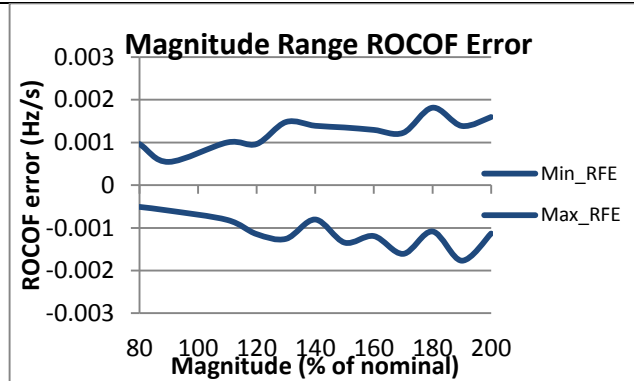


Figure 897:  $F_s = 12$  FPS

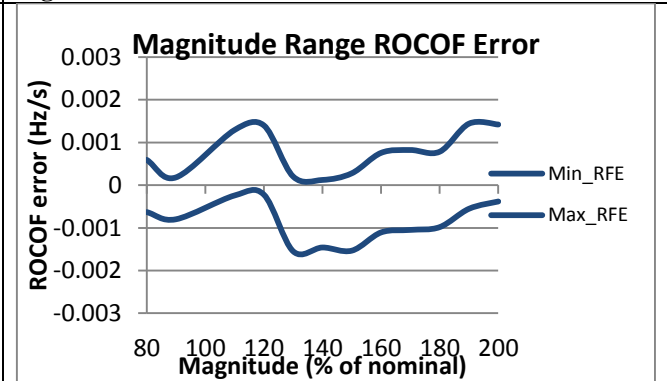


Figure 898:  $F_s = 10$  FPS

### 3.8.6 PMU E steady state signal magnitude ROCOF error: P class

PMU E does not support P class

### 3.8.7 PMU F steady state signal magnitude ROCOF error: P class

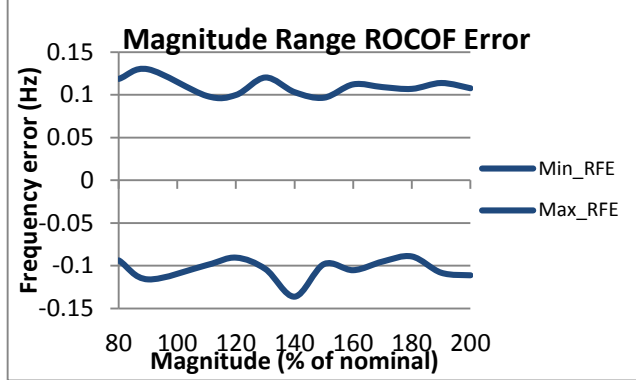


Figure 899:  $F_s = 60$  FPS

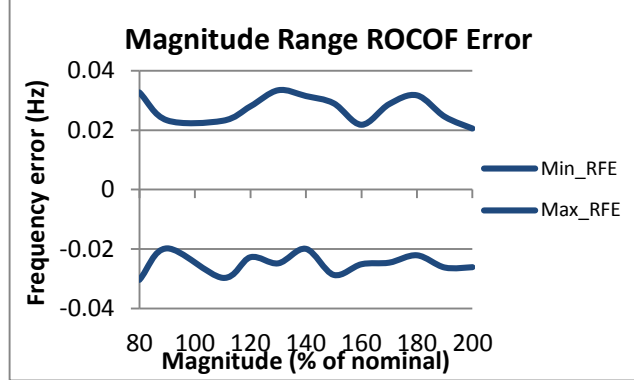


Figure 900:  $F_s = 30$  FPS

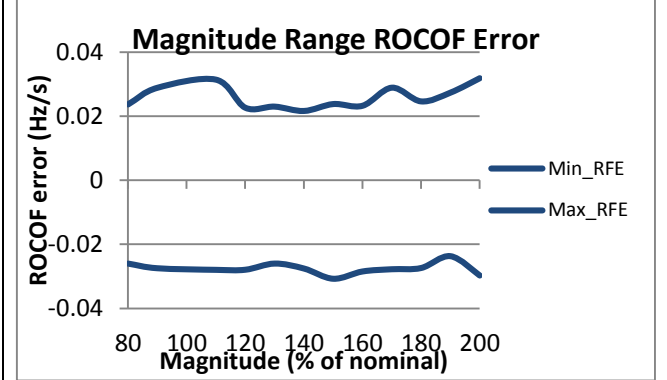


Figure 901:  $F_s = 20$  FPS

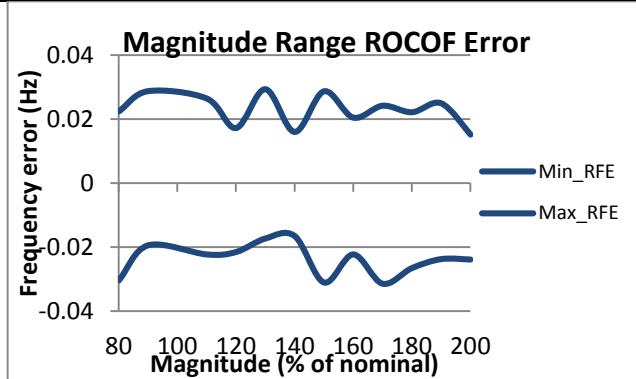


Figure 902:  $F_s = 15$  FPS

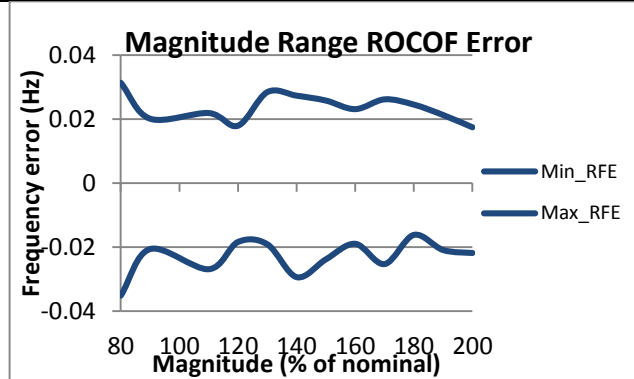


Figure 903:  $F_s = 12$  FPS

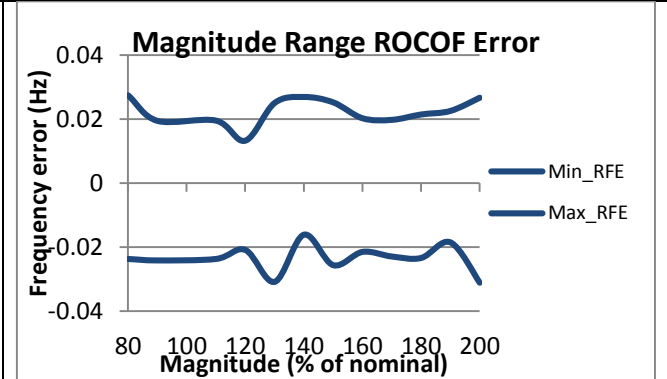


Figure 904:  $F_s = 10$  FPS

### 3.8.8 PMU G steady state signal magnitude ROCOF error: P class

PMU G does not support P class

### 3.8.9 PMU H steady state signal magnitude ROCOF error: P class

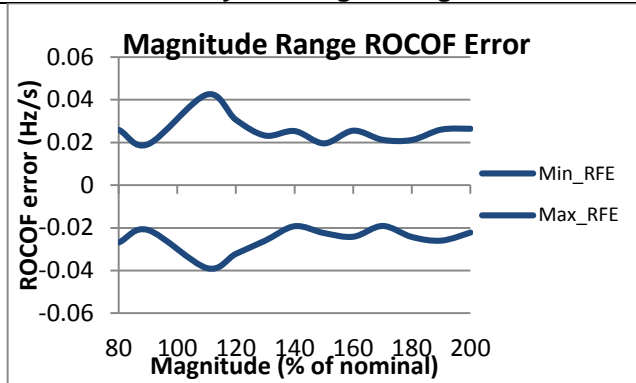


Figure 905:  $F_s = 60$  FPS

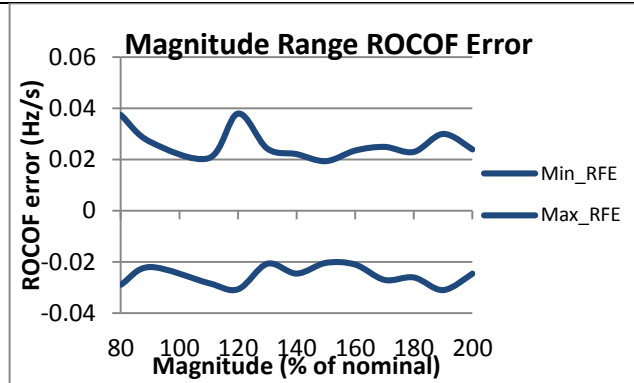


Figure 906:  $F_s = 30$  FPS

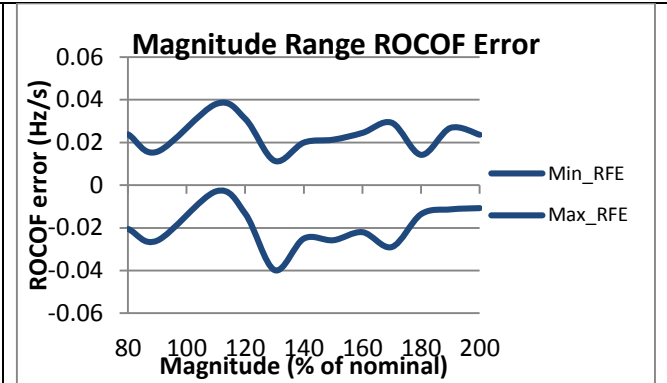


Figure 907:  $F_s = 20$  FPS

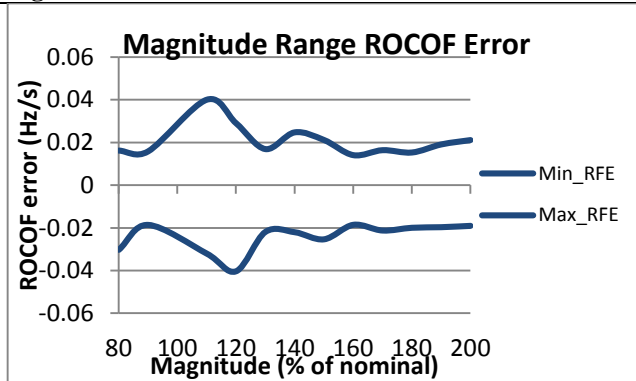


Figure 908:  $F_s = 15$  FPS

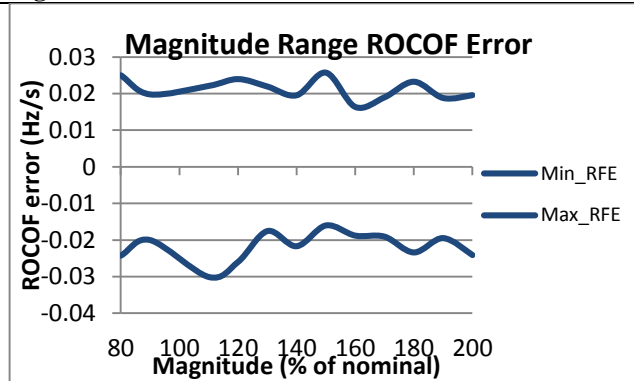


Figure 909:  $F_s = 12$  FPS

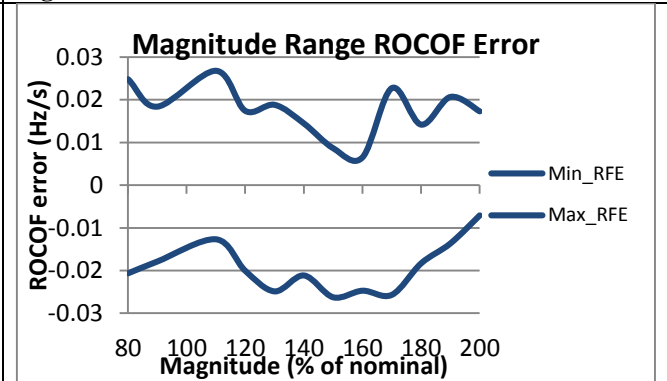


Figure 910:  $F_s = 10$  FPS

### 3.8.10 PMU I steady state signal magnitude ROCOF error: P class

PMU I does not support P class



### 3.8.11 PMU J steady state signal magnitude ROCOF error: P class

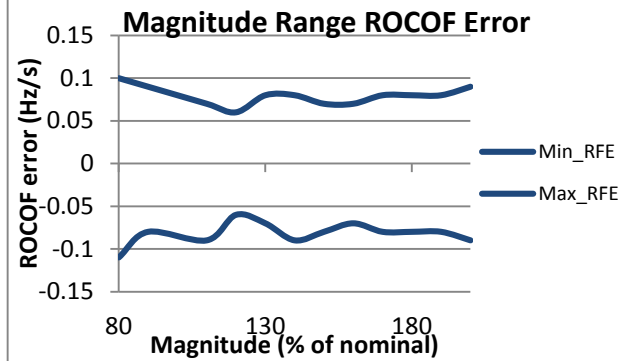


Figure 911:  $F_s = 60$  FPS

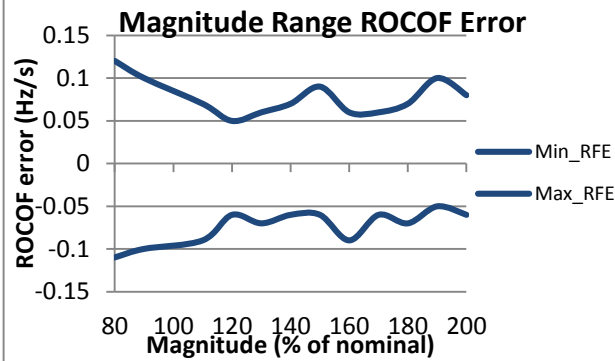


Figure 912:  $F_s = 30$  FPS

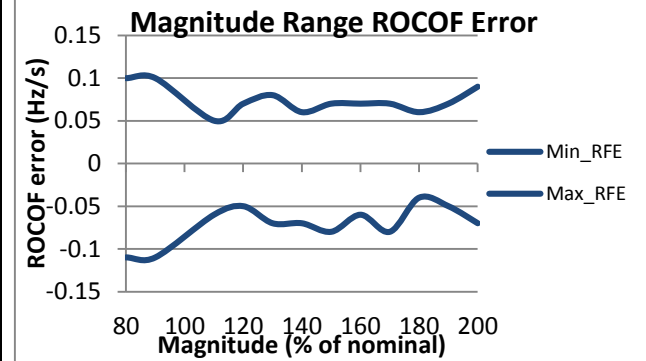


Figure 913:  $F_s = 20$  FPS

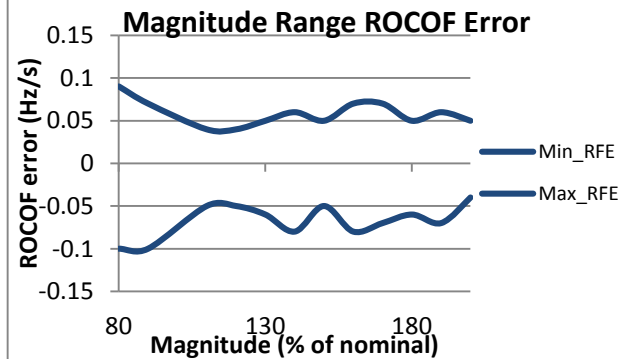


Figure 914:  $F_s = 15$  FPS

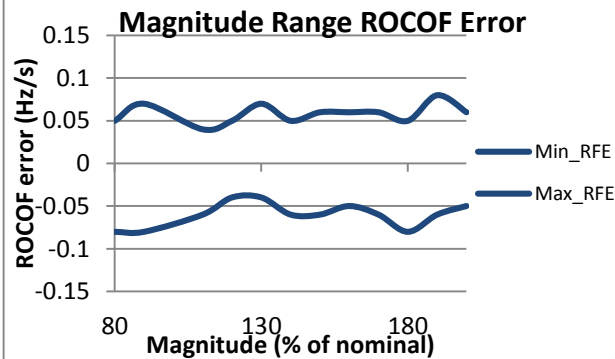


Figure 915:  $F_s = 12$  FPS

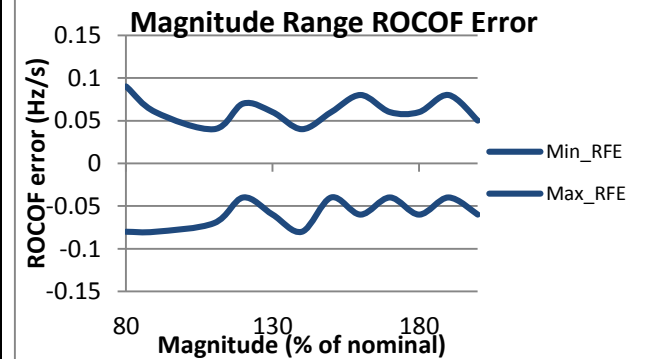


Figure 916:  $F_s = 10$  FPS

## 4. Steady state harmonic distortion

### Table of Contents

4. Steady state harmonic distortion .....	177
4.1 Steady state harmonic distortion voltage TVE: F0 = 60 Hz, M Class .....	182
4.1.1 C37.118.1 Annex C steady state frequency range voltage TVE:, F0 = 60 Hz, M class .....	182
4.1.2 PMU A steady state harmonic distortion voltage TVE: class .....	183
4.1.3 PMU B steady state harmonic distortion voltage TVE: M class .....	184
4.1.4 PMU C steady state harmonic distortion voltage TVE: M class .....	185
4.1.5 PMU D steady state harmonic distortion voltage TVE: M class .....	186
4.1.6 PMU E steady state harmonic distortion voltage TVE: M class .....	187
4.1.7 PMU F steady state harmonic distortion voltage TVE: M class .....	188
4.1.8 PMU G steady state harmonic distortion voltage TVE: M class .....	189
4.1.9 PMU H steady state harmonic distortion voltage TVE: M class .....	190
4.1.10 PMU I steady state harmonic distortion voltage TVE: M class .....	191
4.1.11 PMU J steady state harmonic distortion voltage TVE: M class .....	192
4.2 Steady state harmonic distortion current TVE: M class .....	193
4.2.1 C37.118.1 Annex C steady state harmonic distortion current TVE: M class .....	193
4.2.2 PMU A steady state harmonic distortion current TVE: M class .....	194
4.2.3 PMU B steady state harmonic distortion current TVE: M class .....	195
4.2.4 PMU C steady state harmonic distortion current TVE: M class .....	196
4.2.5 PMU D steady state harmonic distortion current TVE: M class .....	197
4.2.6 PMU E steady state harmonic distortion current TVE: M class .....	198
4.2.7 PMU F steady state harmonic distortion current TVE: M class .....	199
4.2.8 PMU G steady state harmonic distortion current TVE: M class .....	200
4.2.9 PMU H steady state harmonic distortion current TVE: M class .....	201
4.2.10 PMU I steady state harmonic distortion current TVE: M class .....	202
4.2.11 PMU J steady state harmonic distortion current TVE: M class .....	203
4.3 Steady state frequency harmonic distortion frequency error: M class .....	204
4.3.1 C37.118.1 Annex C steady harmonic distortion range frequency error: M class .....	204
4.3.2 PMU A steady state frequency harmonic distortion error: M class .....	205
4.3.3 PMU B steady state frequency harmonic distortion error: M class .....	206
4.3.4 PMU C steady state frequency harmonic distortion error: M class .....	207
4.3.5 PMU D steady state frequency harmonic distortion error: M class .....	208
4.3.6 PMU E steady state harmonic distortion frequency error: M class .....	209
4.3.7 PMU F steady state harmonic distortion frequency error: M class .....	210
4.3.8 PMU G steady state harmonic distortion frequency error: M class .....	211

4.3.9 PMU H steady state harmonic distortion frequency error: M class .....	212
4.3.10 PMU I steady state harmonic distortion frequency error: M class .....	213
4.3.11 PMU J steady state harmonic distortion frequency error: M class .....	214
4.4 Steady state harmonic distortion ROCOF error: M class .....	215
4.4.1 C37.118.1 Annex C steady harmonic distortion range ROCOF error: M class .....	215
4.4.2 PMU A steady state harmonic distortion ROCOF error: M class .....	216
4.4.3 PMU B steady state harmonic distortion ROCOF error: M class .....	217
4.4.4 PMU C steady state harmonic distortion ROCOF error: M class .....	218
4.4.5 PMU D steady state harmonic distortion ROCOF error: M class .....	219
4.4.6 PMU E steady state harmonic distortion ROCOF error: M class .....	220
4.4.7 PMU F steady state harmonic distortion ROCOF error: M class .....	221
4.4.8 PMU G* steady state harmonic distortion ROCOF error: M class .....	222
4.4.9 PMU H steady state harmonic distortion ROCOF error: M class .....	223
4.4.10 PMU I steady state harmonic distortion ROCOF error: M class .....	224
4.4.11 PMU J steady state harmonic distortion ROCOF error: M class .....	225
4.5 Steady state harmonic distortion voltage TVE: P class .....	226
4.5.1 C37.118.1 Annex C steady state frequency range voltage TVE: F0 = 60 Hz, P class .....	226
4.5.2 PMU A steady state harmonic distortion voltage TVE: P class .....	227
4.5.3 PMU B steady state harmonic distortion voltage TVE: P class .....	228
4.5.4 PMU C steady state harmonic distortion voltage TVE: P class .....	229
4.5.5 PMU D steady state harmonic distortion voltage TVE: P class .....	230
4.5.6 PMU E steady state harmonic distortion voltage TVE: P class .....	230
4.5.7 PMU F steady state harmonic distortion voltage TVE: P class .....	231
4.5.8 PMU G steady state harmonic distortion voltage TVE: P class .....	231
4.5.9 PMU H steady state harmonic distortion voltage TVE: P class .....	232
4.5.10 PMU I steady state harmonic distortion voltage TVE: P class .....	232
4.5.11 PMU J steady state harmonic distortion voltage TVE: P class .....	233
4.6 Steady state harmonic distortion current TVE: P class .....	234
4.6.1 C37.118.1 Annex C steady state harmonic distortion current TVE: P class .....	234
4.6.2 PMU A steady state harmonic distortion current TVE: P class .....	235
4.6.3 PMU B steady state harmonic distortion current TVE: P class .....	236
4.6.4 PMU C steady state harmonic distortion current TVE: P class .....	237
4.6.5 PMU D steady state harmonic distortion current TVE: P class .....	238
4.6.6 PMU E steady state harmonic distortion current TVE: P class .....	238
4.6.7 PMU F steady state harmonic distortion current TVE: P class .....	239
4.6.8 PMU G steady state harmonic distortion current TVE: P class .....	239
4.6.9 PMU H steady state harmonic distortion current TVE: P class .....	240
4.6.10 PMU I steady state harmonic distortion current TVE: P class .....	240
4.6.11 PMU J steady state harmonic distortion current TVE: P class .....	241
4.7 Steady state frequency harmonic distortion frequency error: P class .....	242
4.7.1 C37.118.1 Annex C steady harmonic distortion frequency error: P class .....	242

4.7.2 PMU A steady state harmonic distortion frequency error: P class .....	243
4.7.3 PMU B steady state harmonic distortion frequency error: P class .....	244
4.7.4 PMU C steady state harmonic distortion frequency error: P class.....	245
4.7.5 PMU D steady state harmonic distortion frequency error: P class .....	246
4.7.6 PMU E steady state harmonic distortion frequency error: P class.....	246
4.7.7 PMU F steady state harmonic distortion frequency error: P class.....	247
4.7.8 PMU G steady state harmonic distortion frequency error: P class .....	247
4.7.9 PMU H steady state harmonic distortion frequency error: P class .....	248
4.7.10 PMU I steady state harmonic distortion frequency error: P class.....	248
4.7.11 PMU J steady state harmonic distortion frequency error: P class .....	249
4.8 Steady state harmonic distortion ROCOF error: P class.....	250
4.8.1 C37.118.1 Annex C steady harmonic distortion ROCOF error: P class .....	250
4.8.2 PMU A steady state harmonic distortion ROCOF error: P class .....	251
4.8.3 PMU B steady state harmonic distortion ROCOF error: P class .....	252
4.8.4 PMU C steady state harmonic distortion ROCOF error: P class .....	253
4.8.5 PMU D steady state harmonic distortion ROCOF error: P class .....	254
4.8.6 PMU E steady state harmonic distortion ROCOF error: P class.....	254
4.8.7 PMU F steady state harmonic distortion ROCOF error: P class.....	255
4.8.8 PMU G* steady state harmonic distortion ROCOF error: P class .....	255
4.8.9 PMU H steady state harmonic distortion ROCOF error: P class .....	256
4.8.10 PMU I steady state harmonic distortion ROCOF error: P class.....	256
4.8.11 PMU J steady state harmonic distortion ROCOF error: P class .....	257

The steady state response to harmonic distortion is tested by a series of individual steady state tests where the input signal magnitude and frequency is fixed for duration of 5 seconds and a single harmonic is added with the magnitude of the harmonic dependent on the PMU class. The maximum TVE, FE and RFE of all the test runs is compared against the limits for TVE, FE and RFE to determine if the unit passes or fails the test.

The relative phase of the harmonic is not specified by C37.118.1-2011 or by the amendment C37.118.1a-2014. However the relative phase of the harmonic affects the PMU measurement, especially ROCOF, therefore the IEEE Conformance Assessment Program (ICAP) PMU Test Suite Specification requires that the harmonic be in-phase with the fundamental signal by crossing zero in the positive-going direction at the same time the fundamental signal crosses zero in the positive-going direction. That means the second harmonic will be negative sequence, the third harmonic will be zero sequence and the fourth harmonic will be positive sequence, repeating the cycle every three harmonics.

M class limits:

- TVE: 1%
- FE:
  - for  $F_s > 20$  FPS: 0.025 Hz
  - for  $F_s \leq 20$  FPS: 0.005 Hz
- RFE: Limit suspended

P class limits:

- TVE: 1%
- FE: 0.005 Hz
- RFE: 0.4 Hz/s

Test Plan:

- a) Apply input signals at nominal magnitude with the addition of one harmonic, starting with the second harmonic, with the magnitude set to the level specified by IEEE Std C37.118.1-2011 for Class P or M PMUs:
  - 1% of nominal magnitude for P class.
  - 10% of nominal magnitude for M class.
- b) Wait for the system to settle.
- c) Capture the PMU output for 5 seconds.
- d) Calculate the errors: ME, PE, FE, RFE for each report.
- e) Calculate the Max TVE, FE and RFE.
- f) Change to injecting the next harmonic.
- g) Repeat step b) through step f) until all harmonics between 2nd harmonic and 50th harmonic have been tested.

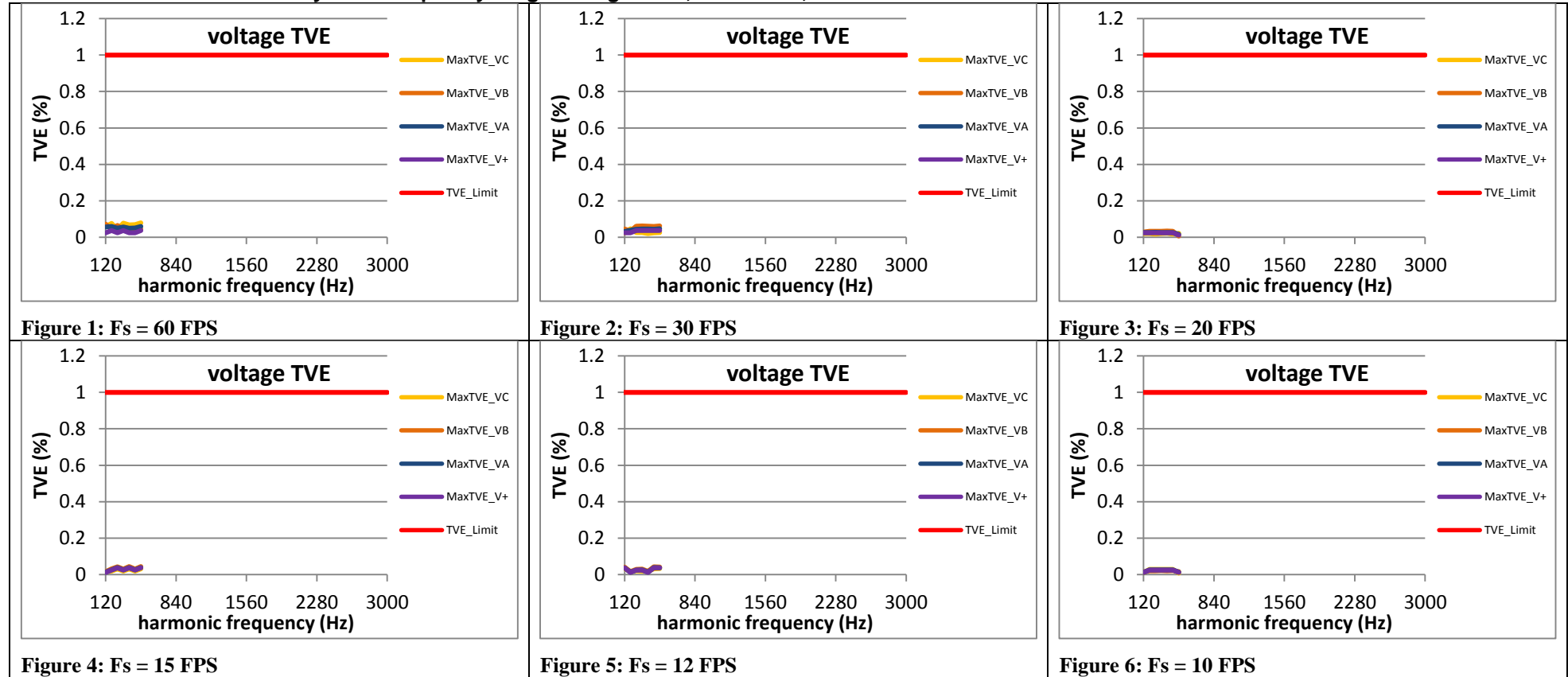
### Steady state harmonic distortion test results

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R			
	V	E	E	V	E	E	V	E	E	V	E	E	V	E	E	V	E	E	V	E	E	V	E	E	V	E	E	V	E	E	V	E	E			
C37.118.1 Annex C	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P
PMU A	P	P	-	P	P	F	P	P	-	P	P	F	P	P	-	P	P	F	P	P	-	P	P	F	P	P	-	P	P	F	P	P	-	P	P	F
PMU B	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P
PMU C	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	F	F
PMU D	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P
PMU E	P	P	-	-	-	-				-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-
PMU F	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P
PMU G	I	P	-	-	-	-	I	P	-	-	-	-	I	P	-	-	-	-	I	P	-	-	-	-	I	P	-	-	-	-	I	P	-	-	-	-
PMU H	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P
PMU I	F	P	-	-	-	-	F	I	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-
PMU J	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P	P	P	-	P	P	P

P = Pass (does not exceed the limit), F = Fails (exceeds the limit), I = Indeterminate within the test equipment uncertainty of the limit.

#### 4.1 Steady state harmonic distortion voltage TVE: F0 = 60 Hz, M Class

##### 4.1.1 C37.118.1 Annex C steady state frequency range voltage TVE:, F0 = 60 Hz, M class



The C37.118.1 Annex C model is a digital simulation with an internal sampling rate of 960 samples per second and so can only be tested with a harmonic frequency up to 420 Hz.

#### 4.1.2 PMU A steady state harmonic distortion voltage TVE: class

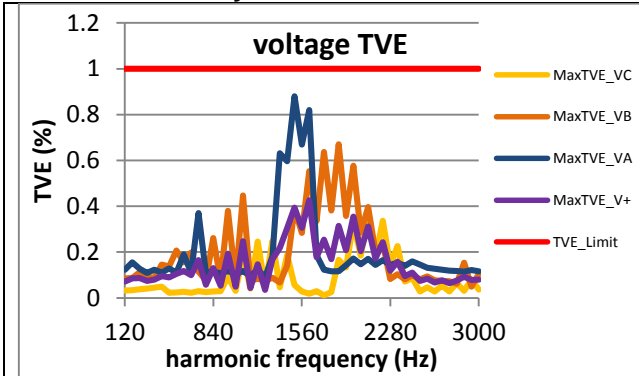


Figure 7:  $F_s = 60$  FPS

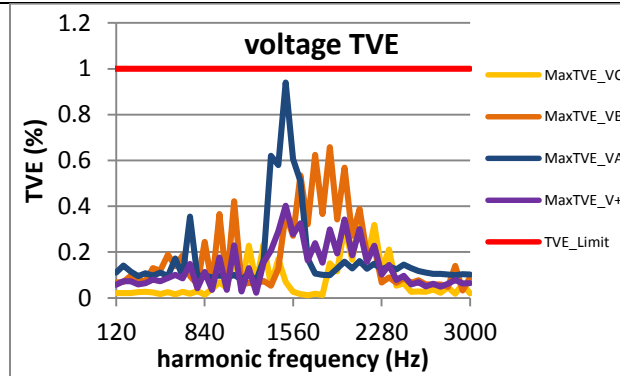


Figure 8:  $F_s = 30$  FPS

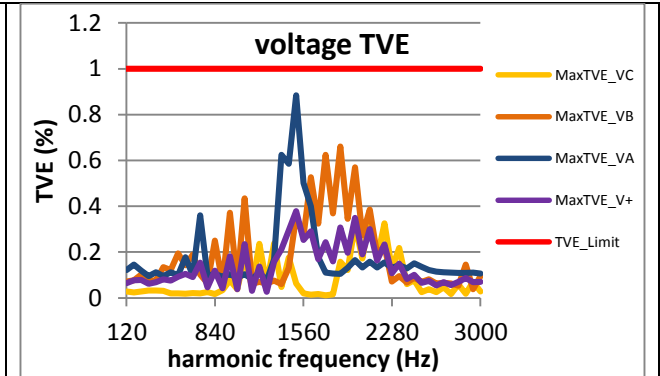


Figure 9:  $F_s = 20$  FPS

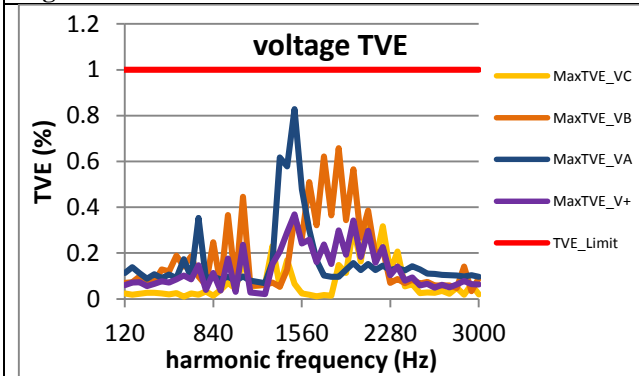


Figure 10:  $F_s = 15$  FPS

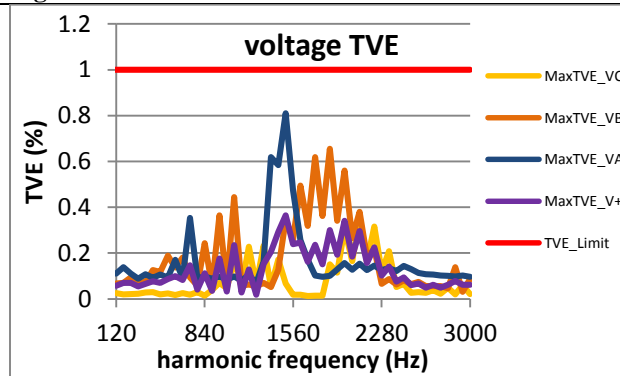


Figure 11:  $F_s = 12$  FPS

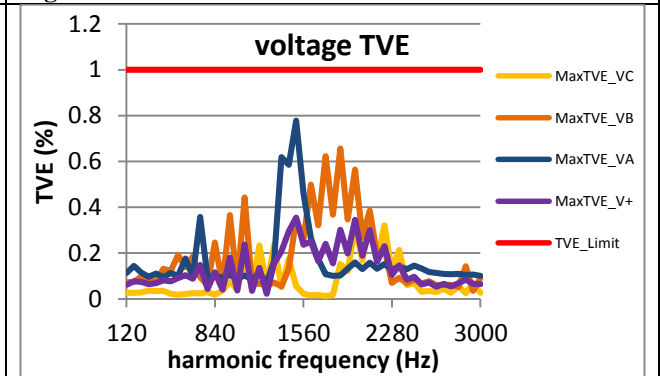


Figure 12:  $F_s = 10$  FPS



#### 4.1.3 PMU B steady state harmonic distortion voltage TVE: M class

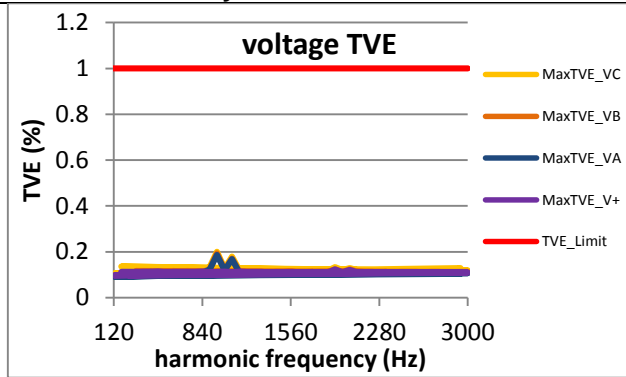


Figure 13:  $F_s = 60$  FPS

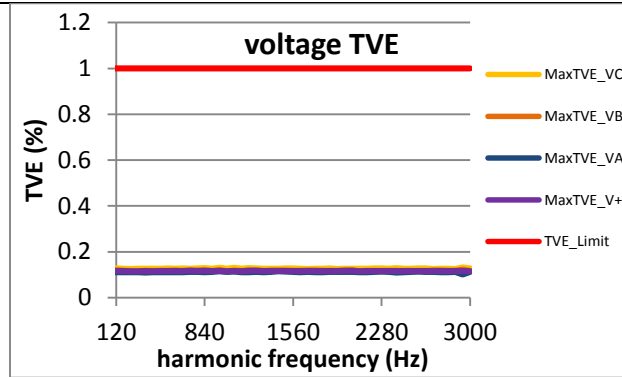


Figure 14:  $F_s = 30$  FPS

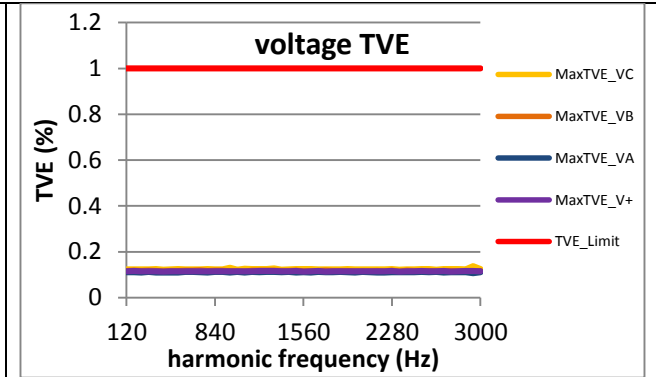


Figure 15:  $F_s = 20$  FPS

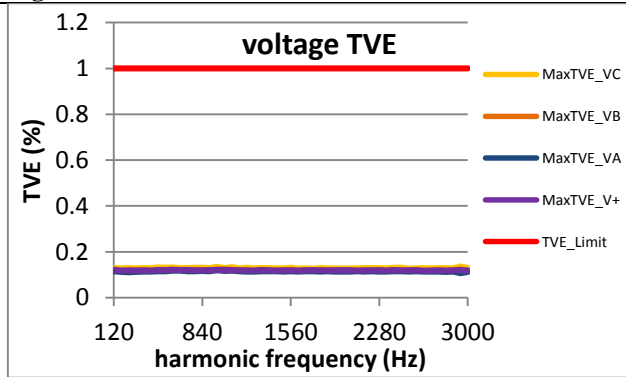


Figure 16:  $F_s = 15$  FPS

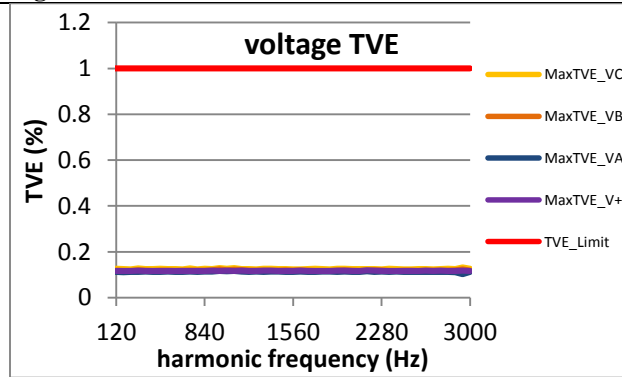


Figure 17:  $F_s = 12$  FPS

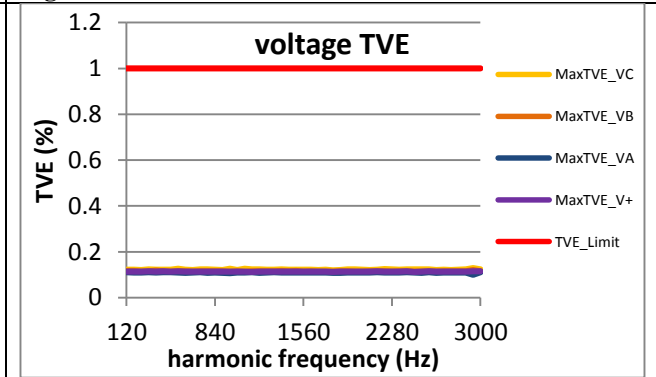


Figure 18:  $F_s = 10$  FPS

#### 4.1.4 PMU C steady state harmonic distortion voltage TVE: M class

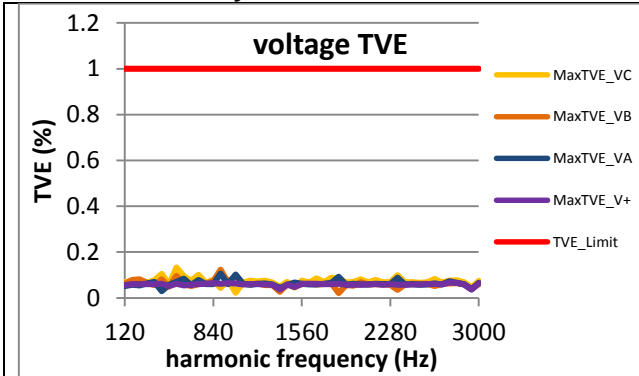


Figure 19: Fs = 60 FPS

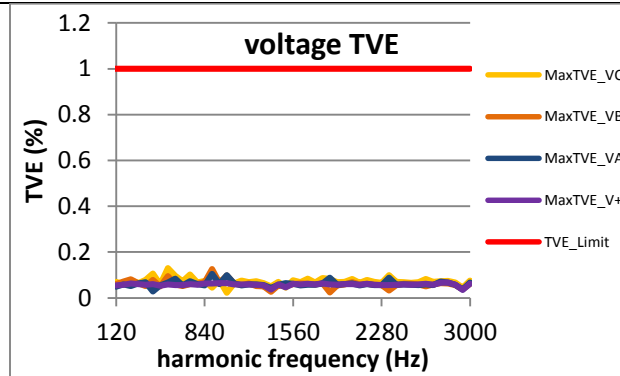


Figure 20: Fs = 30 FPS

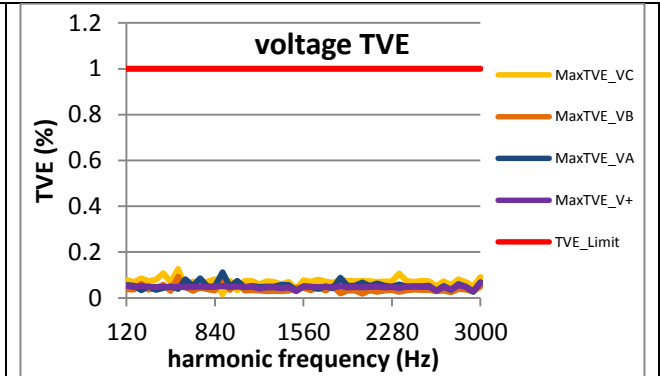


Figure 21: Fs = 20 FPS

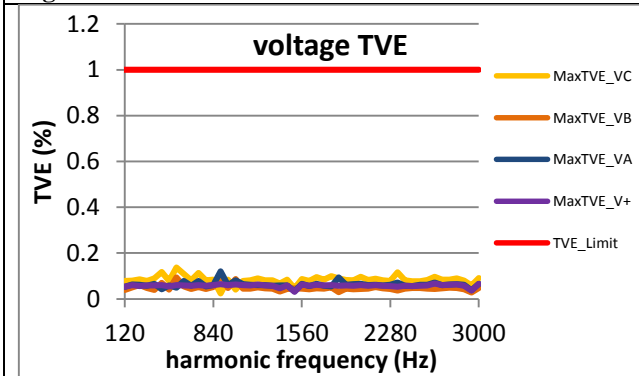


Figure 22: Fs = 15 FPS

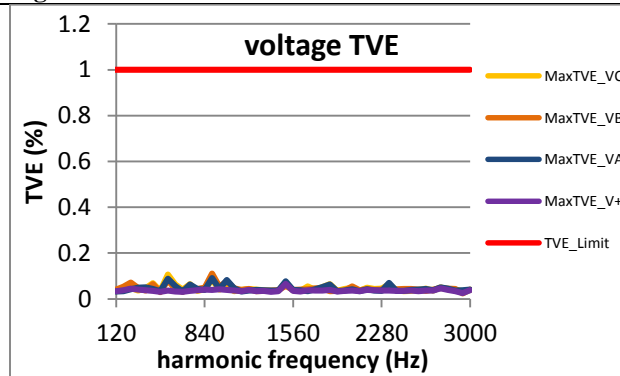


Figure 23: Fs = 12 FPS

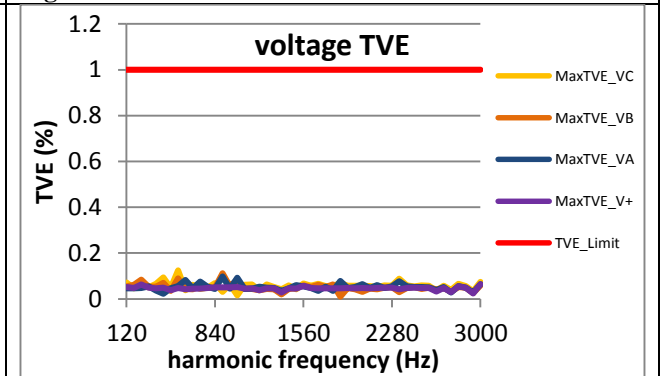


Figure 24: Fs = 10 FPS

#### 4.1.5 PMU D steady state harmonic distortion voltage TVE: M class

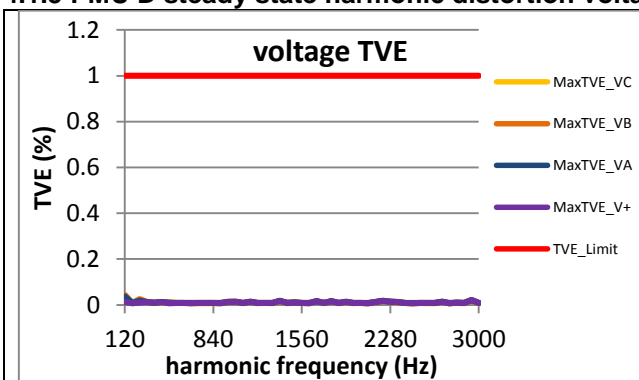


Figure 25:  $F_s = 60$  FPS

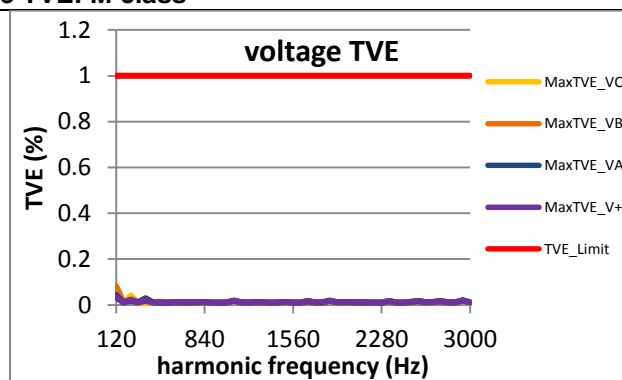


Figure 26:  $F_s = 30$  FPS

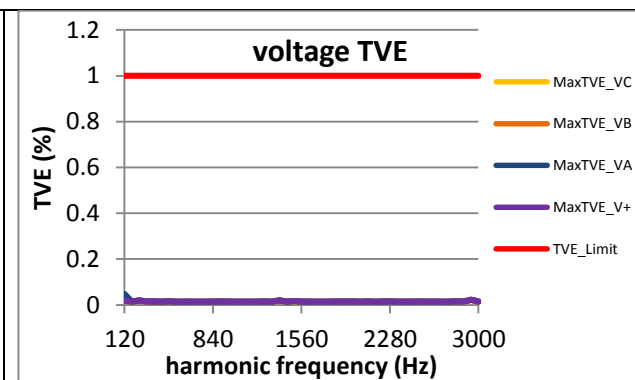


Figure 27:  $F_s = 20$  FPS

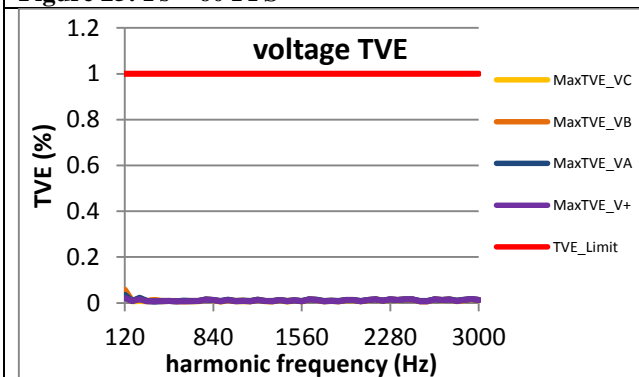


Figure 28:  $F_s = 15$  FPS

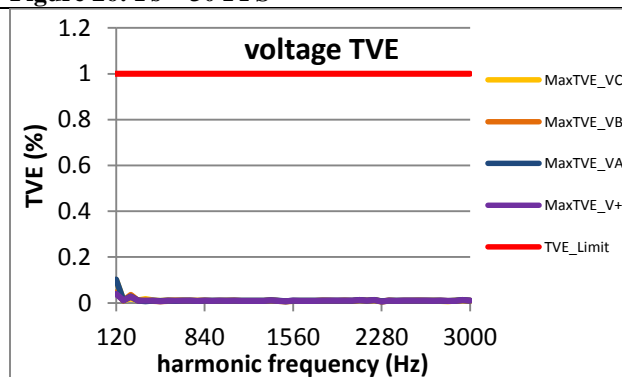


Figure 29:  $F_s = 12$  FPS

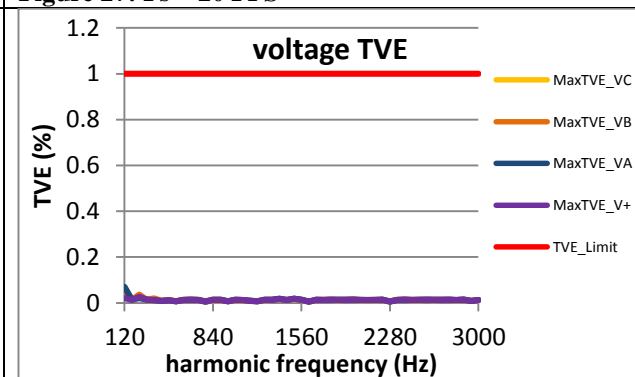


Figure 30:  $F_s = 10$  FPS

#### 4.1.6 PMU E steady state harmonic distortion voltage TVE: M class

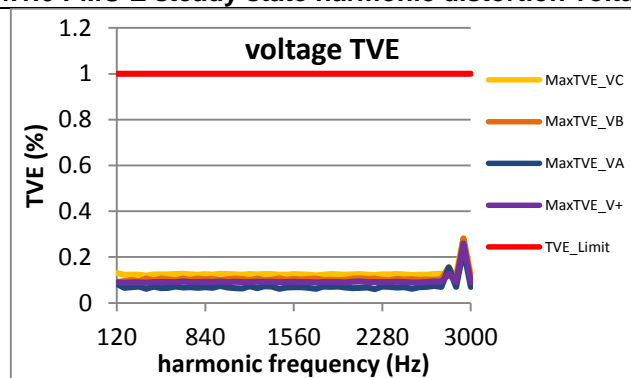


Figure 31: Fs = 60 FPS

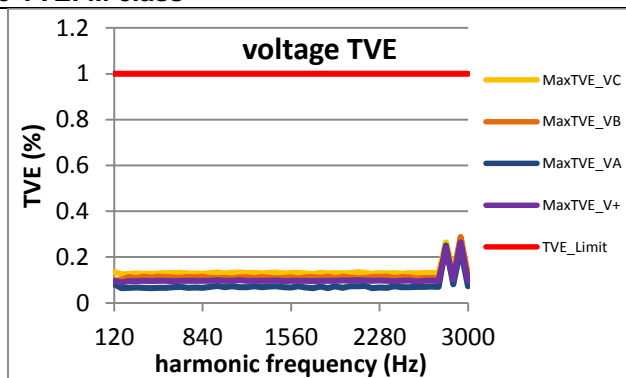


Figure 32: Fs = 30 FPS

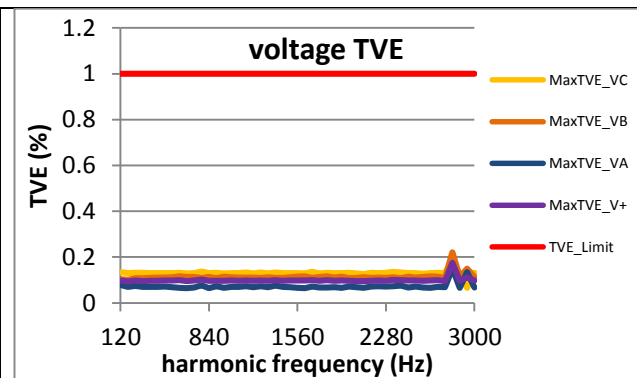


Figure 33: Fs = 20 FPS

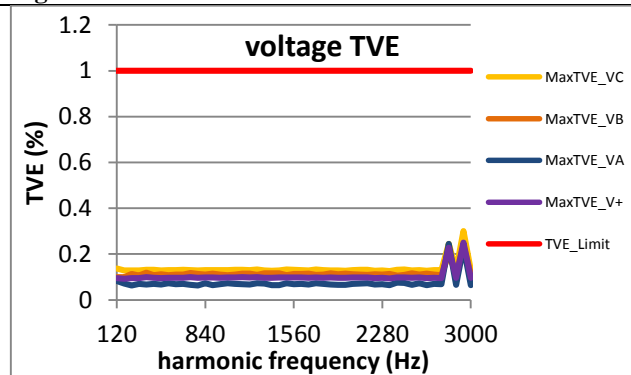


Figure 34: Fs = 15 FPS

Data was lost  
Figure 35: Fs = 12 FPS

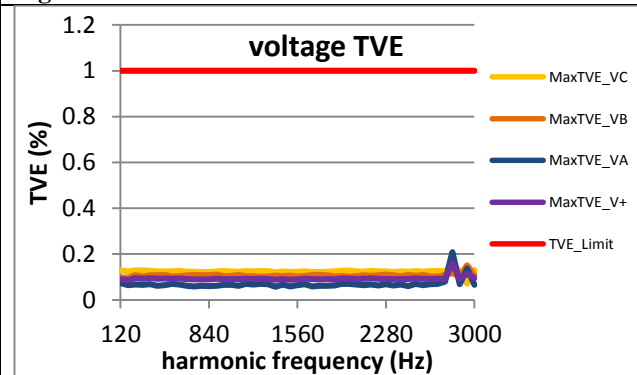


Figure 36: Fs = 10 FPS

#### 4.1.7 PMU F steady state harmonic distortion voltage TVE: M class

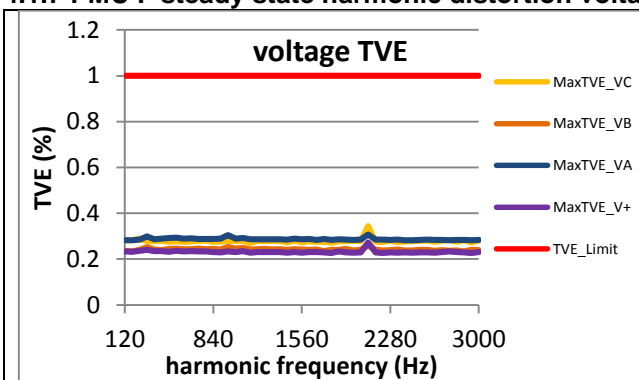


Figure 37:  $F_s = 60$  FPS

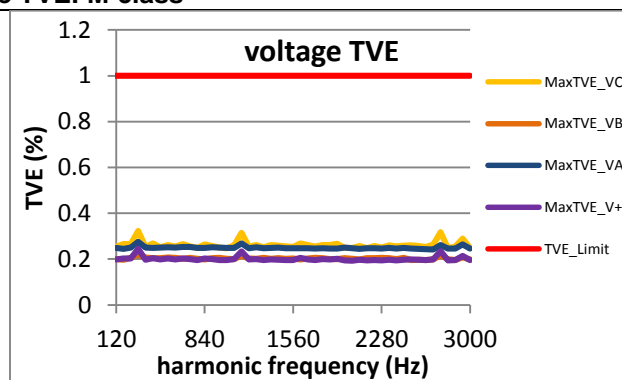


Figure 38:  $F_s = 30$  FPS

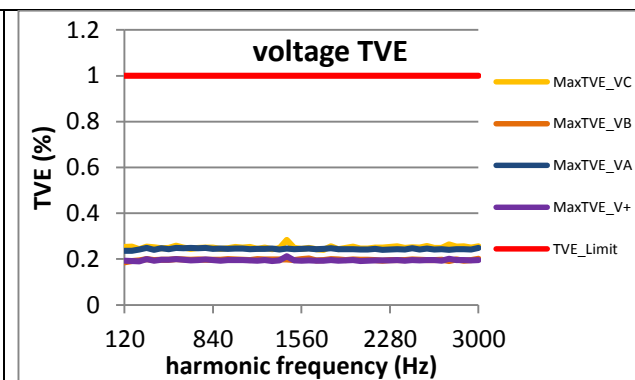


Figure 39:  $F_s = 20$  FPS

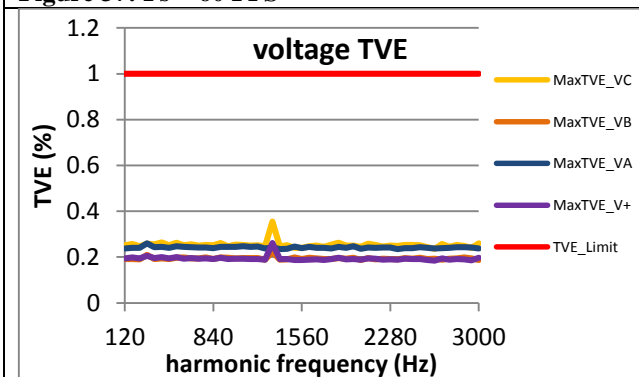


Figure 40:  $F_s = 15$  FPS

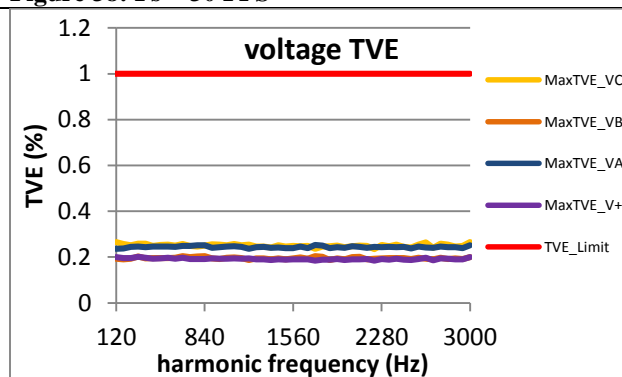


Figure 41:  $F_s = 12$  FPS

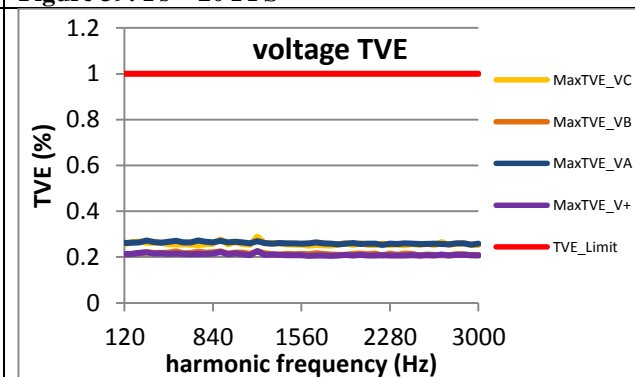


Figure 42:  $F_s = 10$  FPS

#### 4.1.8 PMU G steady state harmonic distortion voltage TVE: M class

Figure 43:  $F_s = 60$  FPS is not supported by this PMU

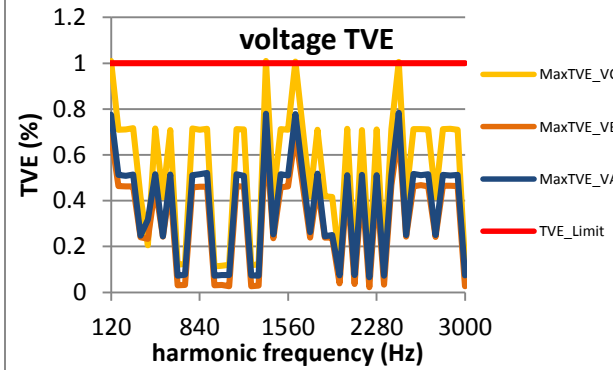


Figure 44:  $F_s = 30$  FPS

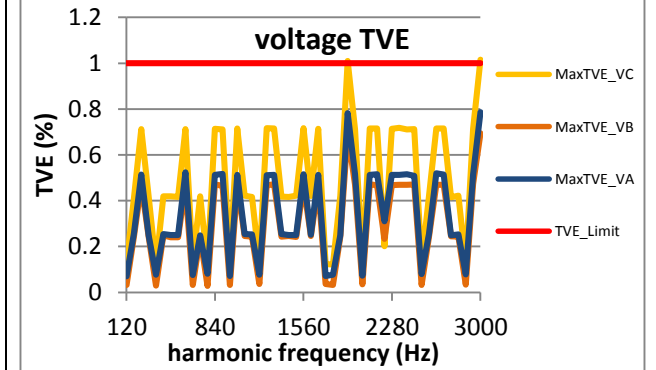


Figure 45:  $F_s = 20$  FPS

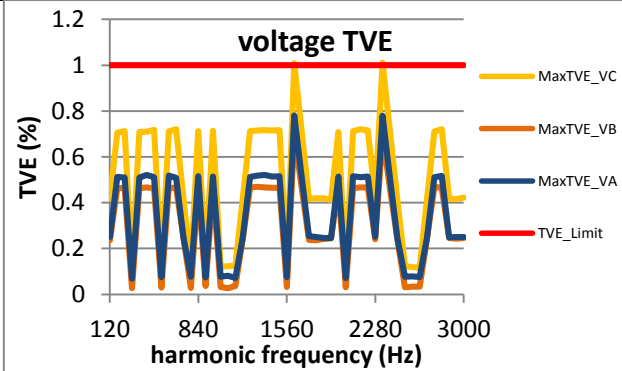


Figure 46:  $F_s = 15$  FPS

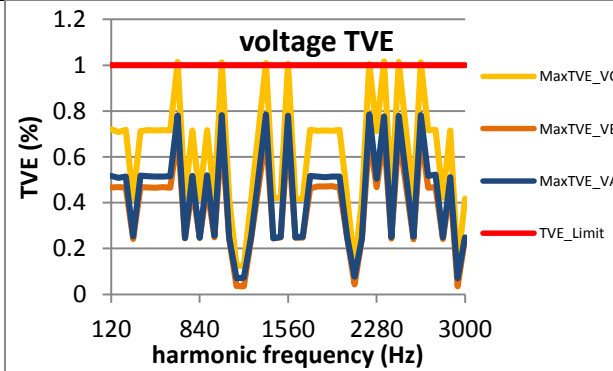


Figure 47:  $F_s = 12$  FPS

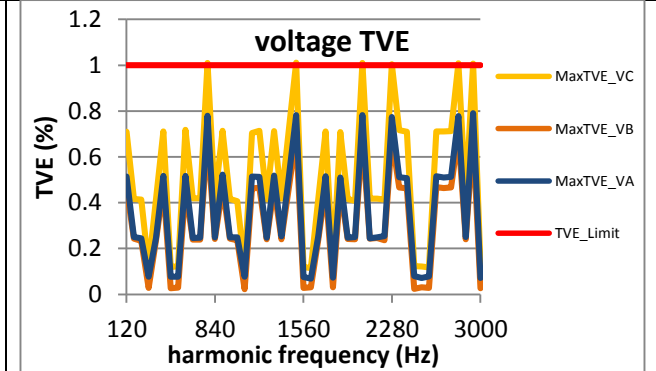


Figure 48:  $F_s = 10$  FPS

#### 4.1.9 PMU H steady state harmonic distortion voltage TVE: M class

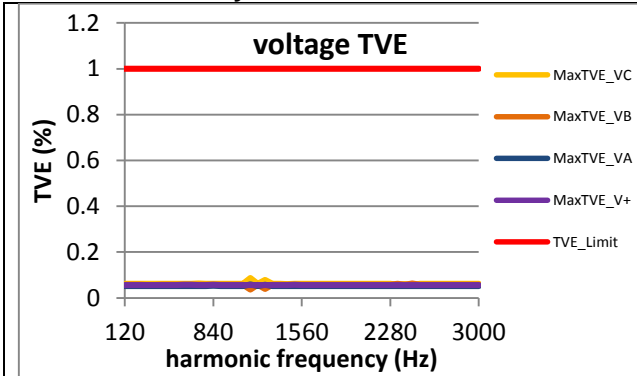


Figure 49:  $F_s = 60$  FPS

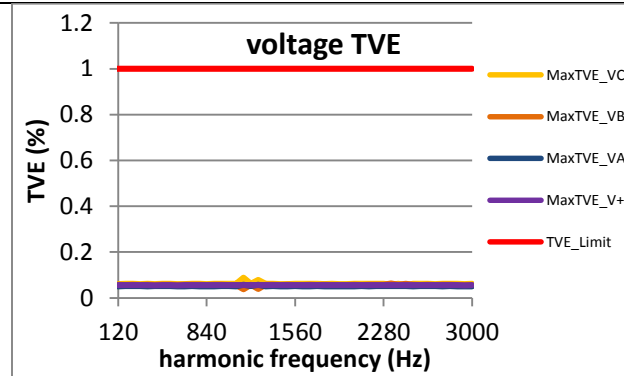


Figure 50:  $F_s = 30$  FPS

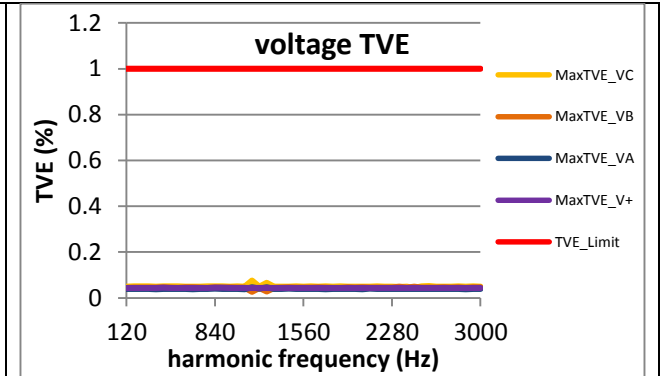


Figure 51:  $F_s = 20$  FPS

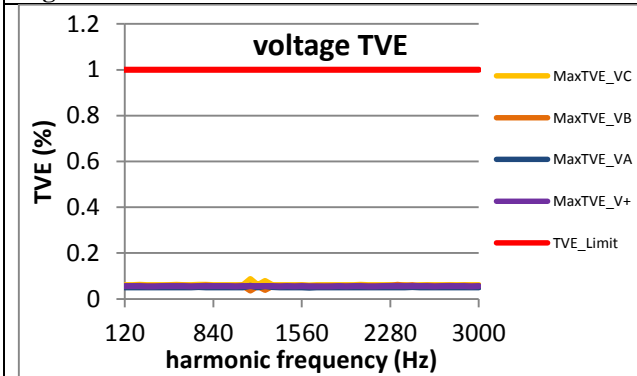


Figure 52:  $F_s = 15$  FPS

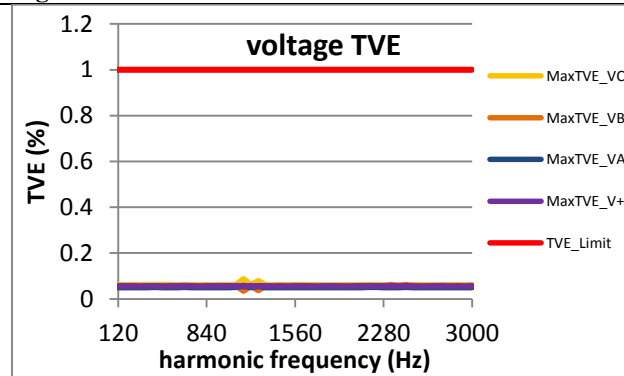


Figure 53:  $F_s = 12$  FPS

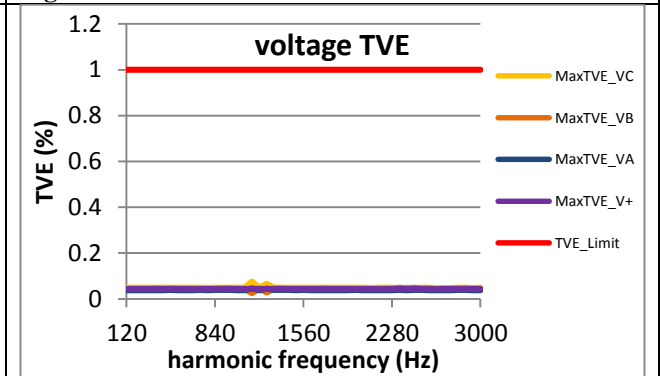


Figure 54:  $F_s = 10$  FPS

#### 4.1.10 PMU I steady state harmonic distortion voltage TVE: M class

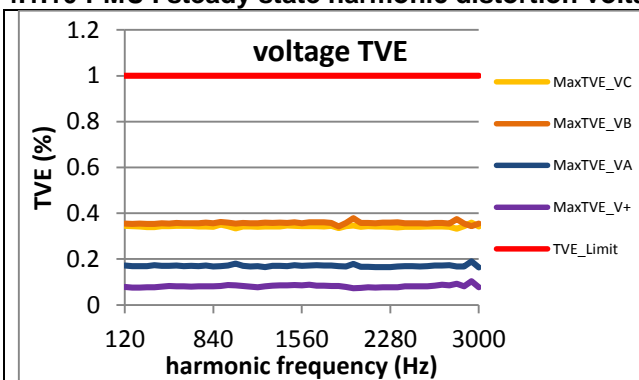


Figure 55:  $F_s = 60$  FPS

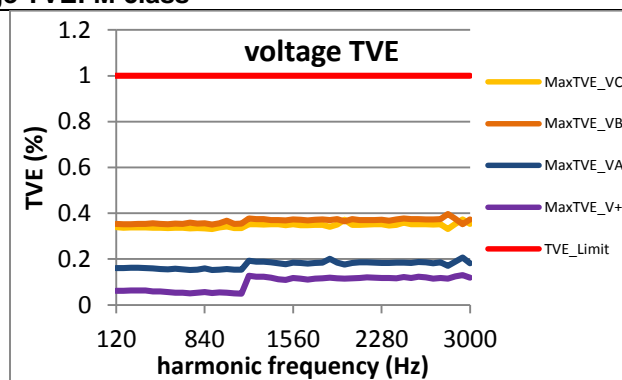


Figure 56:  $F_s = 30$  FPS

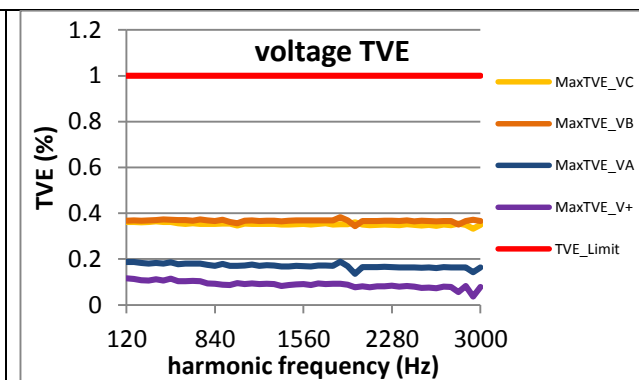


Figure 57:  $F_s = 20$  FPS

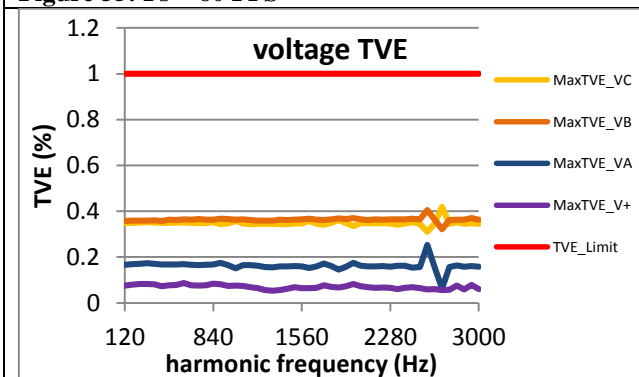


Figure 58:  $F_s = 15$  FPS

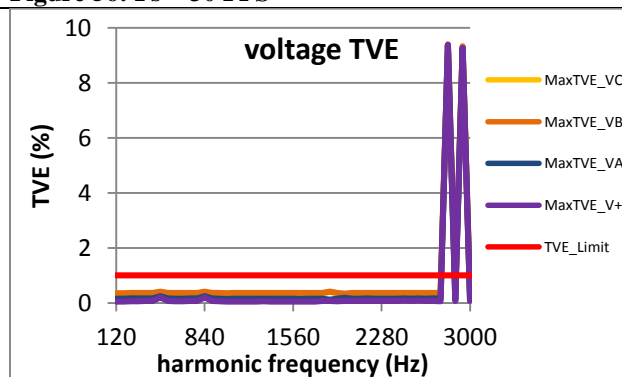


Figure 59:  $F_s = 12$  FPS

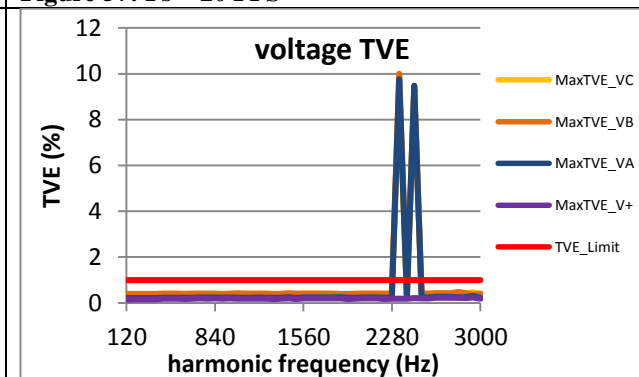


Figure 60:  $F_s = 10$  FPS



#### 4.1.11 PMU J steady state harmonic distortion voltage TVE: M class

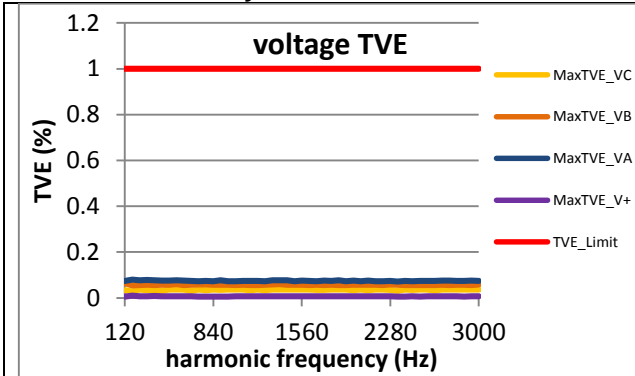


Figure 61:  $F_s = 60$  FPS

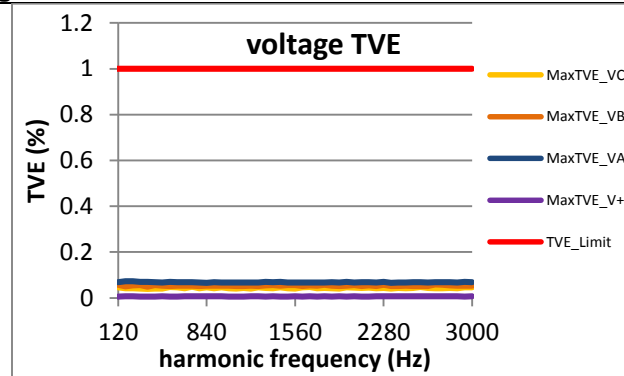


Figure 62:  $F_s = 30$  FPS

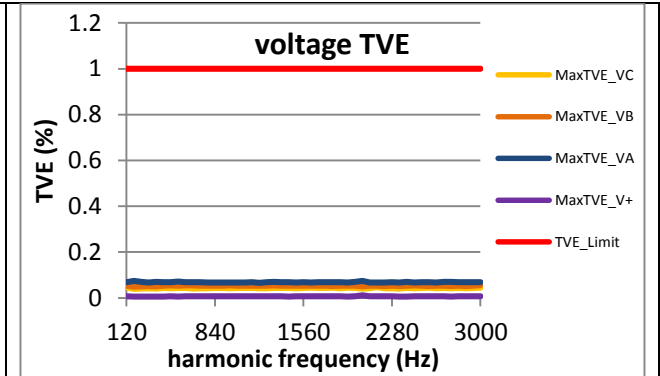


Figure 63:  $F_s = 20$  FPS

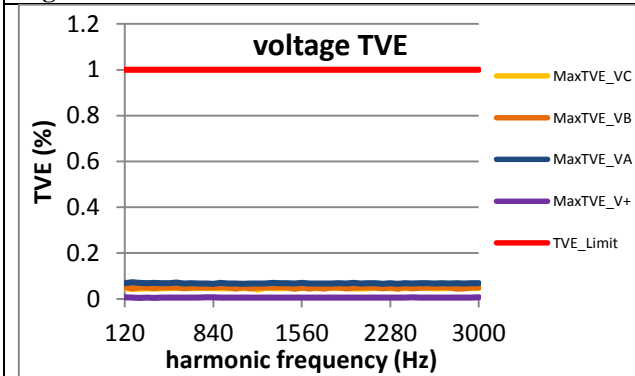


Figure 64:  $F_s = 15$  FPS

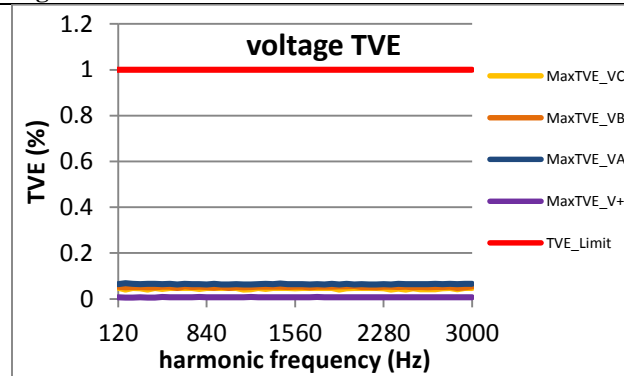


Figure 65:  $F_s = 12$  FPS

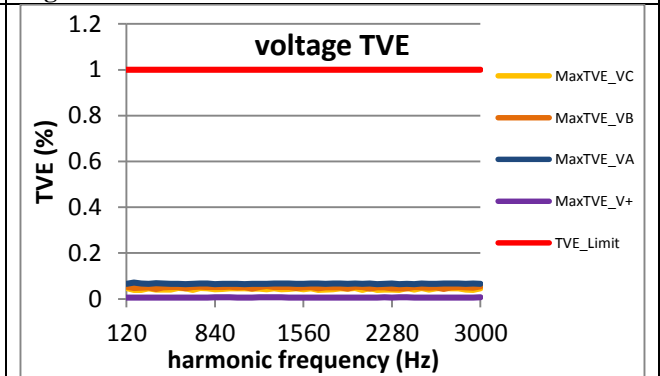
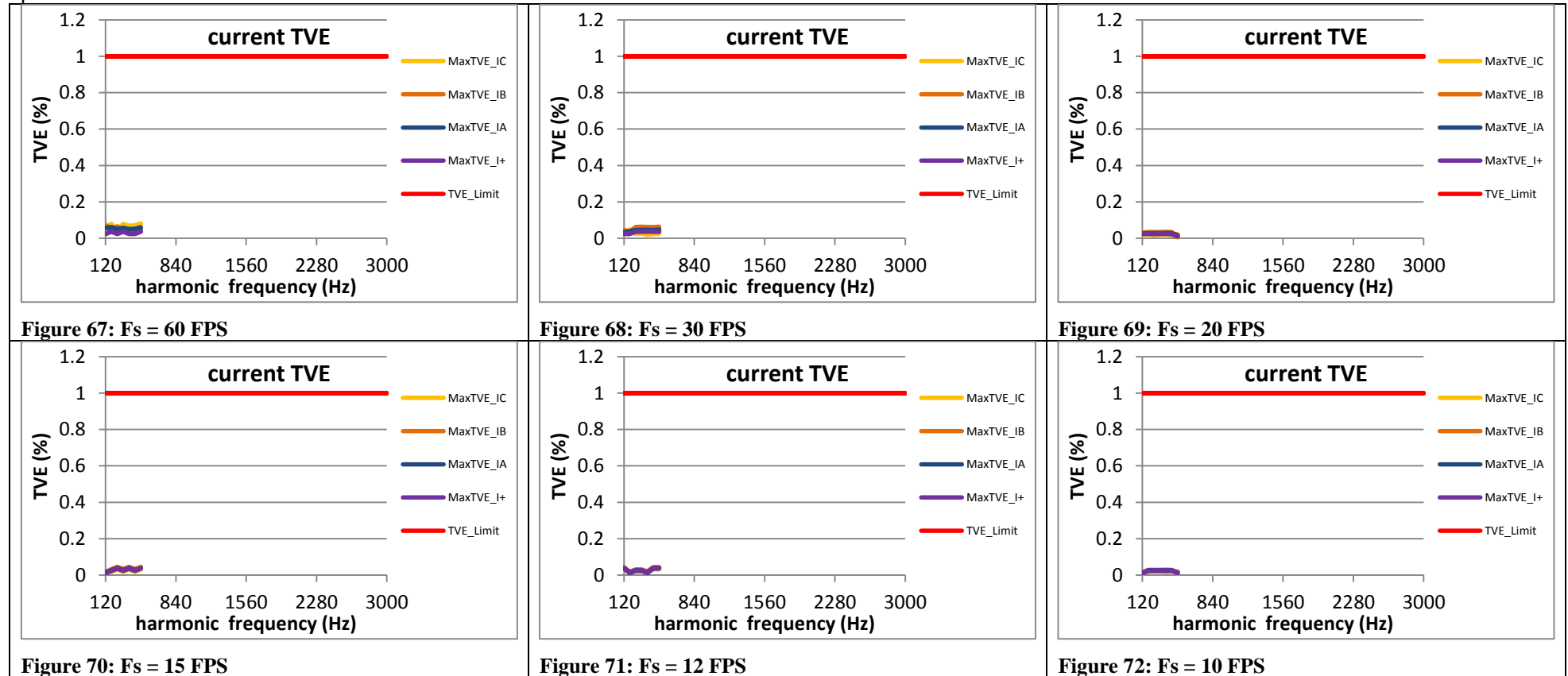


Figure 66:  $F_s = 10$  FPS

## 4.2 Steady state harmonic distortion current TVE: M class

### 4.2.1 C37.118.1 Annex C steady state harmonic distortion current TVE: M class

The C37.118.1 Annex C model is a digital simulation with an internal sampling rate of 960 samples per second and so can only be tested with a harmonic frequency up to 420 Hz.



#### 4.2.2 PMU A steady state harmonic distortion current TVE: M class

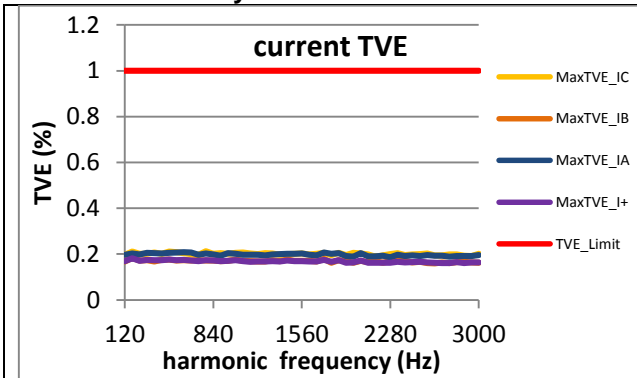


Figure 73:  $F_s = 60$  FPS

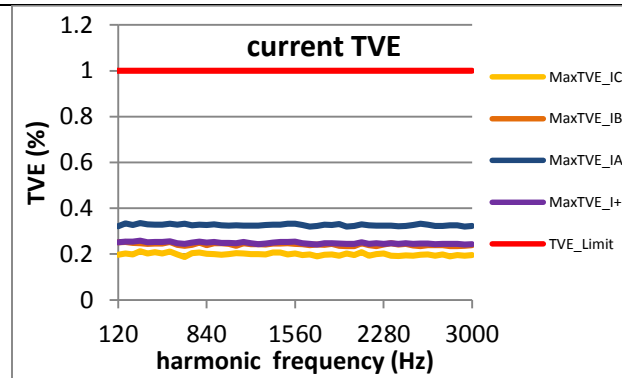


Figure 74:  $F_s = 30$  FPS

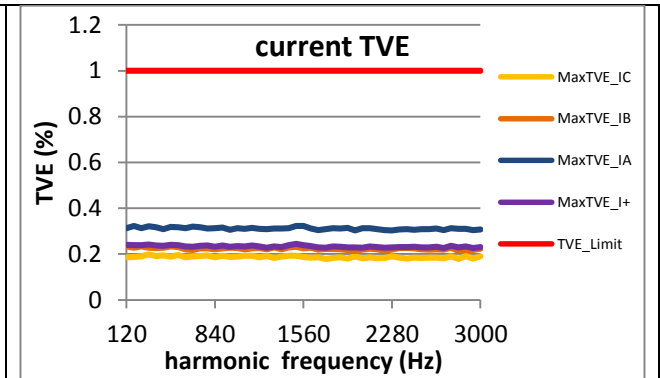


Figure 75:  $F_s = 20$  FPS

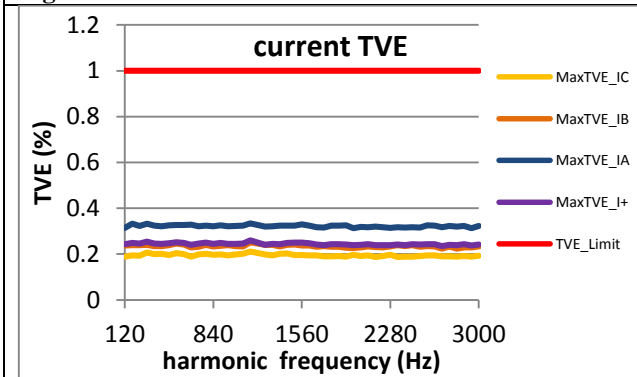


Figure 76:  $F_s = 15$  FPS

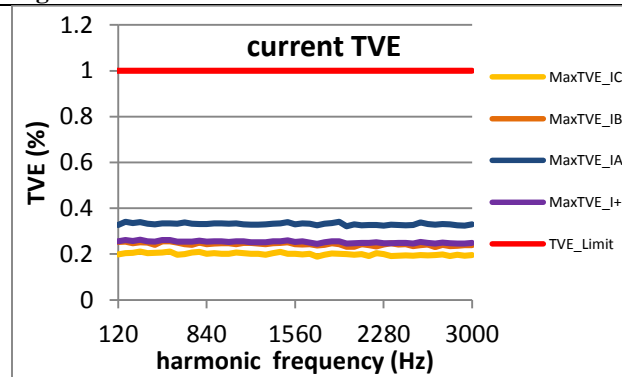


Figure 77:  $F_s = 12$  FPS

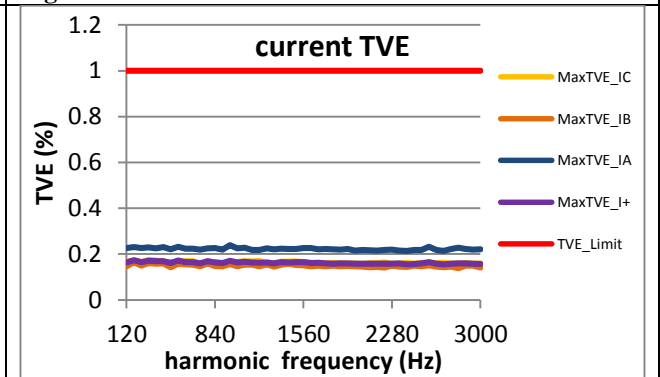
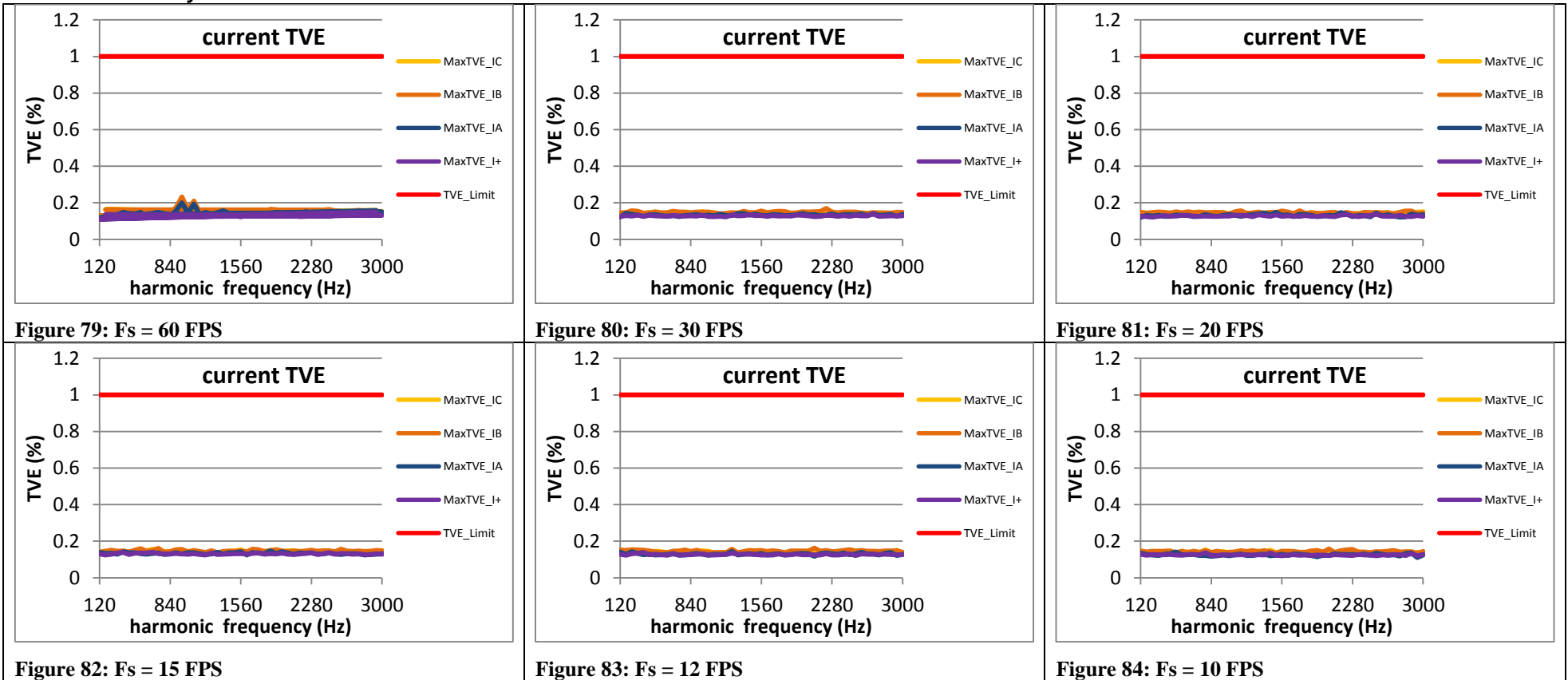
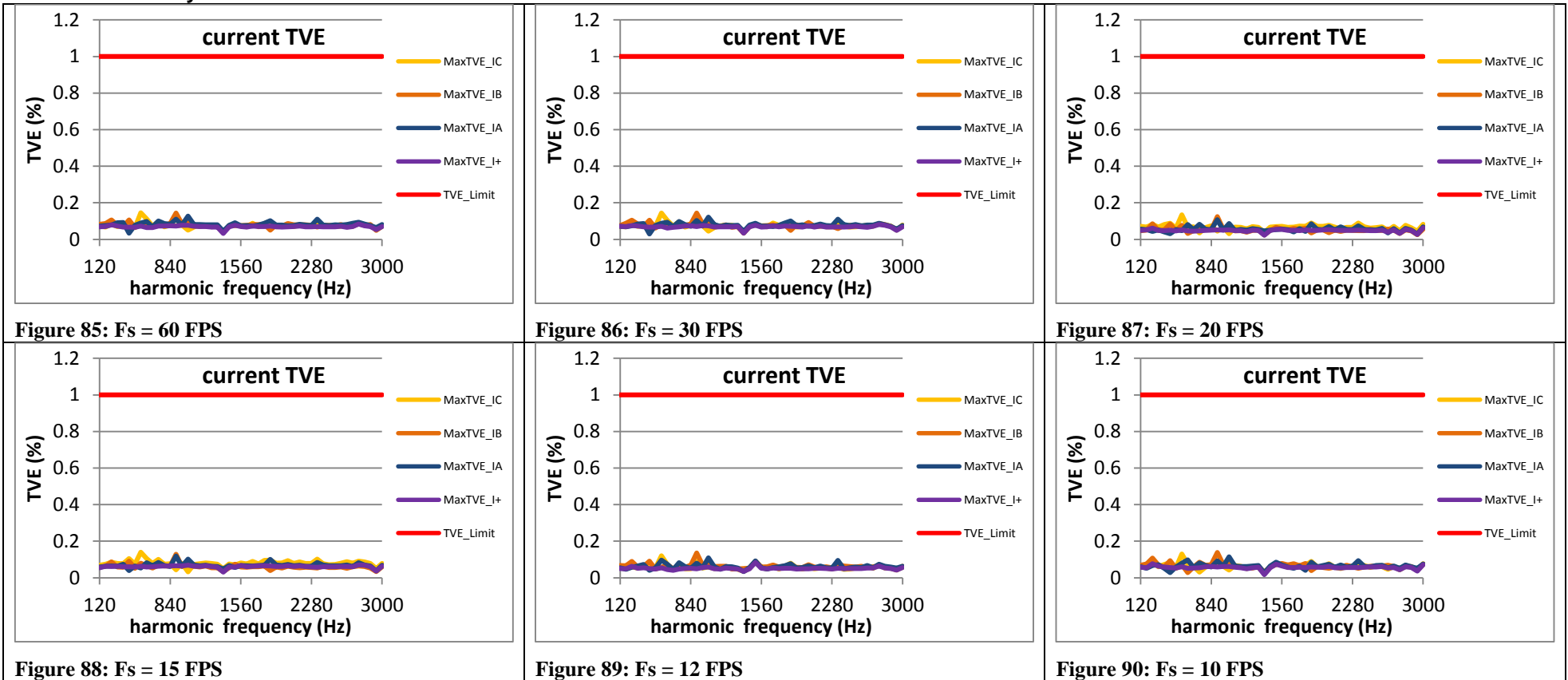


Figure 78:  $F_s = 10$  FPS

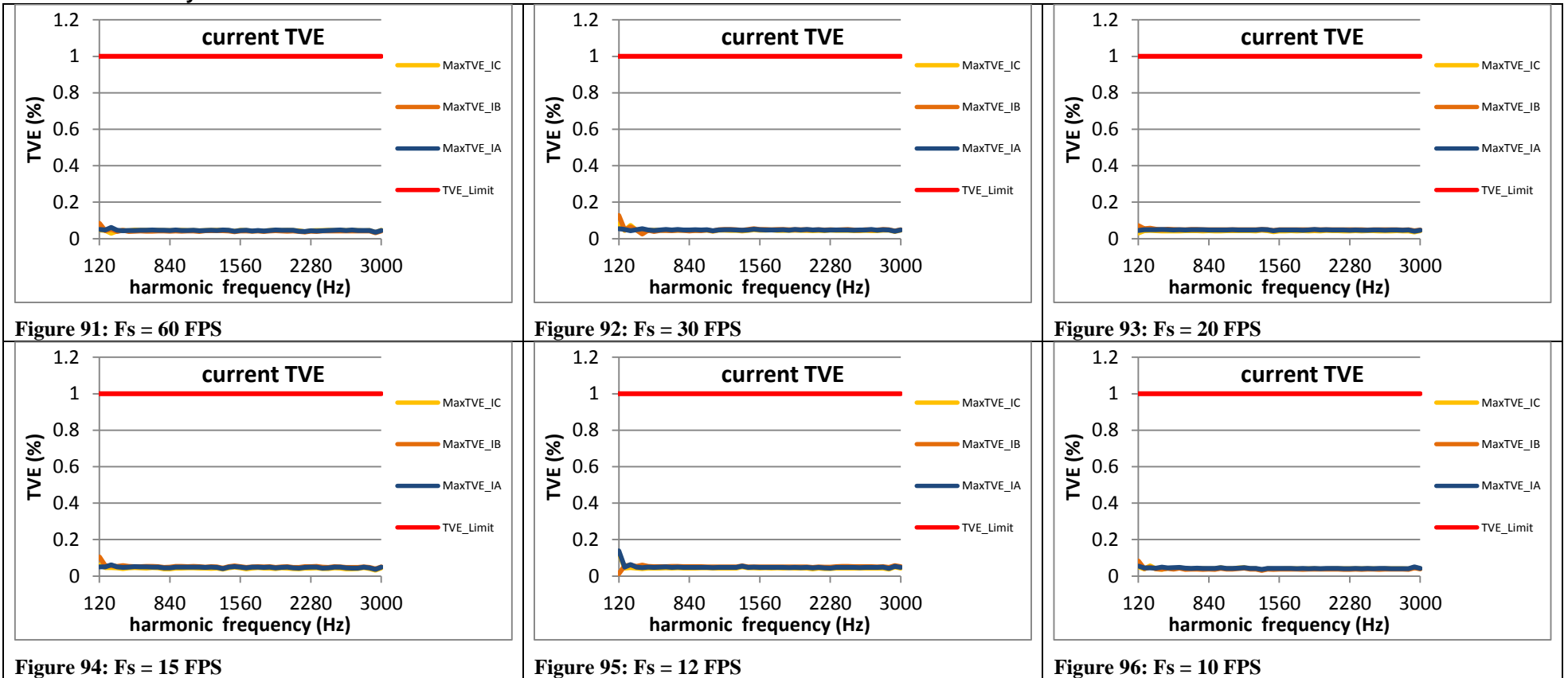
#### 4.2.3 PMU B steady state harmonic distortion current TVE: M class



#### 4.2.4 PMU C steady state harmonic distortion current TVE: M class



#### 4.2.5 PMU D steady state harmonic distortion current TVE: M class



#### 4.2.6 PMU E steady state harmonic distortion current TVE: M class

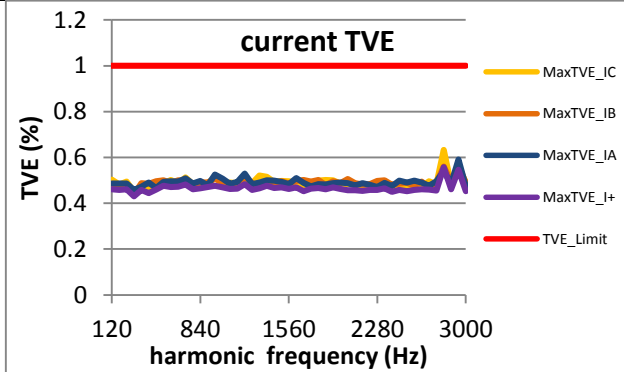


Figure 97: Fs = 60 FPS

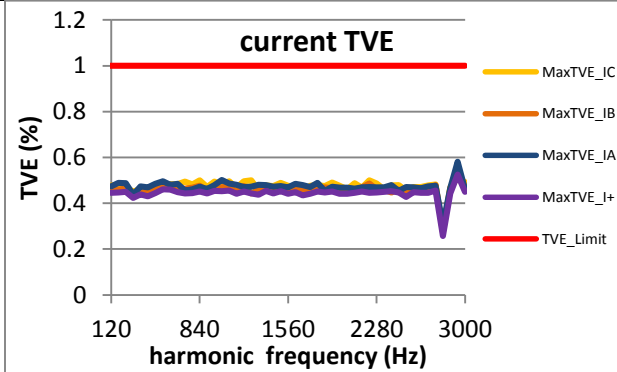


Figure 98: Fs = 30 FPS

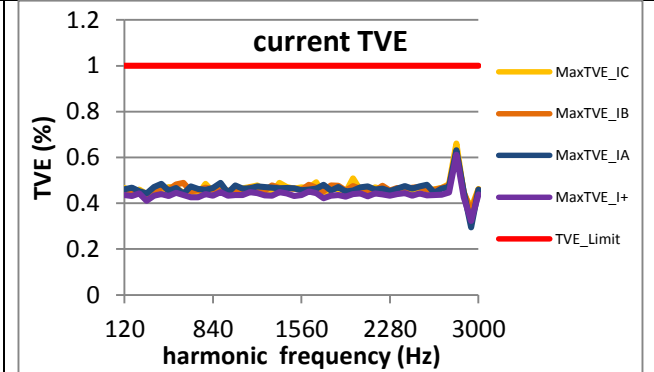


Figure 99: Fs = 20 FPS

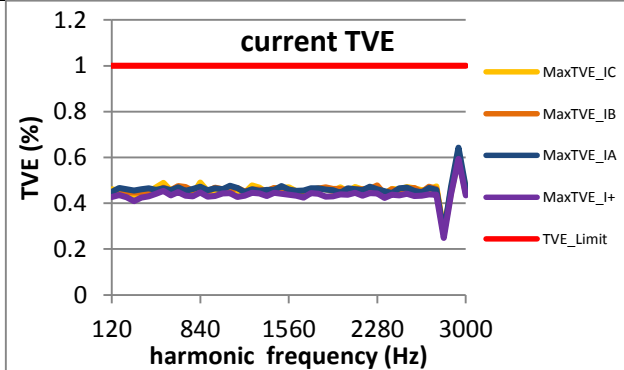


Figure 100: Fs = 15 FPS

data was lost  
Figure 101: Fs = 12 FPS

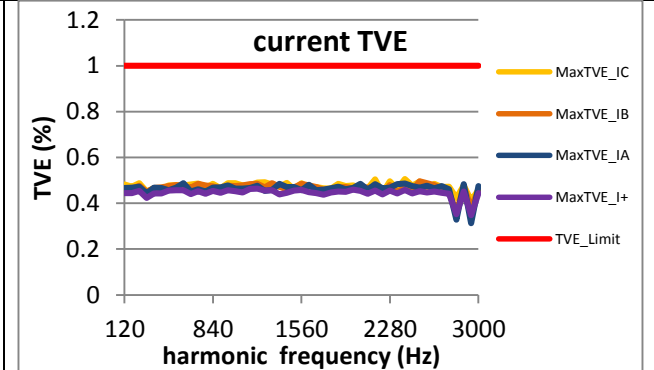


Figure 102: Fs = 10 FPS

#### 4.2.7 PMU F steady state harmonic distortion current TVE: M class

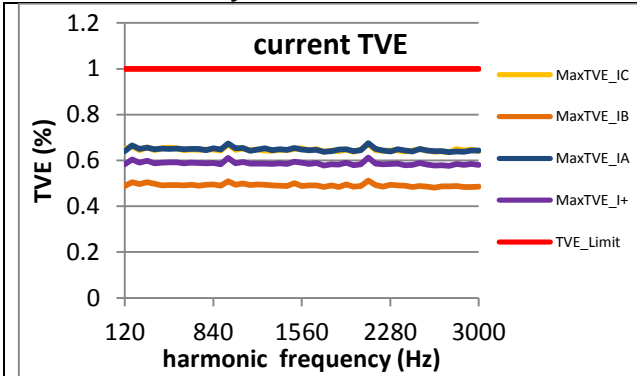


Figure 103:  $F_s = 60$  FPS

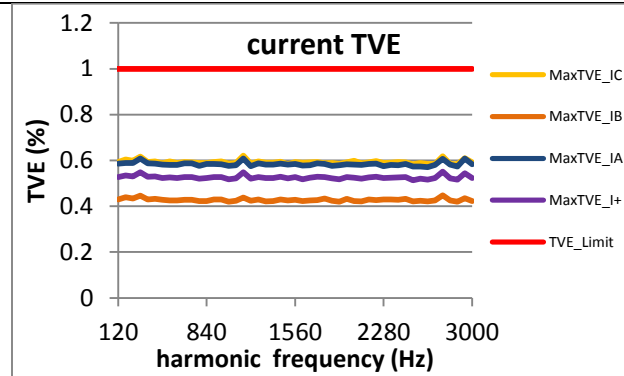


Figure 104:  $F_s = 30$  FPS

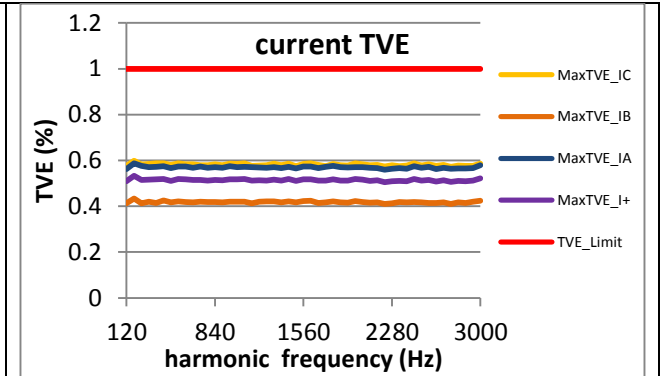


Figure 105:  $F_s = 20$  FPS

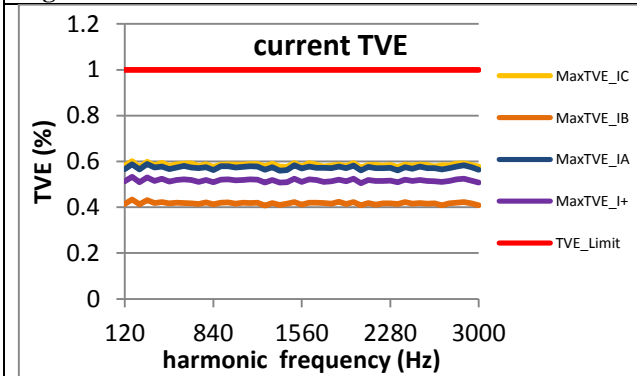


Figure 106:  $F_s = 15$  FPS

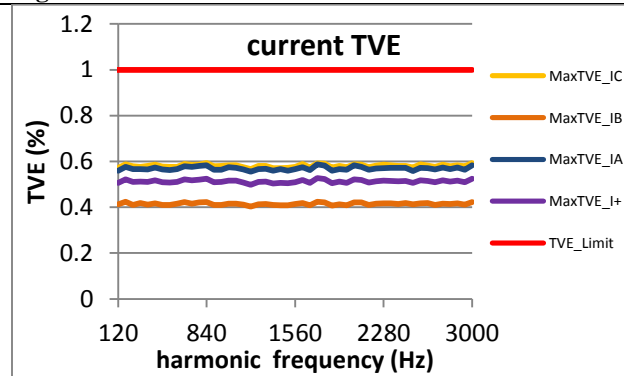


Figure 107:  $F_s = 12$  FPS

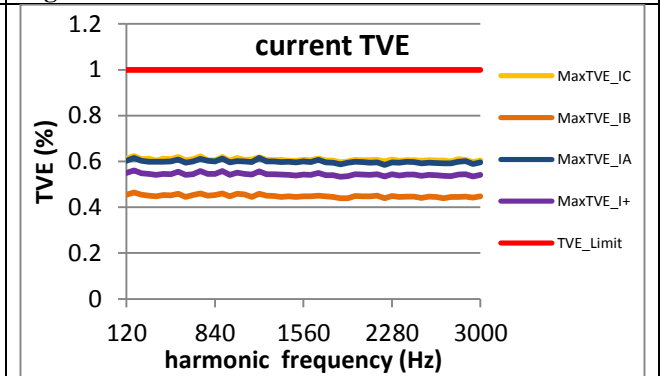


Figure 108:  $F_s = 10$  FPS



#### 4.2.8 PMU G steady state harmonic distortion current TVE: M class

Figure 109:  $F_s = 60$  FPS is not supported by this PMU

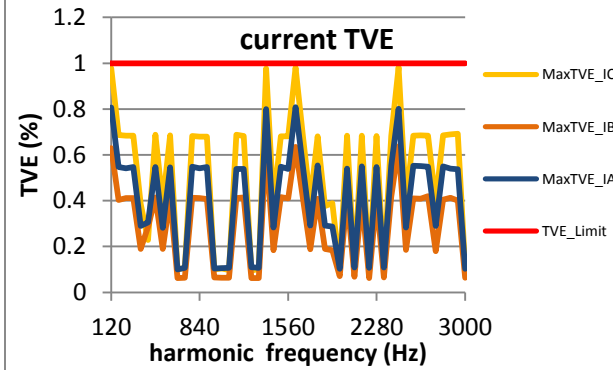


Figure 110:  $F_s = 30$  FPS

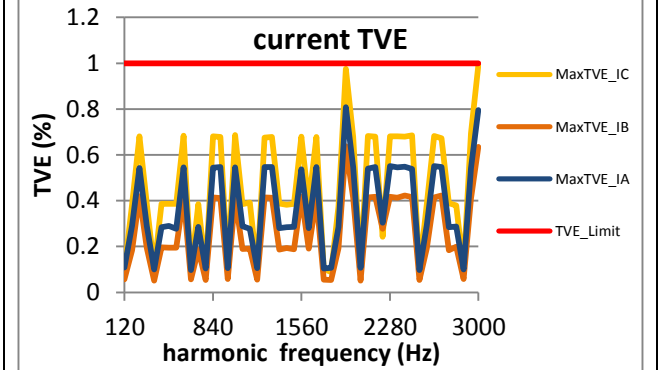


Figure 111:  $F_s = 20$  FPS

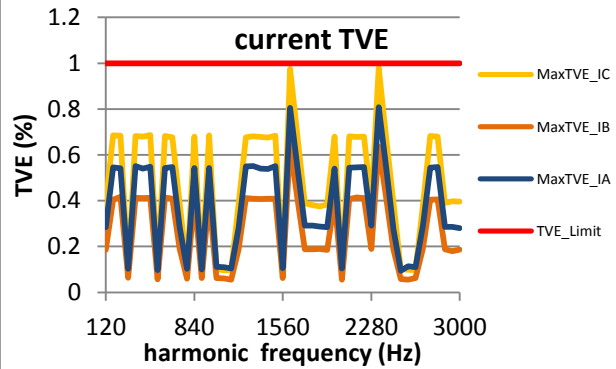


Figure 112:  $F_s = 15$  FPS

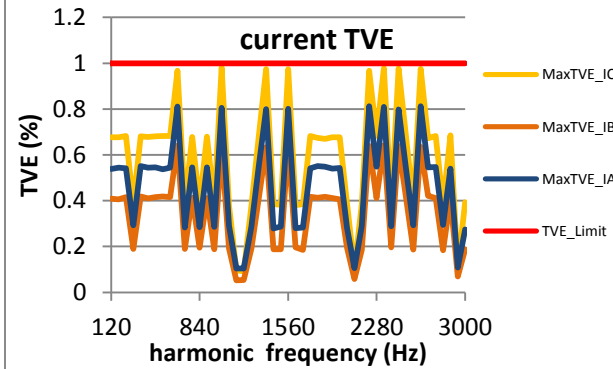


Figure 113:  $F_s = 12$  FPS

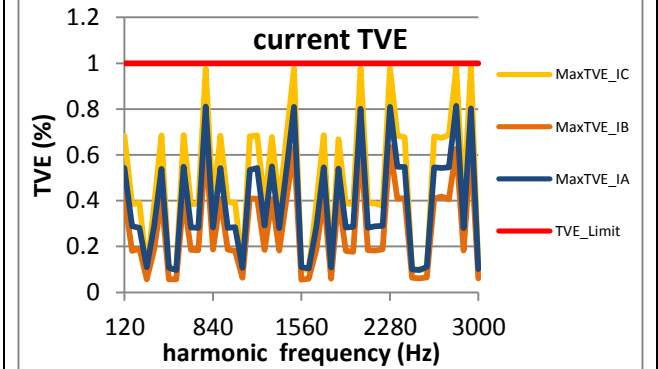


Figure 114:  $F_s = 10$  FPS

#### 4.2.9 PMU H steady state harmonic distortion current TVE: M class

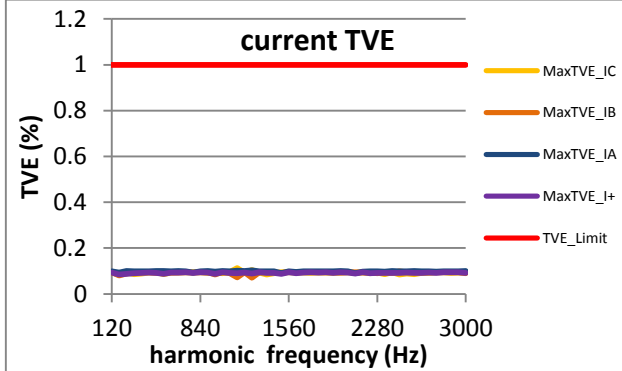


Figure 115:  $F_s = 60$  FPS

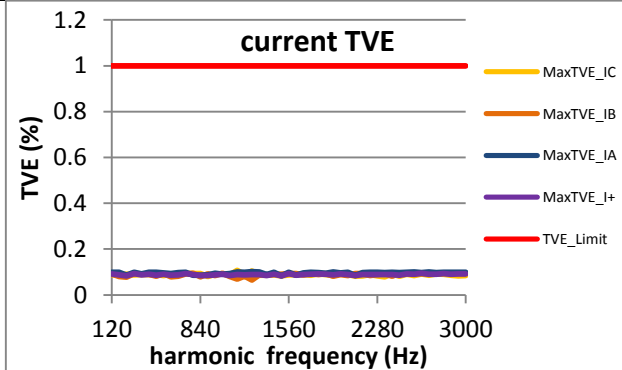


Figure 118:  $F_s = 15$  FPS

data was lost

Figure 116:  $F_s = 30$  FPS

data was lost

Figure 117:  $F_s = 20$  FPS

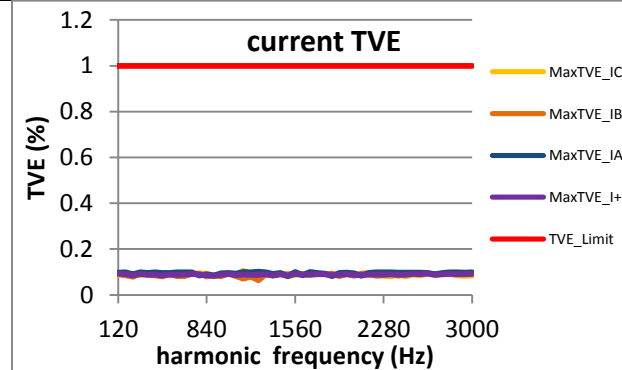


Figure 119:  $F_s = 12$  FPS

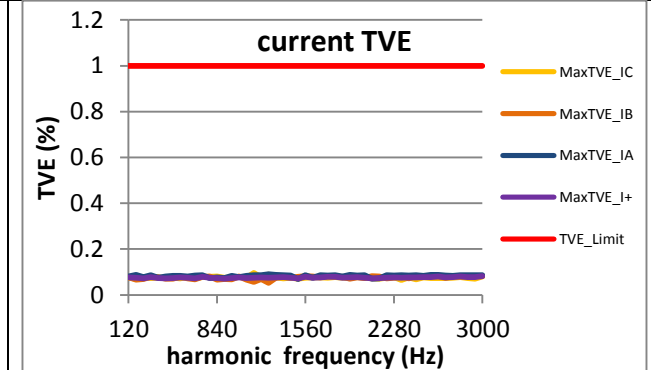
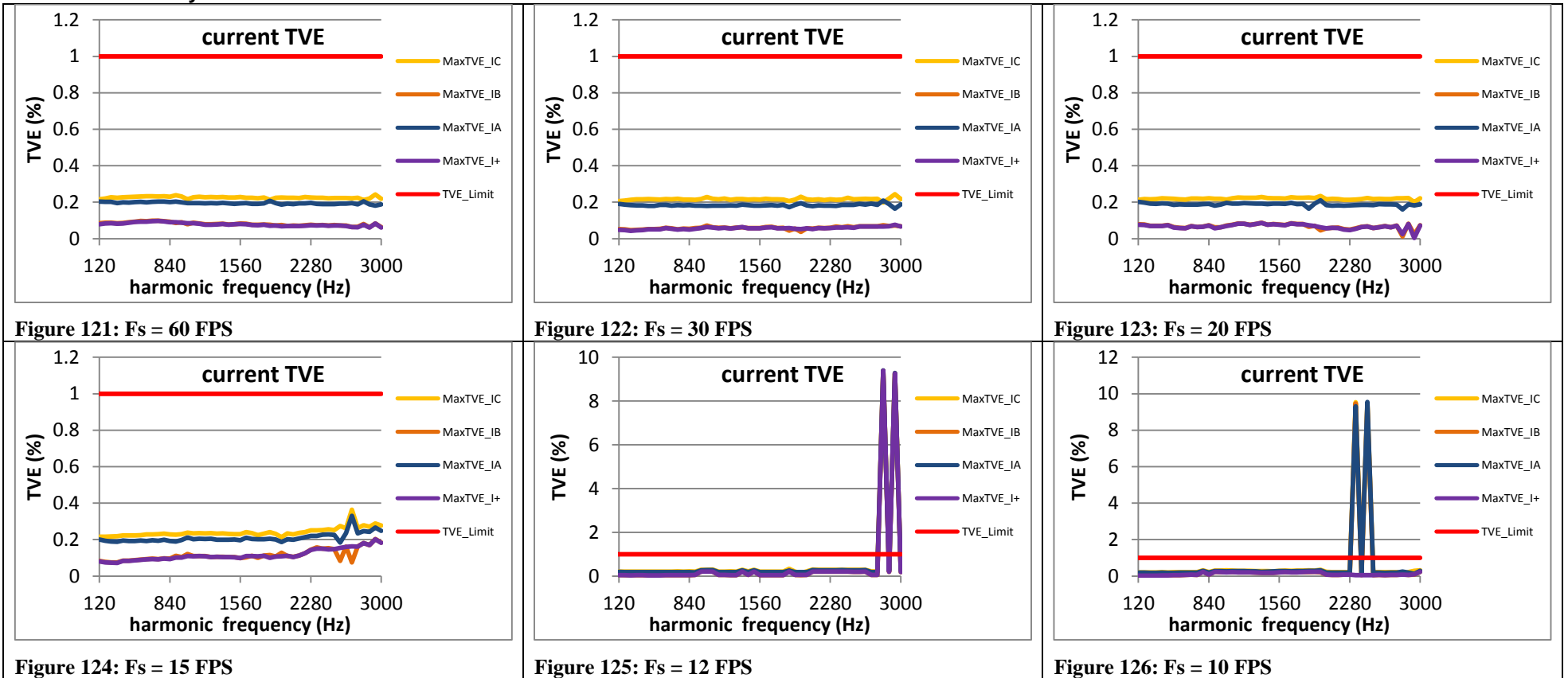


Figure 120:  $F_s = 10$  FPS

#### 4.2.10 PMU I steady state harmonic distortion current TVE: M class



#### 4.2.11 PMU J steady state harmonic distortion current TVE: M class

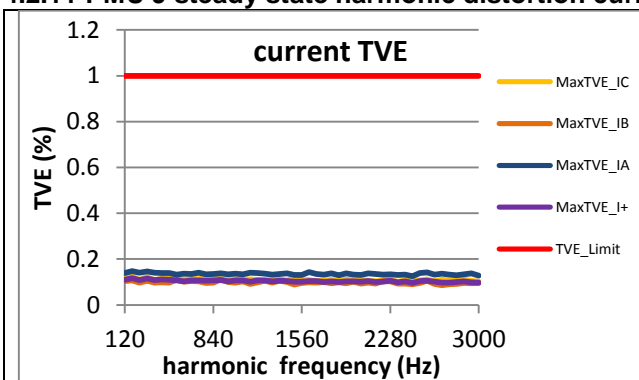


Figure 127:  $F_s = 60$  FPS

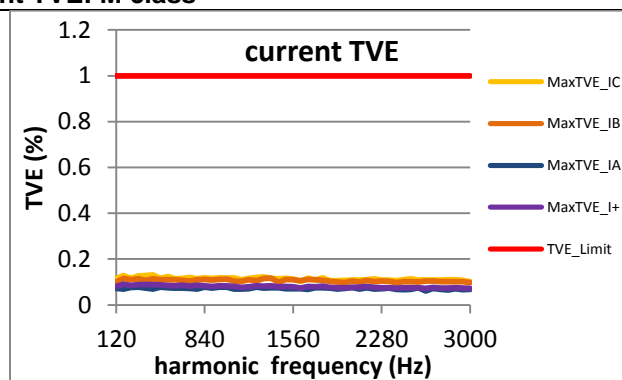


Figure 128:  $F_s = 30$  FPS

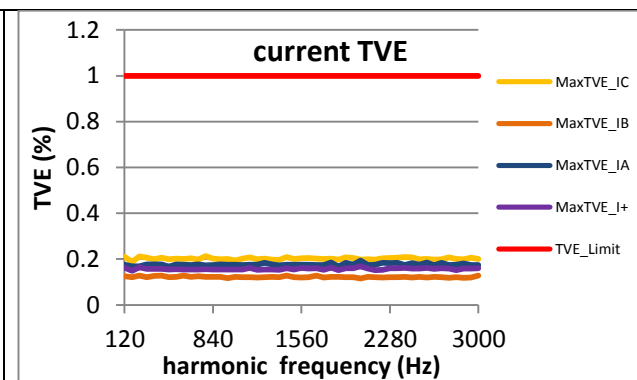


Figure 129:  $F_s = 20$  FPS

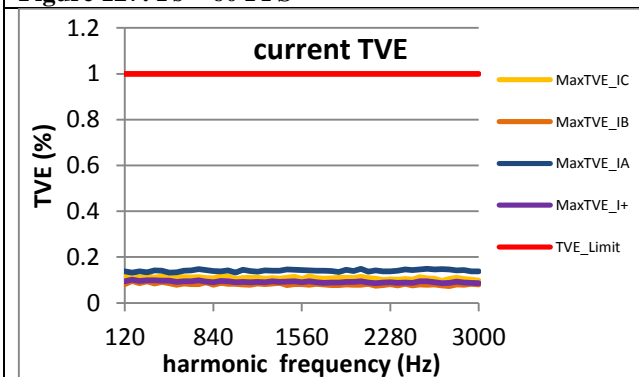


Figure 130:  $F_s = 15$  FPS

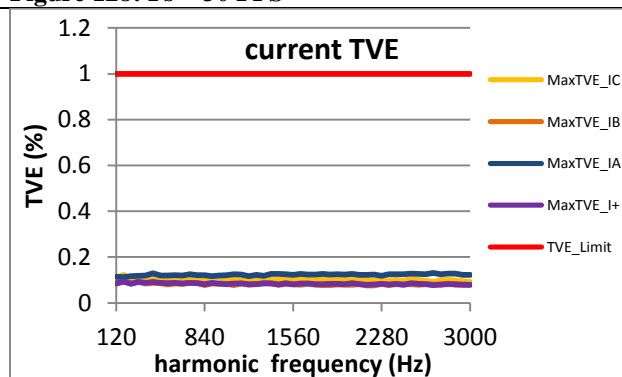


Figure 131:  $F_s = 12$  FPS

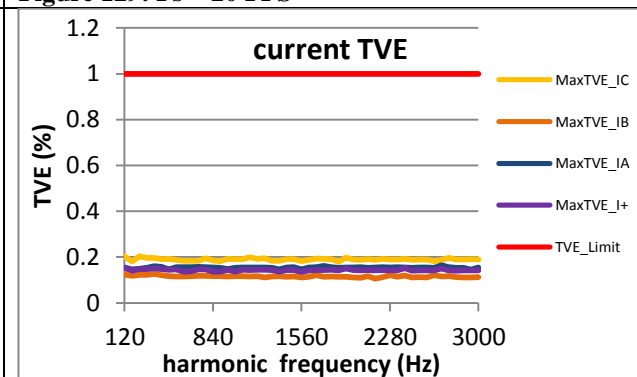
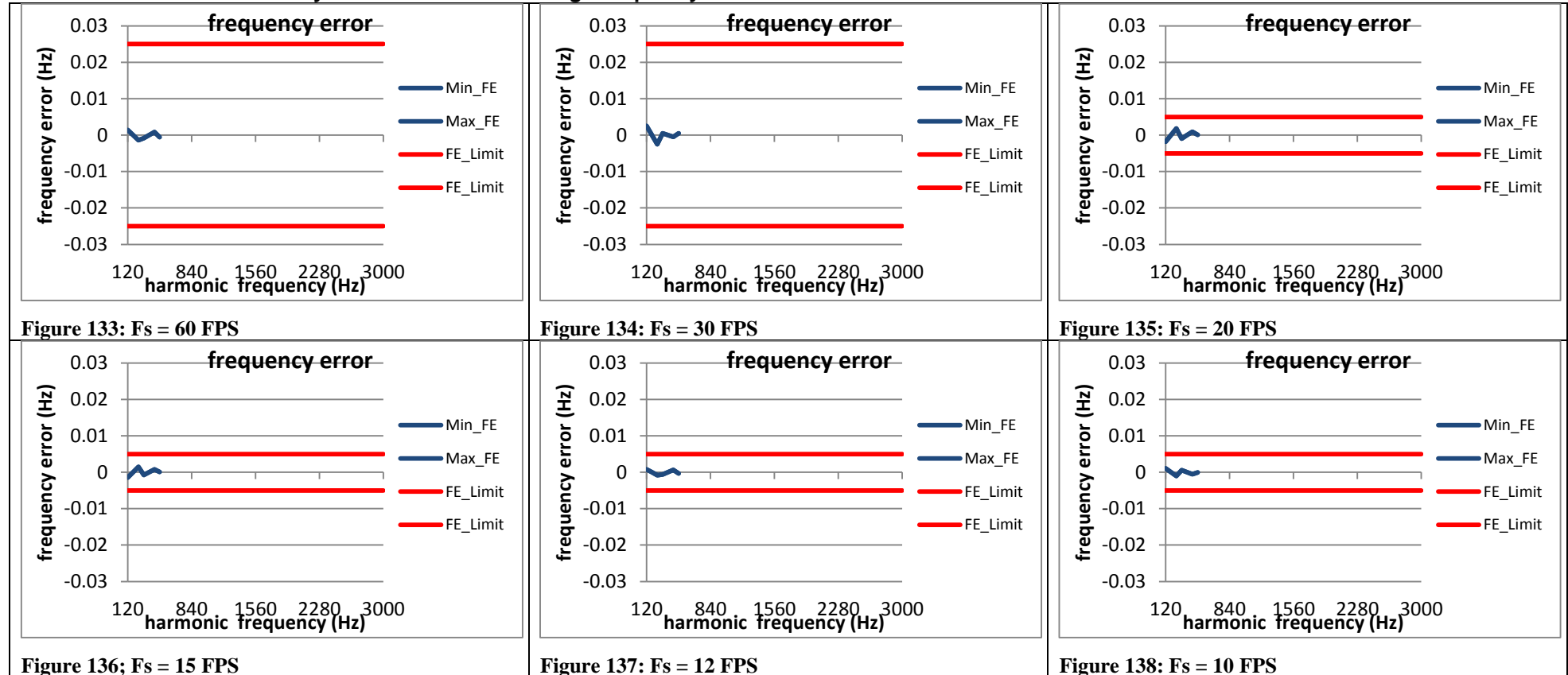


Figure 132:  $F_s = 10$  FPS

### 4.3 Steady state frequency harmonic distortion frequency error: M class

#### 4.3.1 C37.118.1 Annex C steady harmonic distortion range frequency error: M class



The C37.118.1 Annex C model is a digital simulation with an internal sampling rate of 960 samples per second and so can only be tested with a harmonic frequency up to 420 Hz.

#### 4.3.2 PMU A steady state frequency harmonic distortion error: M class

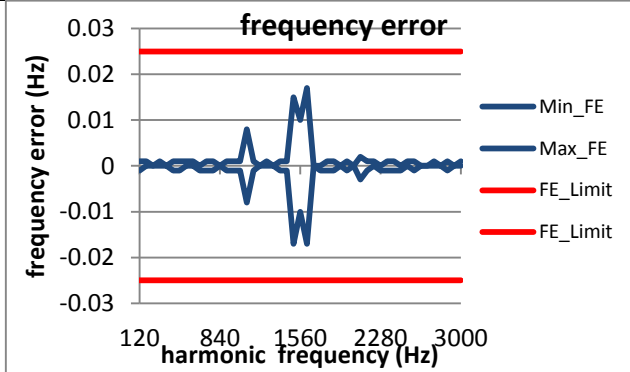


Figure 139:  $F_s = 60$  FPS

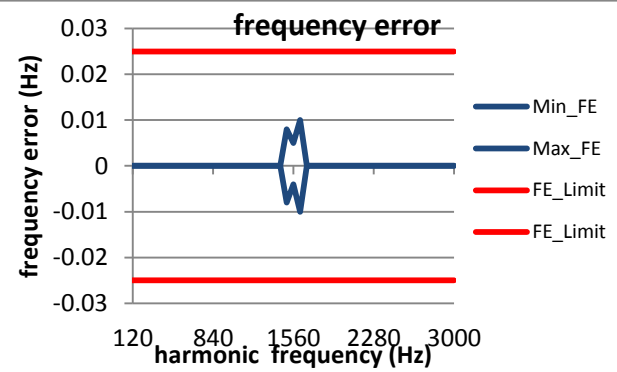


Figure 140:  $F_s = 30$  FPS

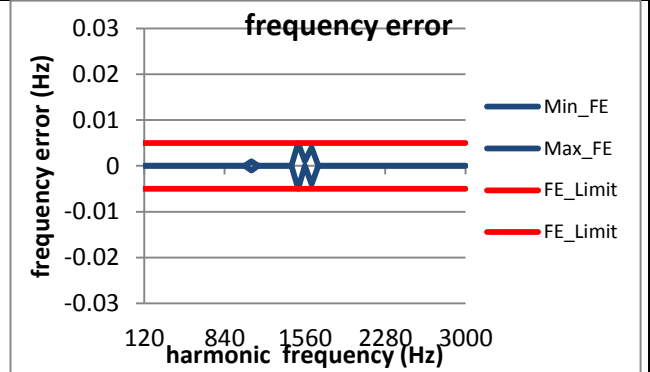


Figure 141:  $F_s = 20$  FPS

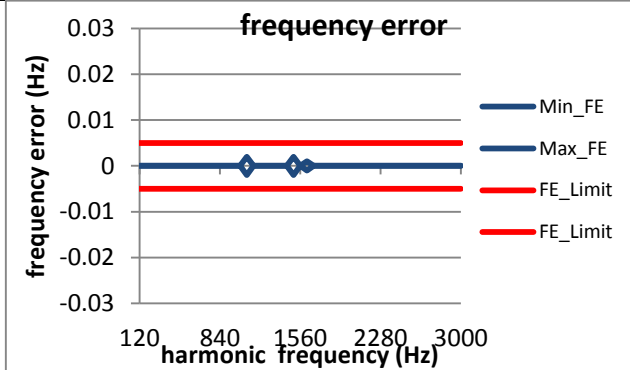


Figure 142:  $F_s = 15$  FPS

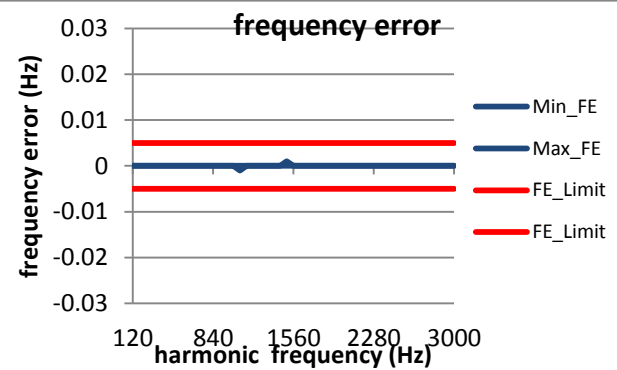


Figure 143:  $F_s = 12$  FPS

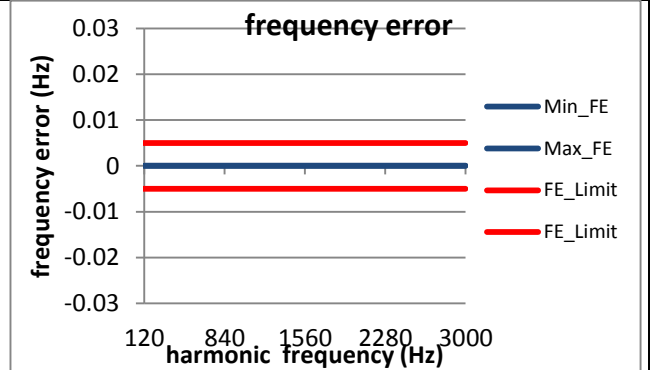


Figure 144:  $F_s = 10$  FPS

#### 4.3.3 PMU B steady state frequency harmonic distortion error: M class

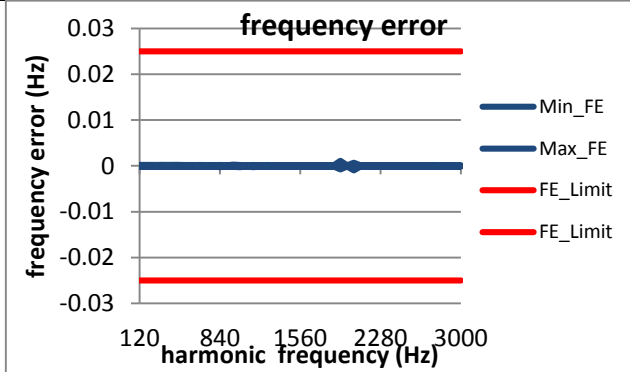


Figure 145:  $F_s = 60$  FPS

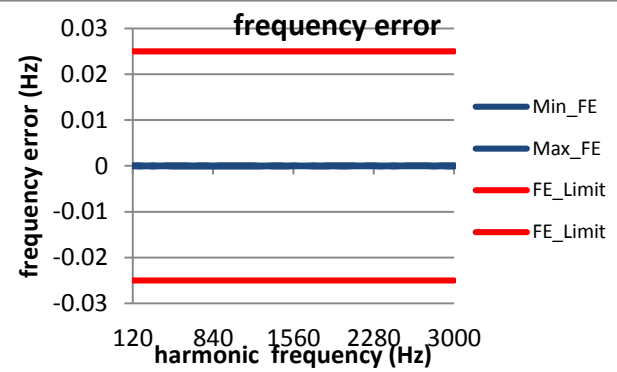


Figure 146:  $F_s = 30$  FPS

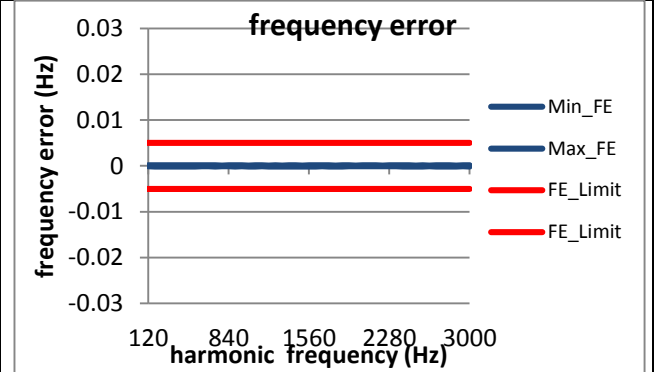


Figure 147:  $F_s = 20$  FPS

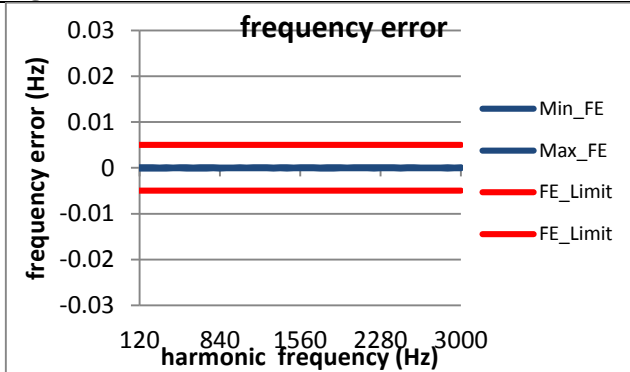


Figure 148:  $F_s = 15$  FPS

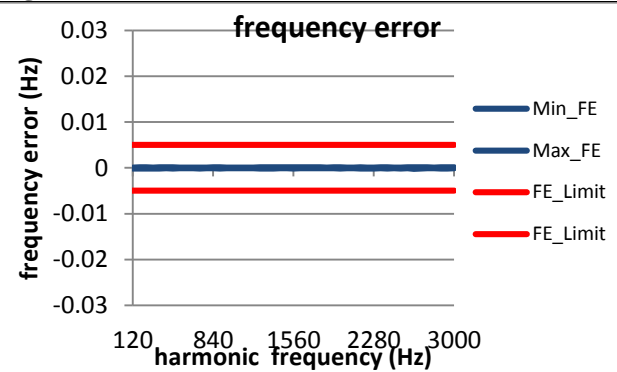


Figure 149:  $F_s = 12$  FPS

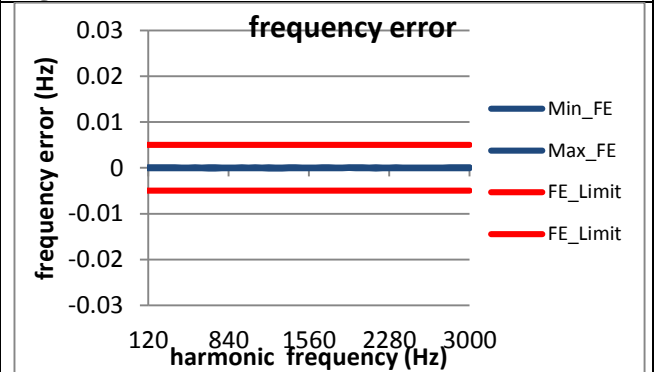


Figure 150:  $F_s = 10$  FPS

#### 4.3.4 PMU C steady state frequency harmonic distortion error: M class

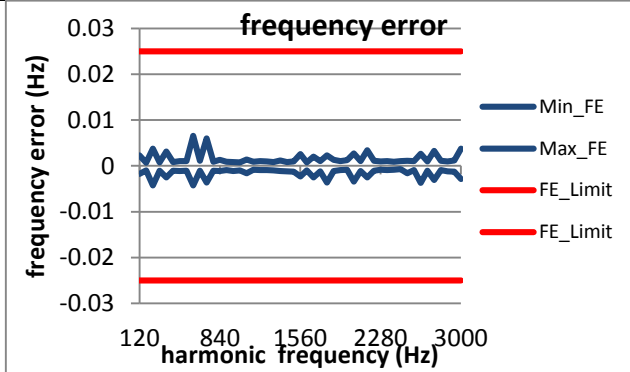


Figure 151:  $F_s = 60$  FPS

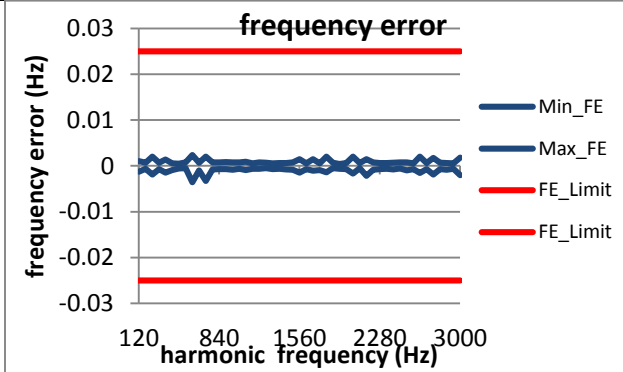


Figure 152:  $F_s = 30$  FPS

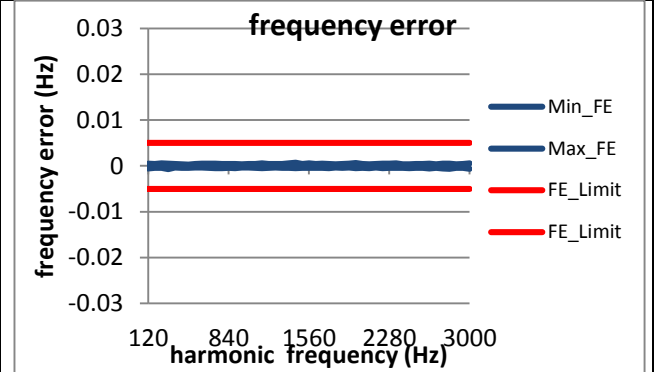


Figure 153:  $F_s = 20$  FPS

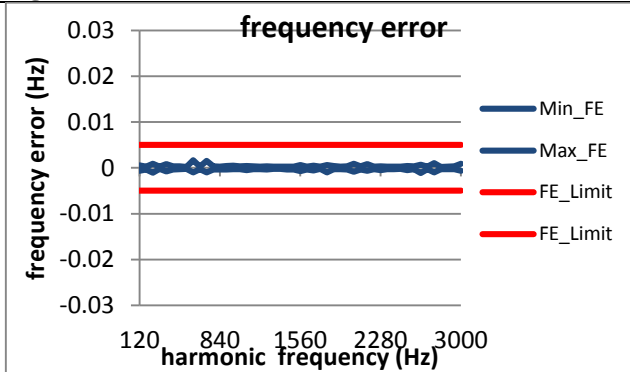


Figure 154:  $F_s = 15$  FPS

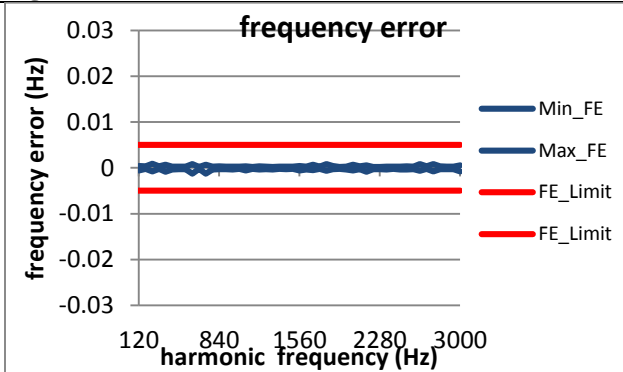


Figure 155:  $F_s = 12$  FPS

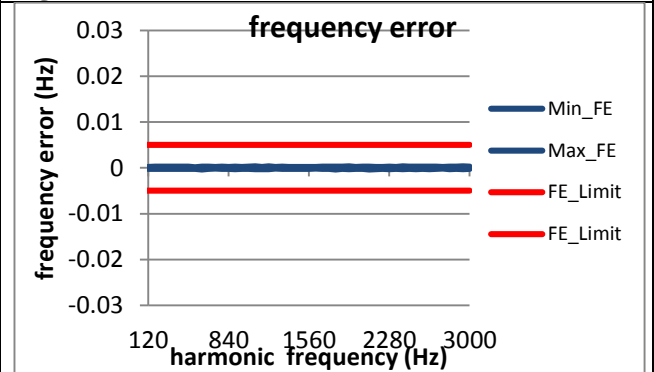


Figure 156:  $F_s = 10$  FPS



#### 4.3.5 PMU D steady state frequency harmonic distortion error: M class

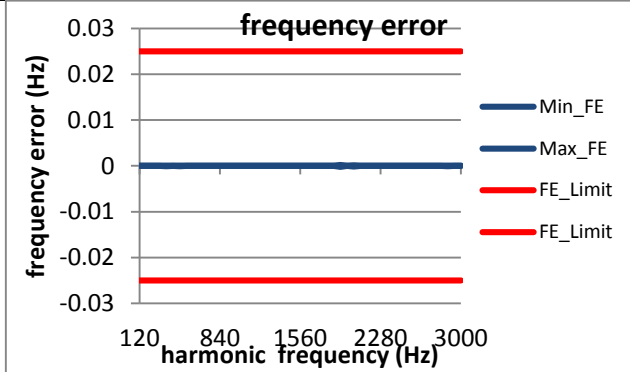


Figure 157:  $F_s = 60$  FPS

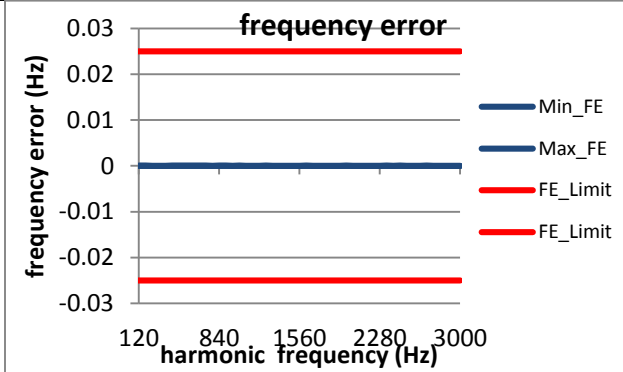


Figure 158:  $F_s = 30$  FPS

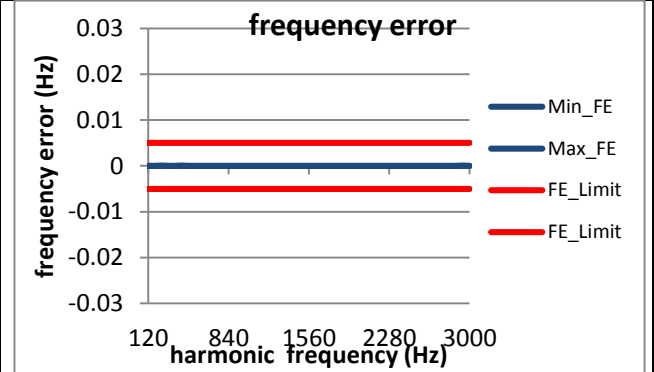


Figure 159:  $F_s = 20$  FPS

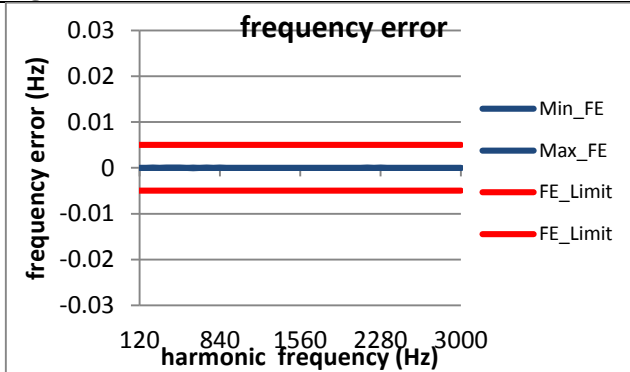


Figure 160:  $F_s = 15$  FPS

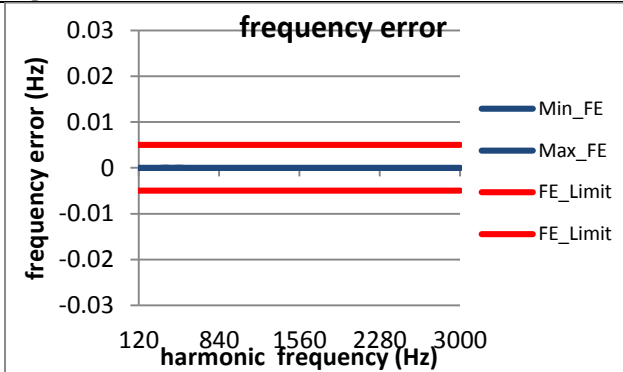


Figure 161:  $F_s = 12$  FPS

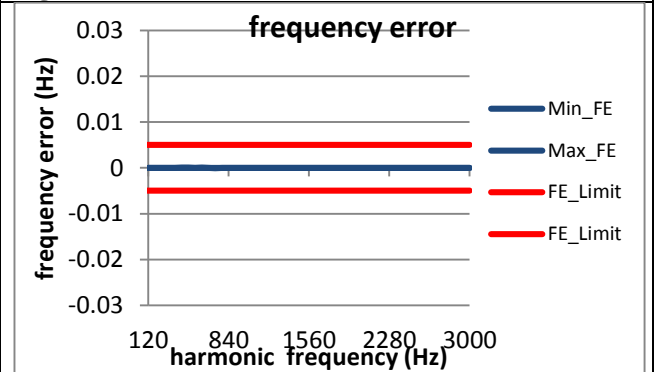


Figure 162:  $F_s = 10$  FPS

#### 4.3.6 PMU E steady state harmonic distortion frequency error: M class

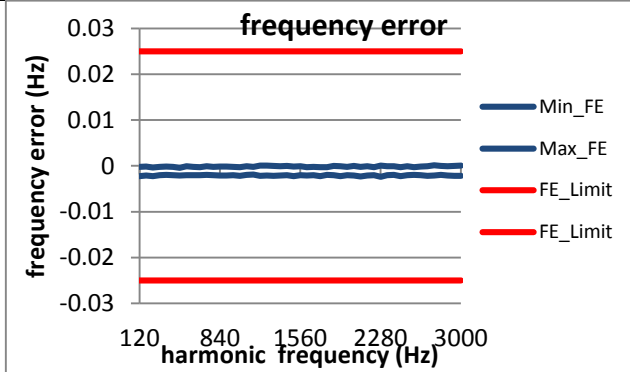


Figure 163:  $F_s = 60$  FPS

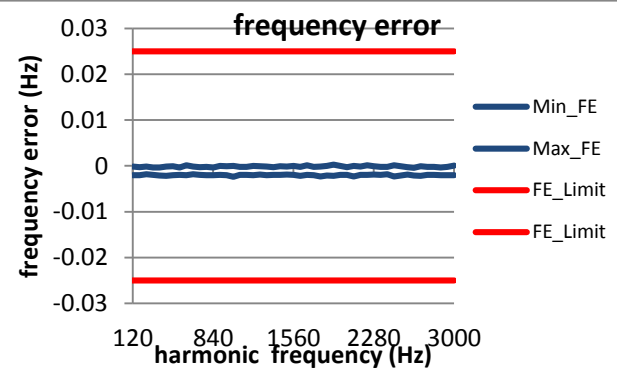


Figure 164:  $F_s = 30$  FPS

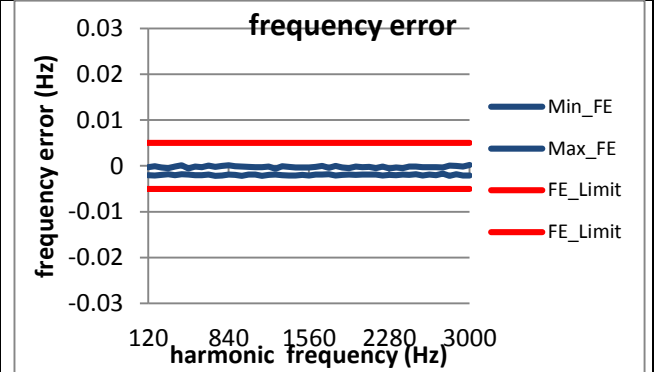


Figure 165:  $F_s = 20$  FPS

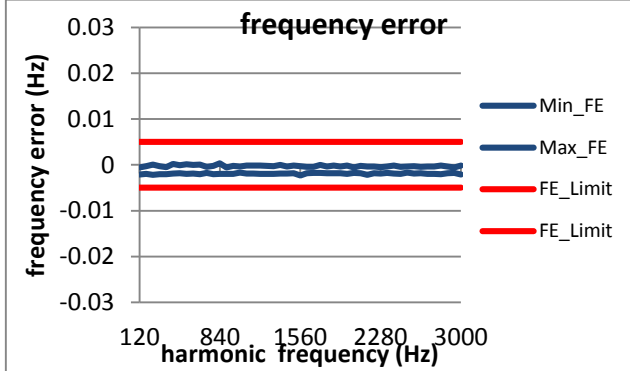


Figure 166:  $F_s = 15$  FPS

data was lost

Figure 167:  $F_s = 12$  FPS

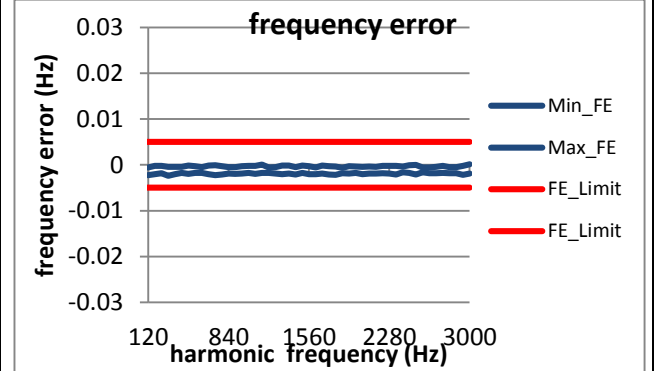
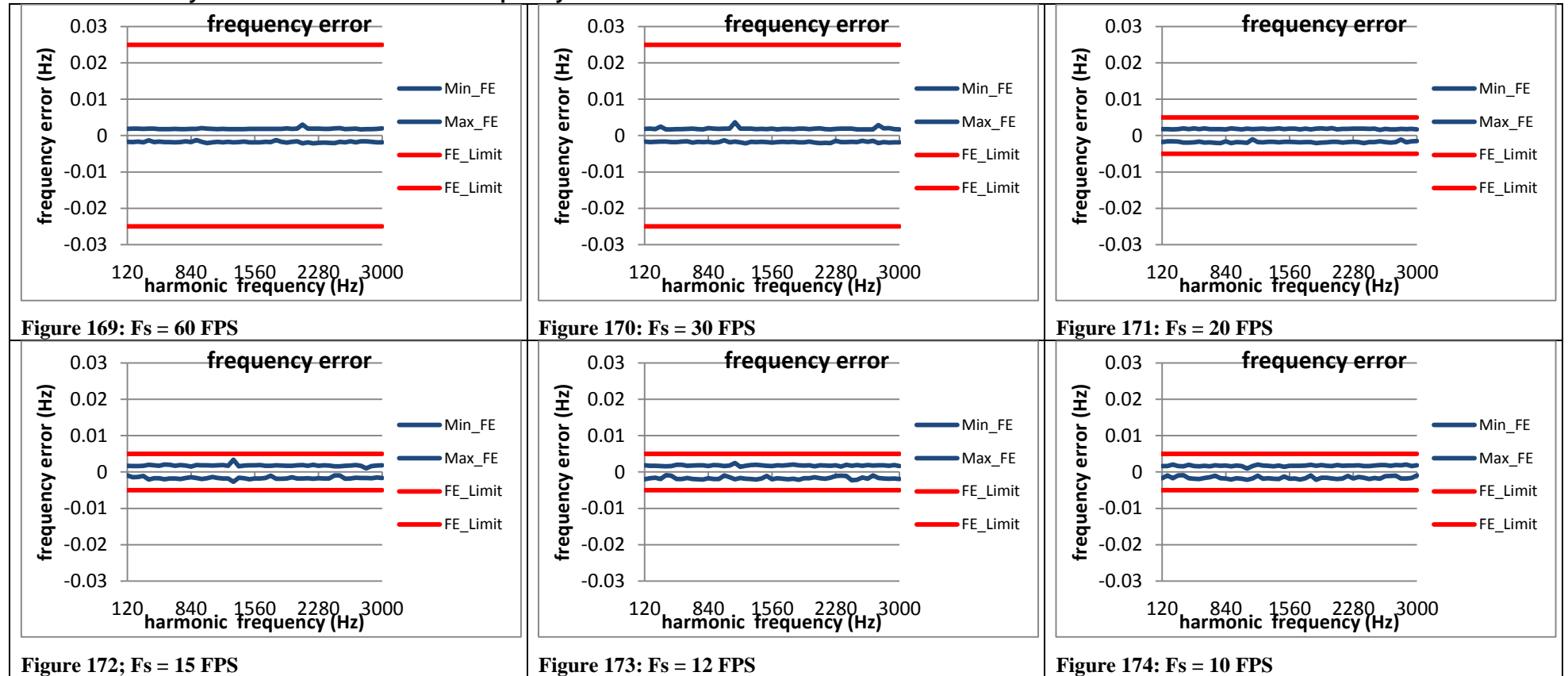


Figure 168:  $F_s = 10$  FPS

#### 4.3.7 PMU F steady state harmonic distortion frequency error: M class



#### 4.3.8 PMU G steady state harmonic distortion frequency error: M class

Figure 175:  $F_s = 60$  FPS is not supported by this PMU

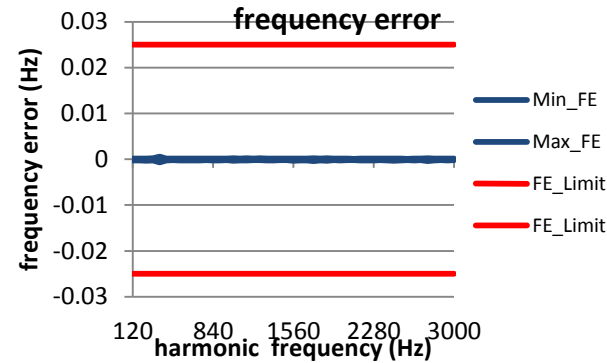


Figure 176:  $F_s = 30$  FPS

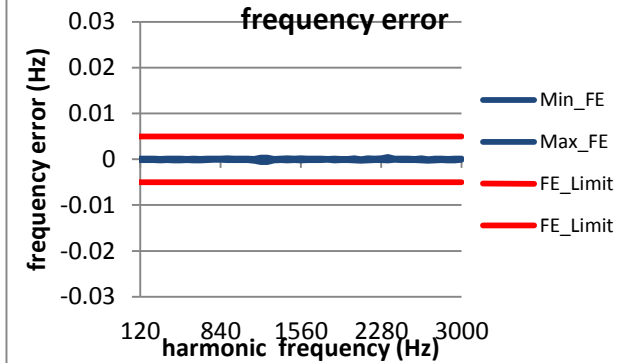


Figure 177:  $F_s = 20$  FPS

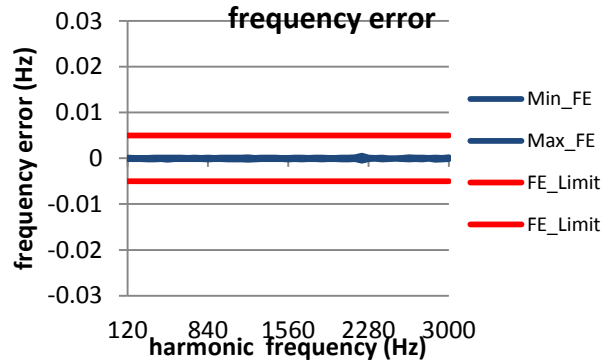


Figure 178:  $F_s = 15$  FPS

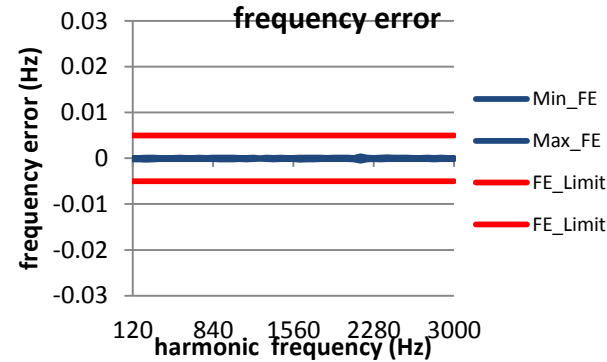


Figure 179:  $F_s = 12$  FPS

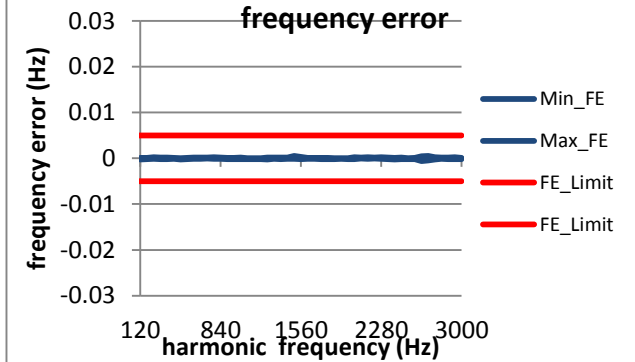


Figure 180:  $F_s = 10$  FPS

#### 4.3.9 PMU H steady state harmonic distortion frequency error: M class

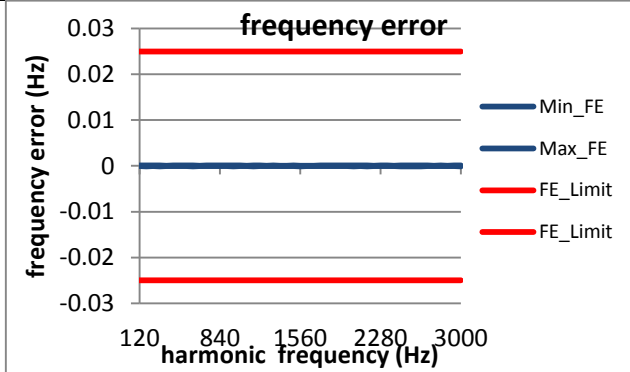


Figure 181:  $F_s = 60$  FPS

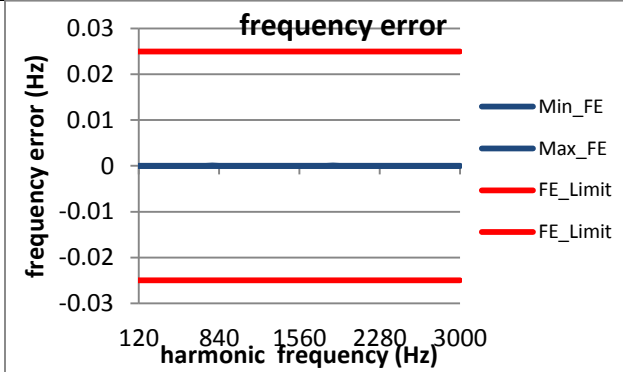


Figure 182:  $F_s = 30$  FPS

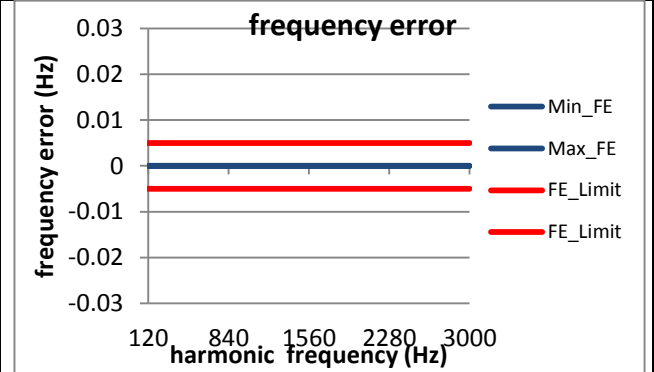


Figure 183:  $F_s = 20$  FPS

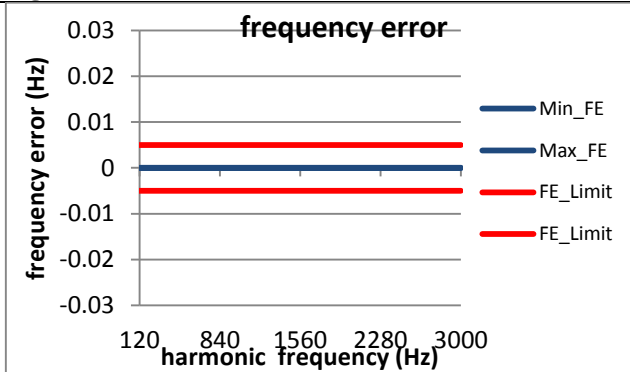


Figure 184:  $F_s = 15$  FPS

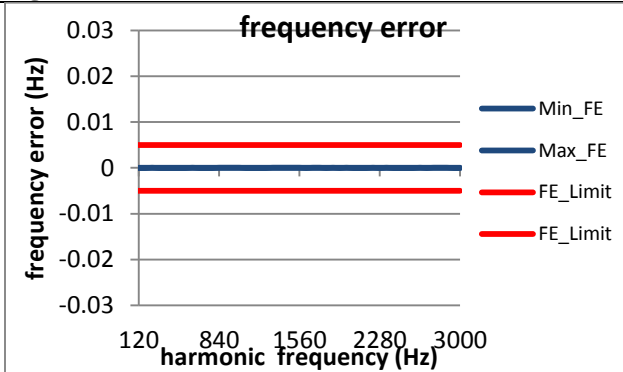


Figure 185:  $F_s = 12$  FPS

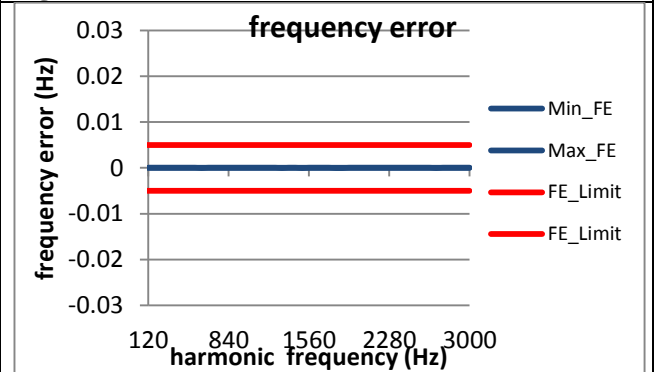
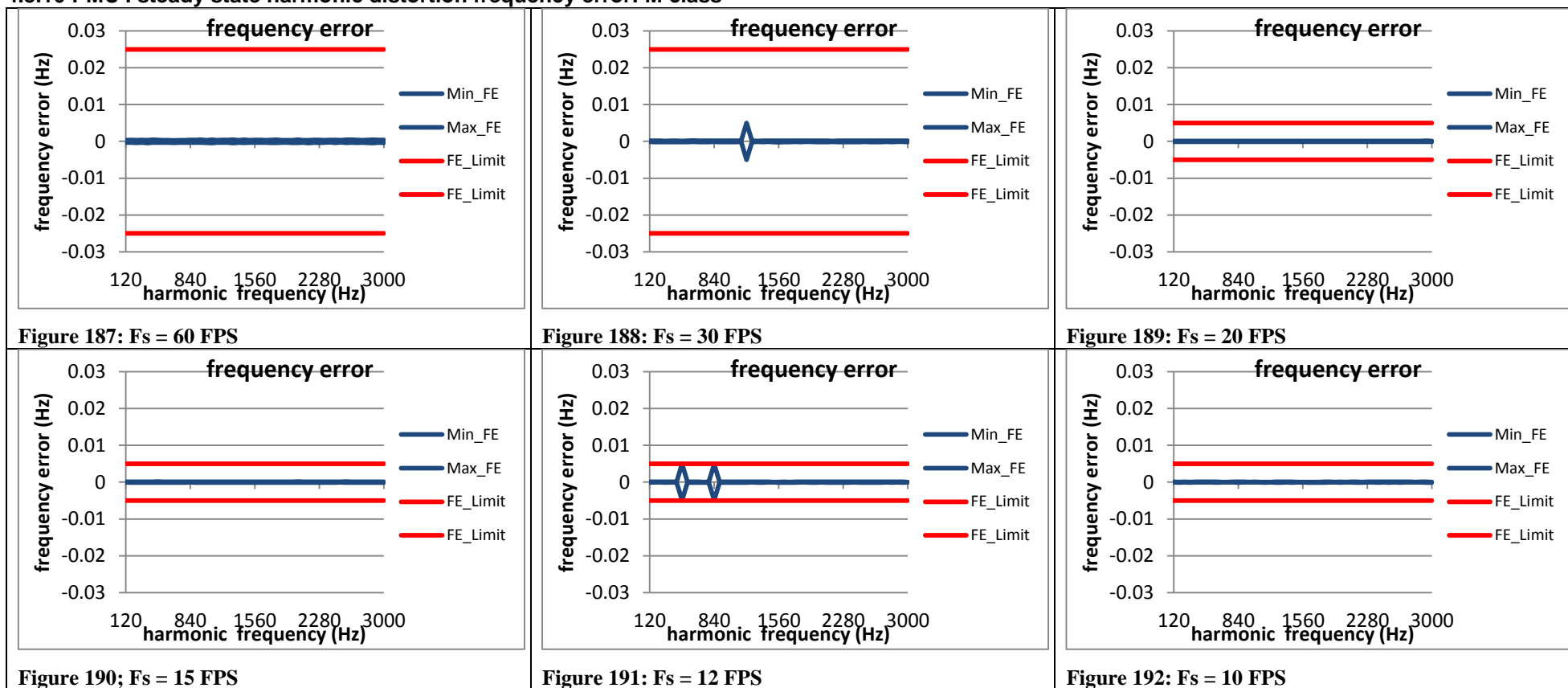


Figure 186:  $F_s = 10$  FPS

#### 4.3.10 PMU I steady state harmonic distortion frequency error: M class



#### 4.3.11 PMU J steady state harmonic distortion frequency error: M class

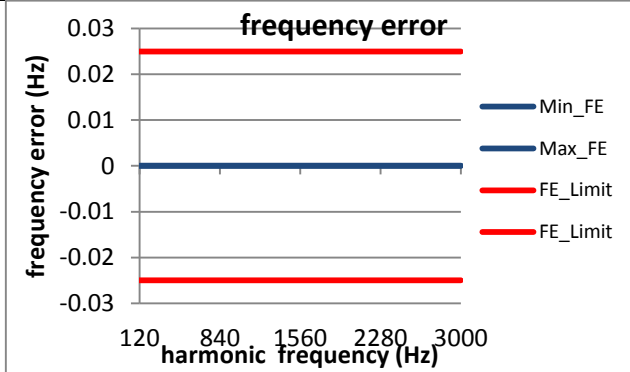


Figure 193:  $F_s = 60$  FPS

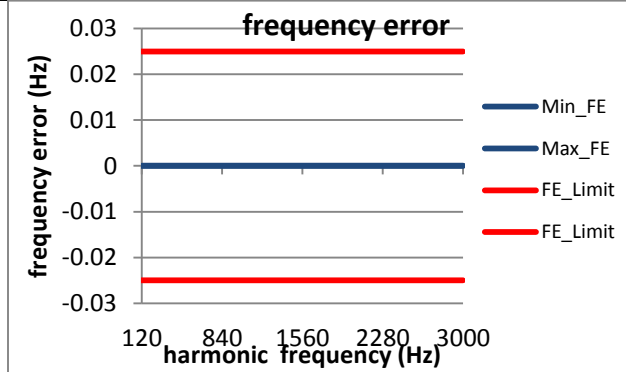


Figure 194:  $F_s = 30$  FPS

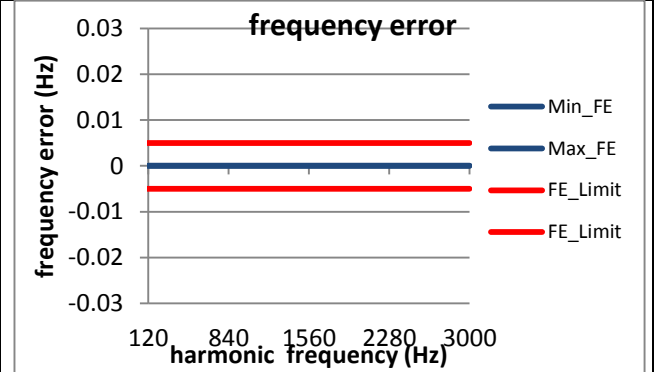


Figure 195:  $F_s = 20$  FPS

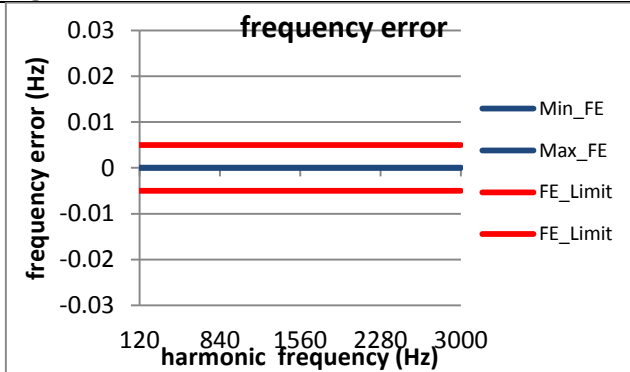


Figure 196:  $F_s = 15$  FPS

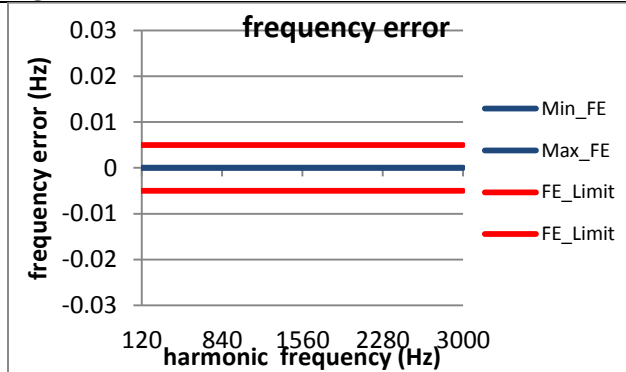


Figure 197:  $F_s = 12$  FPS

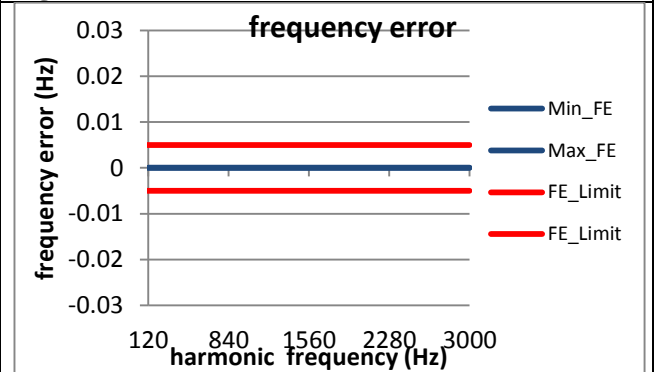
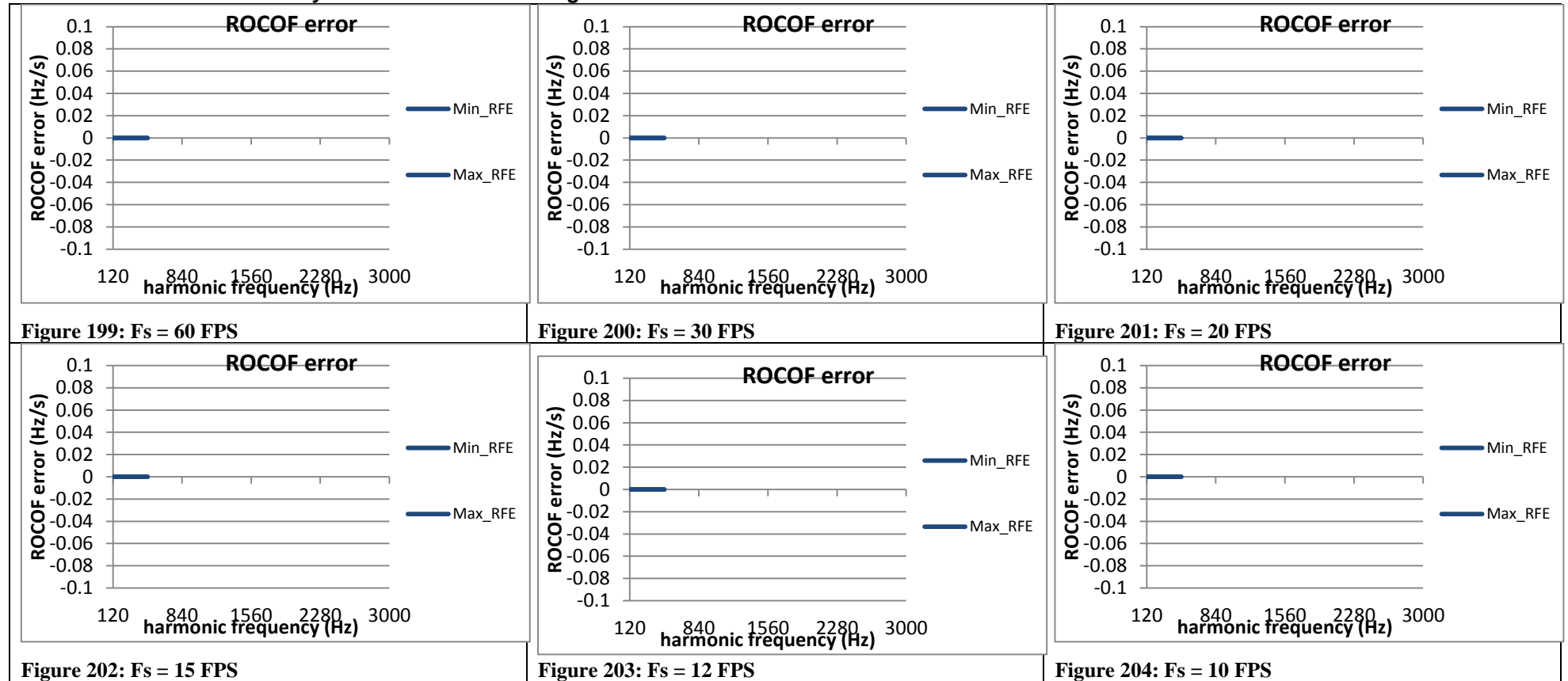


Figure 198:  $F_s = 10$  FPS

#### 4.4 Steady state harmonic distortion ROCOF error: M class

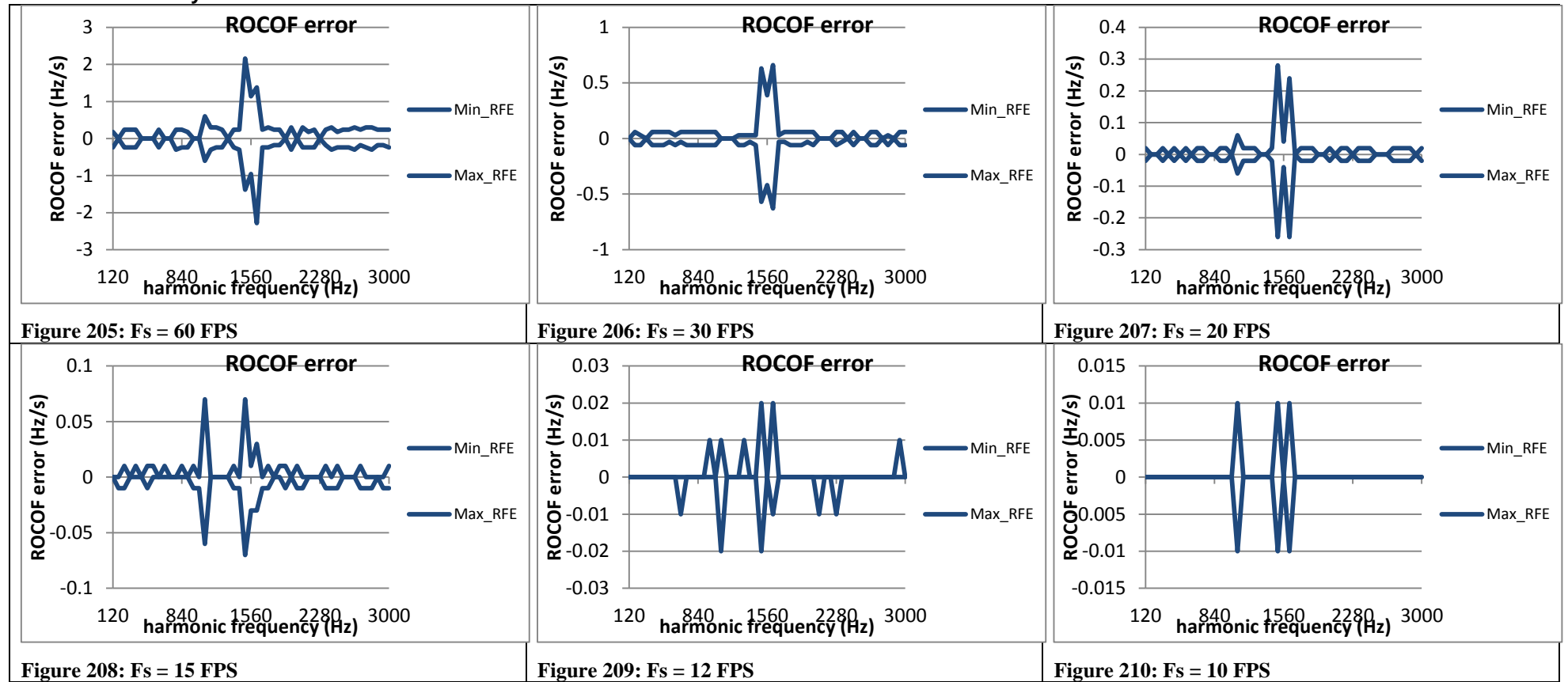
##### 4.4.1 C37.118.1 Annex C steady harmonic distortion range ROCOF error: M class



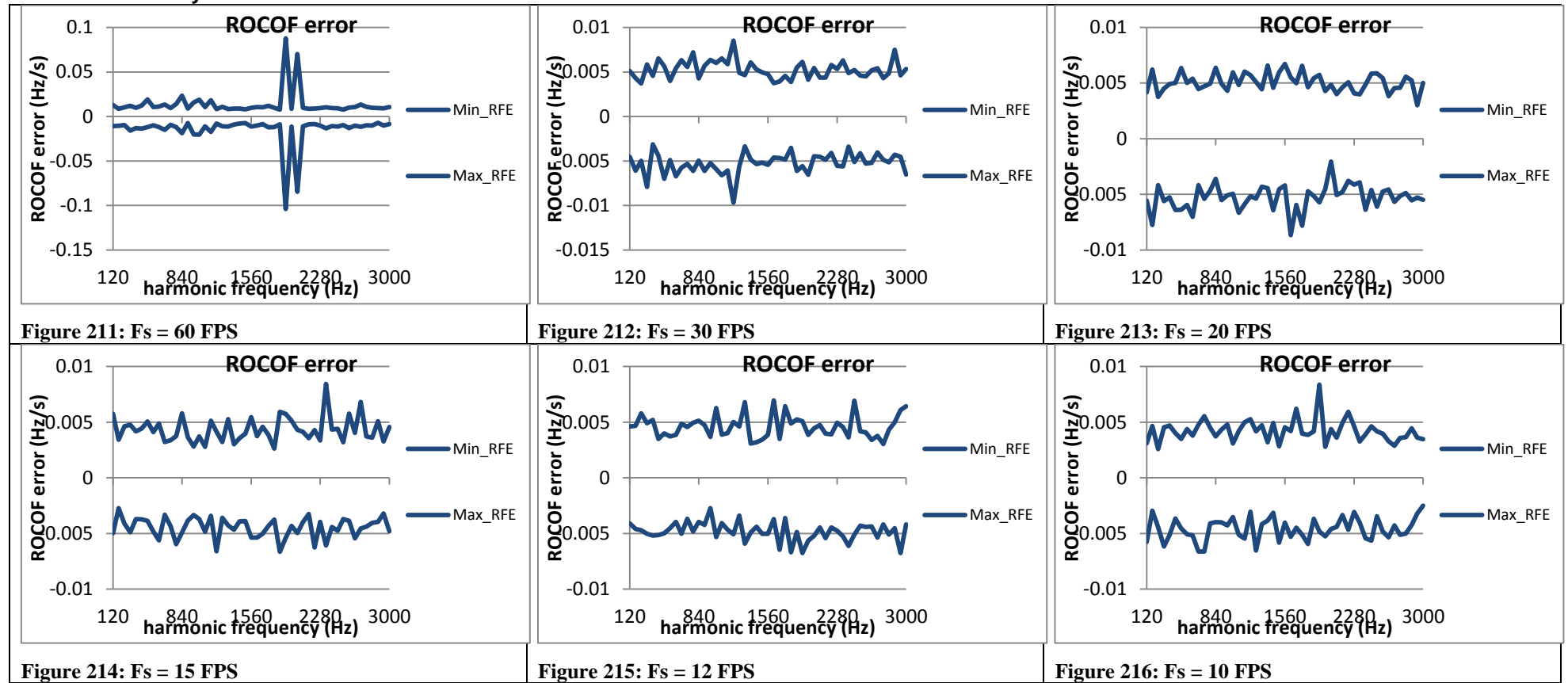
The C37.118.1 Annex C model is a digital simulation with an internal sampling rate of 960 samples per second and so can only be tested with a harmonic frequency up to 420 Hz.



#### 4.4.2 PMU A steady state harmonic distortion ROCOF error: M class



#### 4.4.3 PMU B steady state harmonic distortion ROCOF error: M class



#### 4.4.4 PMU C steady state harmonic distortion ROCOF error: M class

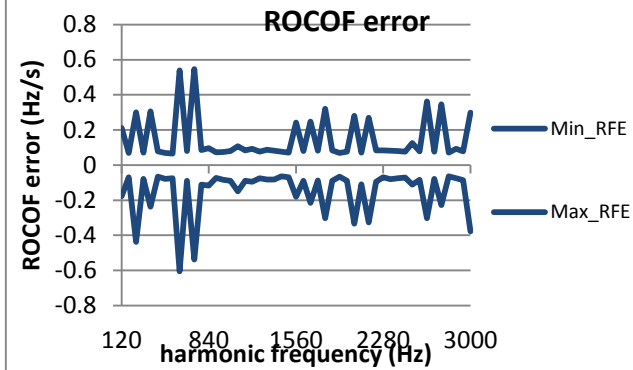


Figure 217:  $F_s = 60$  FPS

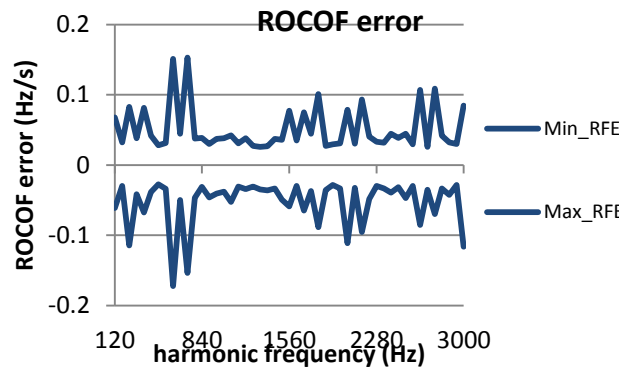


Figure 218:  $F_s = 30$  FPS

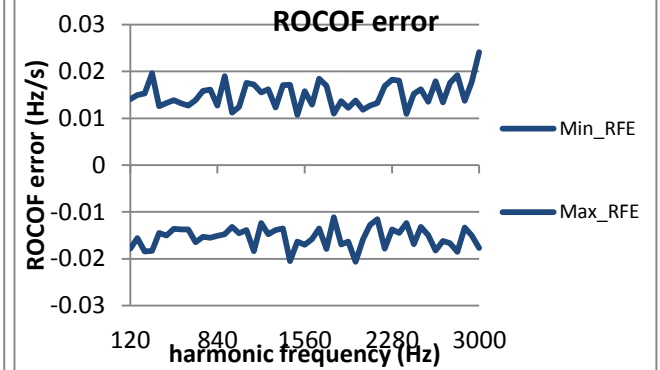


Figure 219:  $F_s = 20$  FPS

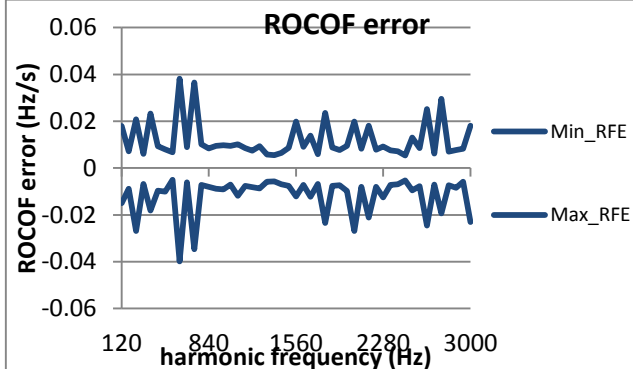


Figure 220:  $F_s = 15$  FPS

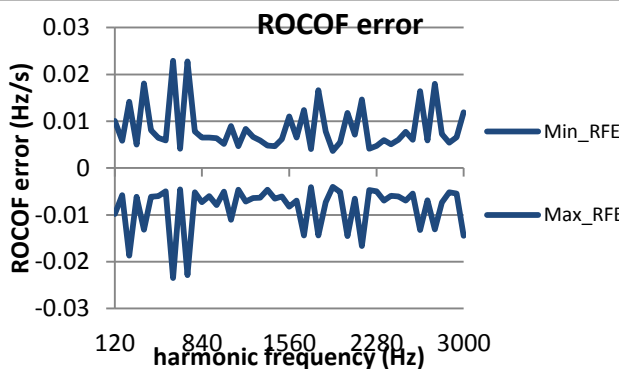


Figure 221:  $F_s = 12$  FPS

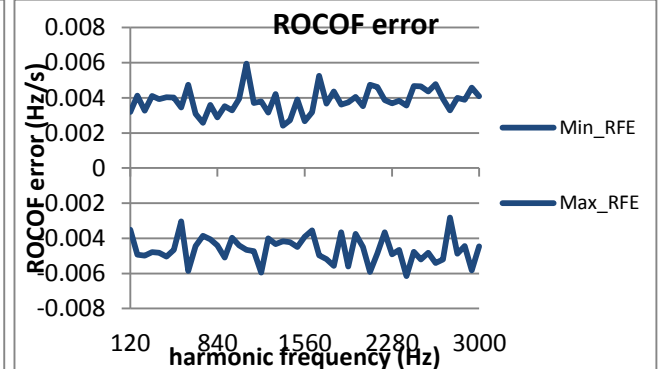
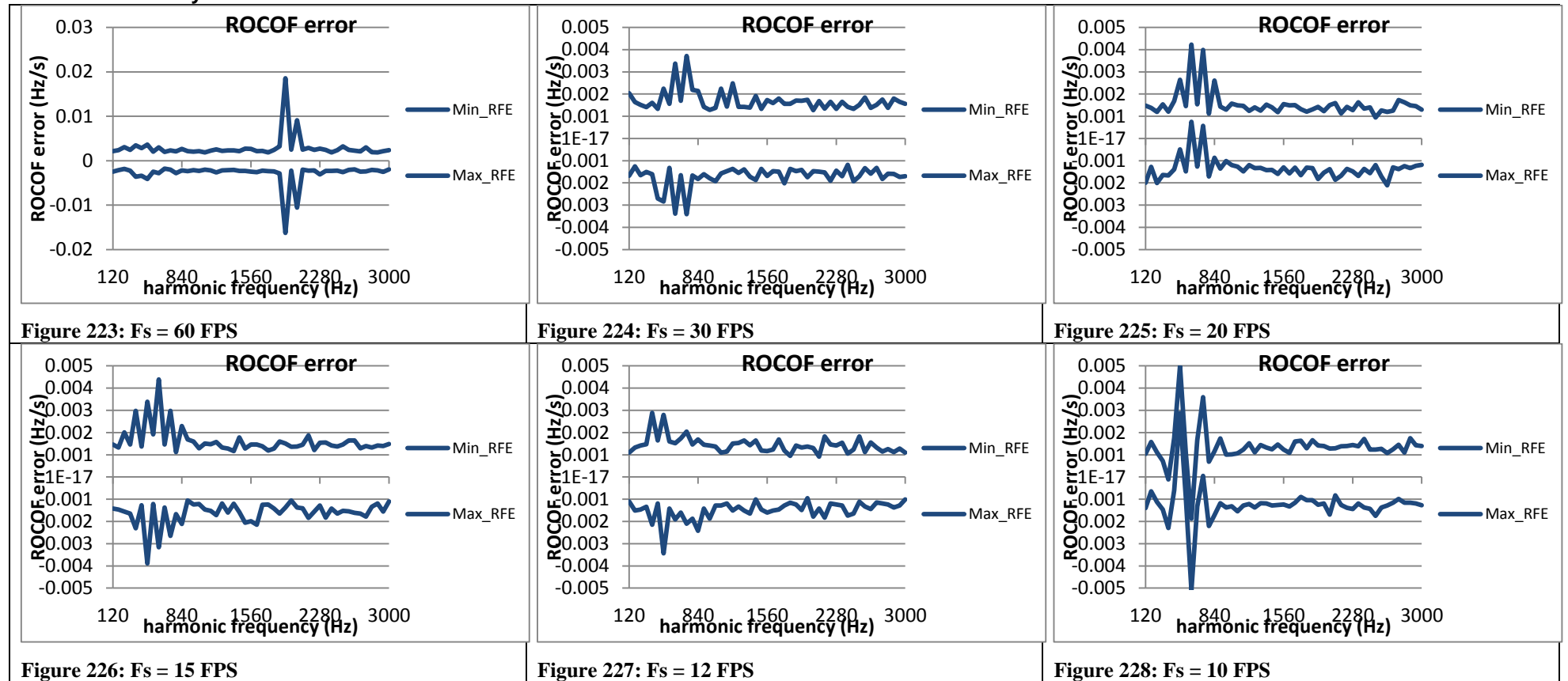


Figure 222:  $F_s = 10$  FPS

#### 4.4.5 PMU D steady state harmonic distortion ROCOF error: M class



#### 4.4.6 PMU E steady state harmonic distortion ROCOF error: M class

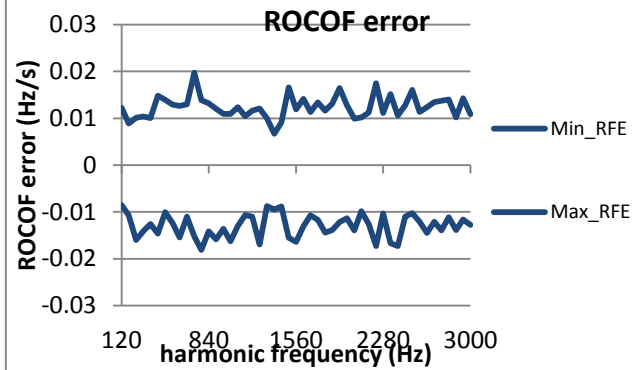


Figure 229:  $F_s = 60$  FPS

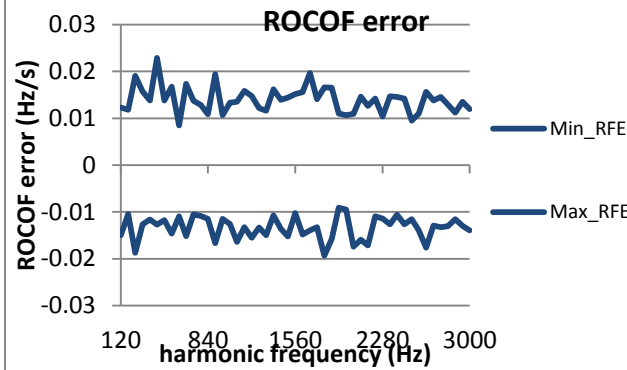


Figure 230:  $F_s = 30$  FPS

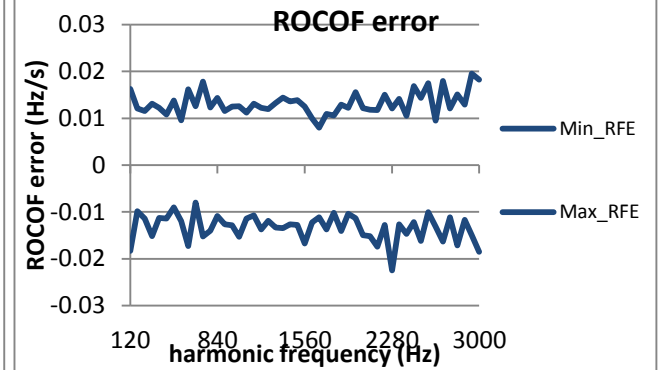


Figure 231:  $F_s = 20$  FPS

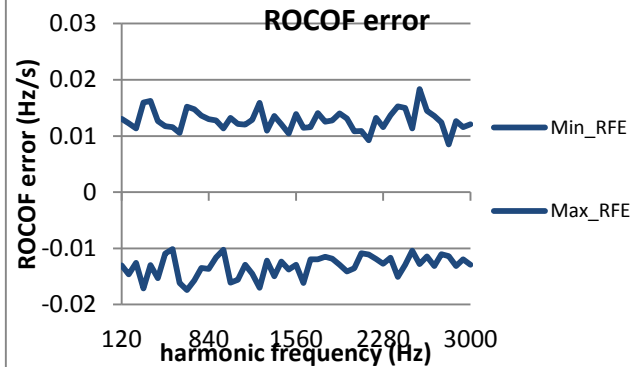


Figure 232:  $F_s = 15$  FPS

data was lost  
Figure 233:  $F_s = 12$  FPS

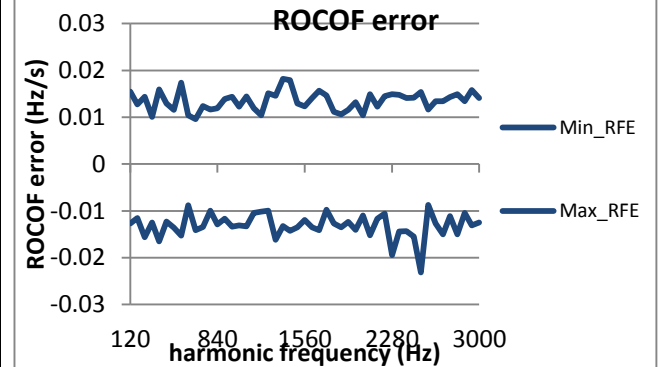


Figure 234:  $F_s = 10$  FPS

#### 4.4.7 PMU F steady state harmonic distortion ROCOF error: M class

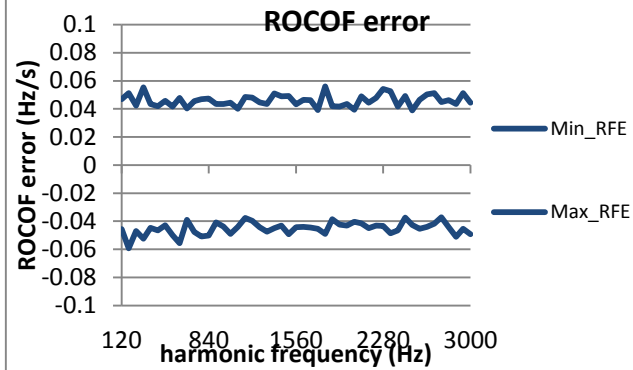


Figure 235:  $F_s = 60$  FPS

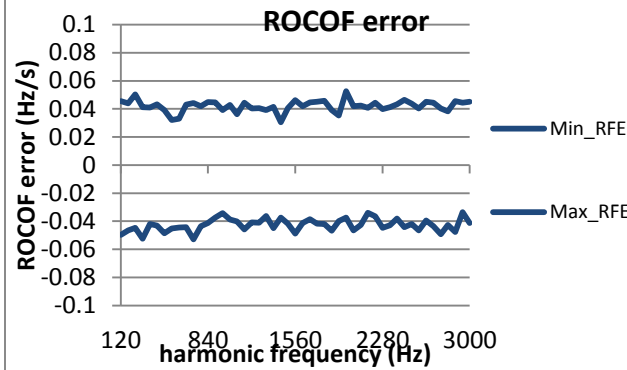


Figure 236:  $F_s = 30$  FPS

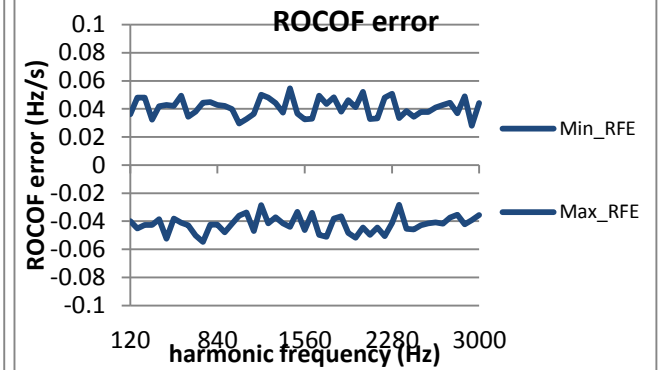


Figure 237:  $F_s = 20$  FPS

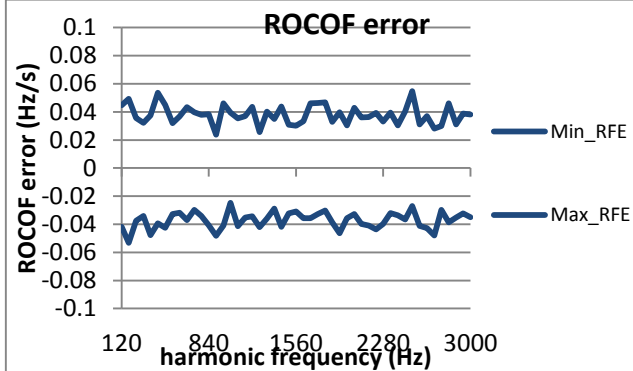


Figure 238:  $F_s = 15$  FPS

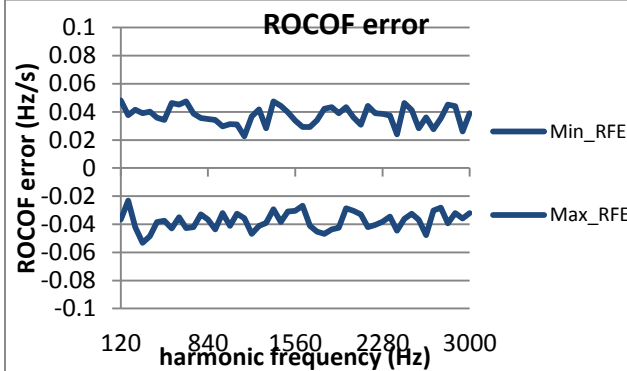


Figure 239:  $F_s = 12$  FPS

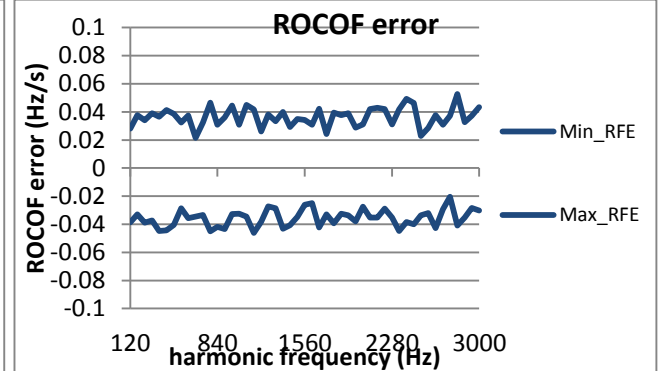
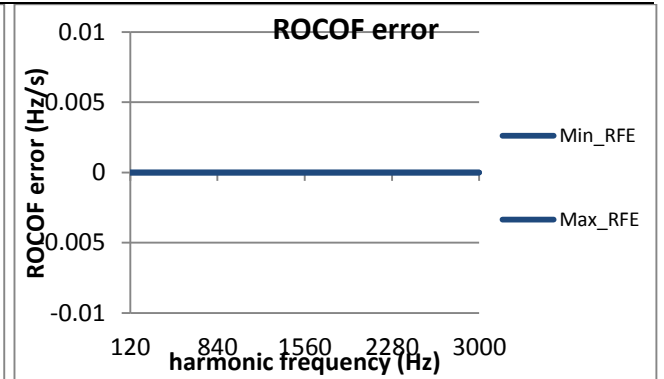
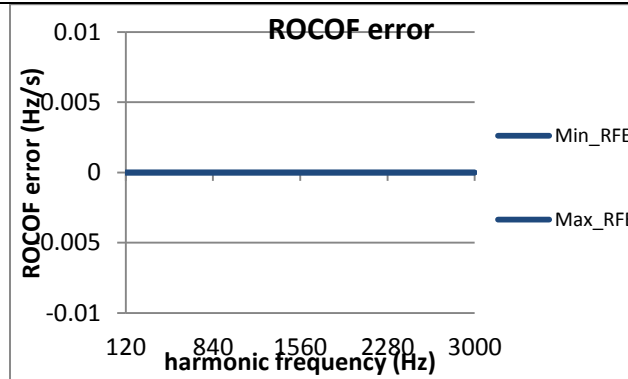


Figure 240:  $F_s = 10$  FPS

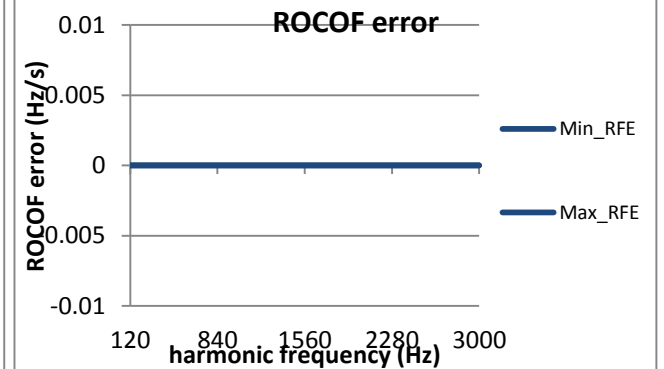
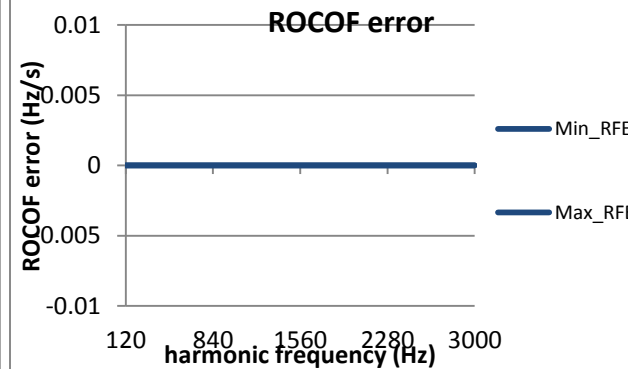
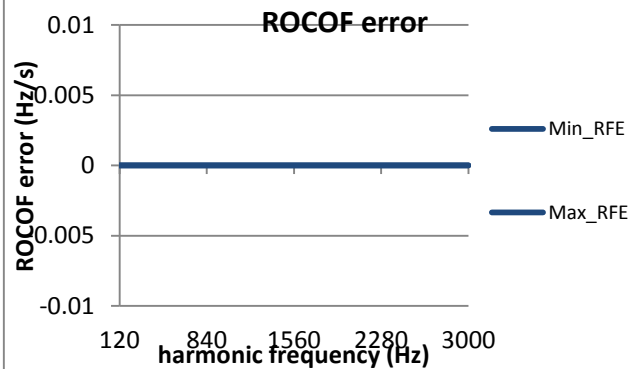
#### 4.4.8 PMU G\* steady state harmonic distortion ROCOF error: M class

**Figure 241:  $F_s = 60$  FPS is not supported by this PMU**



**Figure 242:  $F_s = 30$  FPS**

**Figure 243:  $F_s = 20$  FPS**



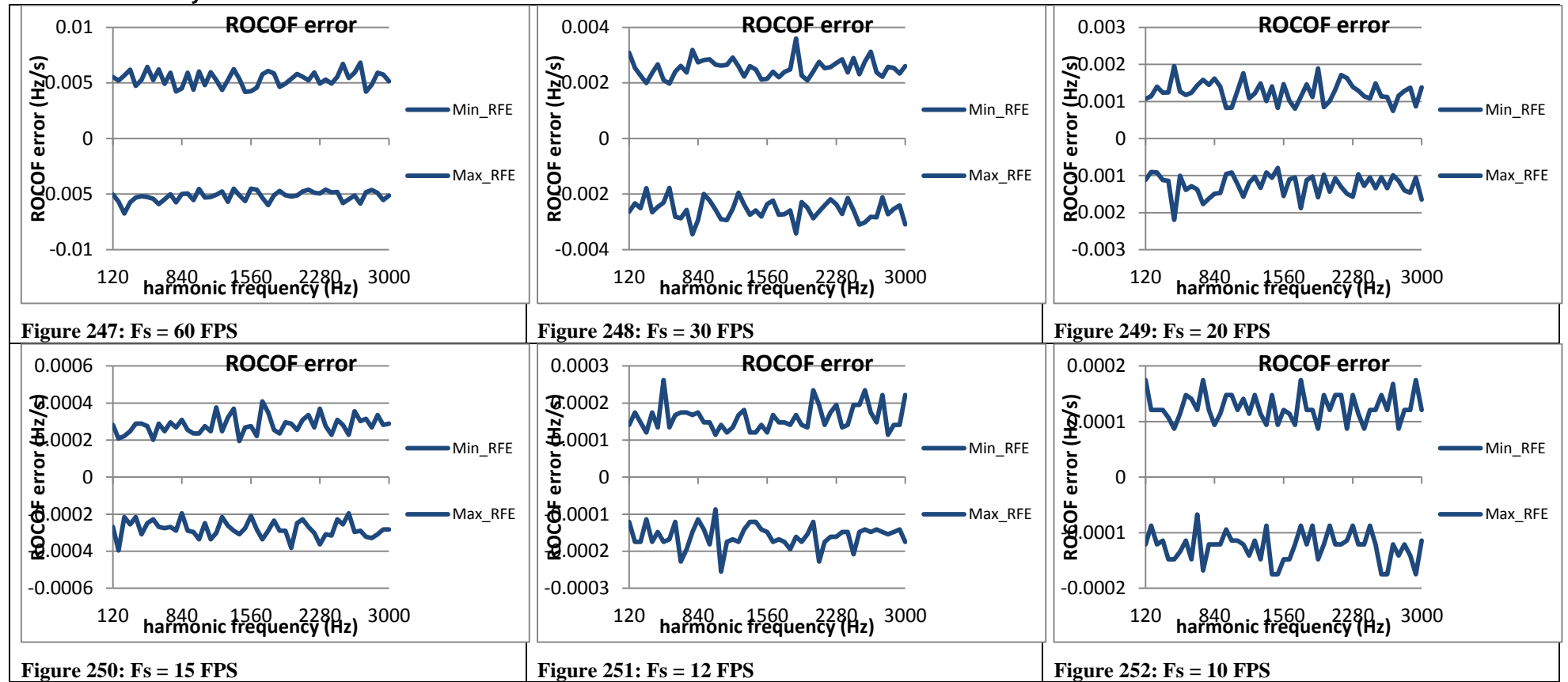
**Figure 244:  $F_s = 15$  FPS**

**Figure 245:  $F_s = 12$  FPS**

**Figure 246:  $F_s = 10$  FPS**

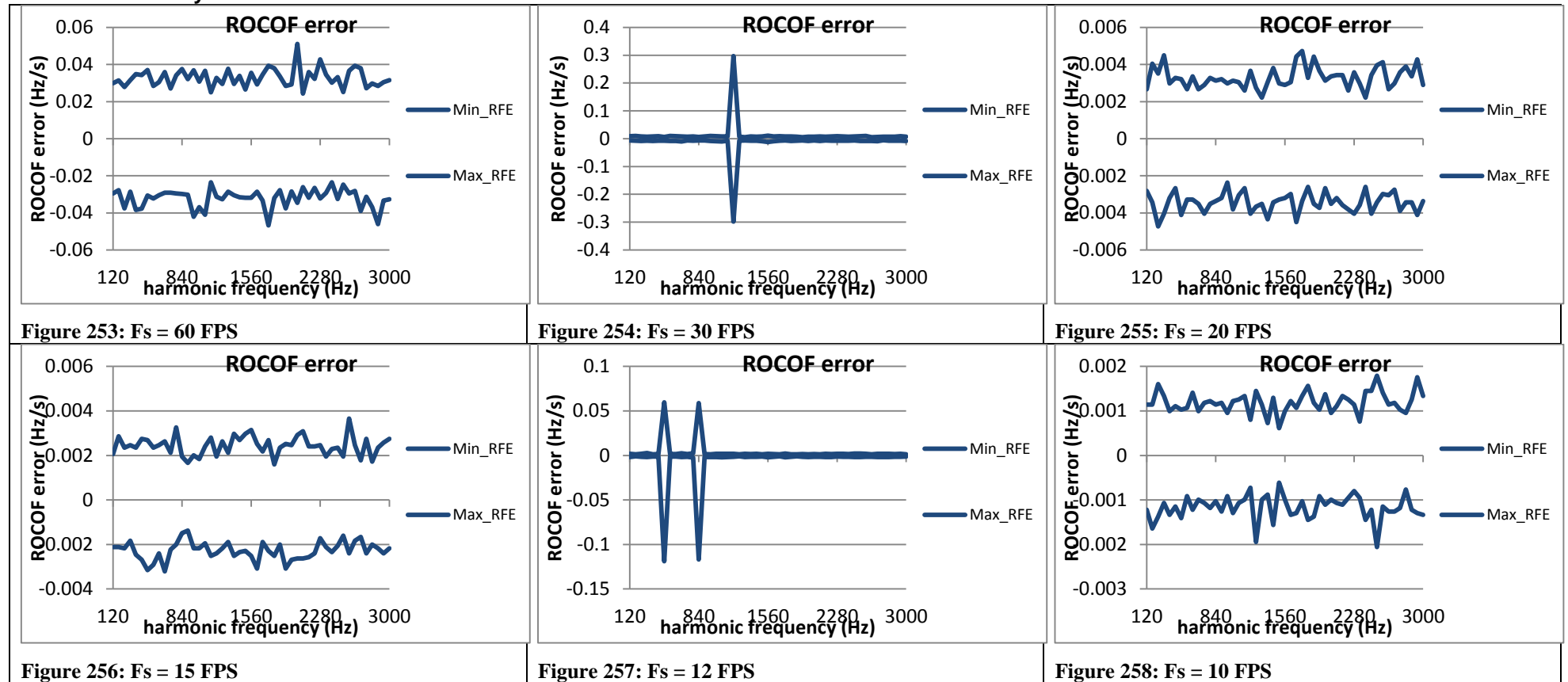
\* PMU G always outputs ROCOF = 0

#### 4.4.9 PMU H steady state harmonic distortion ROCOF error: M class





#### 4.4.10 PMU I steady state harmonic distortion ROCOF error: M class



#### 4.4.11 PMU J steady state harmonic distortion ROCOF error: M class

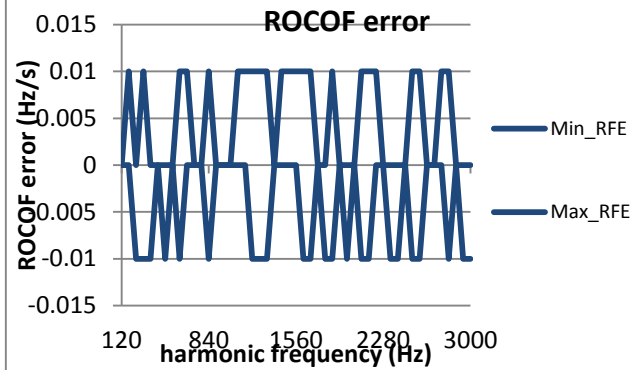


Figure 259:  $F_s = 60$  FPS

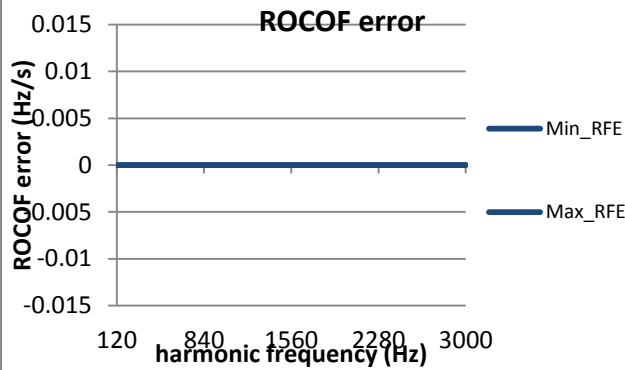


Figure 260:  $F_s = 30$  FPS

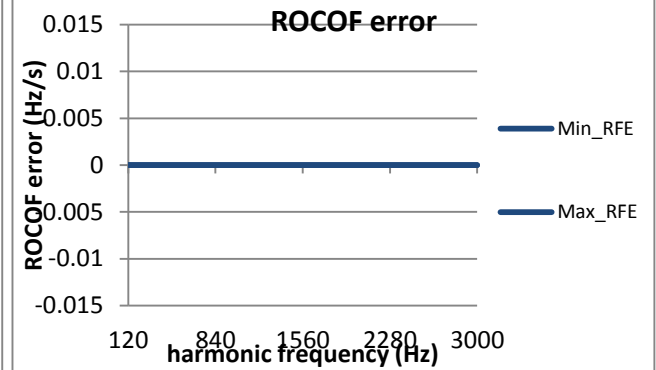


Figure 261:  $F_s = 20$  FPS

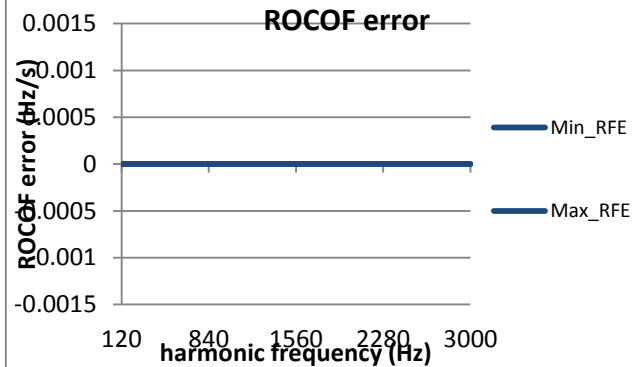


Figure 262:  $F_s = 15$  FPS

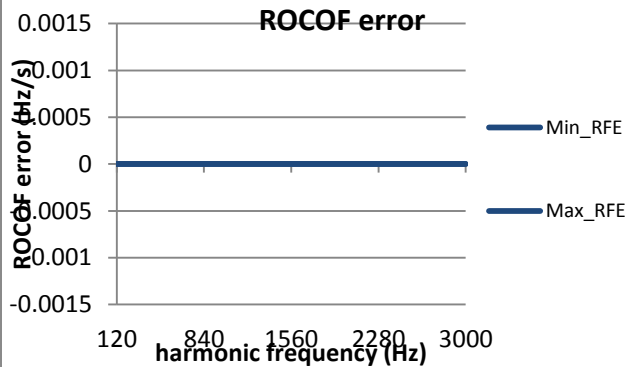


Figure 263:  $F_s = 12$  FPS

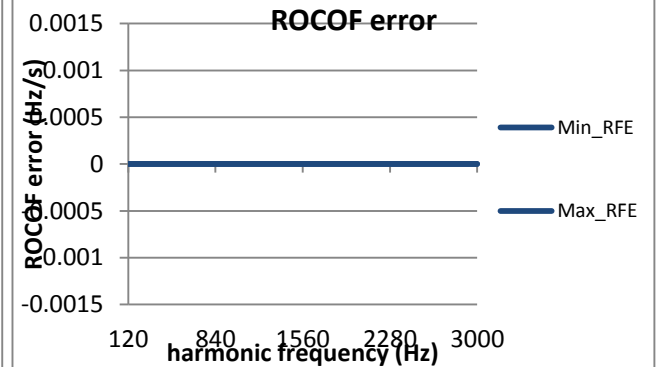
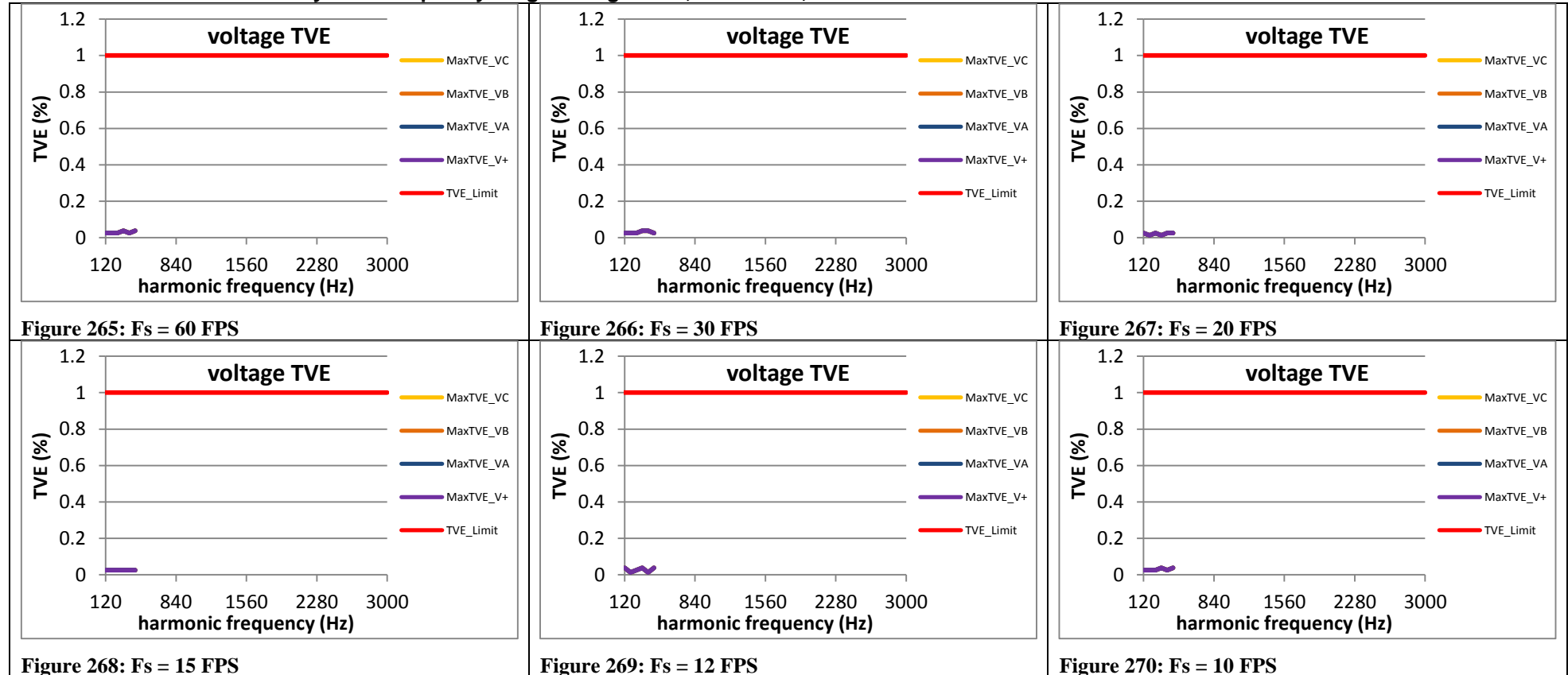


Figure 264:  $F_s = 10$  FPS

## 4.5 Steady state harmonic distortion voltage TVE: P class

### 4.5.1 C37.118.1 Annex C steady state frequency range voltage TVE:, F0 = 60 Hz, P class



The C37.118.1 Annex C model is a digital simulation with an internal sampling rate of 960 samples per second and so can only be tested with a harmonic frequency up to 420 Hz.

#### 4.5.2 PMU A steady state harmonic distortion voltage TVE: P class

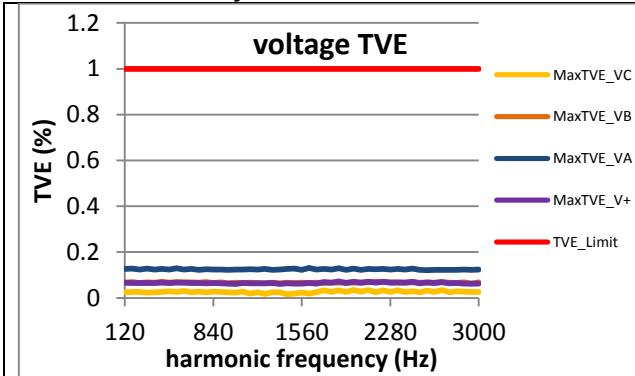


Figure 271:  $F_s = 60$  FPS

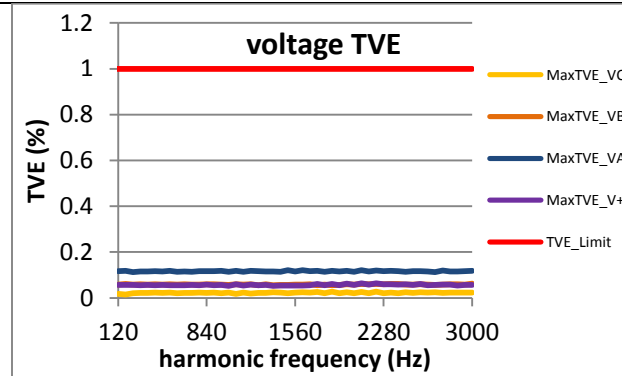


Figure 272:  $F_s = 30$  FPS

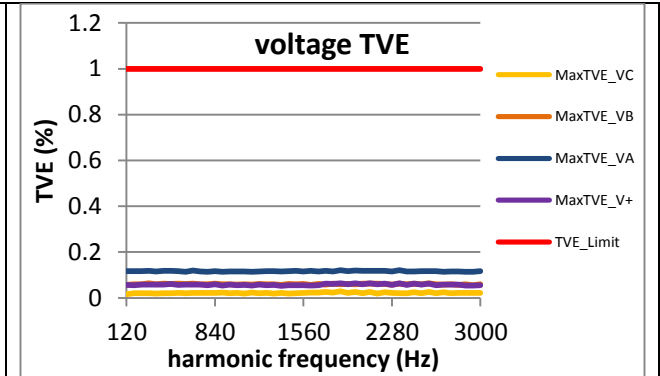


Figure 273:  $F_s = 20$  FPS

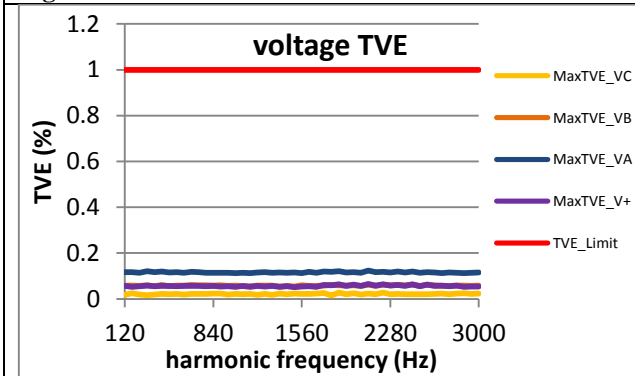


Figure 274:  $F_s = 15$  FPS

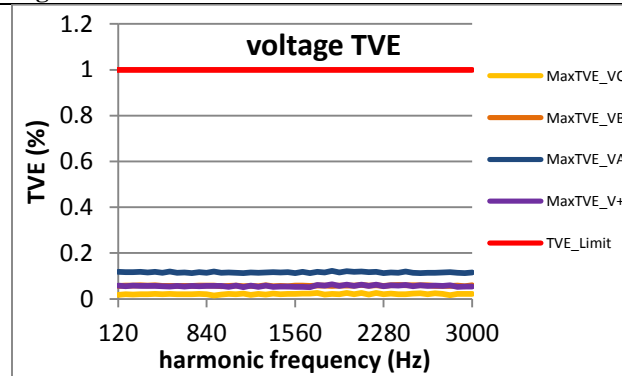
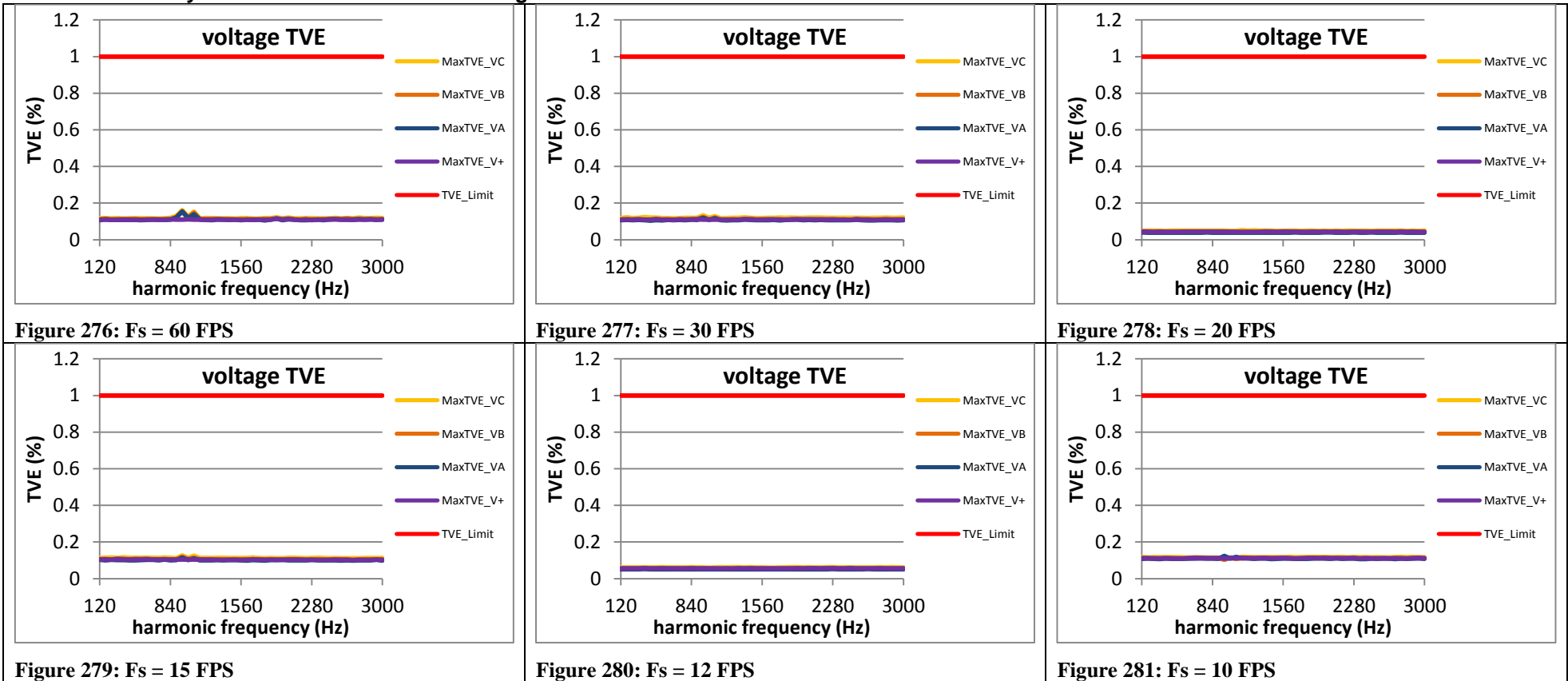
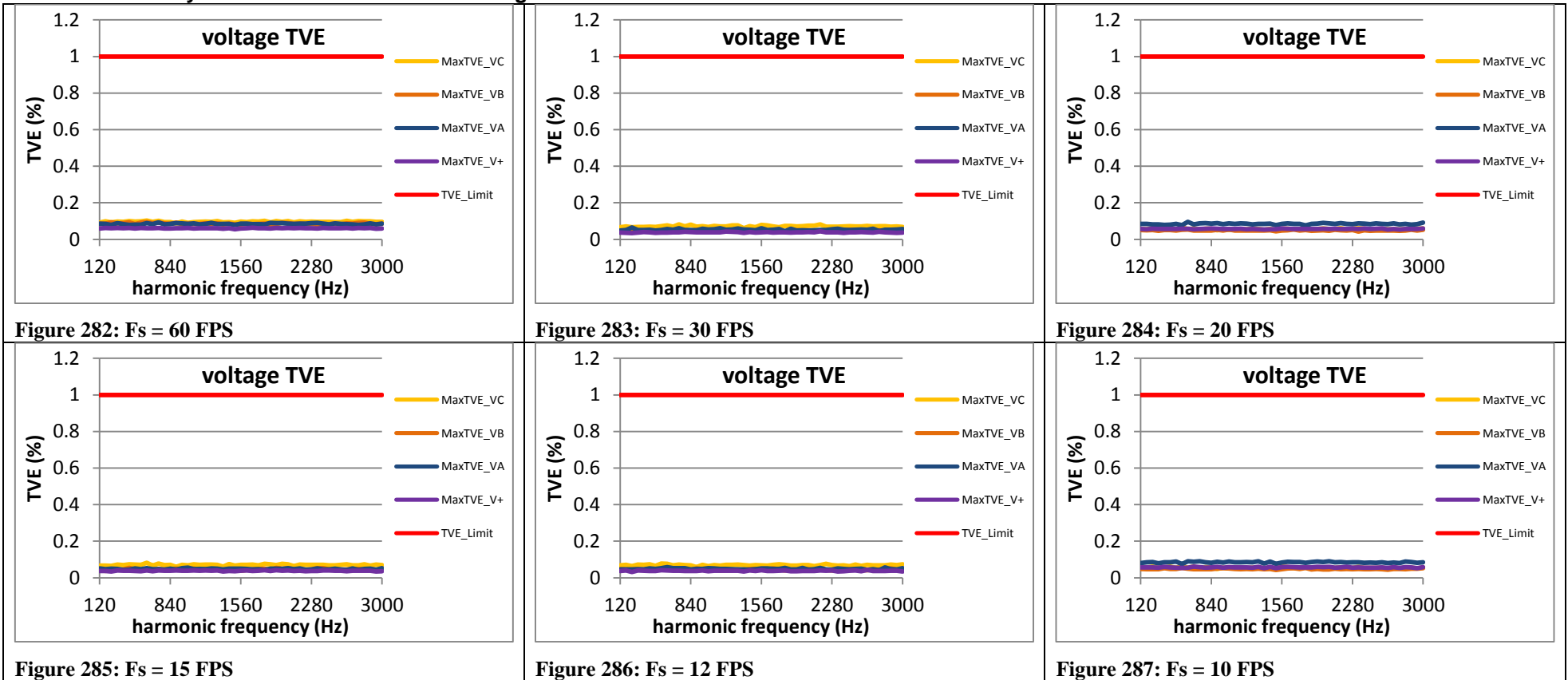


Figure 275:  $F_s = 10$  FPS

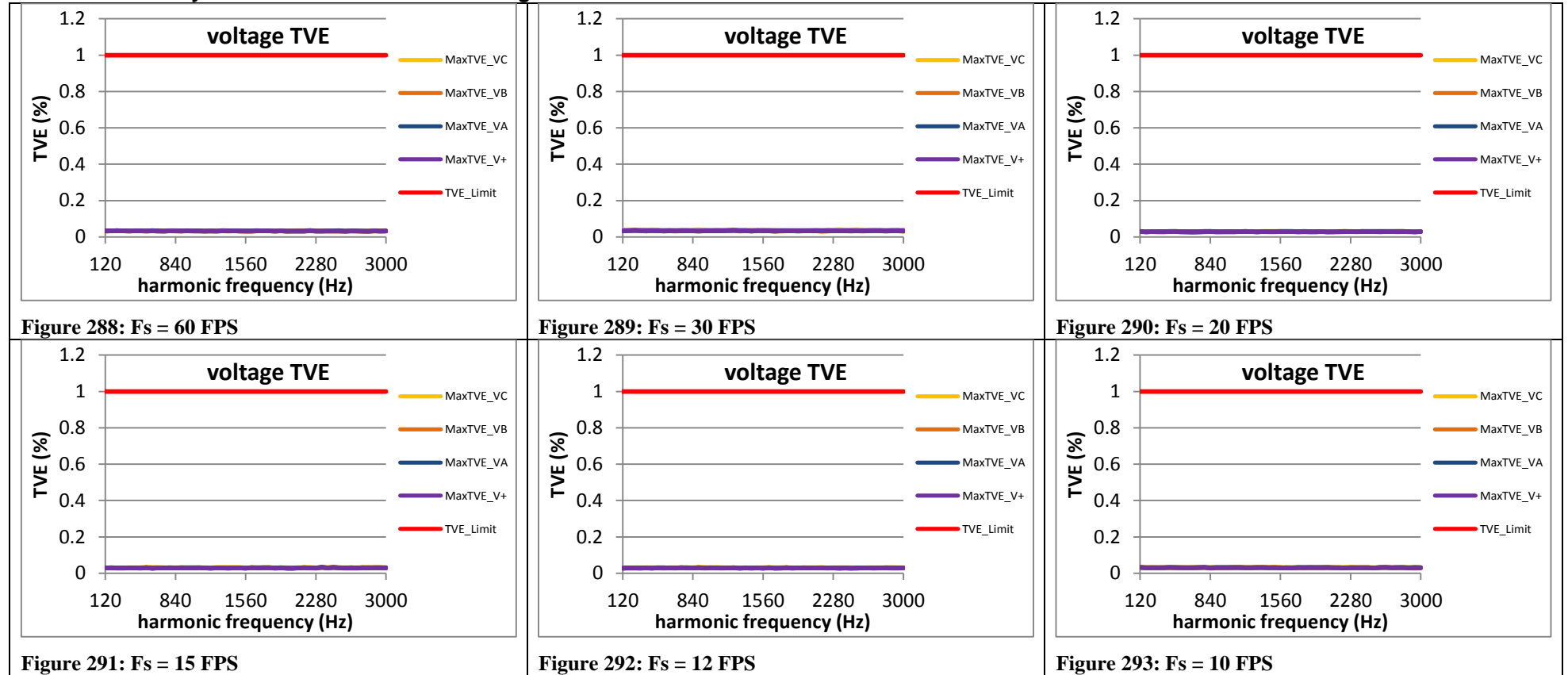
#### 4.5.3 PMU B steady state harmonic distortion voltage TVE: P class



#### 4.5.4 PMU C steady state harmonic distortion voltage TVE: P class



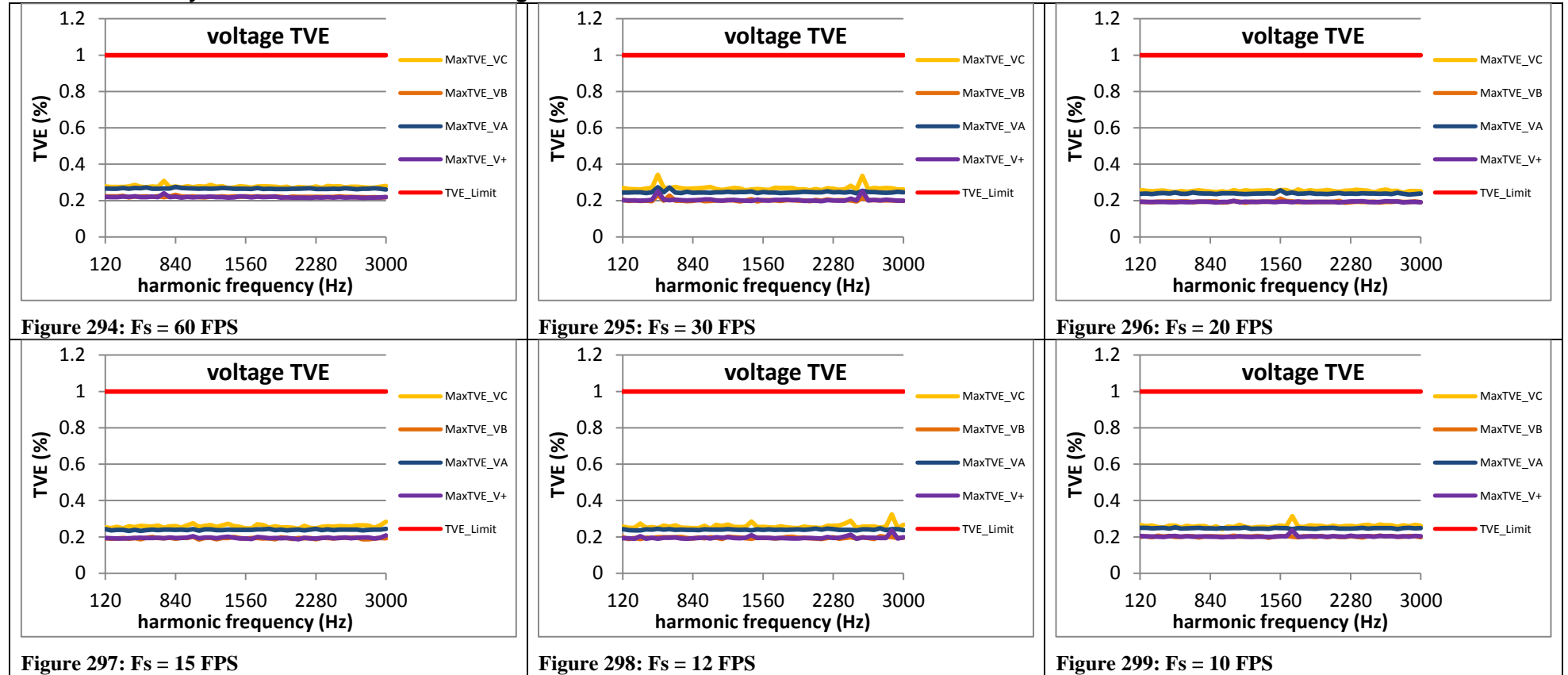
#### 4.5.5 PMU D steady state harmonic distortion voltage TVE: P class



#### 4.5.6 PMU E steady state harmonic distortion voltage TVE: P class

PMU E does not support P Class

#### 4.5.7 PMU F steady state harmonic distortion voltage TVE: P class

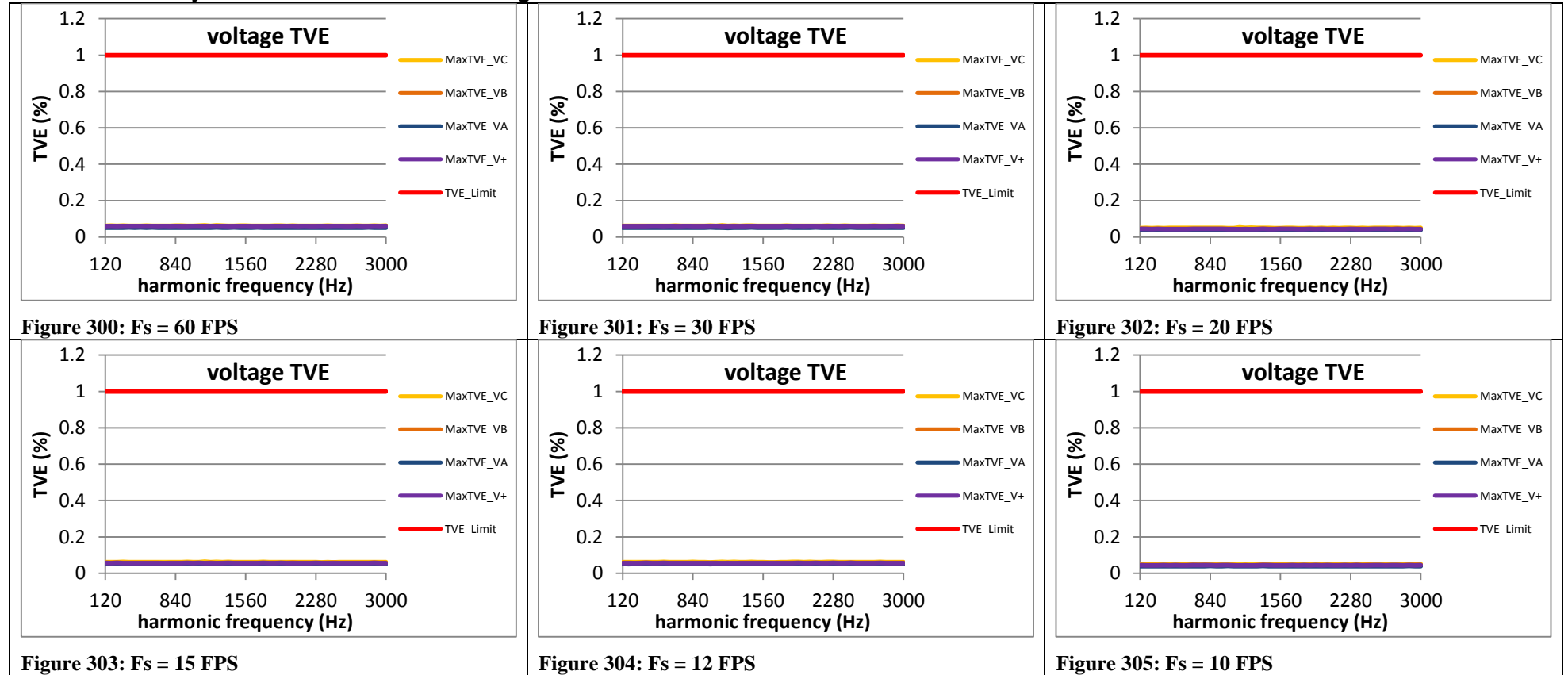


#### 4.5.8 PMU G steady state harmonic distortion voltage TVE: P class

PMU G does not support P class



#### 4.5.9 PMU H steady state harmonic distortion voltage TVE: P class



#### 4.5.10 PMU I steady state harmonic distortion voltage TVE: P class

PMU I does not support P class

#### 4.5.11 PMU J steady state harmonic distortion voltage TVE: P class

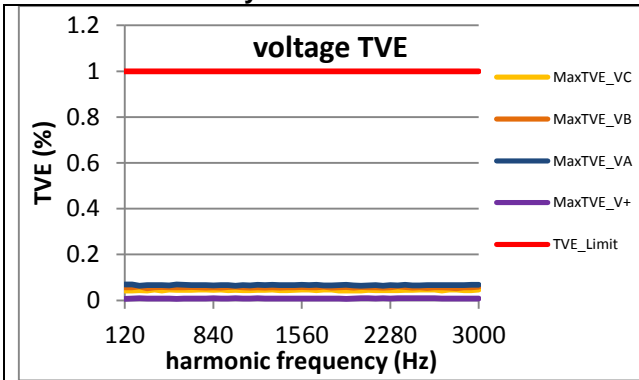


Figure 306:  $F_s = 60$  FPS

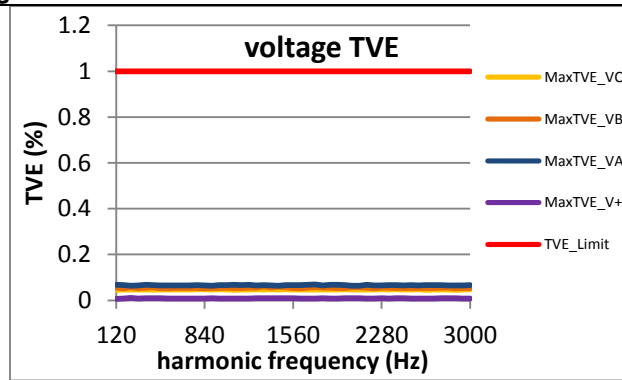


Figure 307:  $F_s = 30$  FPS

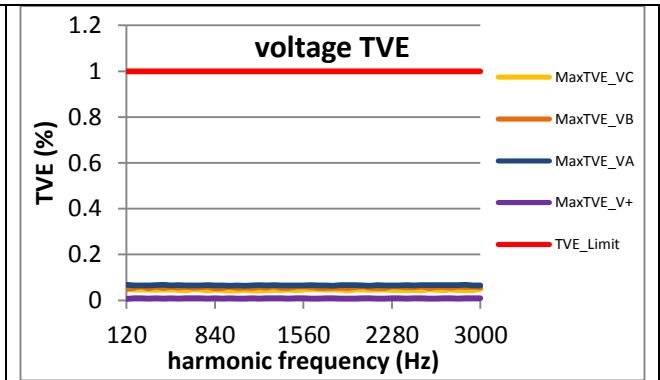


Figure 308:  $F_s = 20$  FPS

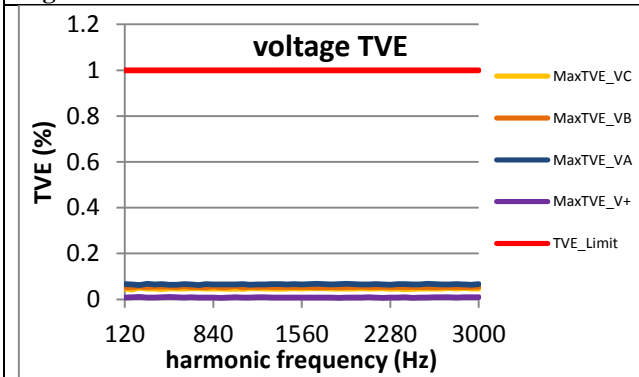


Figure 309:  $F_s = 15$  FPS

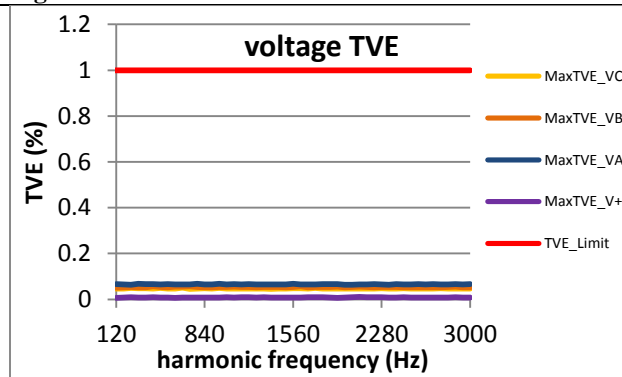


Figure 310:  $F_s = 12$  FPS

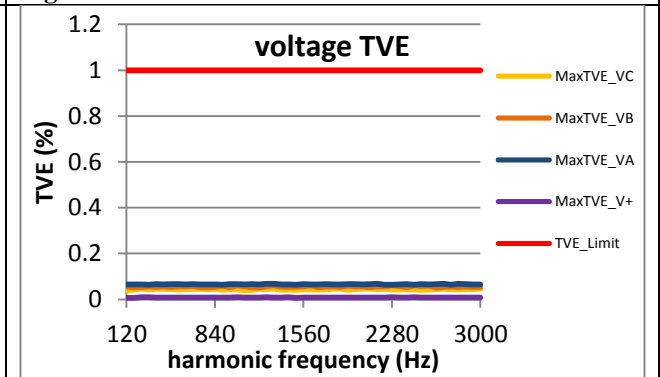
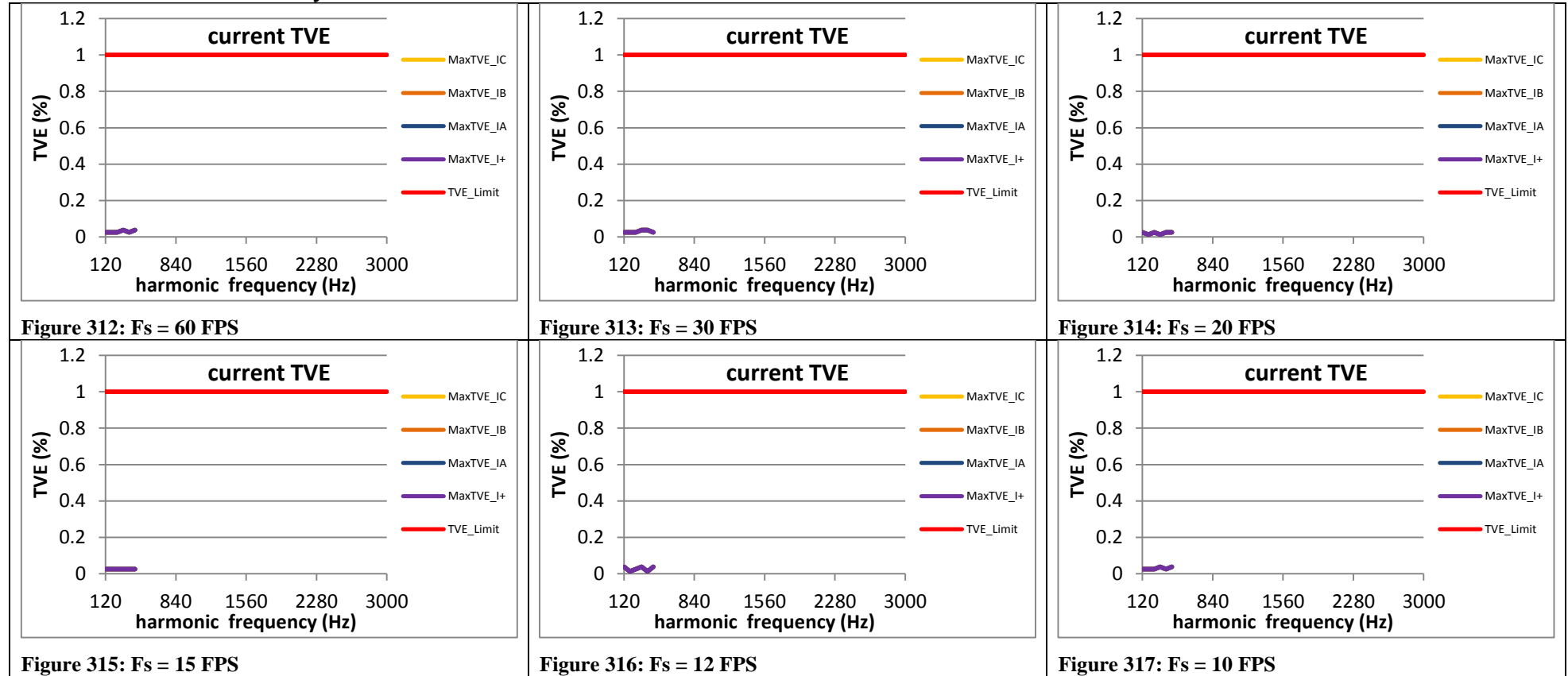


Figure 311:  $F_s = 10$  FPS

## 4.6 Steady state harmonic distortion current TVE: P class

### 4.6.1 C37.118.1 Annex C steady state harmonic distortion current TVE: P class



#### 4.6.2 PMU A steady state harmonic distortion current TVE: P class

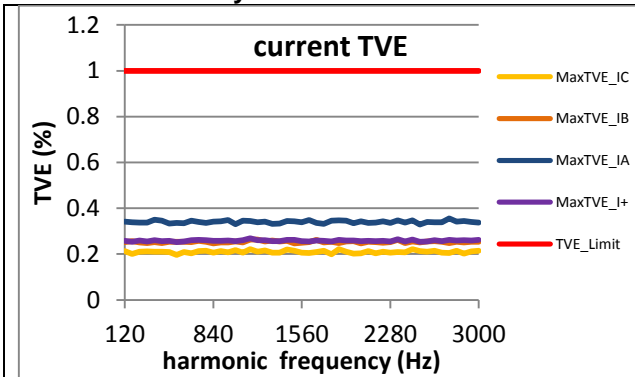


Figure 318:  $F_s = 60$  FPS

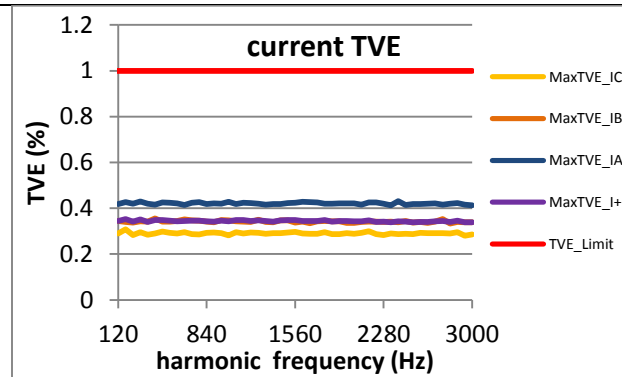


Figure 319:  $F_s = 30$  FPS

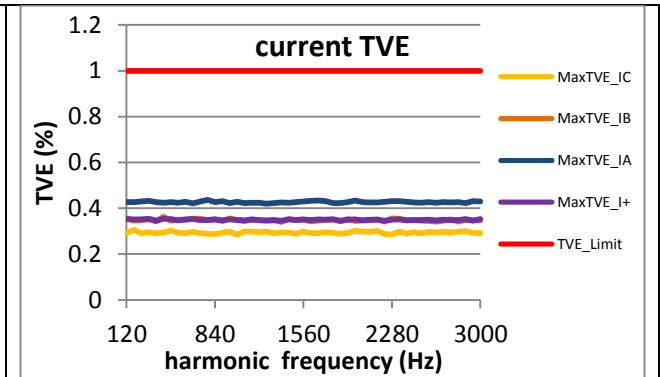


Figure 320:  $F_s = 20$  FPS

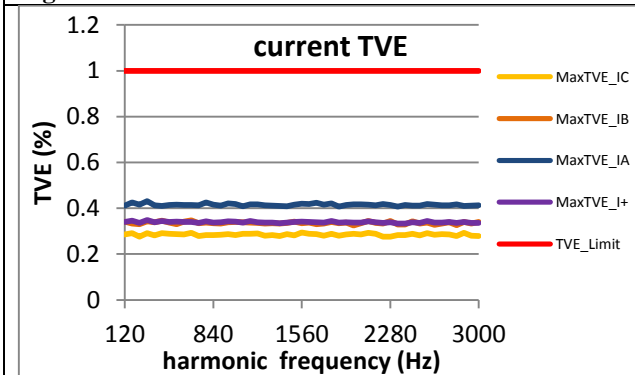


Figure 321:  $F_s = 15$  FPS

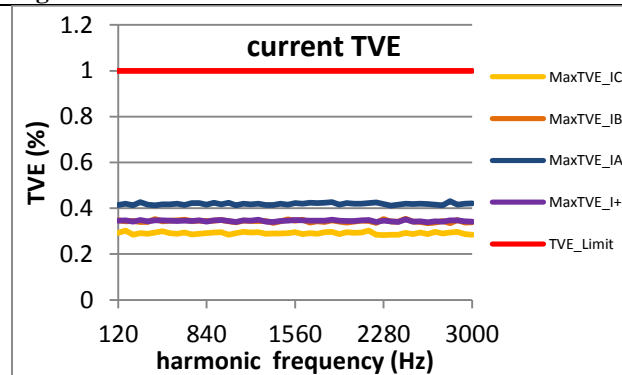
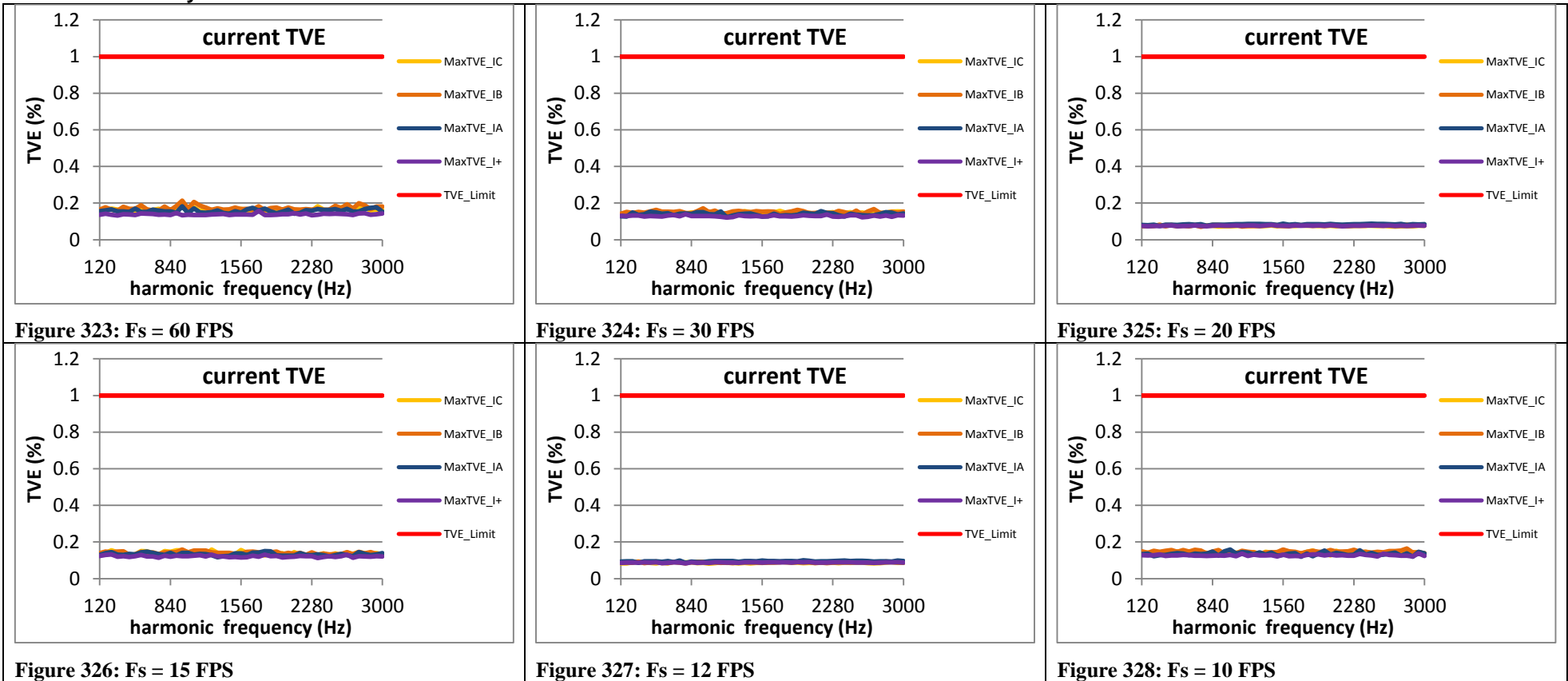
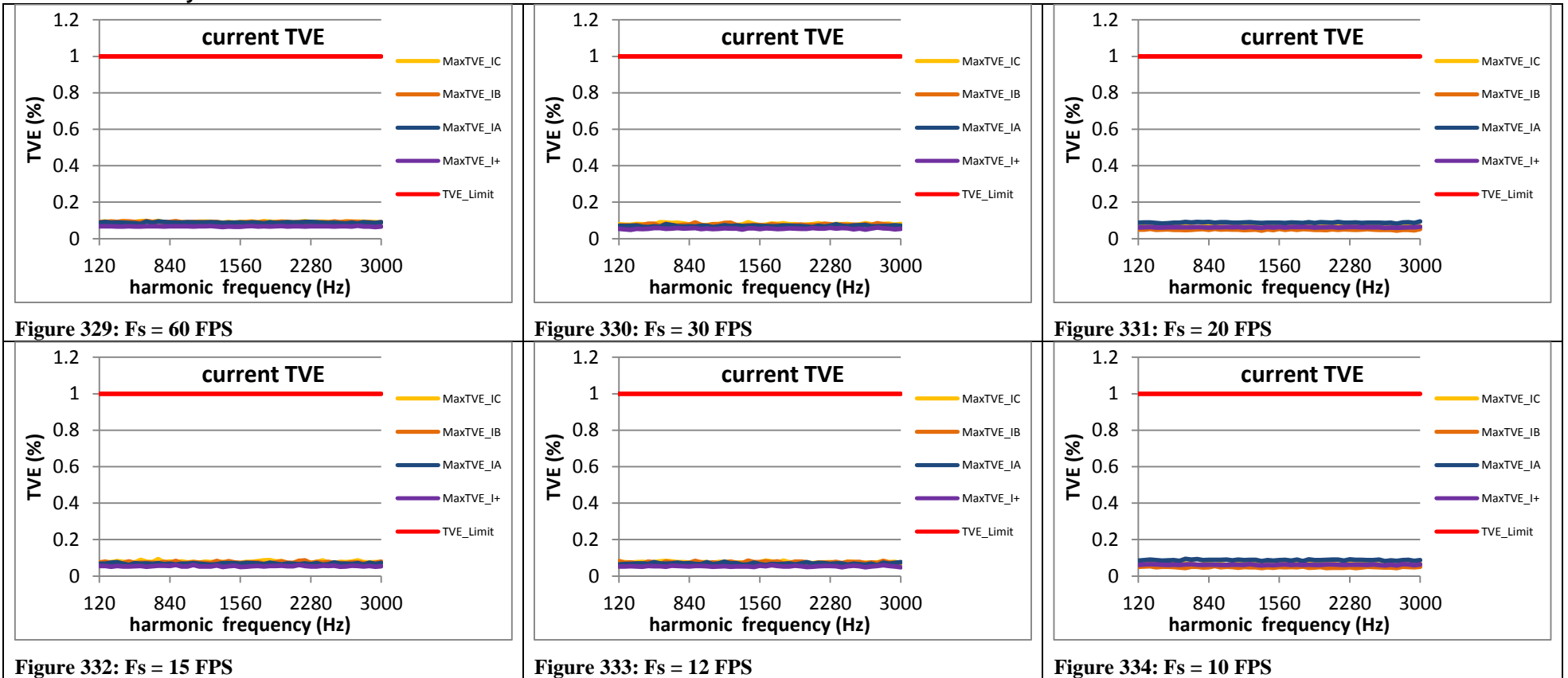


Figure 322:  $F_s = 10$  FPS

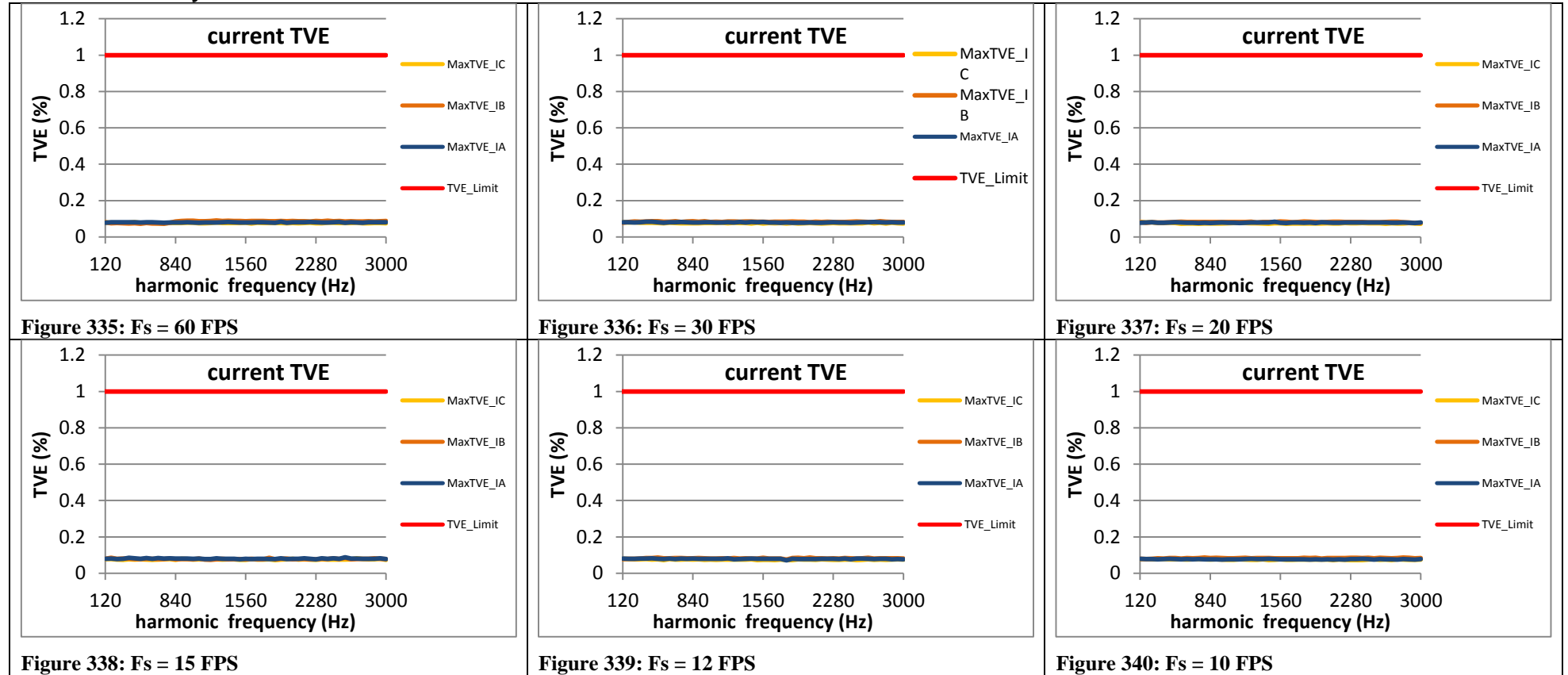
#### 4.6.3 PMU B steady state harmonic distortion current TVE: P class



#### 4.6.4 PMU C steady state harmonic distortion current TVE: P class



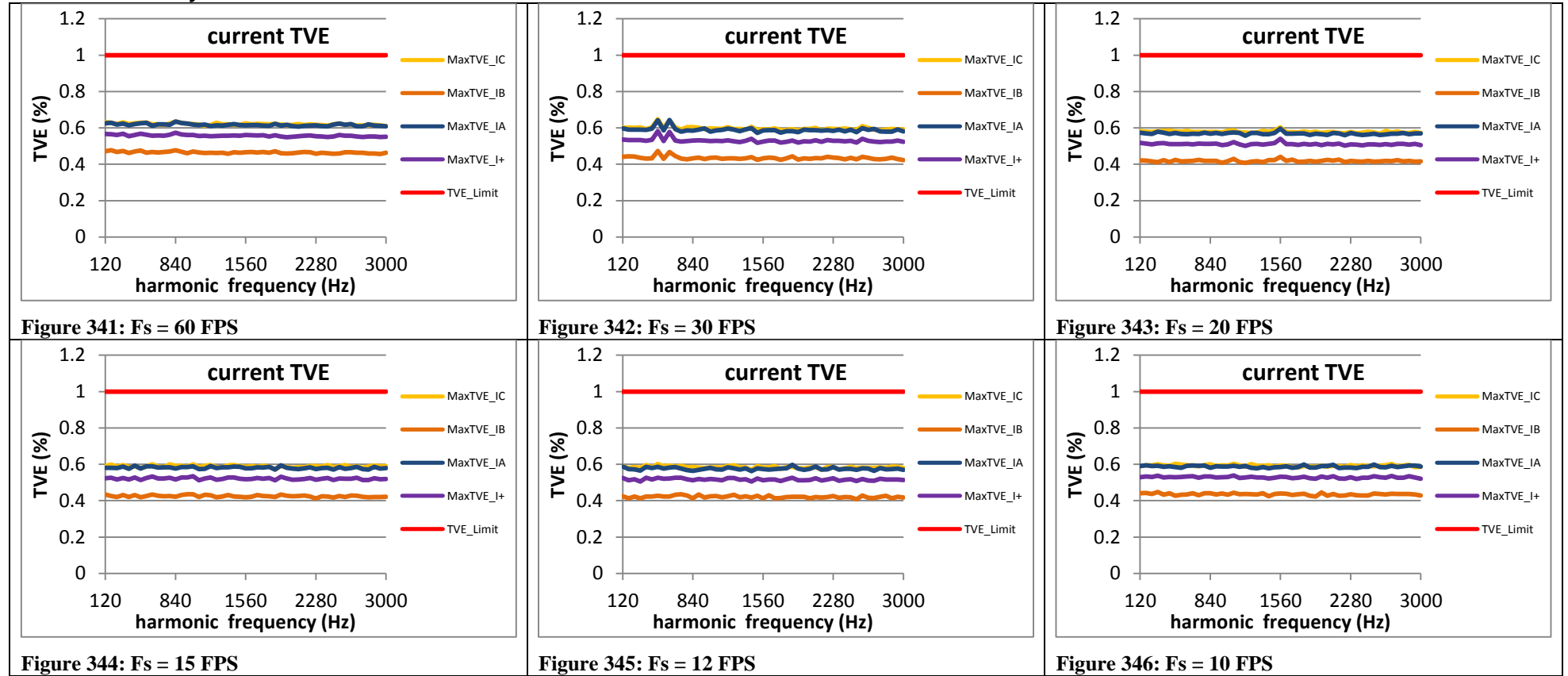
#### 4.6.5 PMU D steady state harmonic distortion current TVE: P class



#### 4.6.6 PMU E steady state harmonic distortion current TVE: P class

PMU E does not support P class

#### 4.6.7 PMU F steady state harmonic distortion current TVE: P class

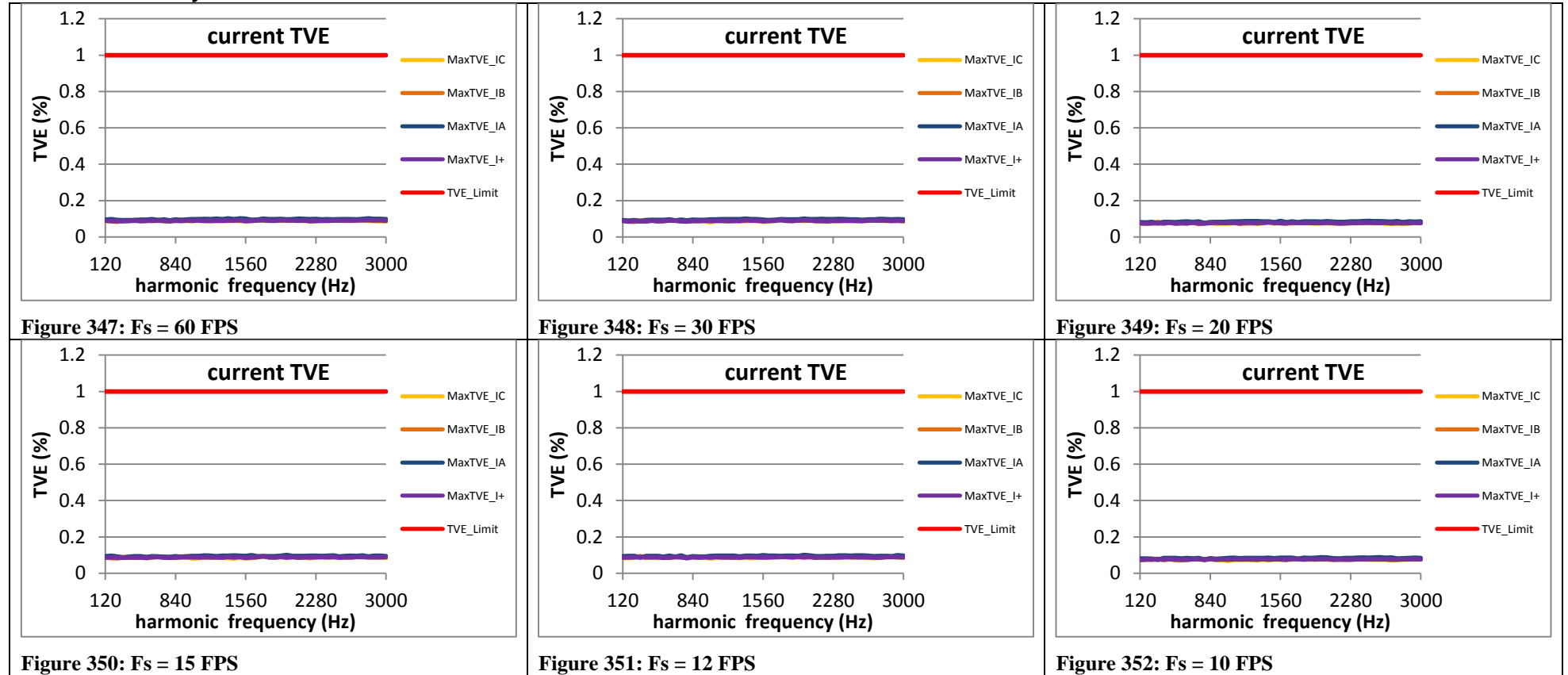


#### 4.6.8 PMU G steady state harmonic distortion current TVE: P class

PMU G does not support P class



#### 4.6.9 PMU H steady state harmonic distortion current TVE: P class



#### 4.6.10 PMU I steady state harmonic distortion current TVE: P class

PMU I does not support P class

#### 4.6.11 PMU J steady state harmonic distortion current TVE: P class

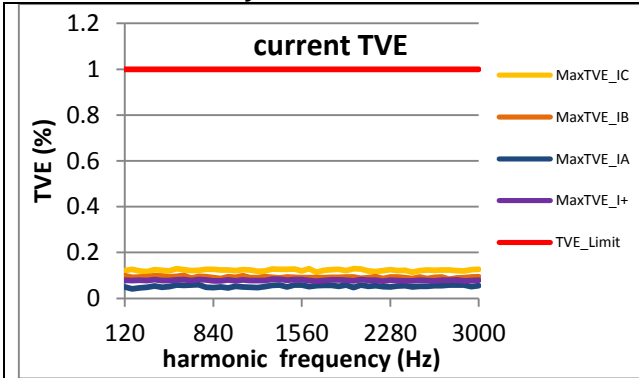


Figure 353:  $F_s = 60$  FPS

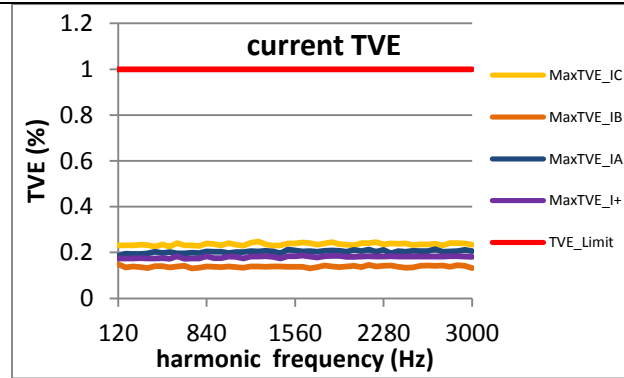


Figure 354:  $F_s = 30$  FPS

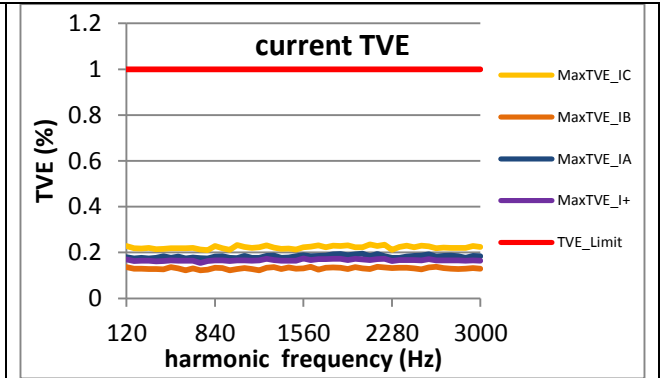


Figure 355:  $F_s = 20$  FPS

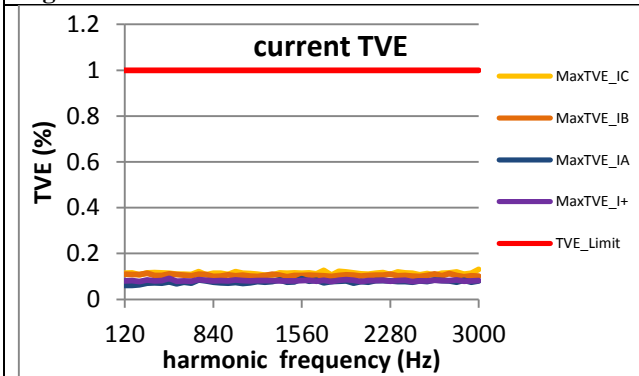


Figure 356:  $F_s = 15$  FPS

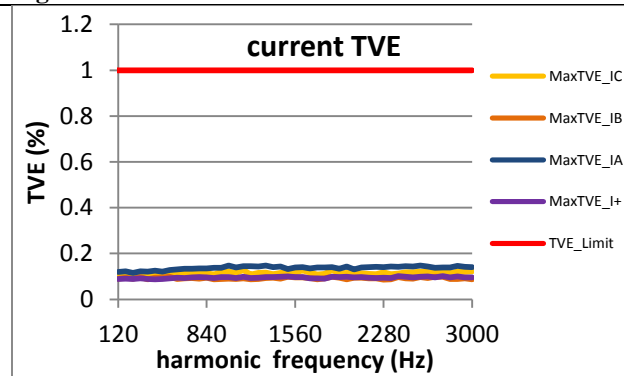


Figure 357:  $F_s = 12$  FPS

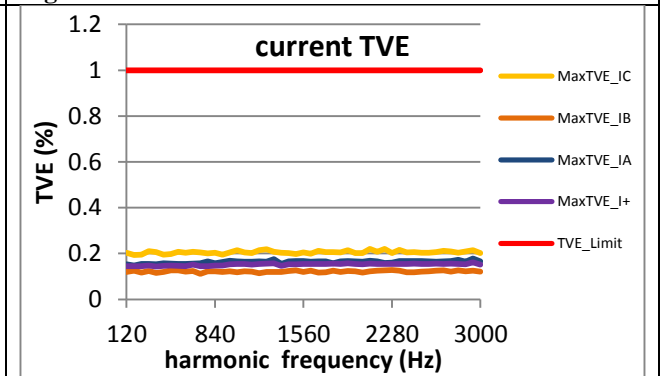
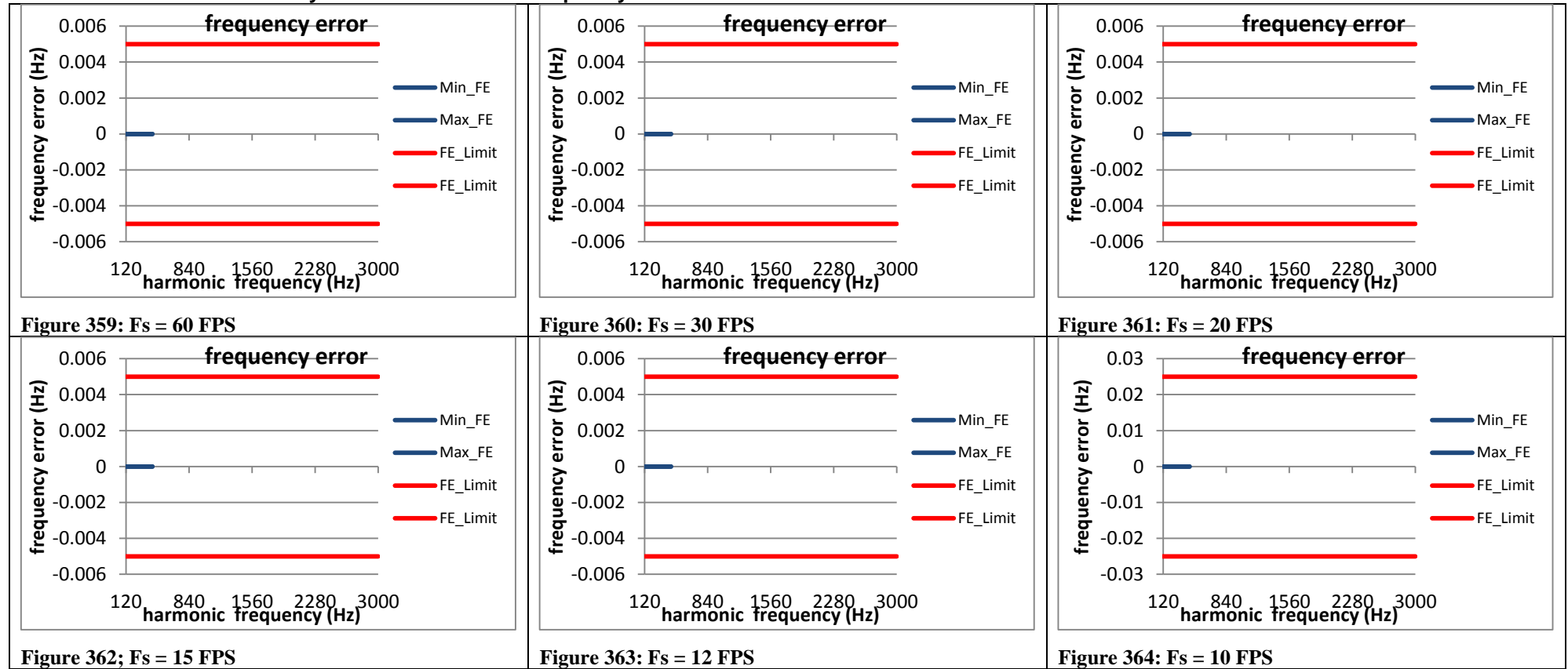


Figure 358:  $F_s = 10$  FPS

## 4.7 Steady state frequency harmonic distortion frequency error: P class

### 4.7.1 C37.118.1 Annex C steady harmonic distortion frequency error: P class



The C37.118.1 Annex C model is a digital simulation with an internal sampling rate of 960 samples per second and so can only be tested with a harmonic frequency up to 420 Hz.

#### 4.7.2 PMU A steady state harmonic distortion frequency error: P class

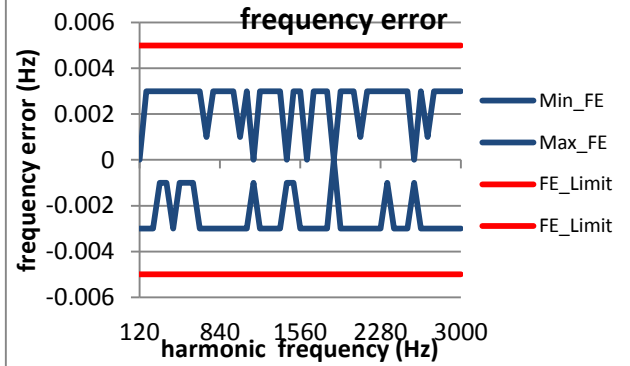


Figure 365:  $F_s = 60$  FPS

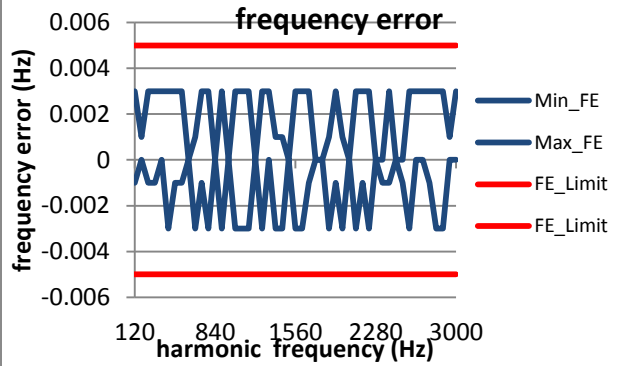


Figure 366:  $F_s = 30$  FPS

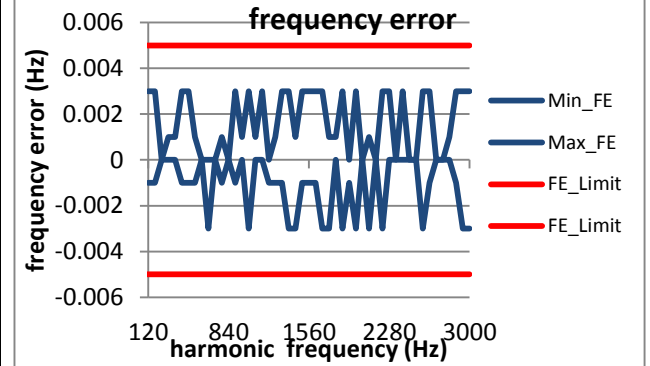


Figure 367:  $F_s = 20$  FPS

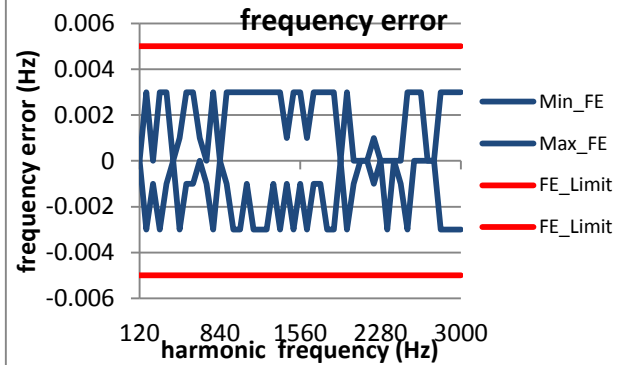


Figure 368:  $F_s = 15$  FPS

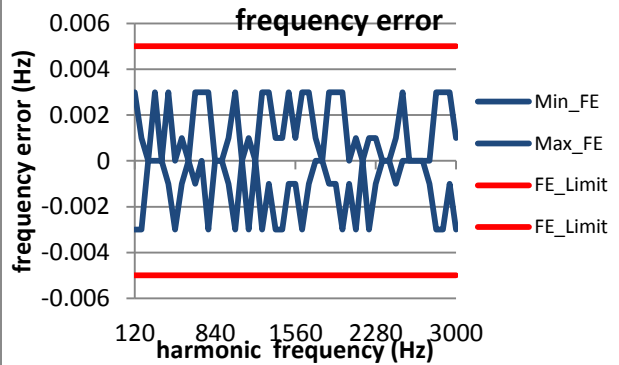


Figure 369:  $F_s = 10$  FPS

#### 4.7.3 PMU B steady state harmonic distortion frequency error: P class

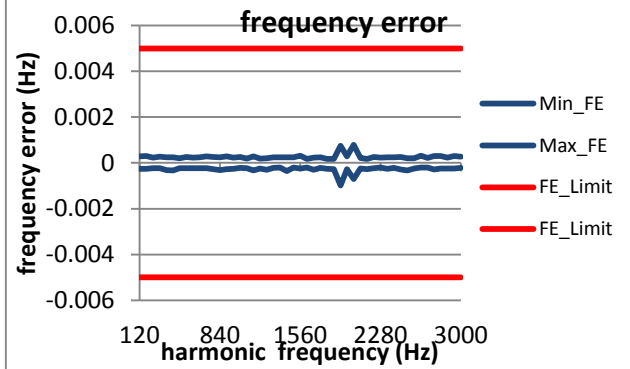


Figure 370:  $F_s = 60$  FPS

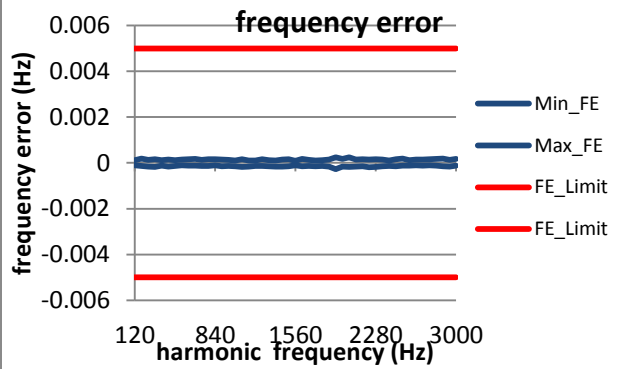


Figure 371:  $F_s = 30$  FPS

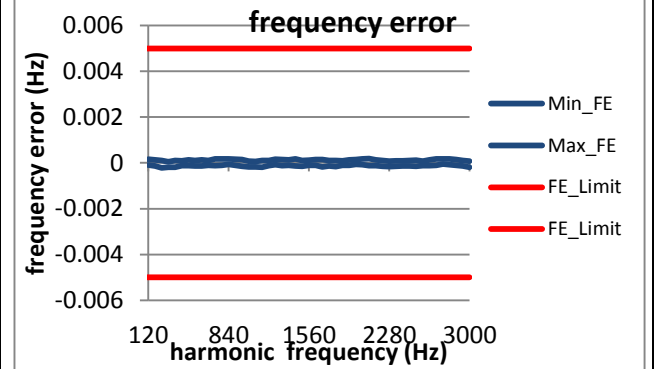


Figure 372:  $F_s = 20$  FPS

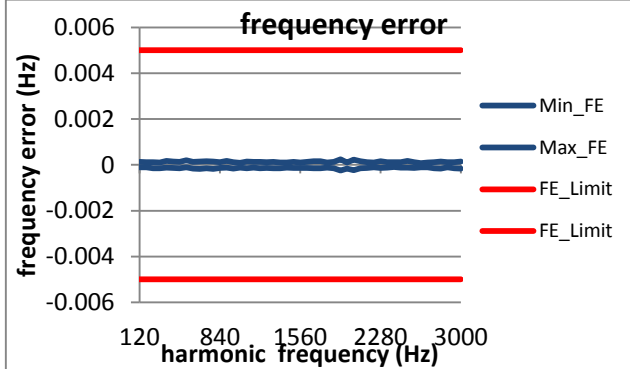


Figure 373:  $F_s = 15$  FPS

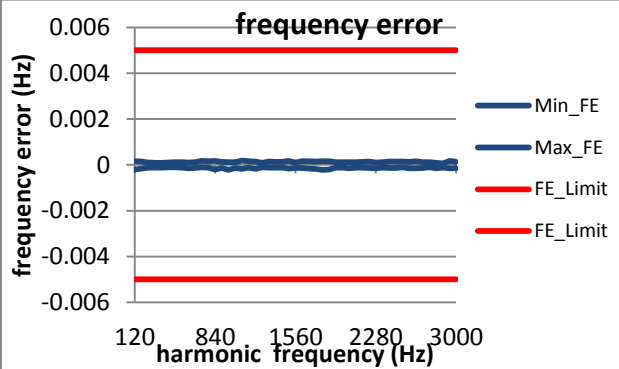


Figure 374:  $F_s = 12$  FPS

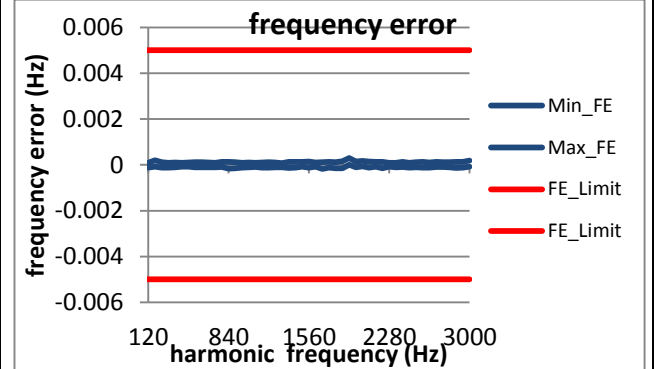
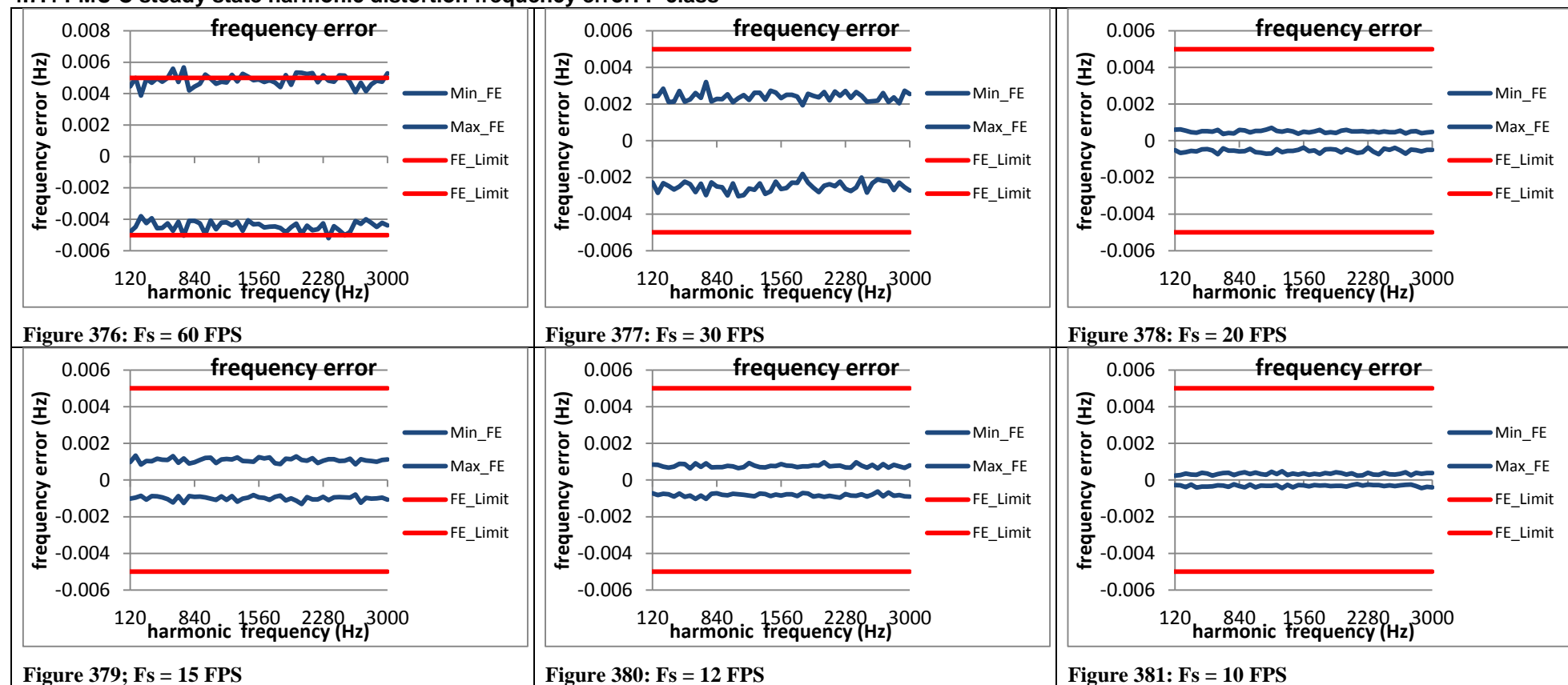
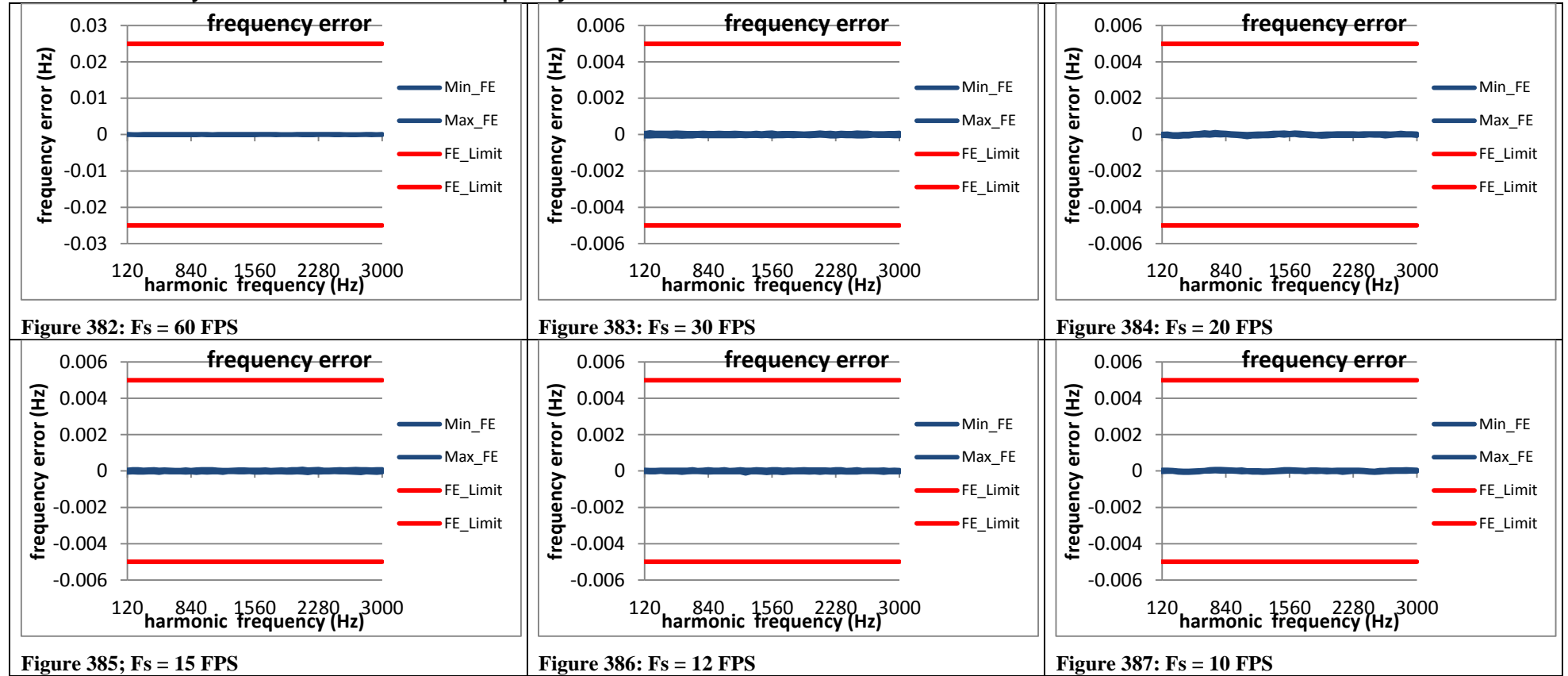


Figure 375:  $F_s = 10$  FPS

#### 4.7.4 PMU C steady state harmonic distortion frequency error: P class



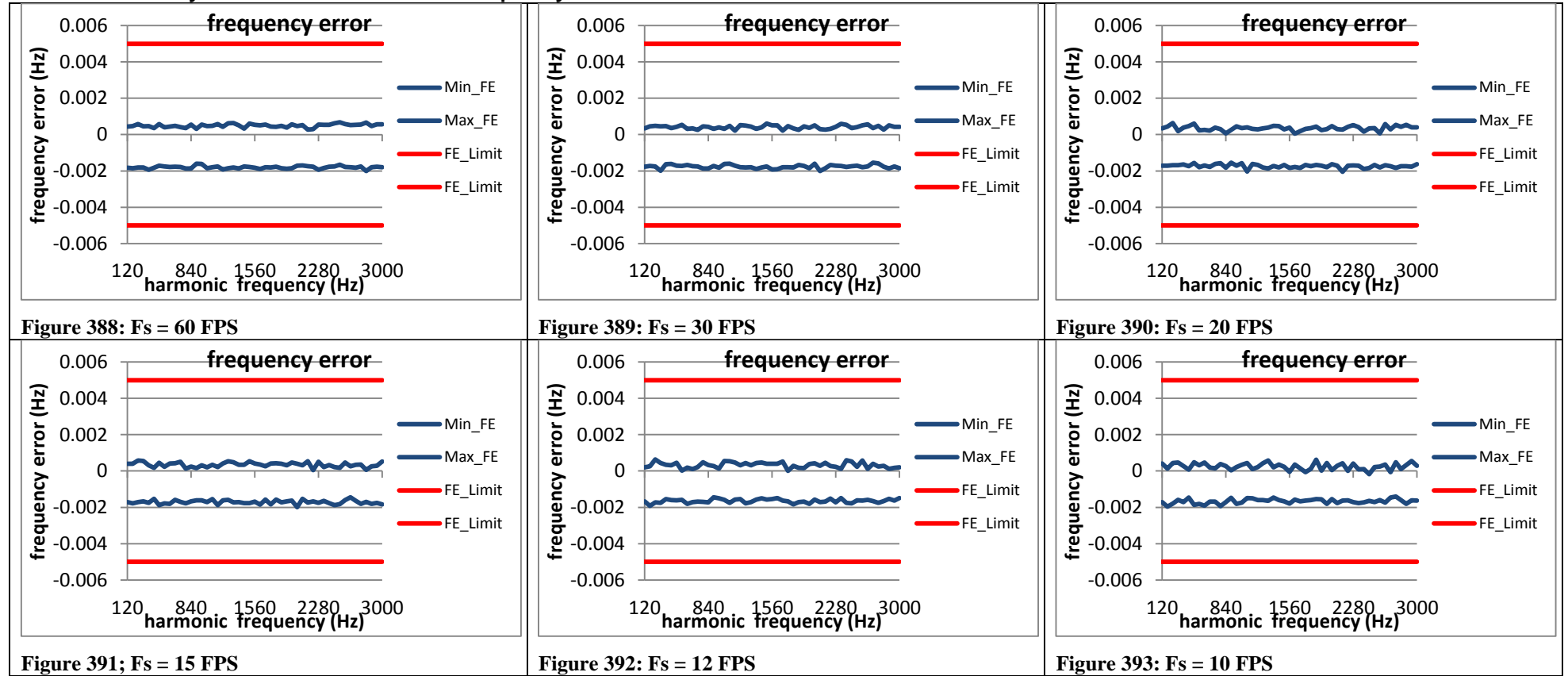
#### 4.7.5 PMU D steady state harmonic distortion frequency error: P class



#### 4.7.6 PMU E steady state harmonic distortion frequency error: P class

PMU E does not support P class

#### 4.7.7 PMU F steady state harmonic distortion frequency error: P class

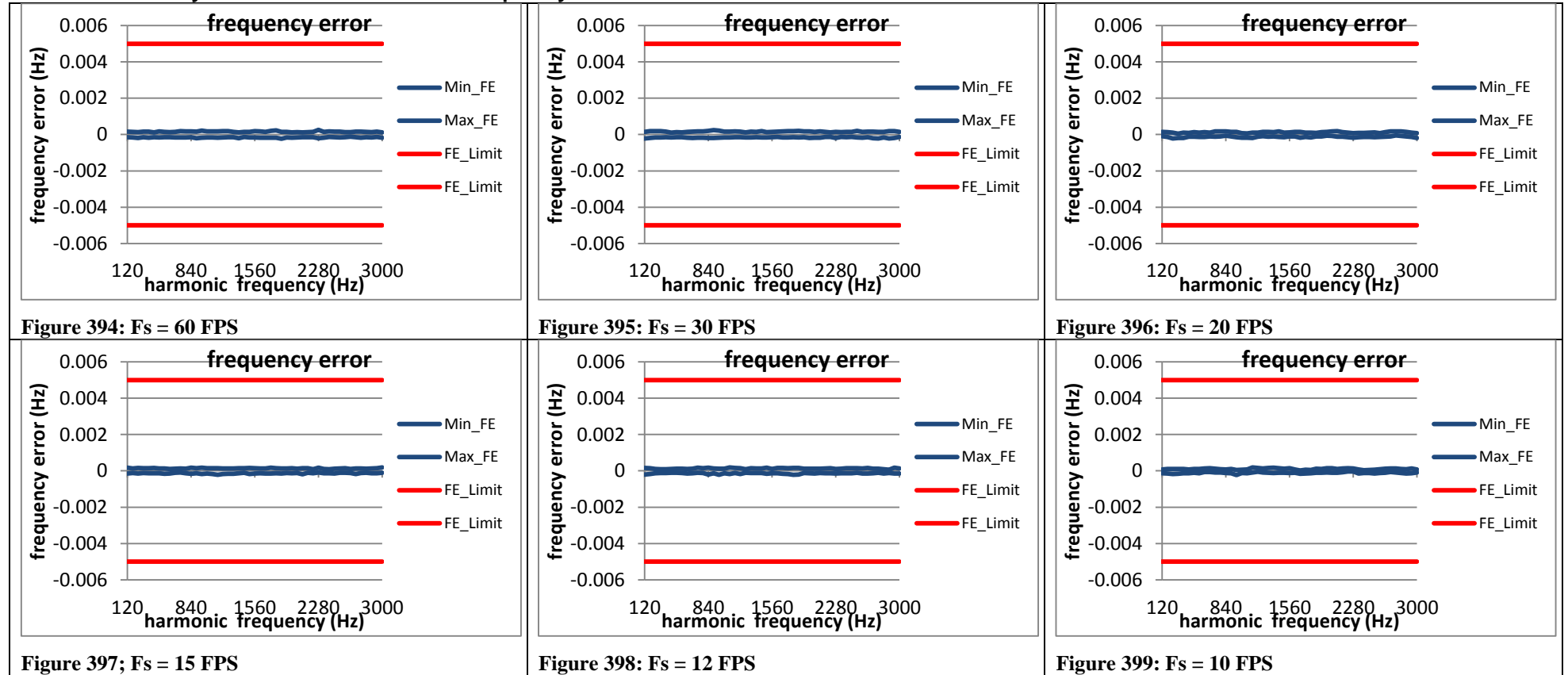


#### 4.7.8 PMU G steady state harmonic distortion frequency error: P class

PMU G does not support P class



#### 4.7.9 PMU H steady state harmonic distortion frequency error: P class



#### 4.7.10 PMU I steady state harmonic distortion frequency error: P class

PMU I does not support P class

#### 4.7.11 PMU J steady state harmonic distortion frequency error: P class

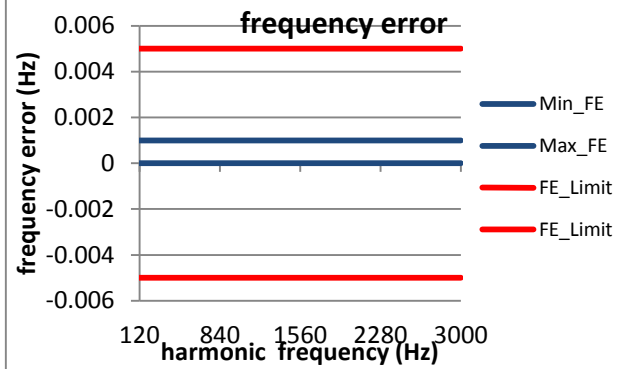


Figure 400:  $F_s = 60$  FPS

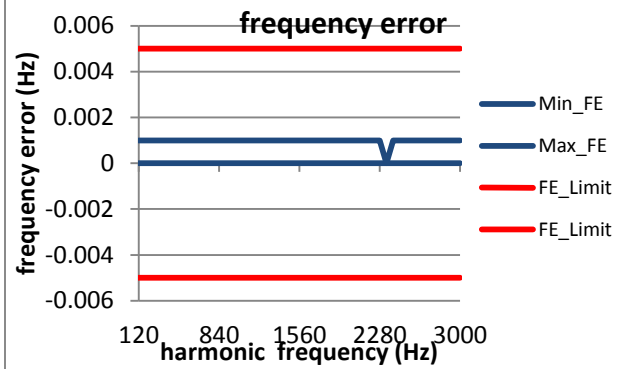


Figure 401:  $F_s = 30$  FPS

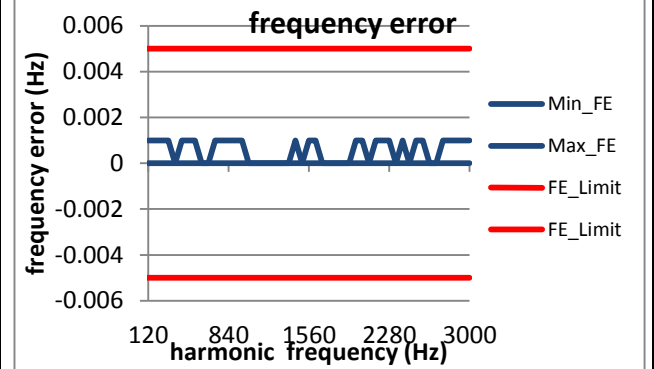


Figure 402:  $F_s = 20$  FPS

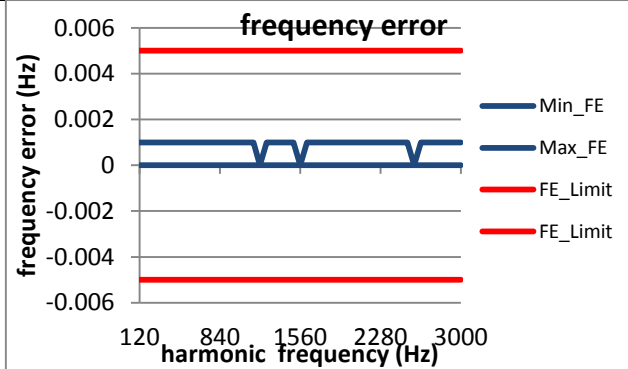


Figure 403:  $F_s = 15$  FPS

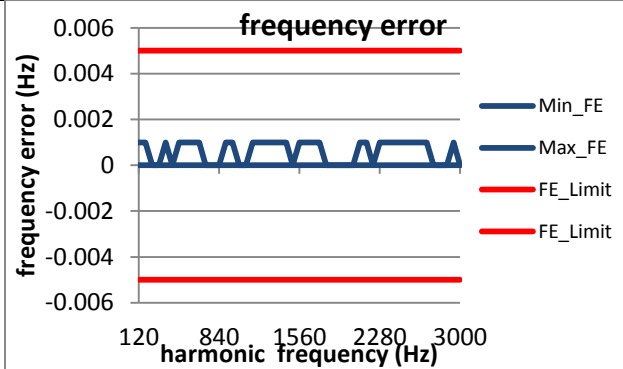


Figure 404:  $F_s = 12$  FPS

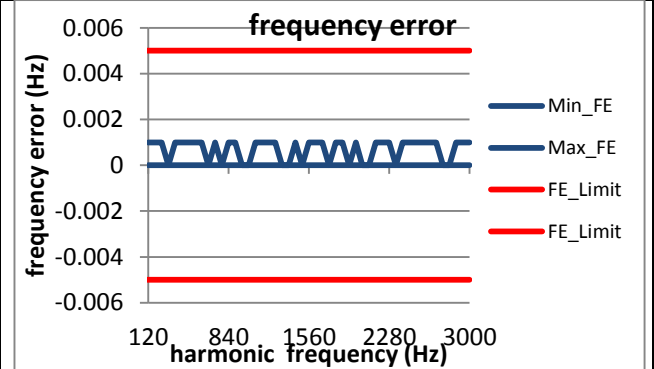
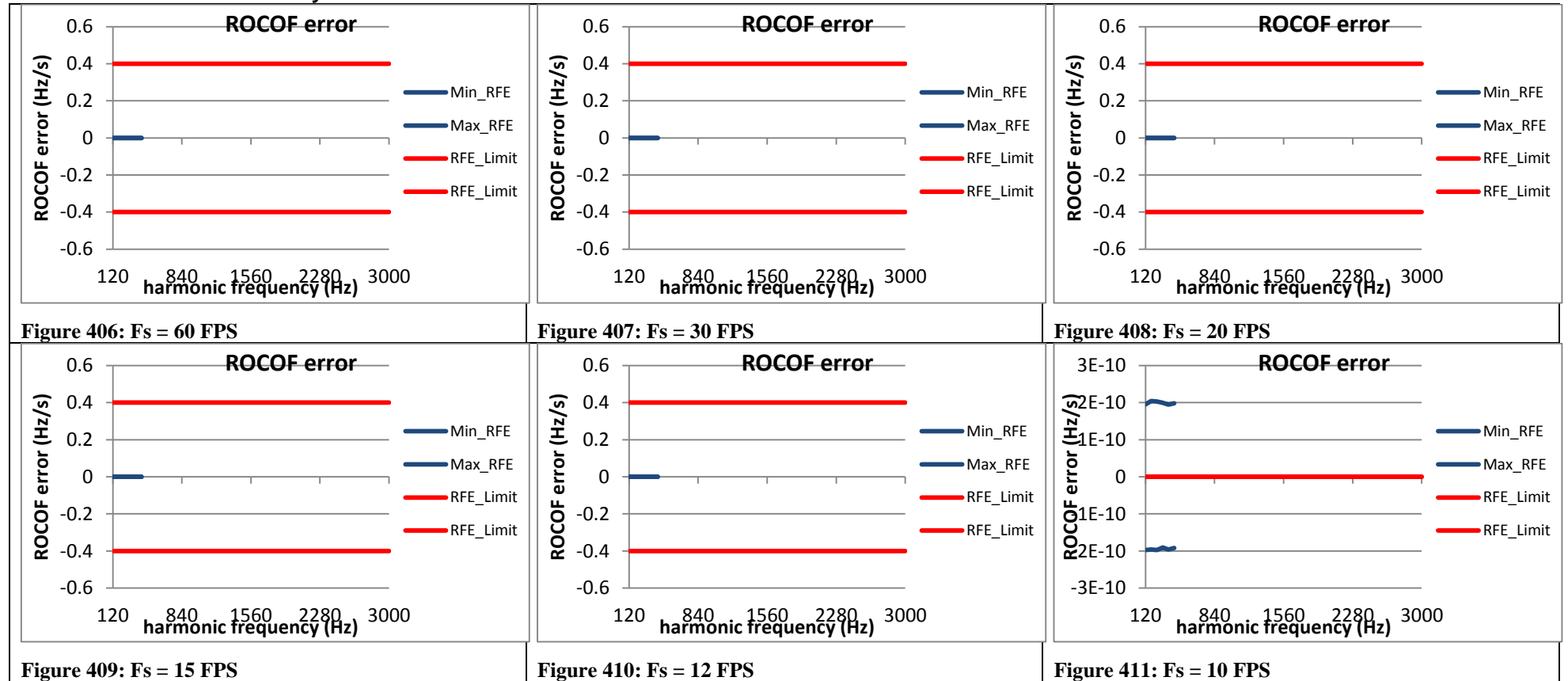


Figure 405:  $F_s = 10$  FPS

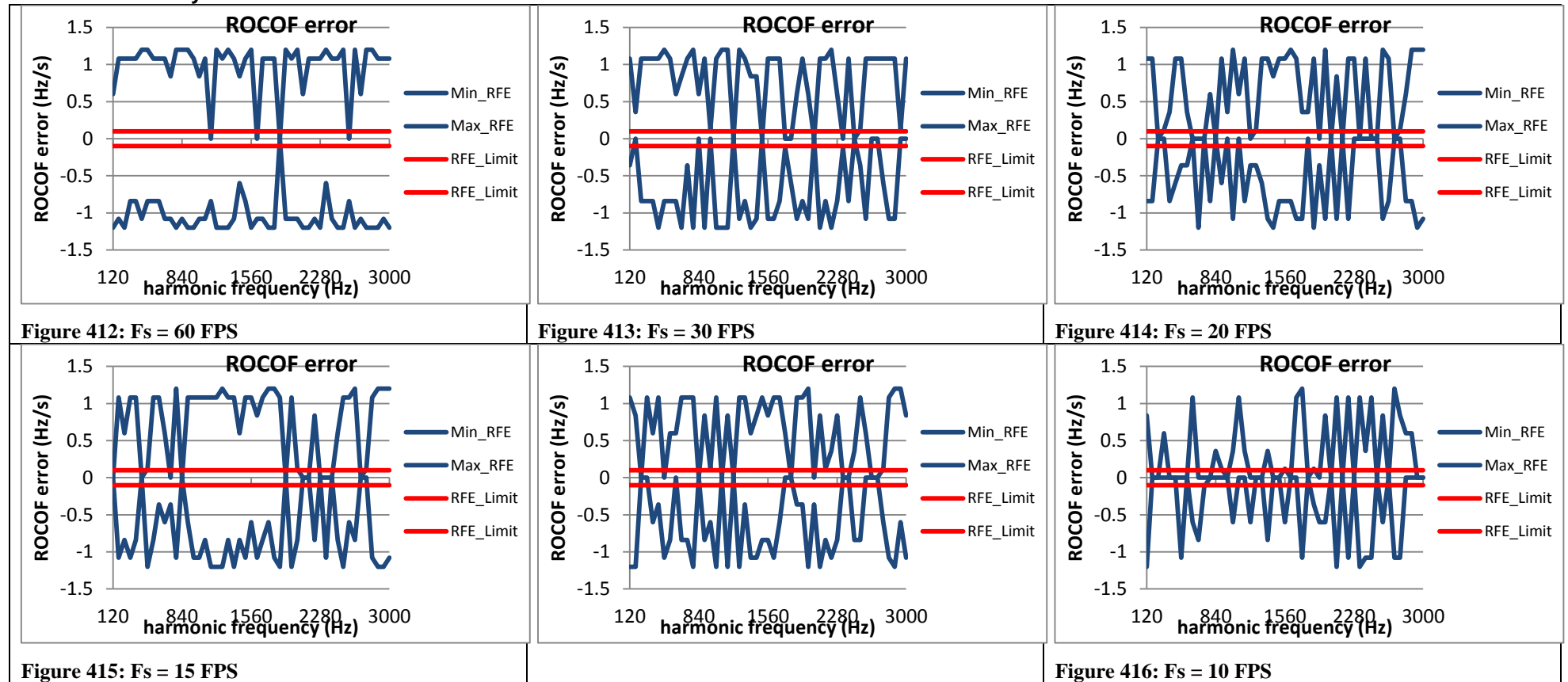
## 4.8 Steady state harmonic distortion ROCOF error: P class

### 4.8.1 C37.118.1 Annex C steady harmonic distortion ROCOF error: P class

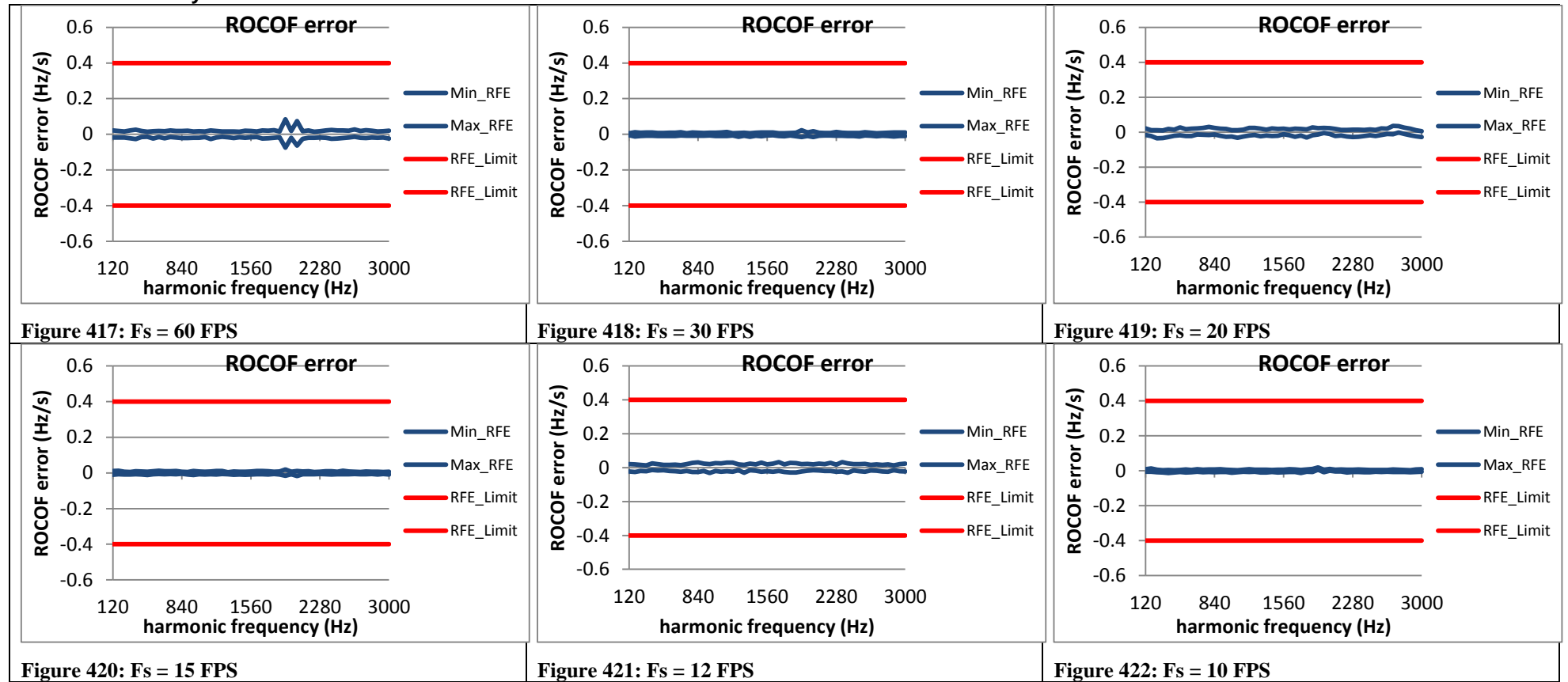


The C37.118.1 Annex C model is a digital simulation with an internal sampling rate of 960 samples per second and so can only be tested with a harmonic frequency up to 420 Hz.

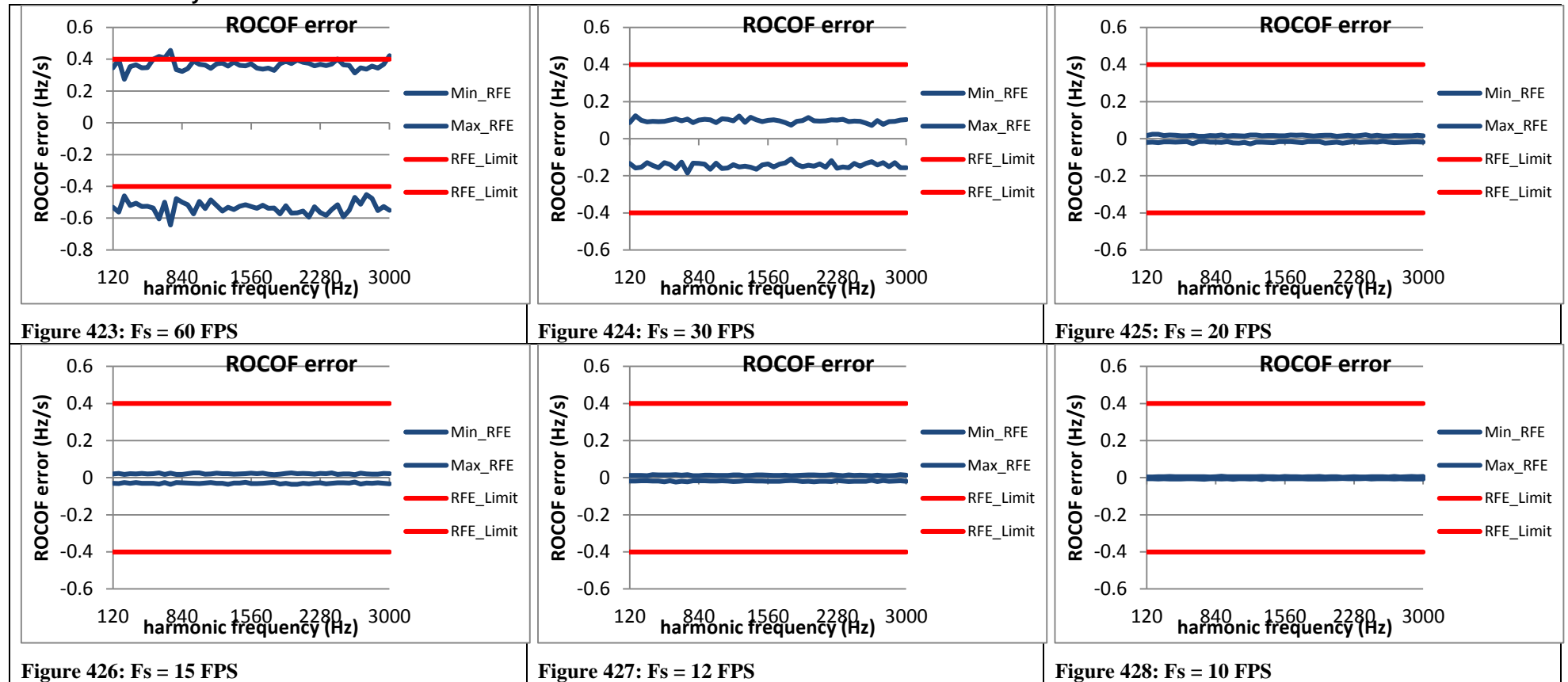
#### 4.8.2 PMU A steady state harmonic distortion ROCOF error: P class



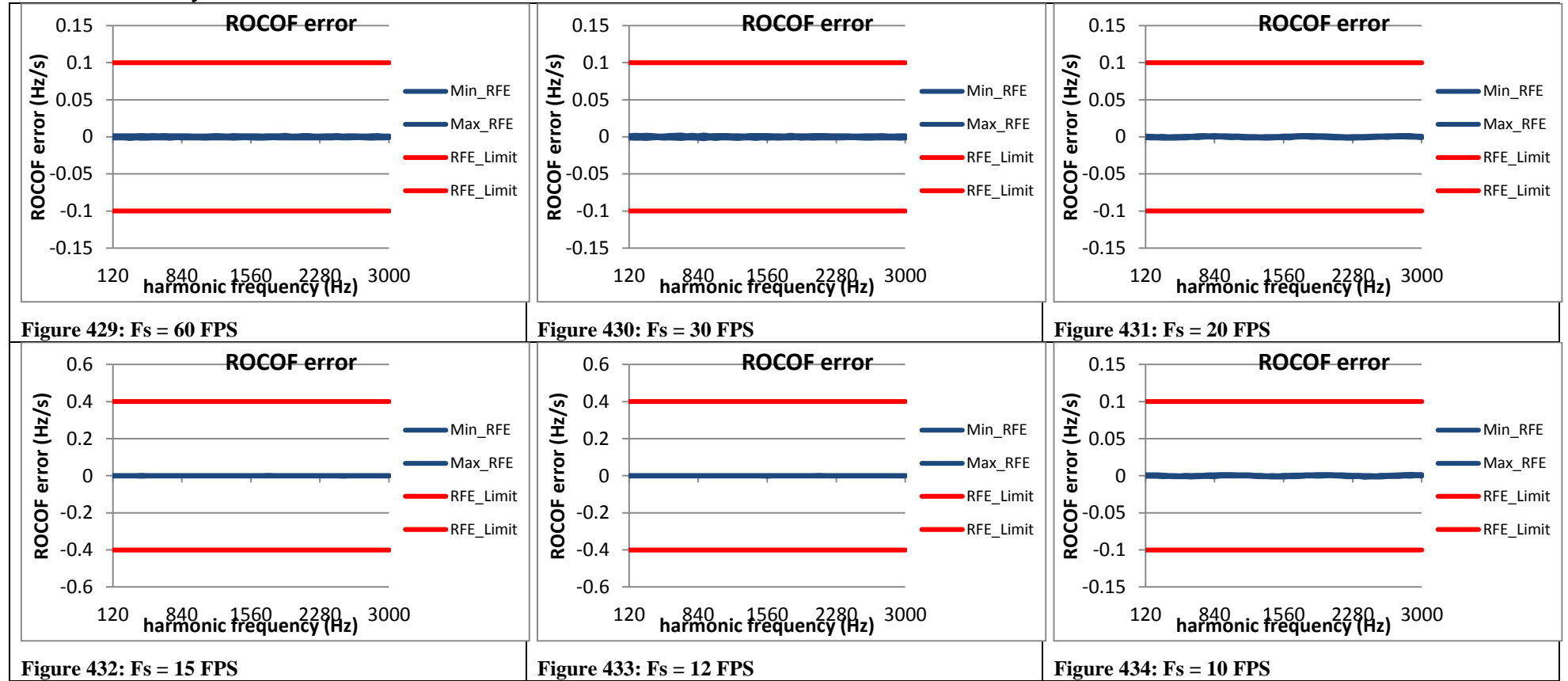
#### 4.8.3 PMU B steady state harmonic distortion ROCOF error: P class



#### 4.8.4 PMU C steady state harmonic distortion ROCOF error: P class



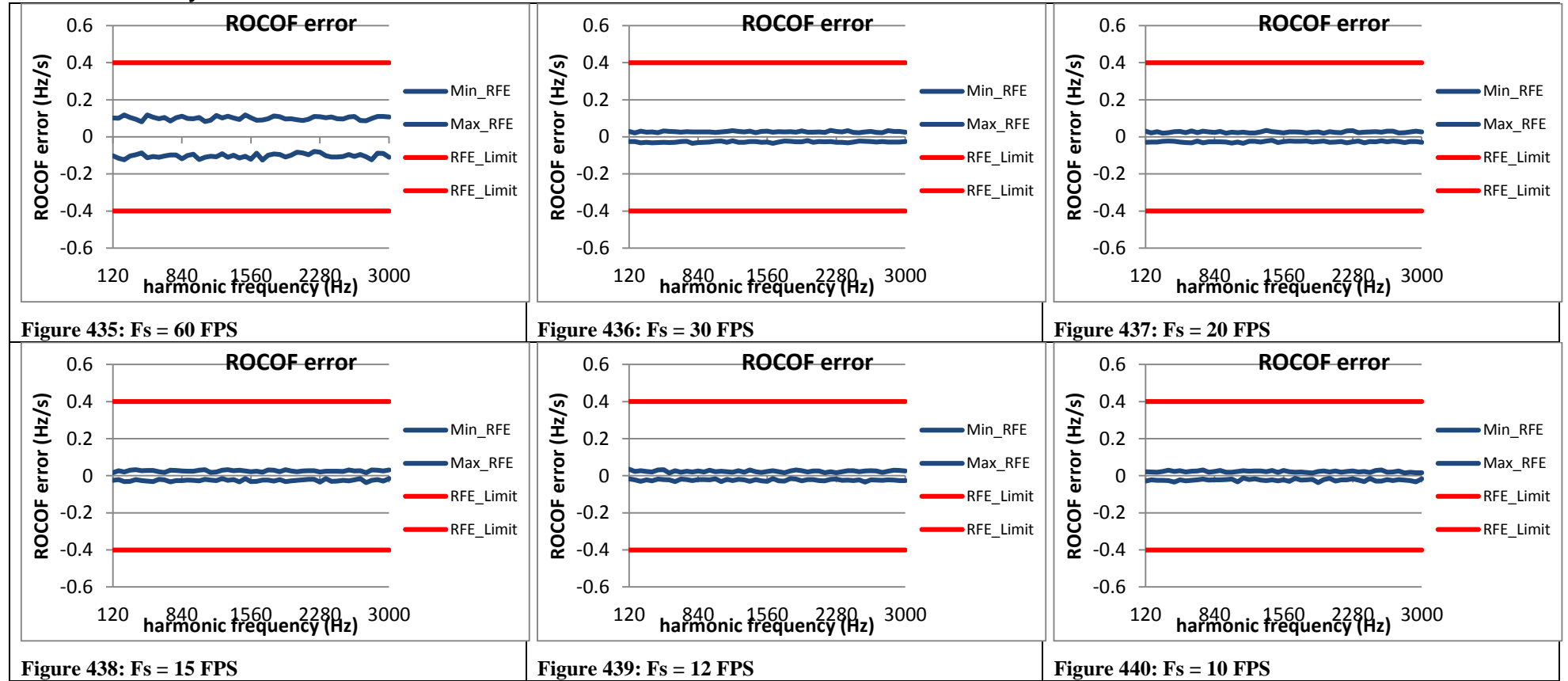
#### 4.8.5 PMU D steady state harmonic distortion ROCOF error: P class



#### 4.8.6 PMU E steady state harmonic distortion ROCOF error: P class

PMU E does not support P class

#### 4.8.7 PMU F steady state harmonic distortion ROCOF error: P class

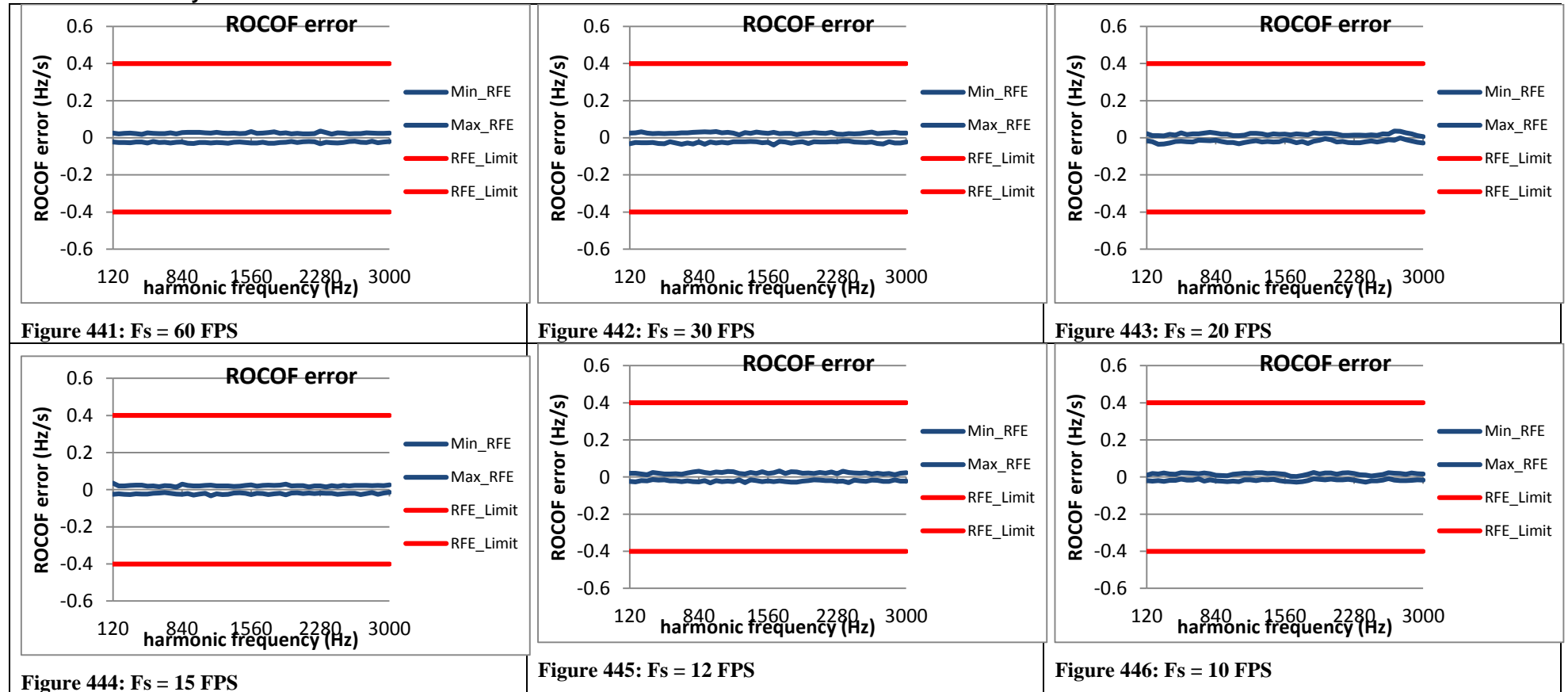


#### 4.8.8 PMU G\* steady state harmonic distortion ROCOF error: P class

PMU G does not support P class



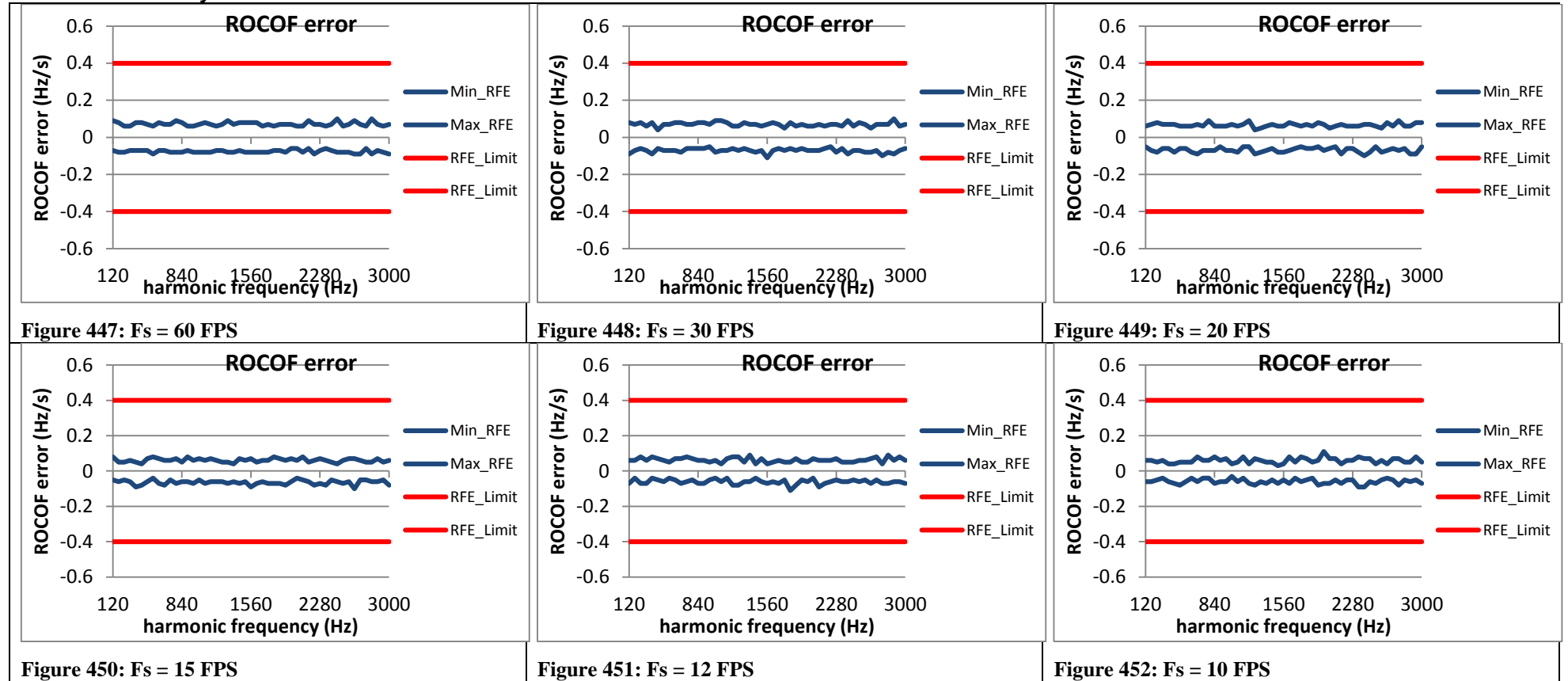
#### 4.8.9 PMU H steady state harmonic distortion ROCOF error: P class



#### 4.8.10 PMU I steady state harmonic distortion ROCOF error: P class

PMU I does not support P class

#### 4.8.11 PMU J steady state harmonic distortion ROCOF error: P class



## 5. Steady state out of band interfering signals test

5. Steady state out of band interfering signals test.....	258
5.1 Steady state out of band interfering signals test voltage TVE: M class.....	264
5.1.1 C37.118.1 Annex C out of band interfering signals voltage TVE: M class.....	264
5.1.2 PMU A out of band interfering signals voltage TVE: M class.....	266
5.1.3 PMU B steady state out of band interfering signals voltage TVE: M class .....	268
5.1.4 PMU C steady state out of band interfering signals voltage TVE: M class .....	270
5.1.5 PMU D steady state out of band interfering signals voltage TVE: M class .....	272
5.1.6 PMU E steady state out of band interfering signal voltage TVE: M class .....	274
5.1.7 PMU F steady state out of band interfering signal voltage TVE: M class .....	276
5.1.8 PMU G steady state out of band interfering signal voltage TVE: M class.....	278
5.1.9 PMU H steady state out of band interfering signal voltage TVE: M class.....	280
5.1.10 PMU I steady state out of band interfering signal voltage TVE: M class .....	282
5.1.11 PMU J steady state out of band interfering signal voltage TVE: M class.....	284
5.2 Steady state out of band interfering signals test current TVE: M class.....	286
5.2.1 C37.118.1 Annex C out of band interfering signals current TVE: M class.....	286
5.2.2 PMU A out of band interfering signals current TVE: M class.....	288
5.2.3 PMU B out of band interfering signals current TVE: M class.....	290
5.2.4 PMU C out of band interfering signals current TVE: M class.....	292
5.2.5 PMU D out of band interfering signals current TVE: M class.....	294
5.2.6 PMU E out of band interfering signals current TVE: M class .....	296
5.2.7 PMU F out of band interfering signals current TVE: M class .....	298
5.2.8 PMU G out of band interfering signals current TVE: M class .....	300
5.2.9 PMU H out of band interfering signals current TVE: M class.....	302
5.2.10 PMU I out of band interfering signals current TVE: M class .....	304
5.2.11 PMU J out of band interfering signals current TVE: M class.....	306
5.3 Steady state out of band interfering signals: frequency error: M class .....	308
5.3.1 C37.118.1 Annex C steady state out of band interfering signals frequency error: M class.....	308
5.3.2 PMU A steady state out of band interfering signals frequency error : M class.....	310
5.3.3 PMU B steady state out of band interfering signals frequency error : M class .....	312
5.3.4 PMU C out of band interfering signals frequency error: M class .....	314
5.3.5 PMU D out of band interfering signals frequency error: M class .....	316
5.3.6 PMU E out of band interfering signals frequency error: M class.....	318
5.3.7 PMU F out of band interfering signals frequency error: M class.....	320
5.3.8 PMU G out of band interfering signals frequency error: M class .....	322
5.3.9 PMU H out of band interfering signals frequency error: M class .....	324
5.3.10 PMU I out of band interfering signals frequency error: M class.....	326
5.3.11 PMU J out of band interfering signals frequency error: M class .....	328
5.4 Steady state out of band interfering signals: ROCOF error: M class .....	330

5.4.1 C37.118.1 Annex C steady state out of band interfering signals ROCOF error: M class.....	330
5.4.2 PMU A steady state out of band interfering signals ROCOF error: M class.....	332
5.4.3 PMU B steady state out of band interfering signals ROCOF error: M class.....	334
5.4.4 PMU C steady state out of band interfering signals ROCOF error: M class.....	336
5.4.5 PMU D steady state out of band interfering signals ROCOF error: M class .....	338
5.4.6 PMU E steady state out of band interfering signals ROCOF error: M class .....	340
5.4.7 PMU F steady state out of band interfering signals ROCOF error: M class .....	342
5.4.8 PMU G* steady state out of band interfering signals ROCOF error: M class .....	344
5.4.9 PMU H steady state out of band interfering signals ROCOF error: M class .....	346
5.4.10 PMU I steady state out of band interfering signals ROCOF error: M class .....	348
5.4.11 PMU J steady state out of band interfering signals ROCOF error: M class.....	350

The steady state out of band interfering signals test is a series of tests where the PMU input signal is a combination of a fundamental frequency at nominal magnitude and an “out of band interfering signal” at 10% of nominal magnitude. Individual tests evaluate the PMU performance for steady state (unchanging in magnitude or frequency) for 5 seconds per test. In each subsequent test, the frequency of the interfering signal is incremented between 10 Hz and the nominal frequency minus the Nyquist frequency of the reporting rate ( $F_0 - F_s/2$ ) then from the nominal frequency plus the Nyquist frequency of the reporting rate ( $F_0 + F_s/2$ ) up to the second harmonic of the nominal frequency. This set of interfering signals is repeated for three fundamental frequencies: nominal frequency minus 10% of the Nyquist of the reporting rate ( $F_0 - 0.1F_s/2$ ), the nominal frequency ( $F_0$ ) and nominal frequency plus 10% of the Nyquist frequency ( $F_0 + 0.1F_s/2$ ).

Test Plan:

Apply a steady-state, balanced, three-phase signal to both current and voltage inputs, at nominal steady-state magnitude and nominal system frequency (50 Hz or 60 Hz). Inject into the voltage and current inputs a positive-sequence interharmonic at

Frequency  $f_i$  where  $|f_i - f_0| \geq F_s/2$

where

$F_s$  is the reporting rate

$f_0$  is the nominal frequency

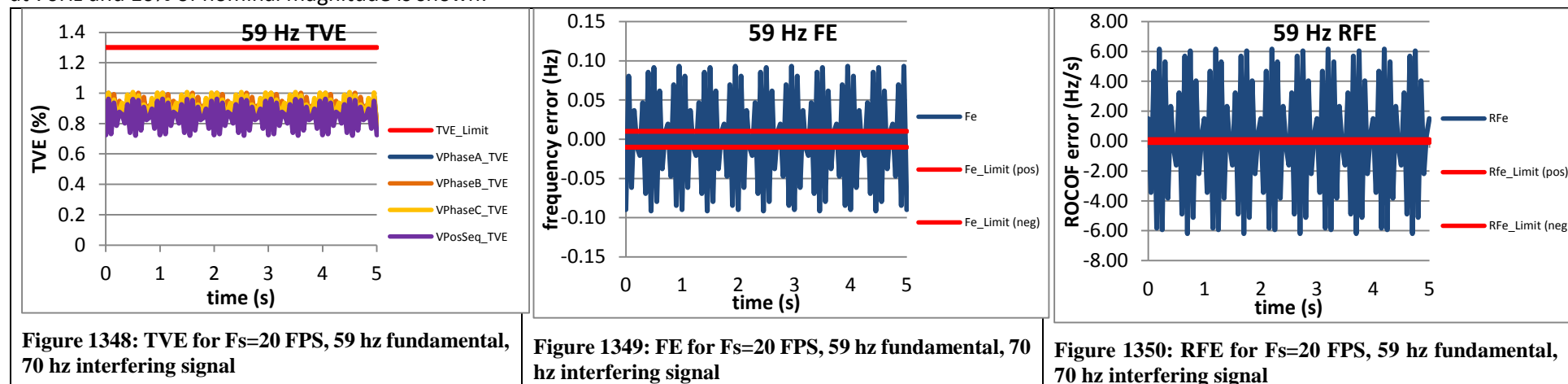
$f_i$  is the frequency of the interfering signal

- a) Add an interharmonic signal at  $f_i = f_0 - F_s/2$  at 10% nominal magnitude.
- b) Wait for the system to settle.
- c) Capture the PMU output for 5 seconds.
- d) Calculate the errors: TVE, FE, RFE for each report.
- e) Calculate the Max TVE, and FE.
- f) Run step b) through step e) repeatedly, decreasing the interharmonic frequency exponentially until it reaches 10 Hz:
  - For each test run, the interharmonic frequency decrements exponentially, thus providing many tests near  $f_i = f_0 - F_s/2$  and fewer tests further away from  $f_i = f_0 - F_s/2$ . For example, the first decrease should be 0.1 Hz ( $f_0 - F_s/2 - 0.1$ ), the next decrease 0.2 Hz ( $f_0 - F_s/2 - 0.2$ ), the third decrease 0.4 Hz ( $f_0 - F_s/2 - 0.4$ ), then 0.8 Hz ( $f_0 - F_s/2 - 0.8$ ) until an interharmonic frequency below 10 Hz is reached. For the last frequency, use 10 Hz rather than the frequency below 10 Hz.
- g) Add an interharmonic signal at  $f_i = f_0 + F_s/2$  at 10% nominal magnitude.
- h) Run step b) through step e) repeatedly, increasing the interharmonic frequency exponentially until it reaches  $2 \times f_0$ :
  - For each test run, the interharmonic frequency increments exponentially, thus providing many tests near  $f_i = f_0 + F_s/2$  and fewer tests further away from  $f_i = f_0 + F_s/2$ . For example, the first increase should be 0.1 Hz ( $f_0 + F_s/2 + 0.1$ ), the next increase 0.2 Hz ( $f_0 + F_s/2 + 0.2$ ), the third increase 0.4 Hz ( $f_0$

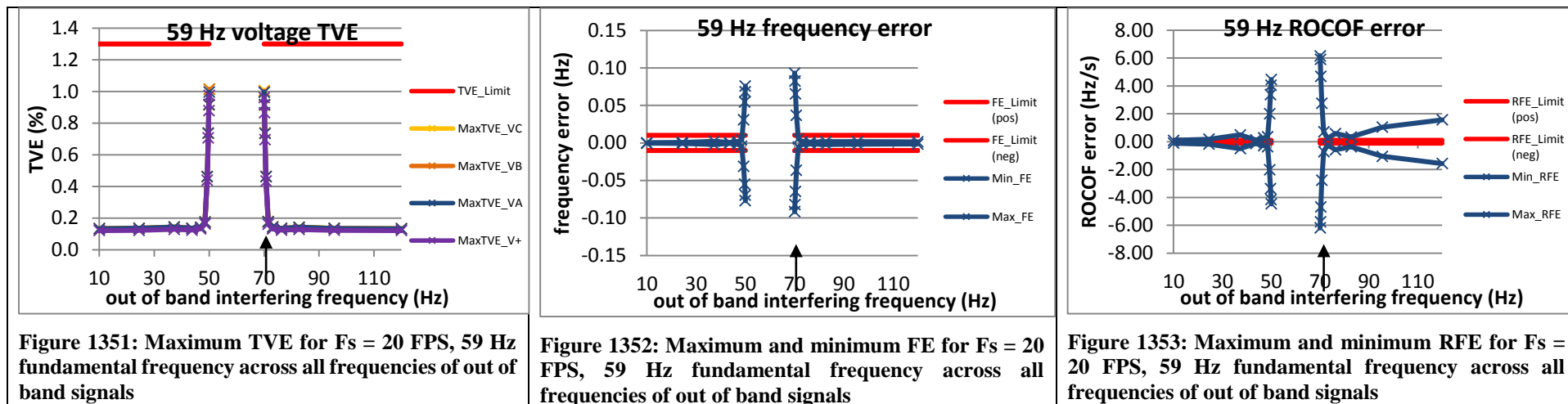
+  $F_s/2 + 0.4$ ), then 0.8 Hz ( $f_0 + F_s/2 + 0.8$ ), until an interharmonic frequency above  $2 \times f_0$  is reached. For the last frequency use  $2 \times f_0$  rather than the frequency above  $2 \times f_0$ .

- i) Run all steps a) through h) two more times with the input signal frequency at nominal frequency plus and minus 10% of  $F_s/2$  (the Nyquist frequency of the reporting rate,  $F_s$ ).

An example of TVE, FE and RFE from a single OOB test run taken at  $F_0 = 60$  Hz,  $F_s = 20$  FPS, M class with a fundamental frequency at 59 Hz and out of band signal at 70 Hz and 10% of nominal magnitude is shown:



The maximum value from the above plots becomes a single data point from the below plots of TVE, FE and RFE for  $F_s = 20$  FPS, at 59 Hz fundamental frequency. The data point is shown with a black arrow. Individual test runs insert a single out of band interfering frequency from 10 Hz to 120 Hz excluding the in-band frequencies between 50 Hz and 70 Hz.



Out of band interfering signals tests are run at three separate fundamental frequencies. For each measured result (TVE, FE, RFE), a table of plots is shown. Each row of three plots is from a single reporting rate ( $F_s$ ), one for each of the input fundamental frequencies ( $F_0 - 0.1F_s/2$ ), ( $F_0$ ), ( $F_0 + 0.1F_s/2$ ). The x-axis of all plots shows the frequency of the interfering signal (one interfering signal per test run). The y-axis of the TVE plots show the maximum TVE and the TVE limit in red. The Y-axis of both the frequency error and ROCOF error plots show the maximum and minimum errors and the positive and negative error limits. When determining if the performance passes or fails a test, the maximum absolute value of the error can be compared against a positive error limit, showing both the maximum and minimum error allows us to see asymmetries and offsets in the error.

**Results from steady state out of band interfering signals test**

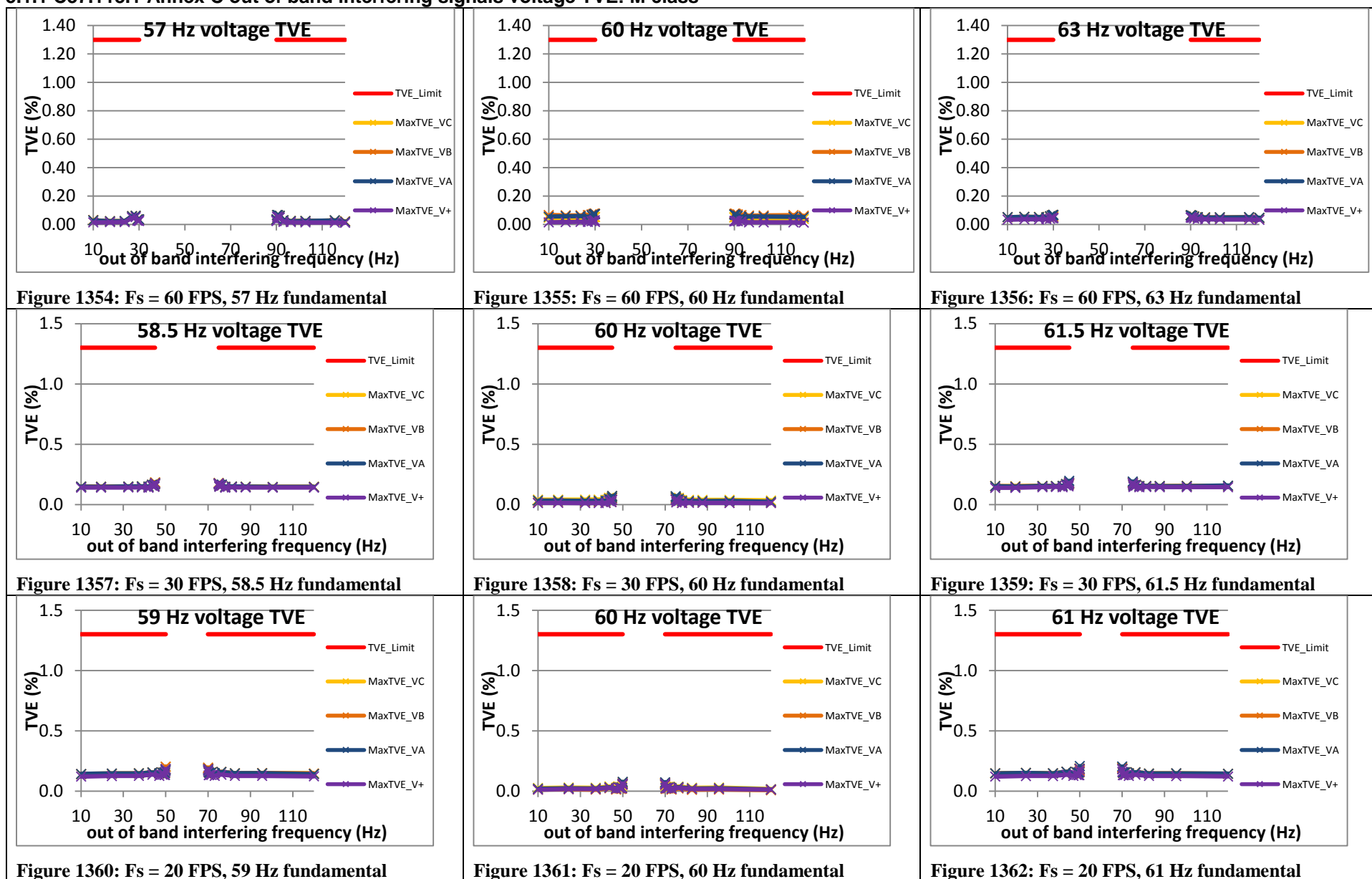
Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E			
C37.118.1 Annex C	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-
PMU A	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-
PMU B	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-
PMU C	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	P	F	-	-	-	-
PMU D	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-
PMU E	F	F	-	-	-	-				-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	P	F	-	-	-	-
PMU F	P	I	-	-	-	-	P	I	-	-	-	-	P	I	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-
PMU G*	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	F	F	-	-	-	-	-	-	-	-	-	-
PMU H	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-
PMU I	P	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-	P	F	-	-	-	-
PMU J	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-	P	P	-	-	-	-

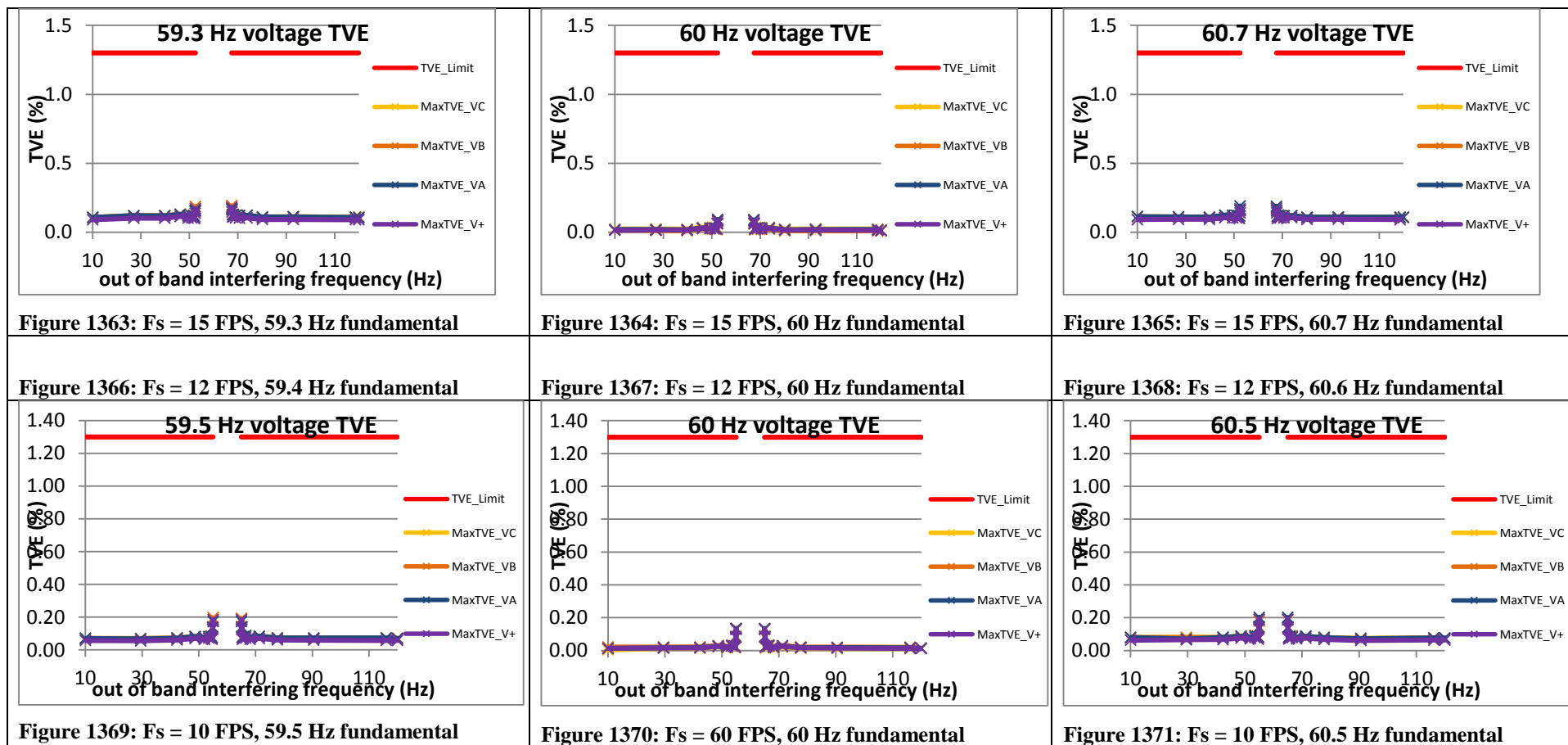
P = Pass, F = Fail, I = Indeterminate



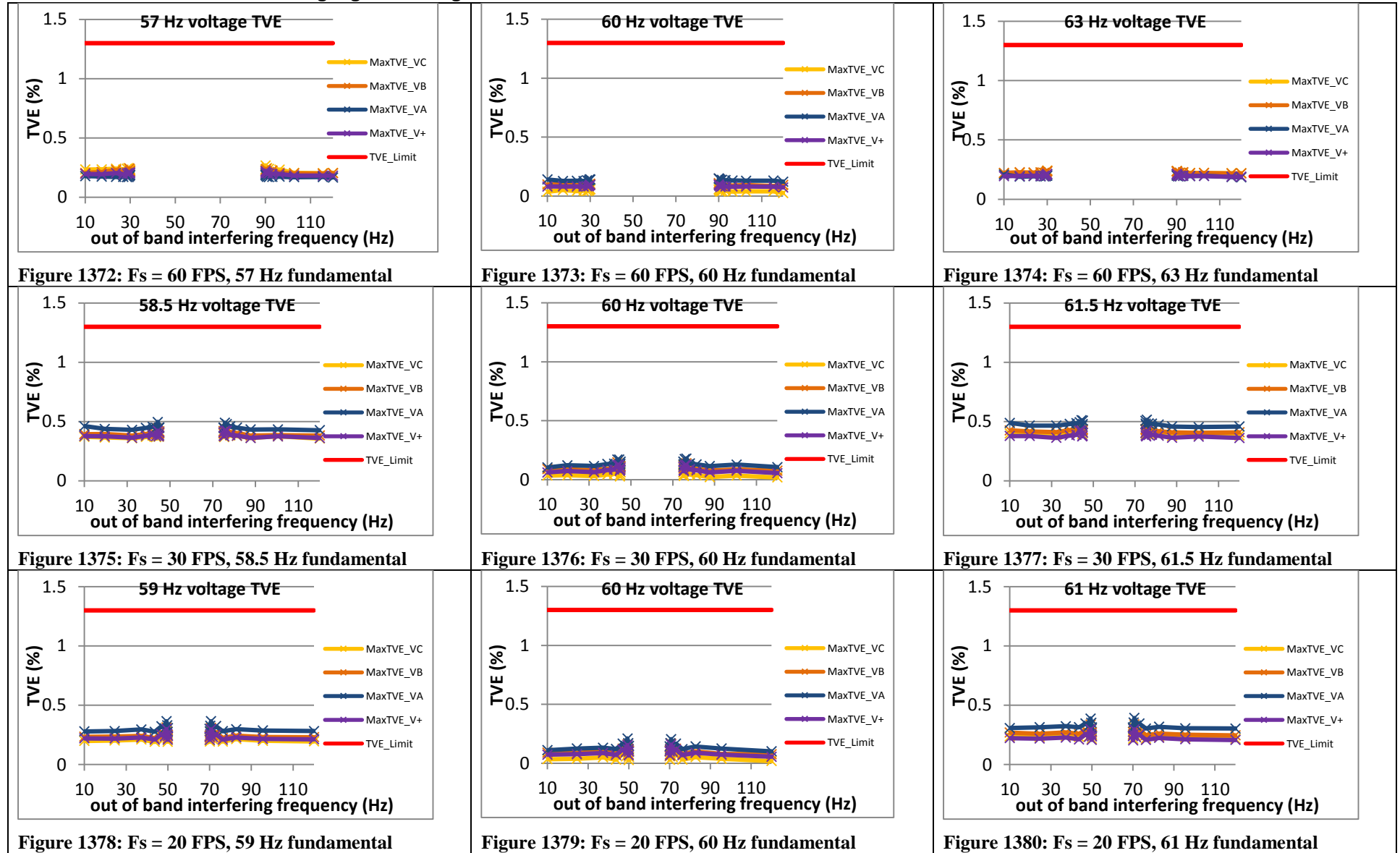
## 5.1 Steady state out of band interfering signals test voltage TVE: M class

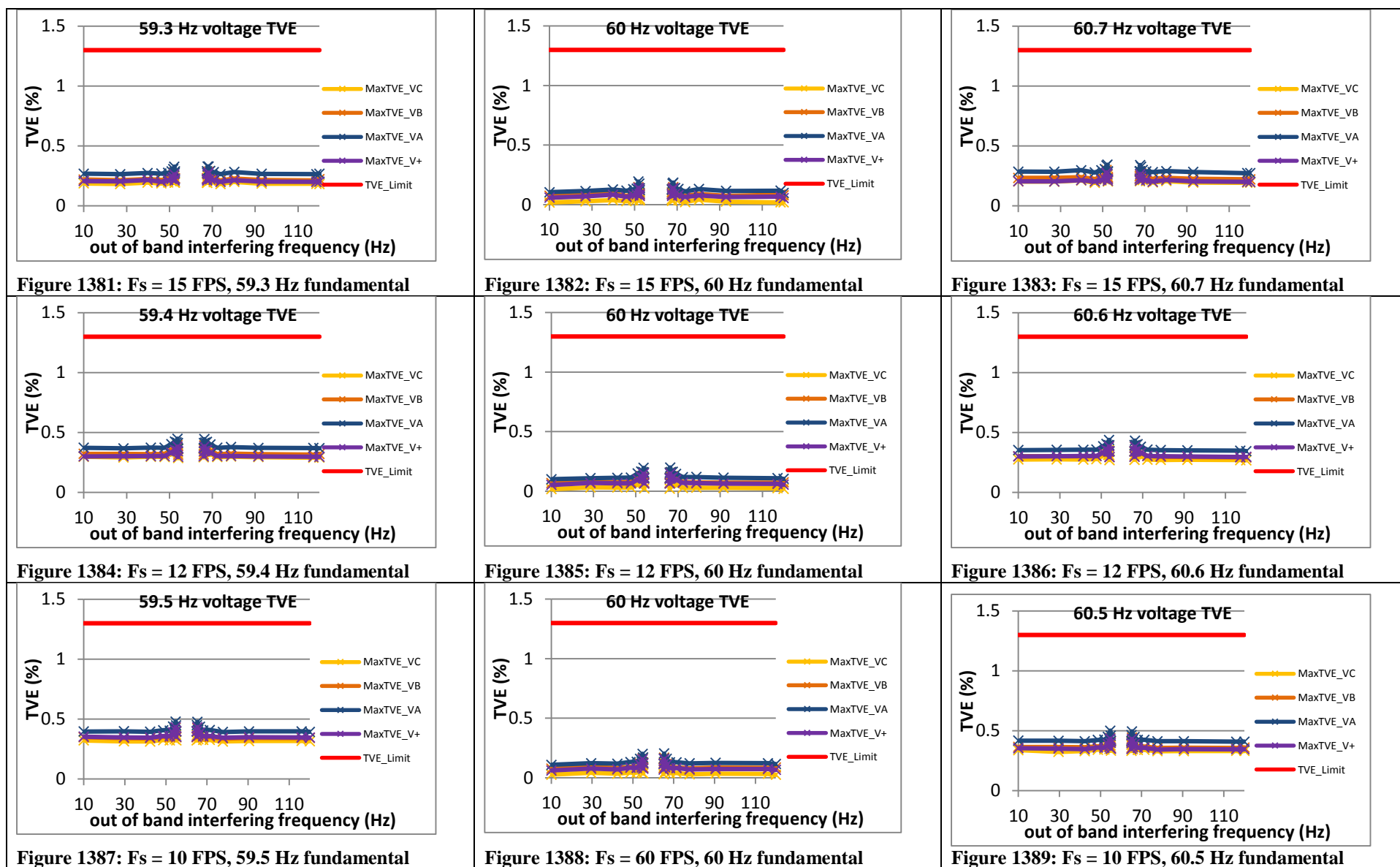
### 5.1.1 C37.118.1 Annex C out of band interfering signals voltage TVE: M class



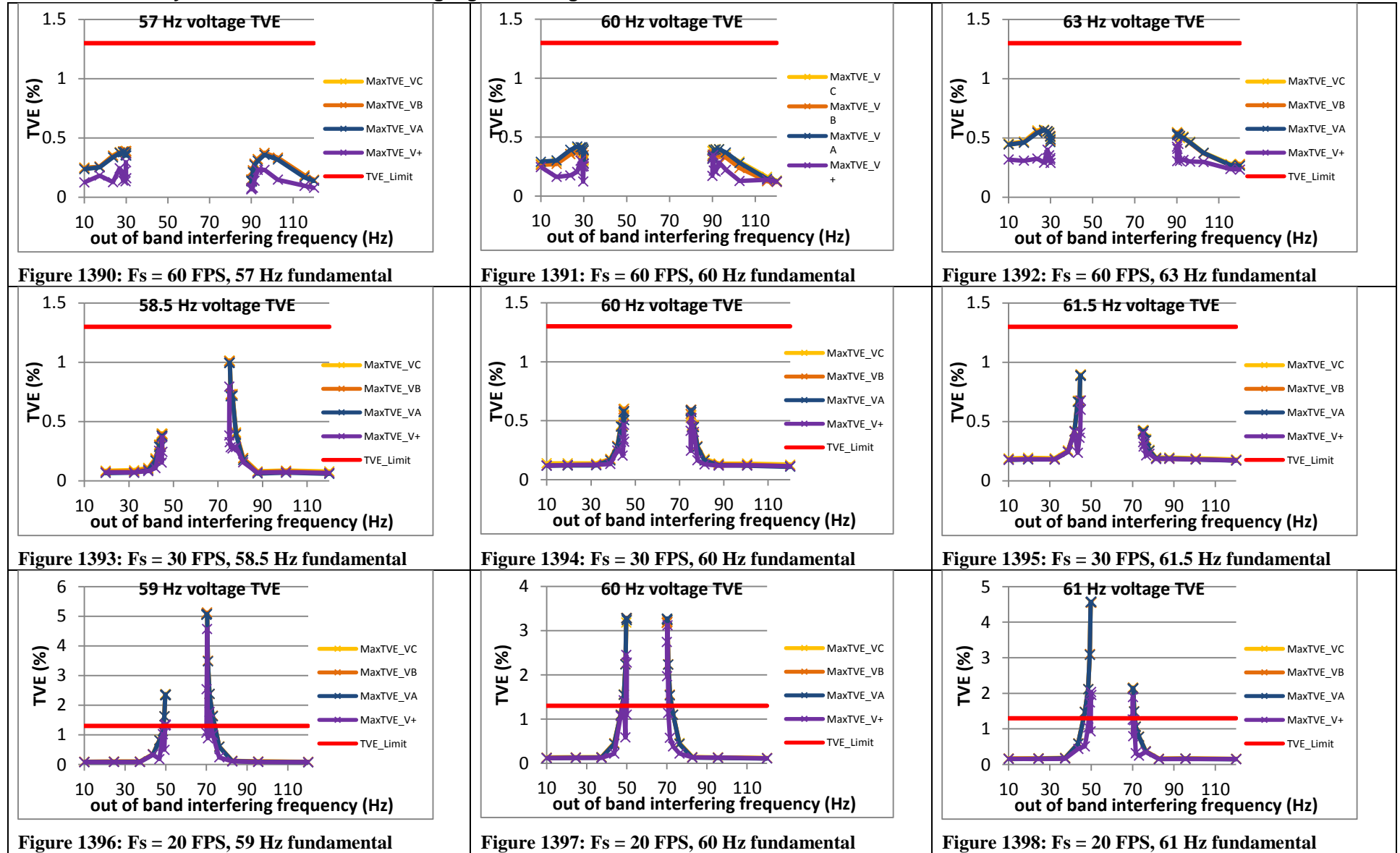


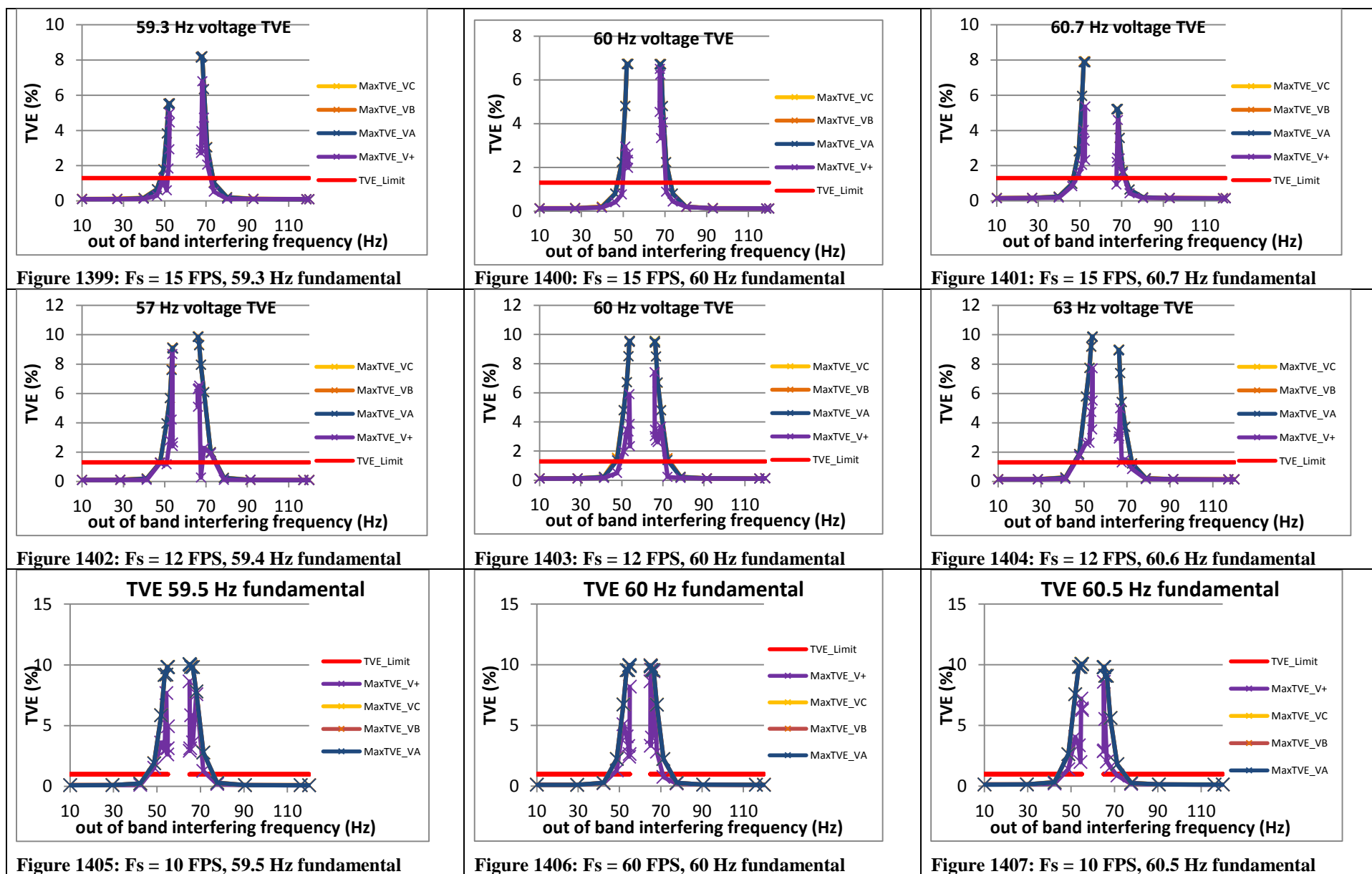
### 5.1.2 PMU A out of band interfering signals voltage TVE: M class



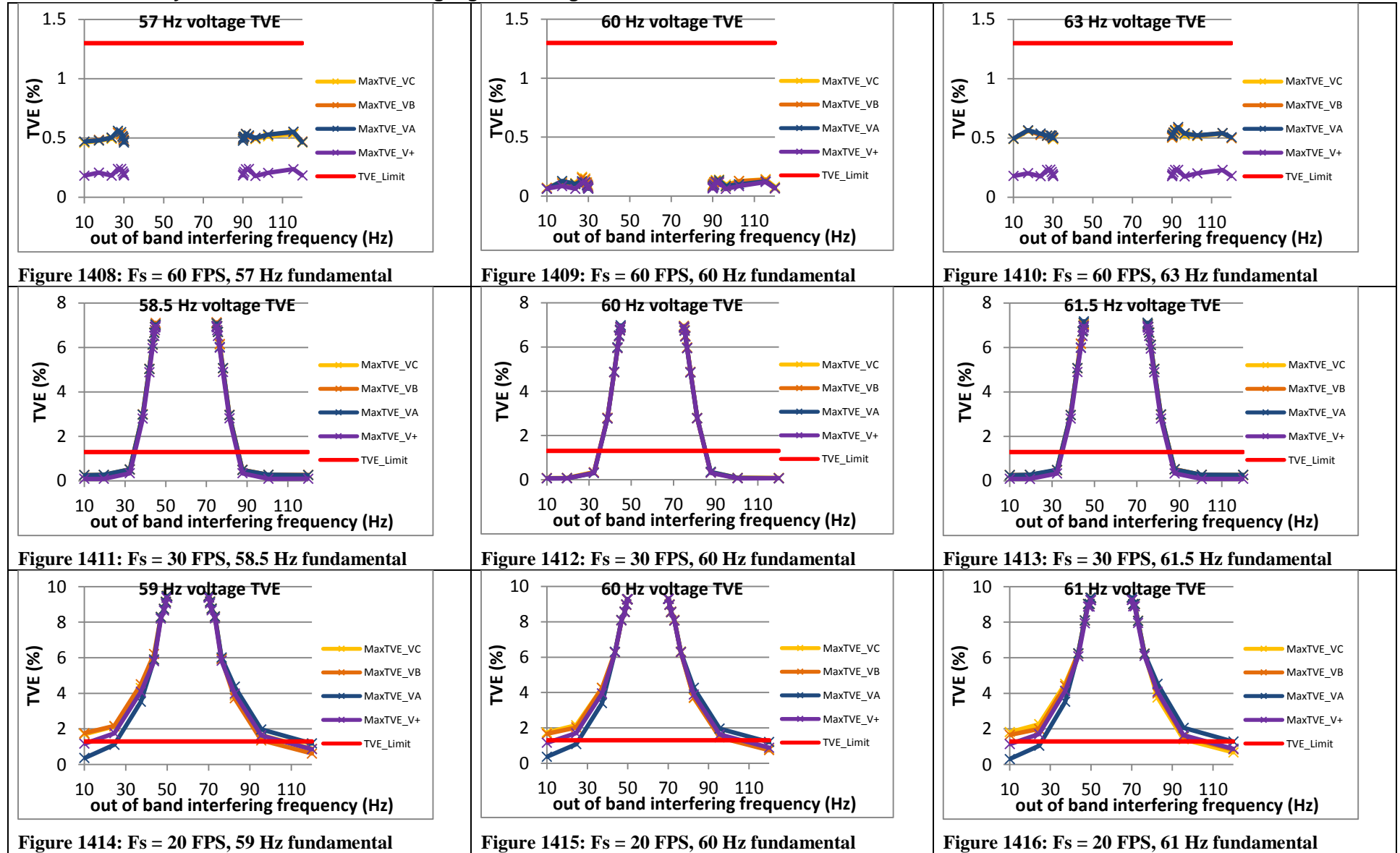


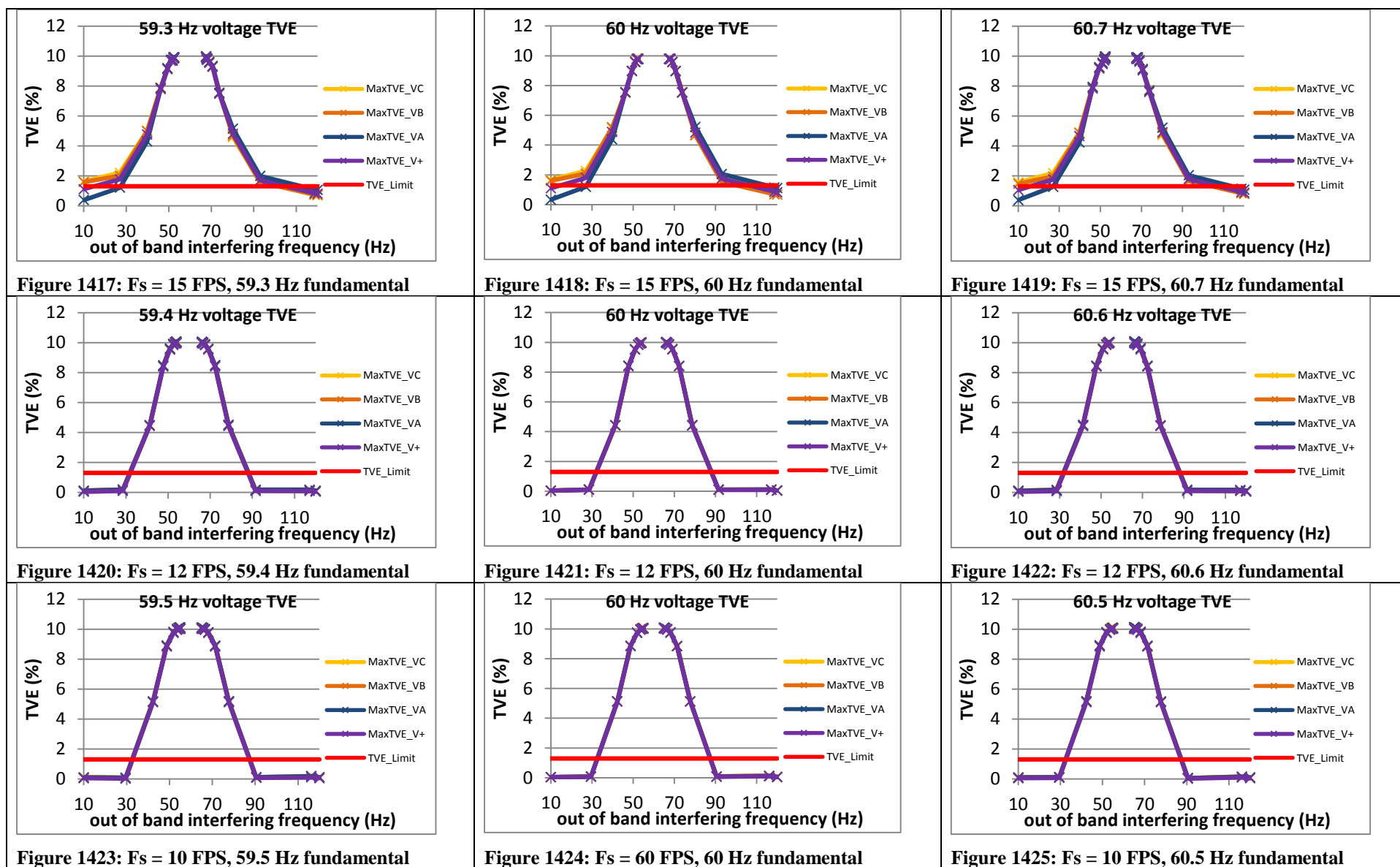
### 5.1.3 PMU B steady state out of band interfering signals voltage TVE: M class





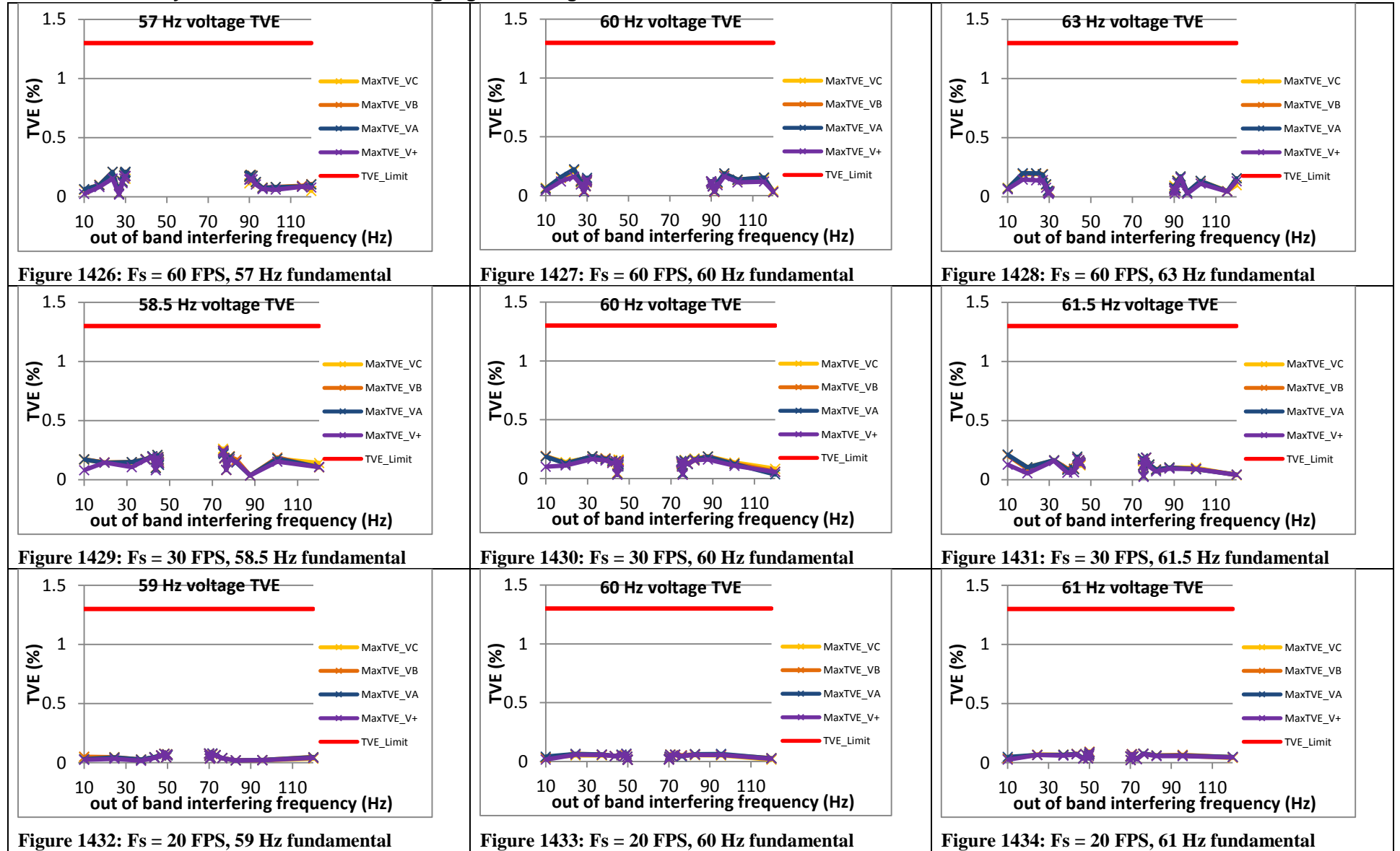
#### 5.1.4 PMU C steady state out of band interfering signals voltage TVE: M class

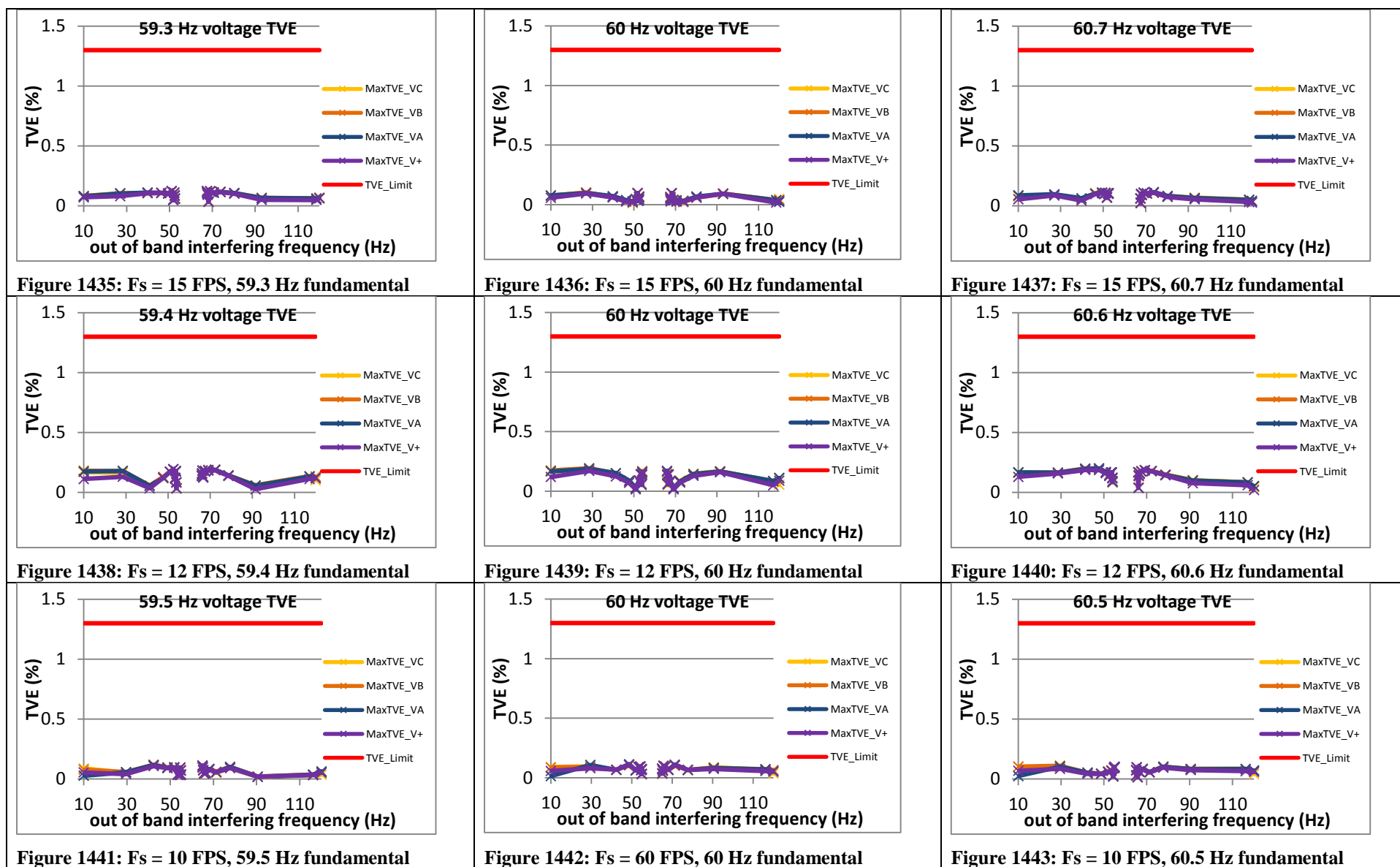




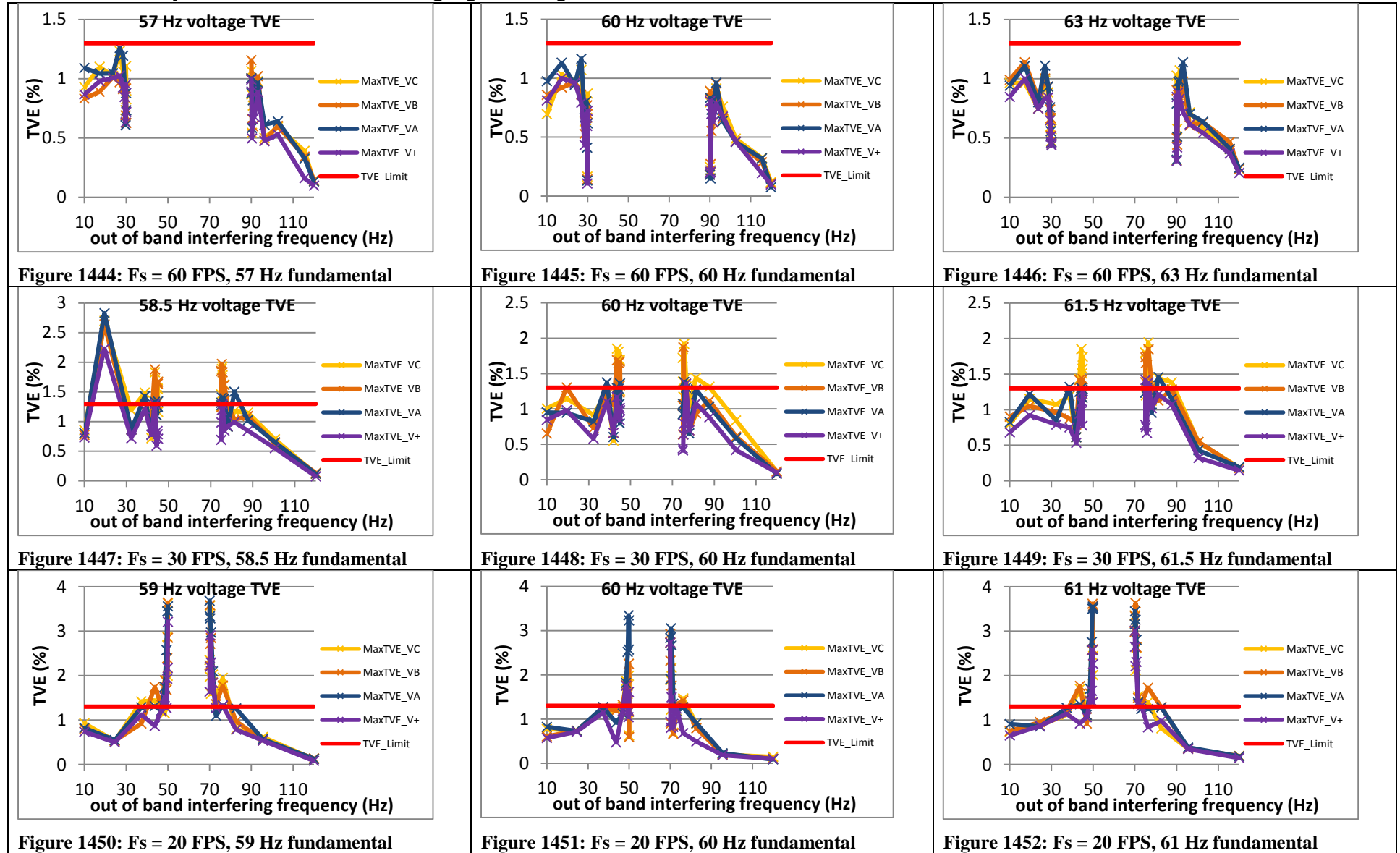


### 5.1.5 PMU D steady state out of band interfering signals voltage TVE: M class





### 5.1.6 PMU E steady state out of band interfering signal voltage TVE: M class



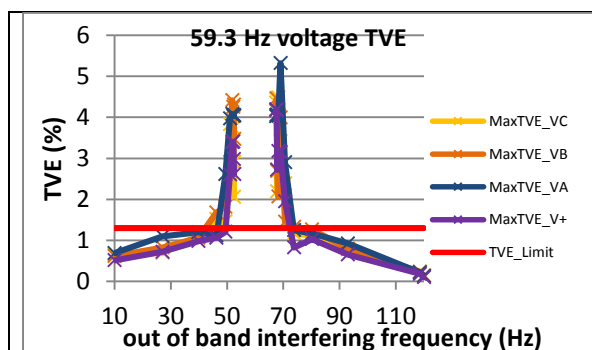


Figure 1453:  $F_s = 15$  FPS, 59.3 Hz fundamental

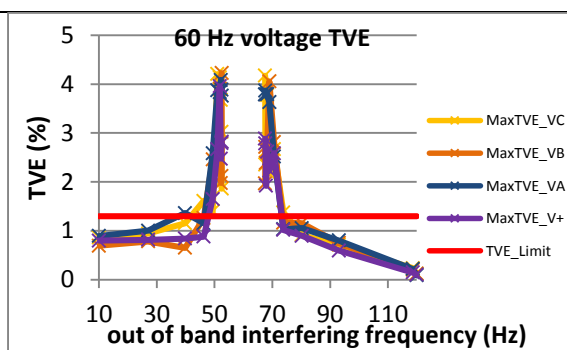


Figure 1454:  $F_s = 15$  FPS, 60 Hz fundamental

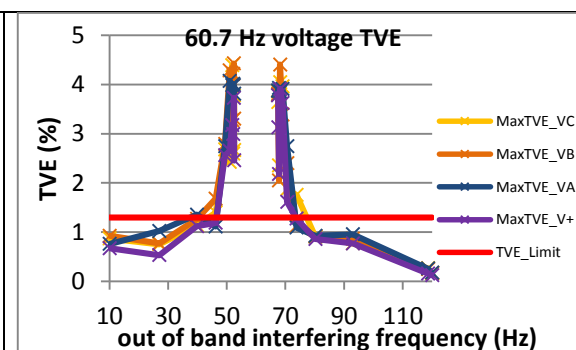


Figure 1455:  $F_s = 15$  FPS, 60.7 Hz fundamental

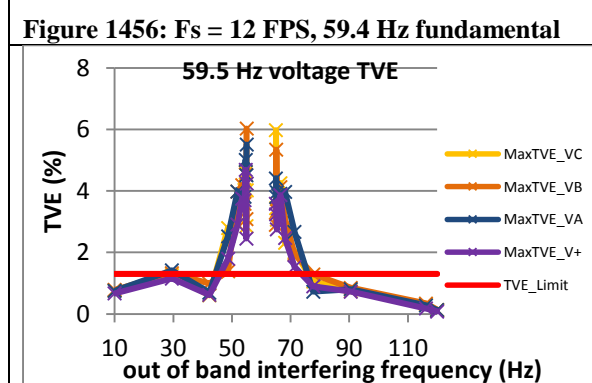


Figure 1456:  $F_s = 12$  FPS, 59.4 Hz fundamental

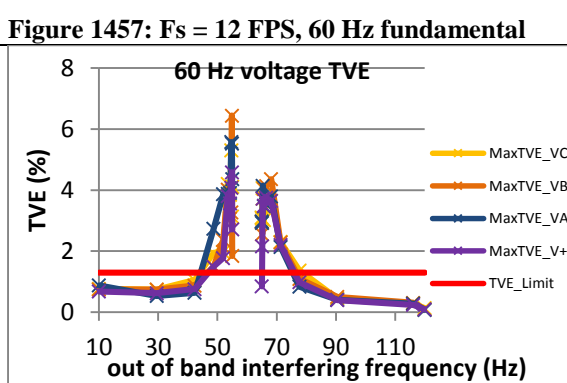


Figure 1457:  $F_s = 12$  FPS, 60 Hz fundamental

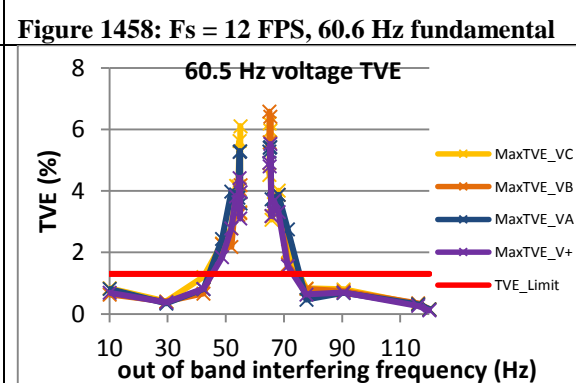


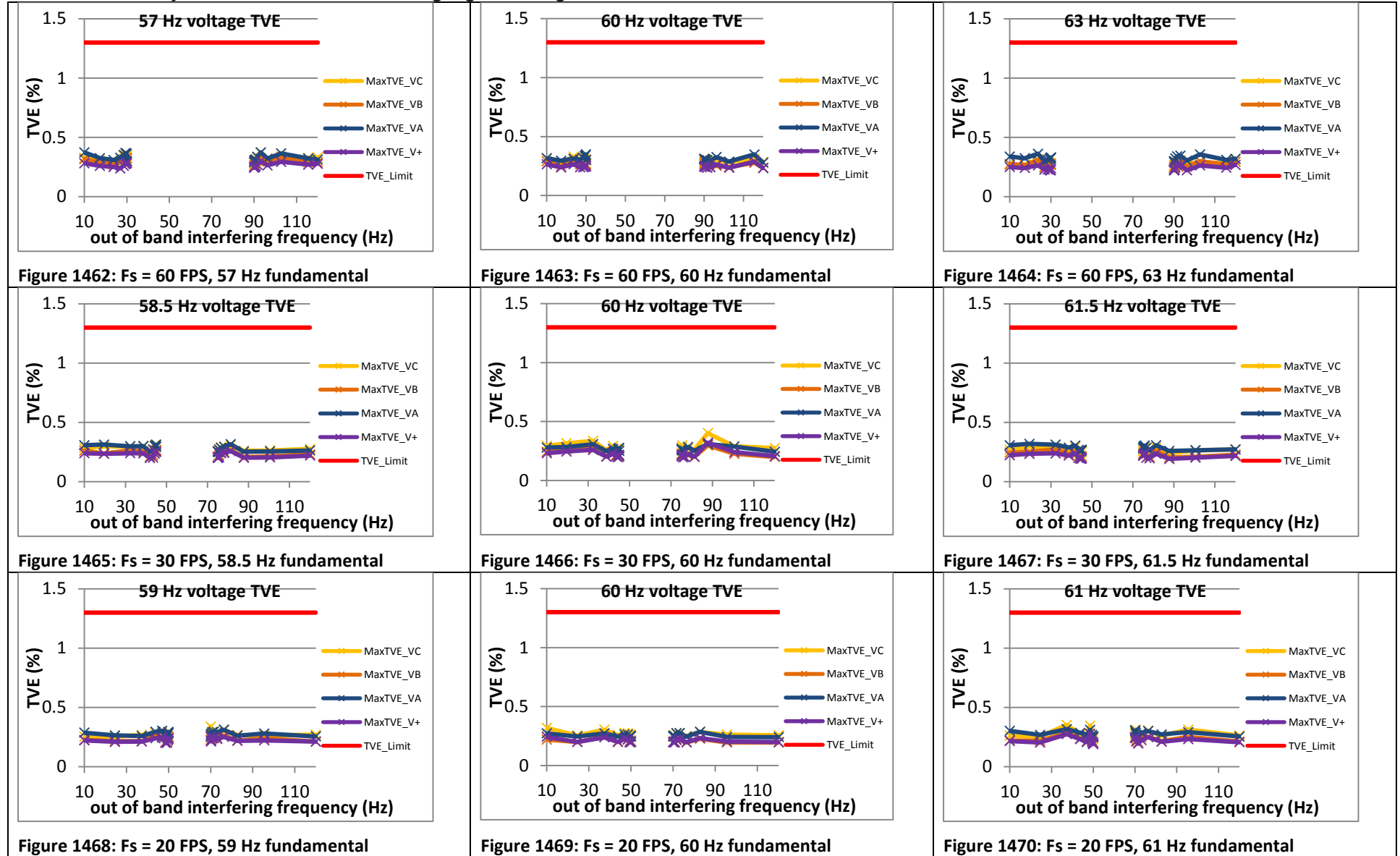
Figure 1458:  $F_s = 12$  FPS, 60.6 Hz fundamental

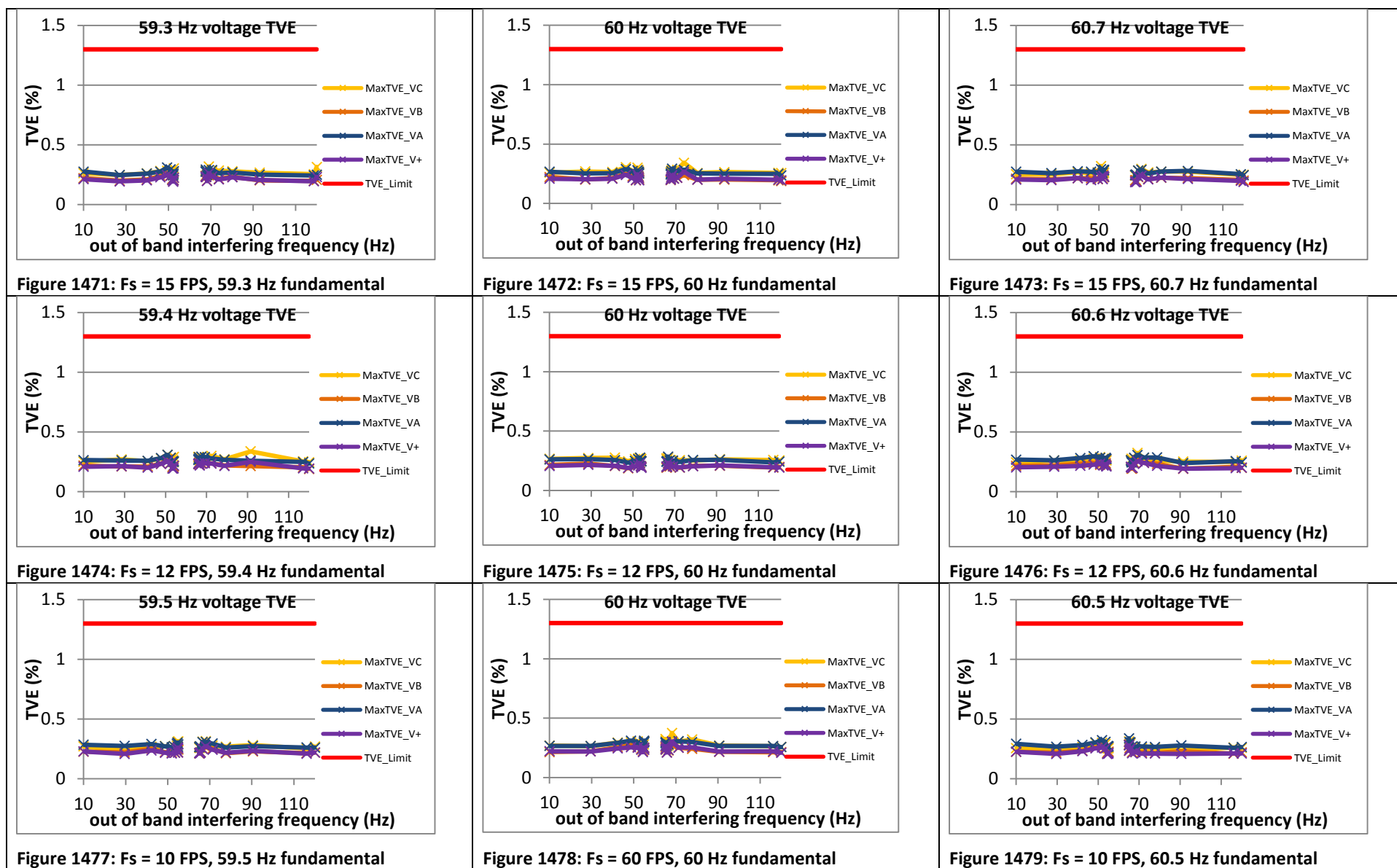
Figure 1459:  $F_s = 10$  FPS, 59.5 Hz fundamental

Figure 1460:  $F_s = 60$  FPS, 60 Hz fundamental

Figure 1461:  $F_s = 10$  FPS, 60.5 Hz fundamental

### 5.1.7 PMU F steady state out of band interfering signal voltage TVE: M class





### 5.1.8 PMU G steady state out of band interfering signal voltage TVE: M class

Figure 1480:  $F_s = 60$  FPS, is not supported by this PMU

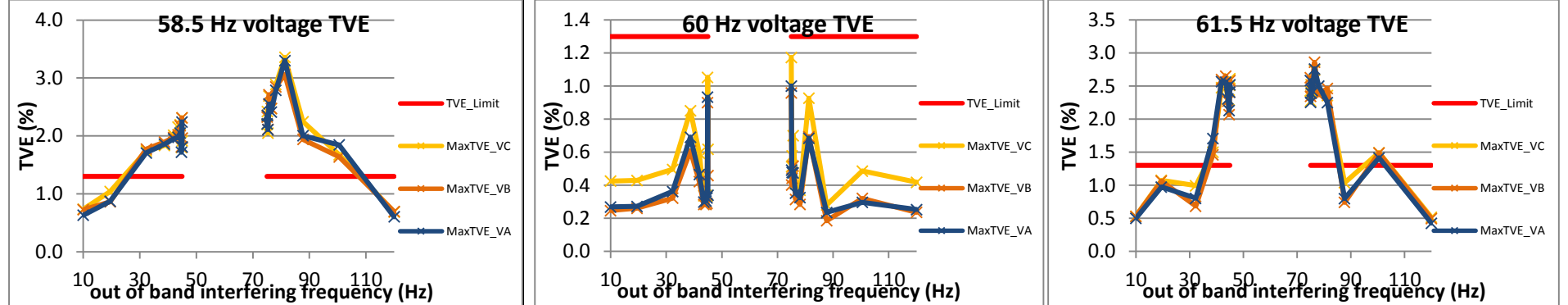


Figure 1481:  $F_s = 30$  FPS, 58.5 Hz fundamental

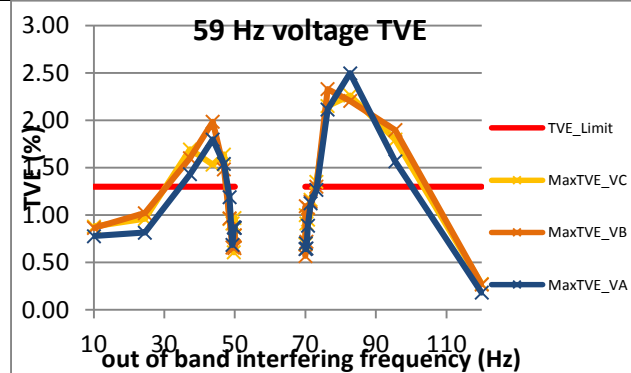


Figure 1482:  $F_s = 30$  FPS, 60 Hz fundamental

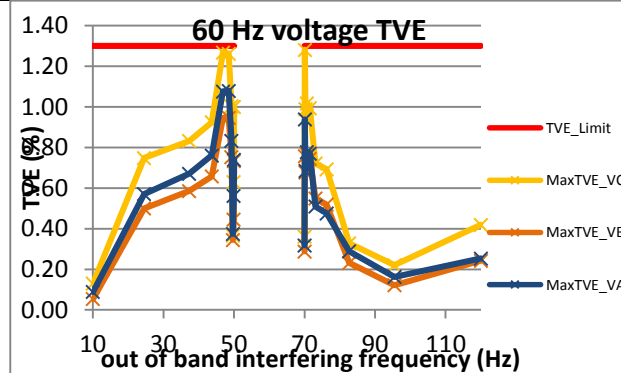


Figure 1483:  $F_s = 30$  FPS, 61.5 Hz fundamental

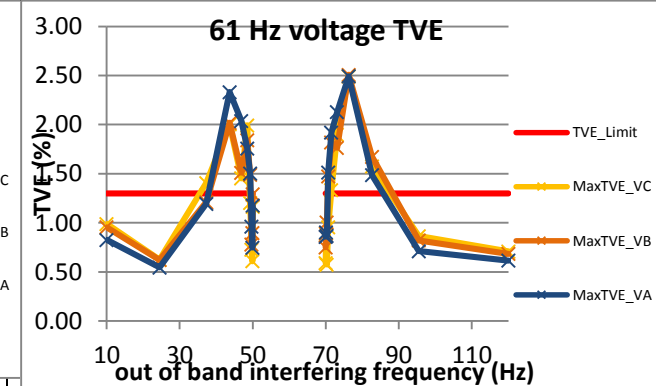


Figure 1484:  $F_s = 20$  FPS, 59 Hz fundamental

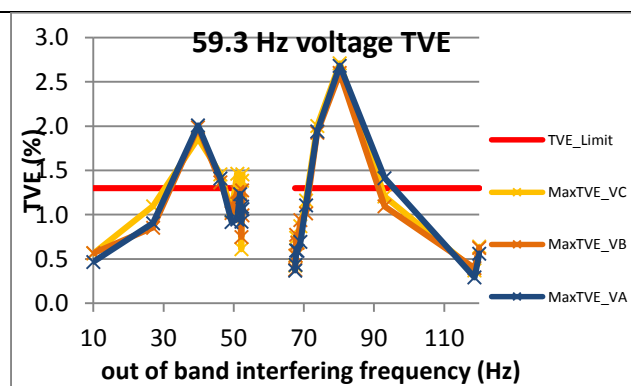


Figure 1485:  $F_s = 20$  FPS, 60 Hz fundamental

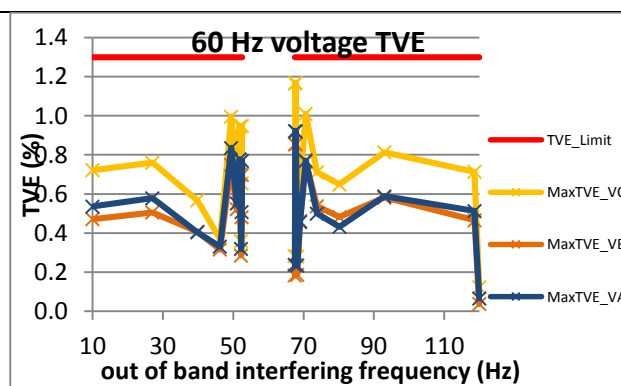
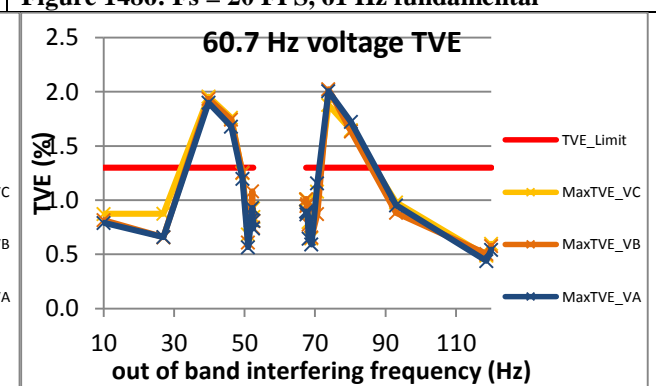
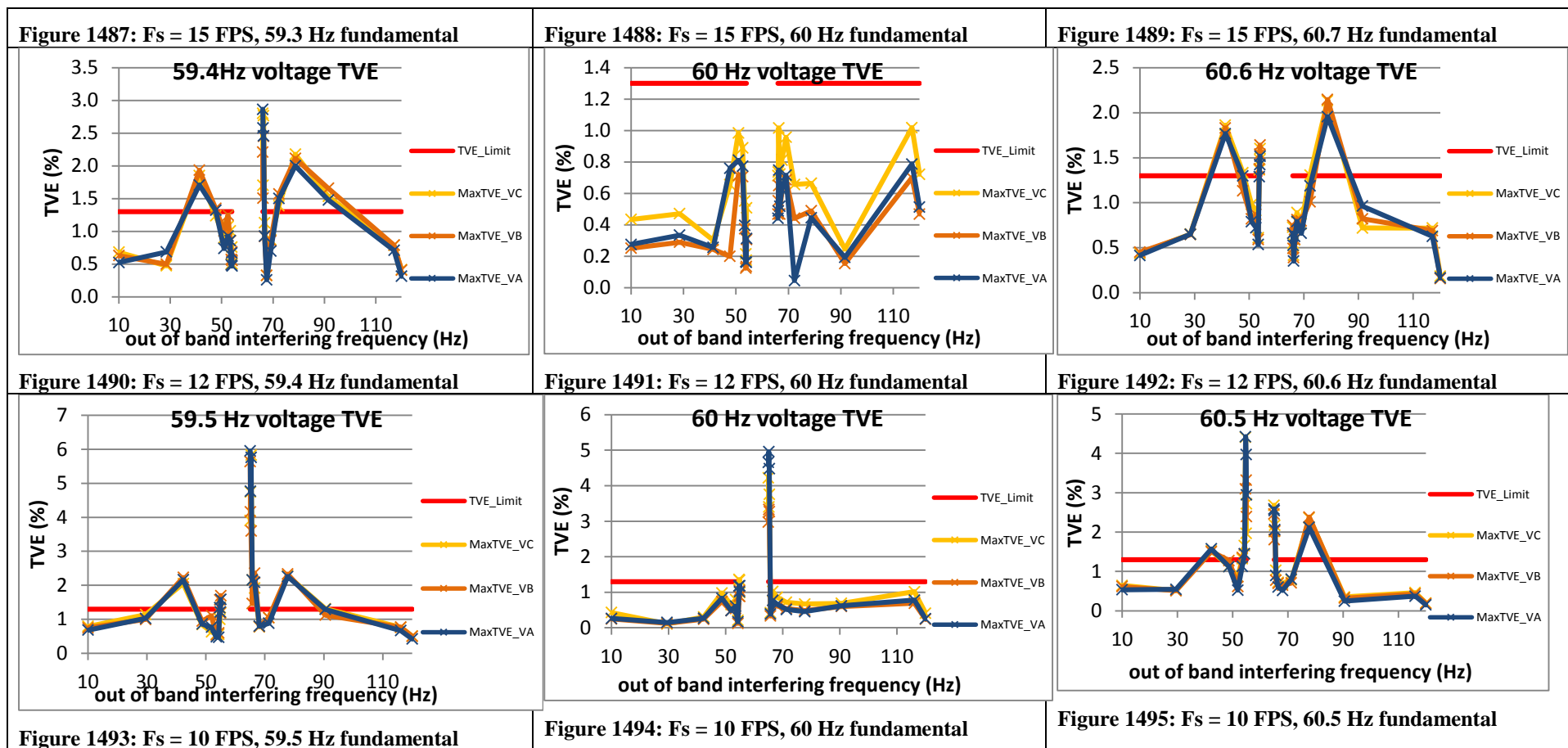


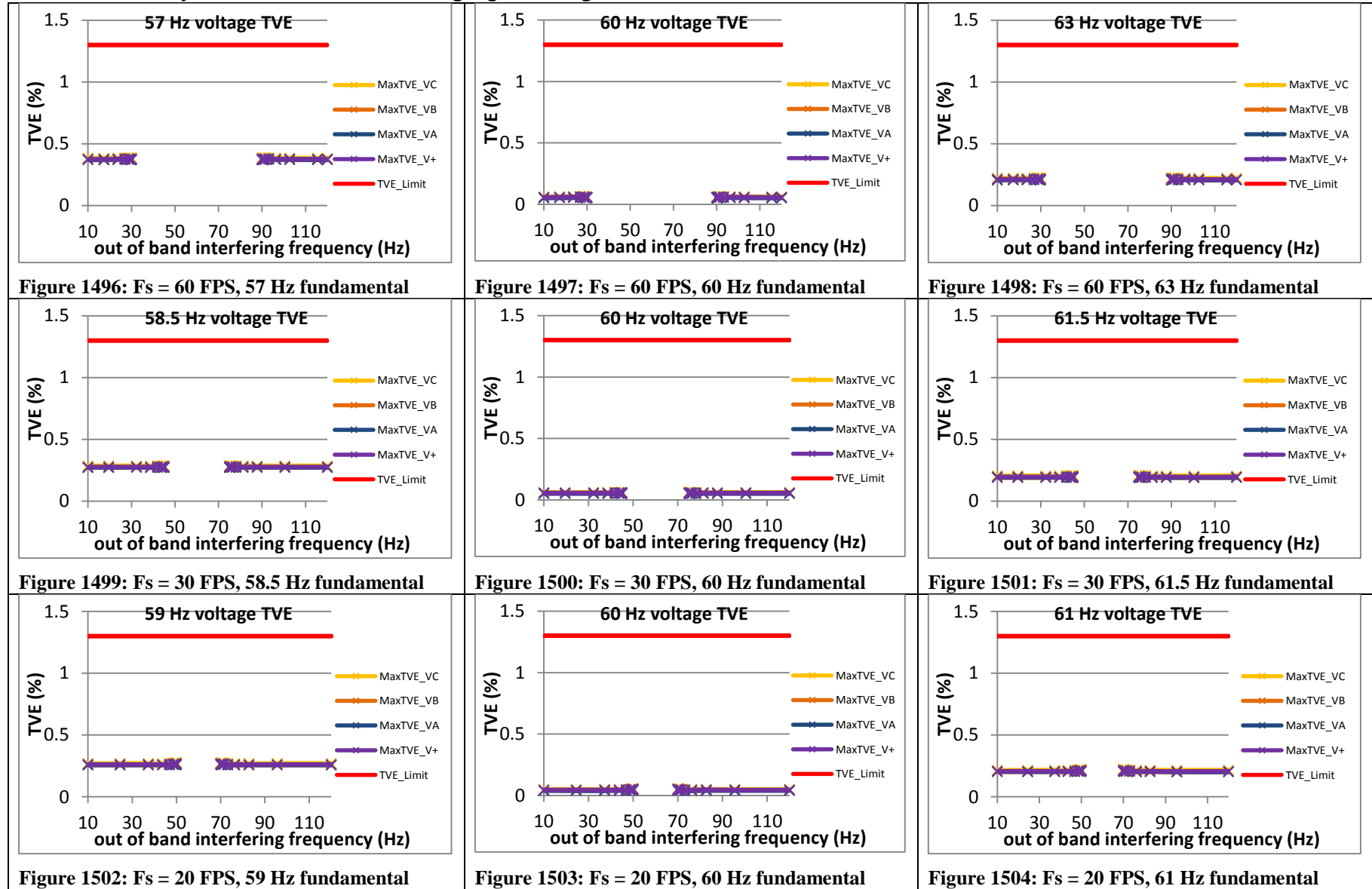
Figure 1486:  $F_s = 20$  FPS, 61 Hz fundamental







### 5.1.9 PMU H steady state out of band interfering signal voltage TVE: M class



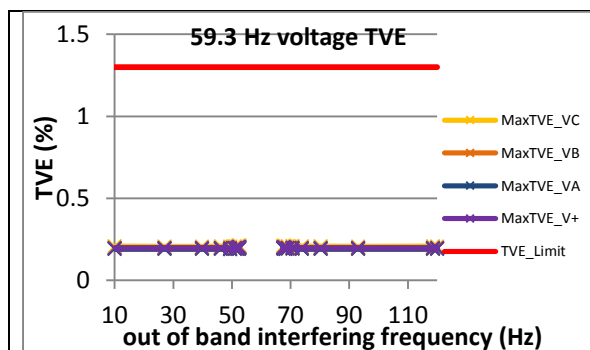


Figure 1505:  $F_s = 15$  FPS, 59.3 Hz fundamental

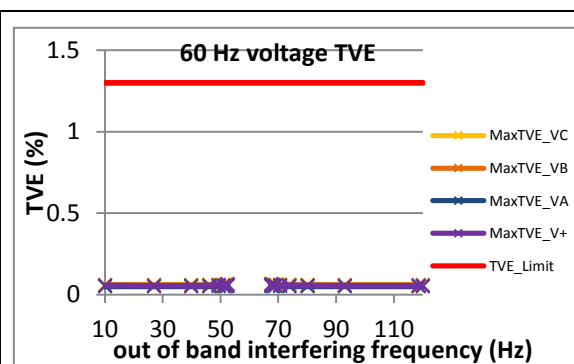


Figure 1506:  $F_s = 15$  FPS, 60 Hz fundamental

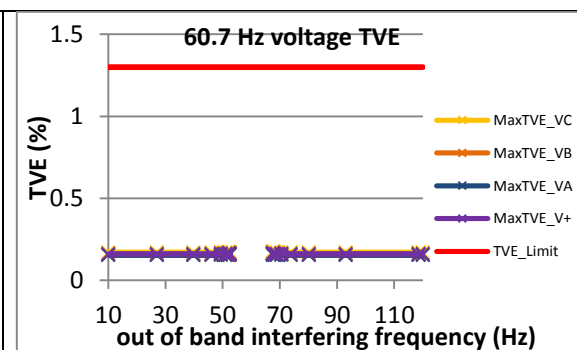


Figure 1507:  $F_s = 15$  FPS, 60.7 Hz fundamental

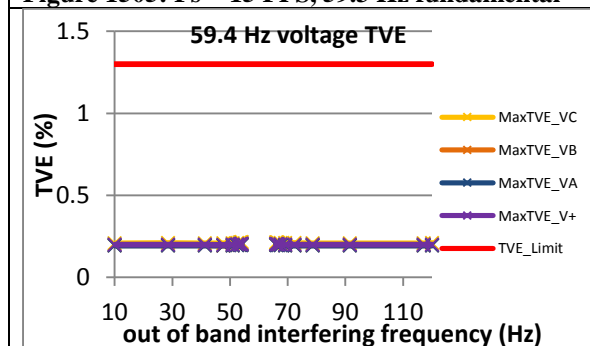


Figure 1508:  $F_s = 12$  FPS, 59.4 Hz fundamental

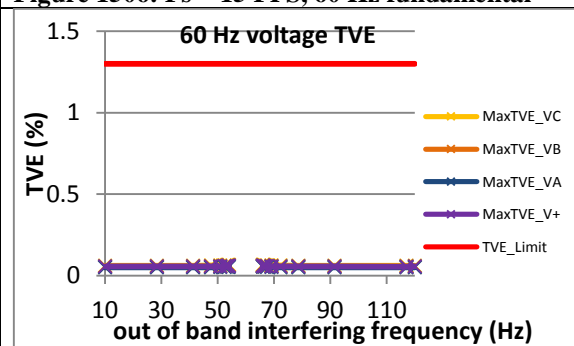


Figure 1509:  $F_s = 12$  FPS, 60 Hz fundamental

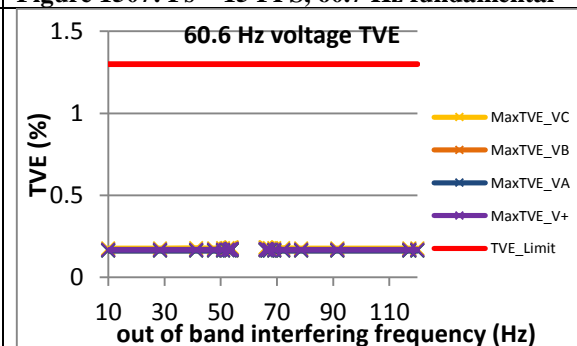


Figure 1510:  $F_s = 12$  FPS, 60.6 Hz fundamental

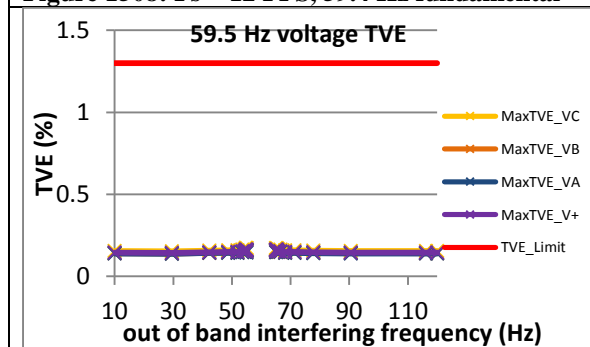


Figure 1511:  $F_s = 10$  FPS, 59.5 Hz fundamental

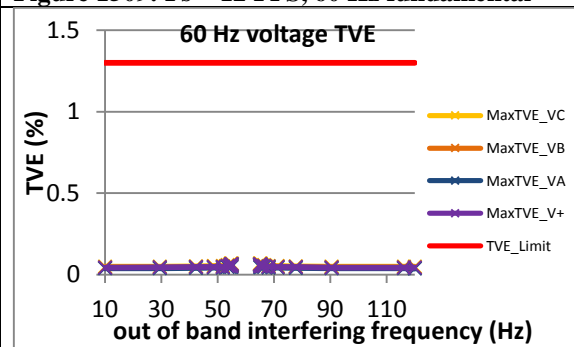


Figure 1512:  $F_s = 60$  FPS, 60 Hz fundamental

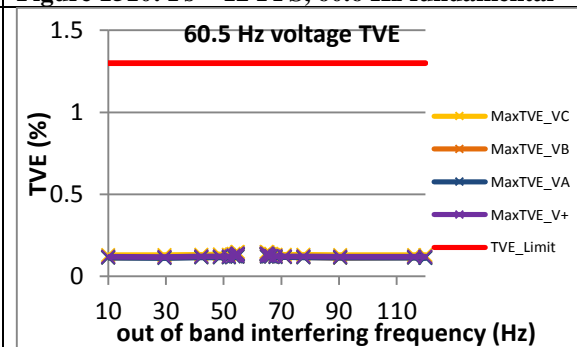
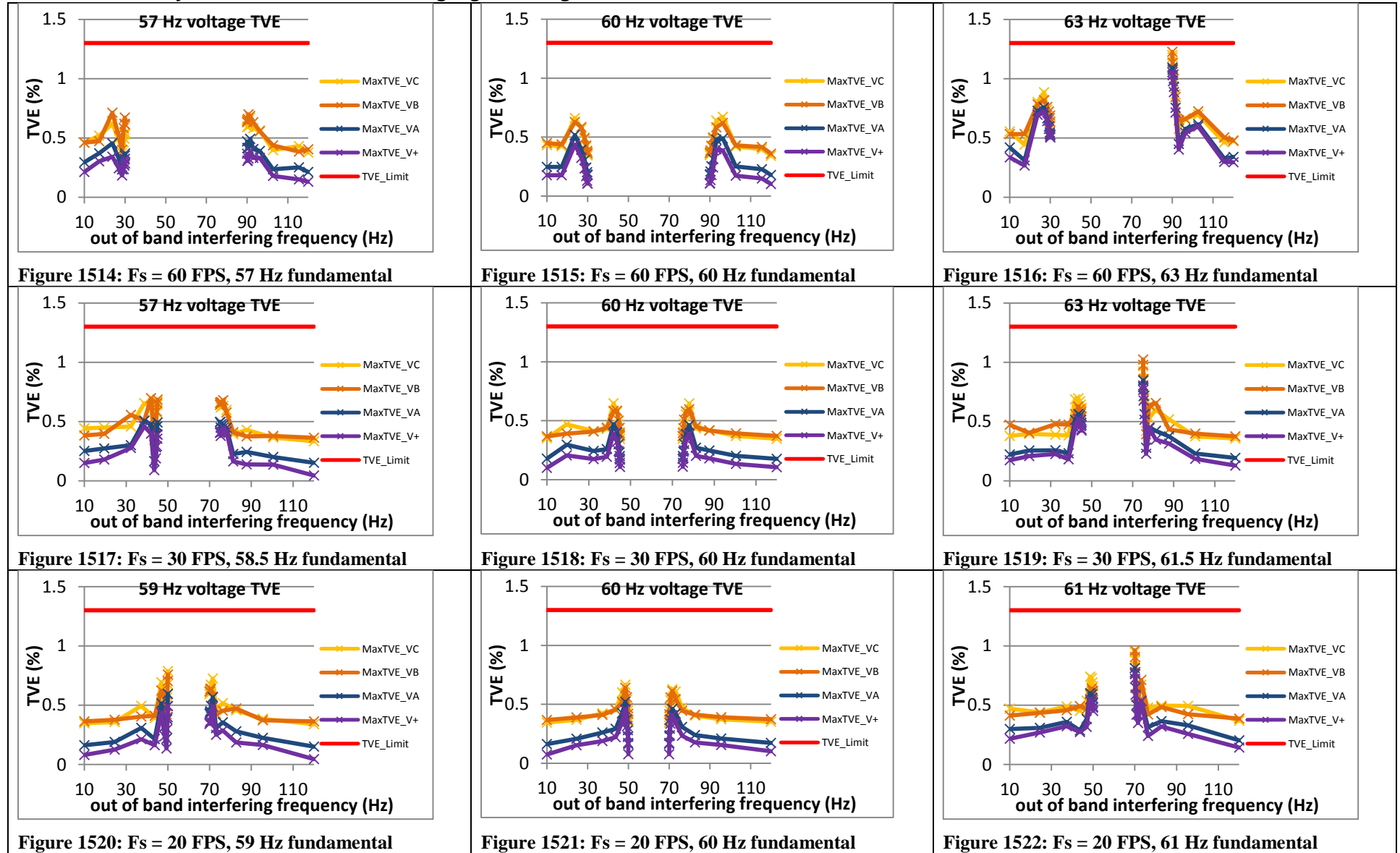
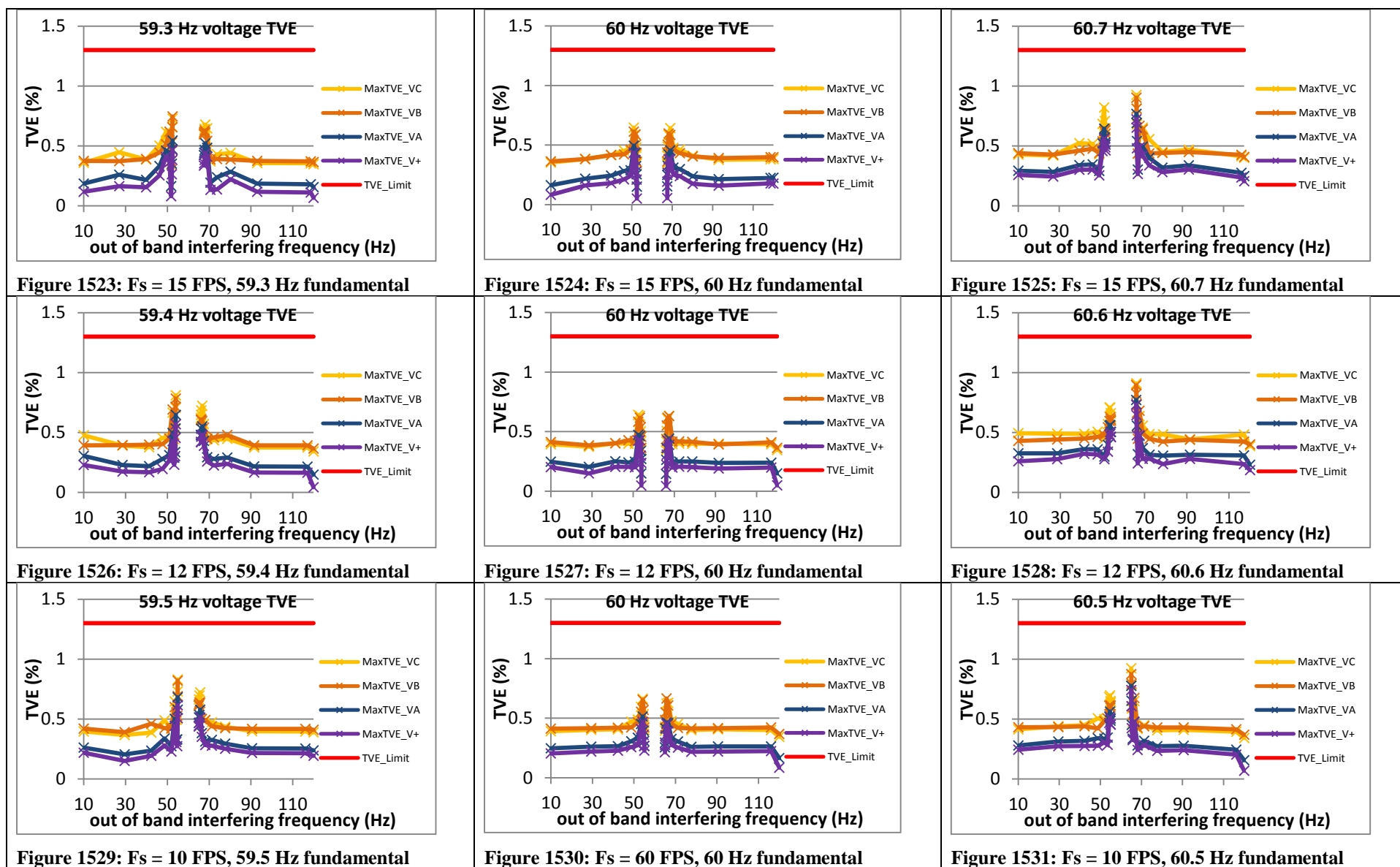


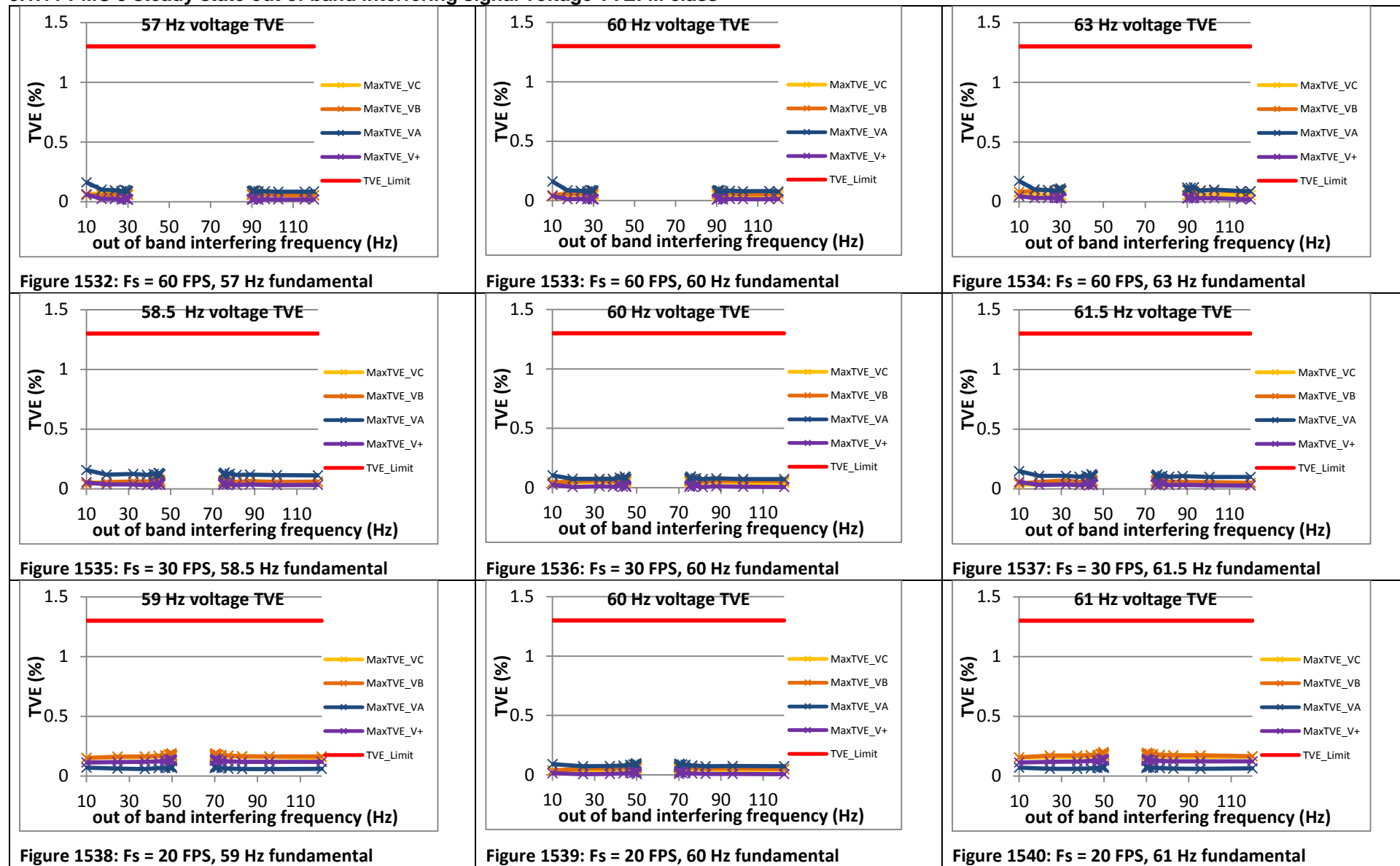
Figure 1513:  $F_s = 10$  FPS, 60.5 Hz fundamental

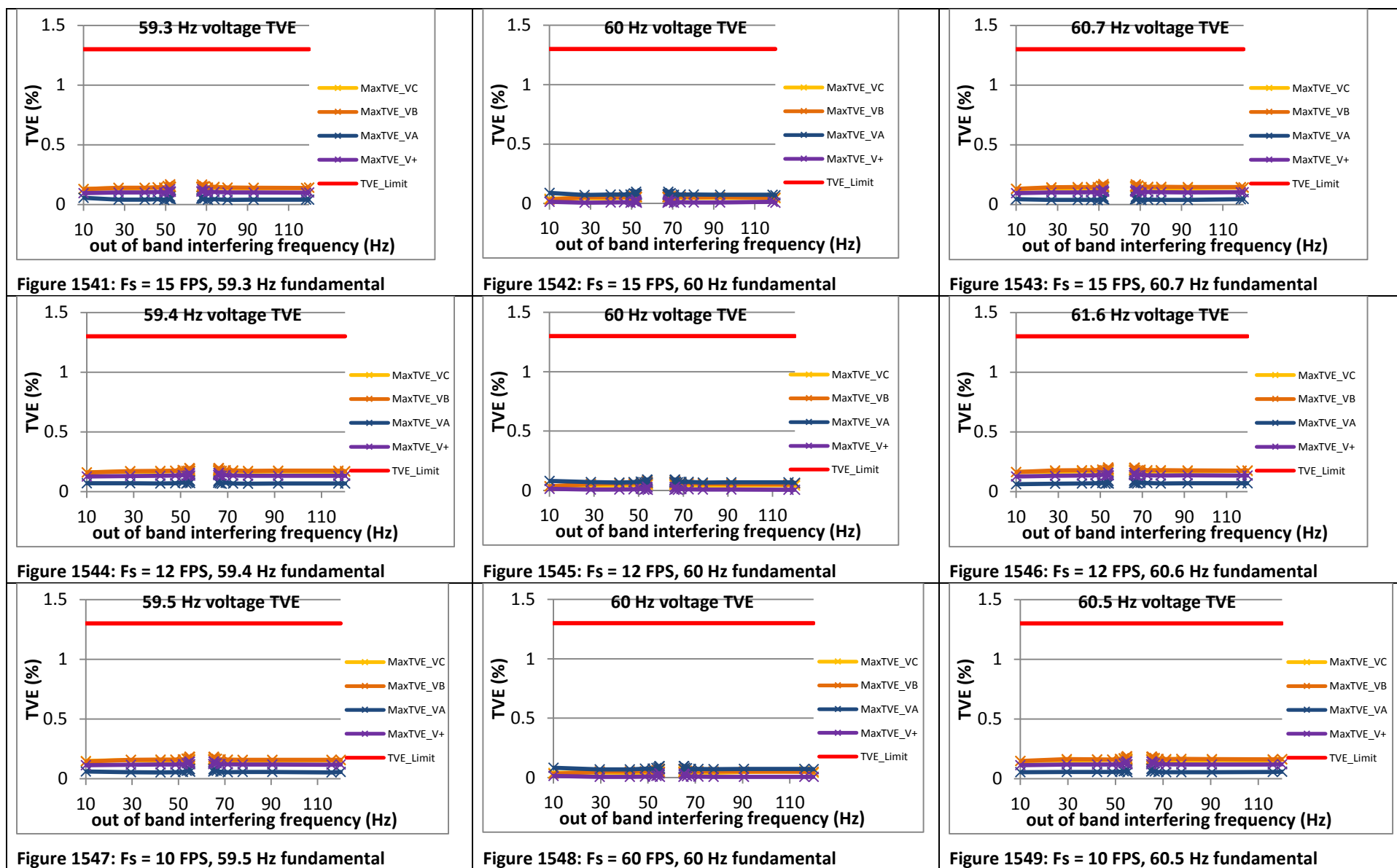
### 5.1.10 PMU I steady state out of band interfering signal voltage TVE: M class





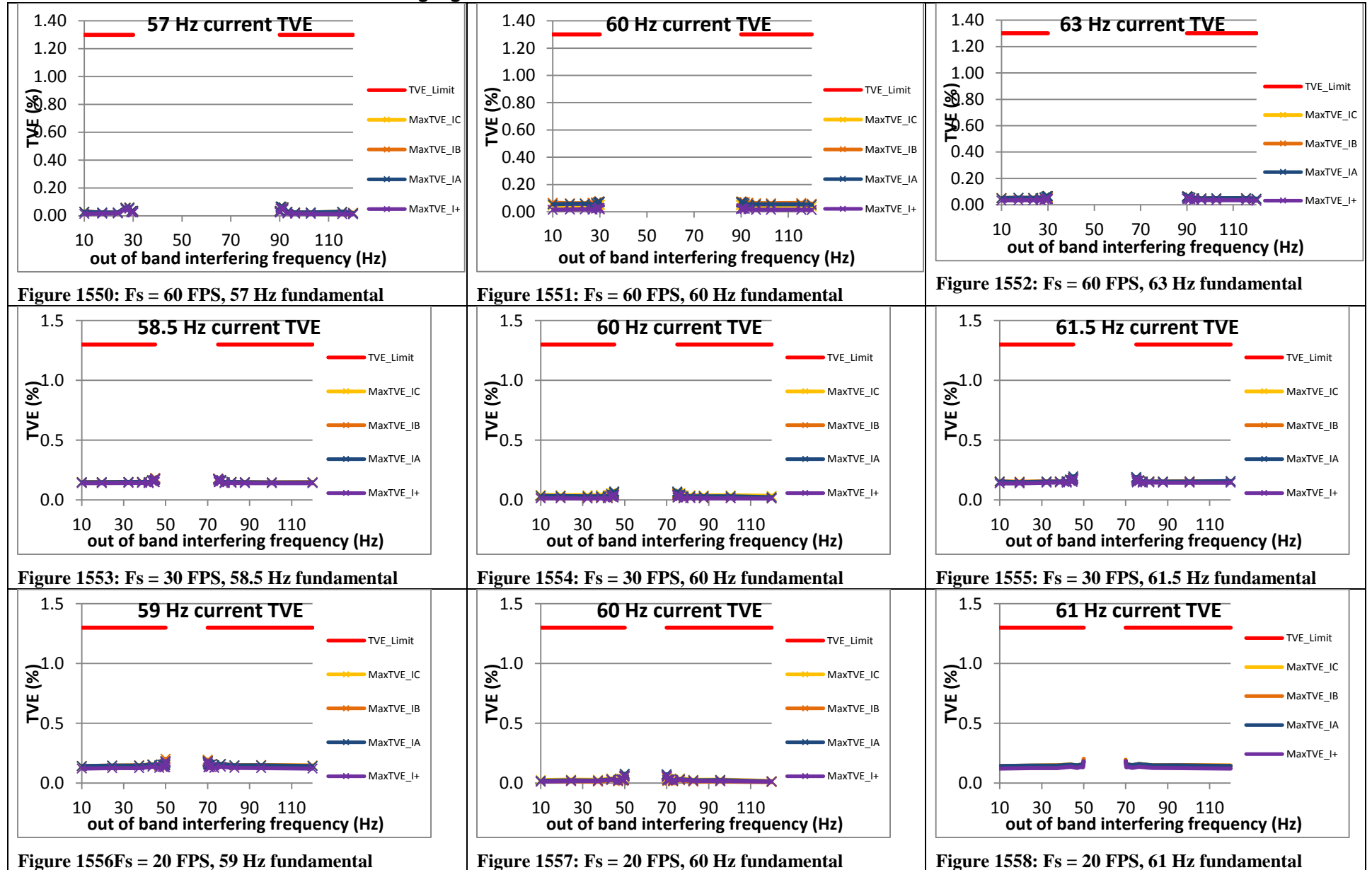
### 5.1.11 PMU J steady state out of band interfering signal voltage TVE: M class

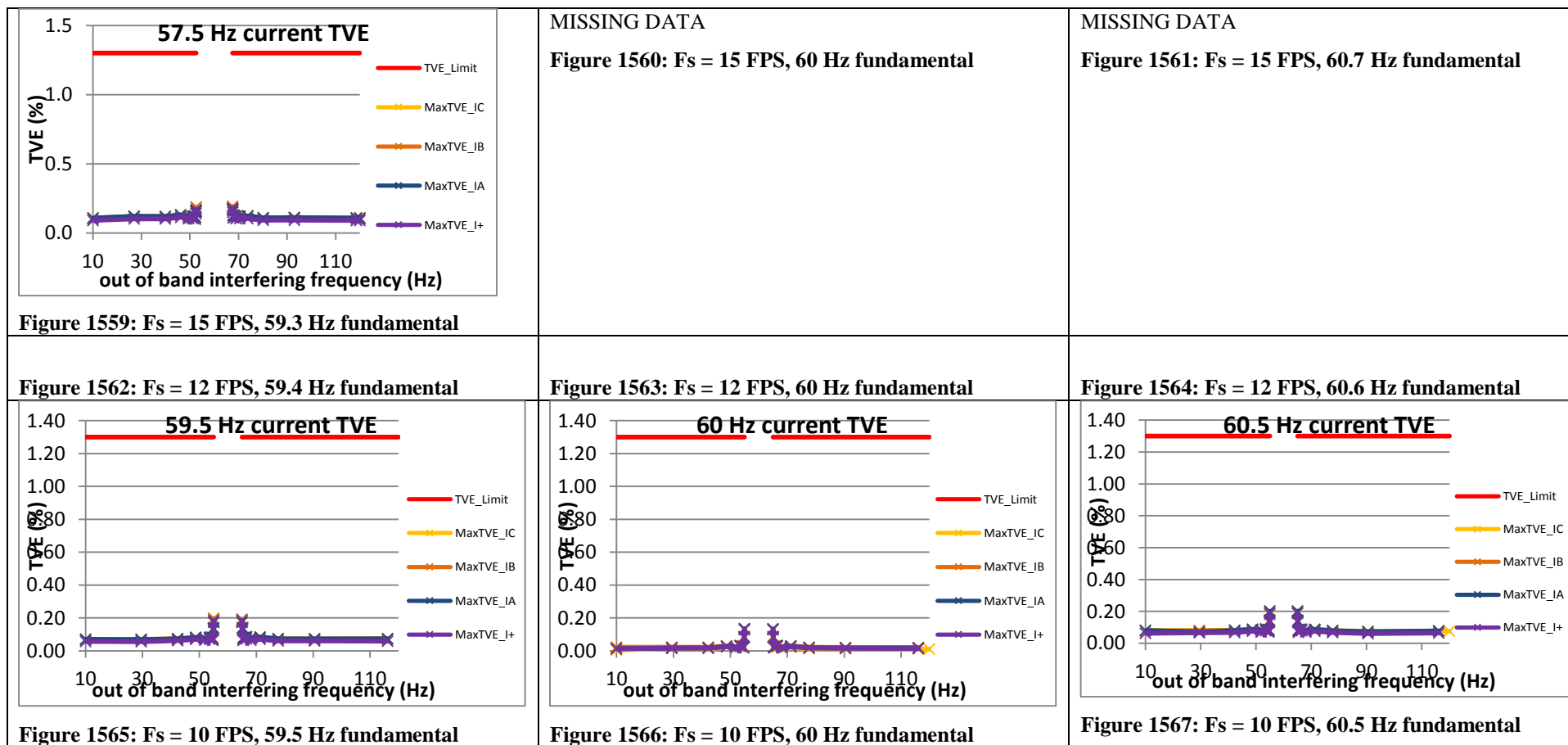




## 5.2 Steady state out of band interfering signals test current TVE: M class

### 5.2.1 C37.118.1 Annex C out of band interfering signals current TVE: M class







## 5.2.2 PMU A out of band interfering signals current TVE: M class

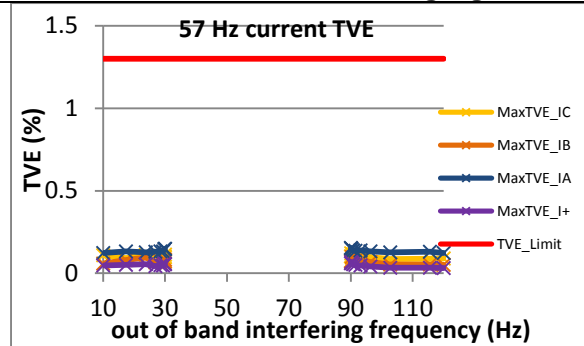


Figure 1568:  $F_s = 60$  FPS, 57 Hz fundamental

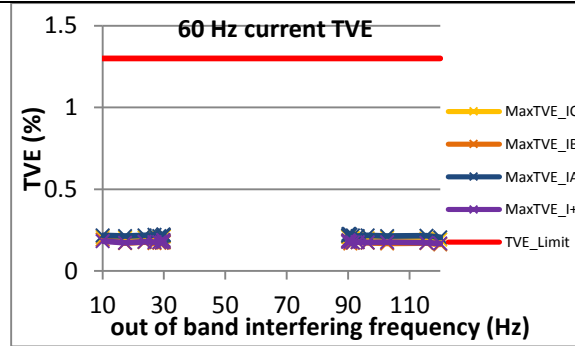


Figure 1569:  $F_s = 60$  FPS, 60 Hz fundamental

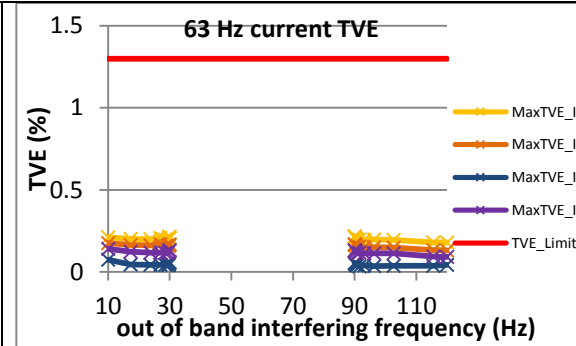


Figure 1570:  $F_s = 60$  FPS, 63 Hz fundamental

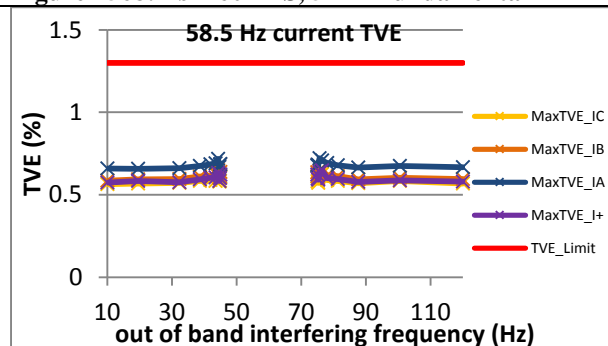


Figure 1571:  $F_s = 30$  FPS, 58.5 Hz fundamental

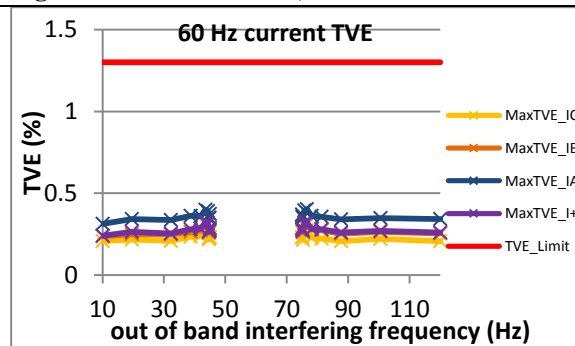


Figure 1572:  $F_s = 30$  FPS, 60 Hz fundamental

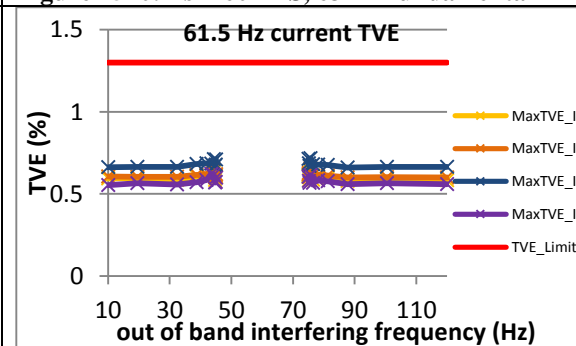


Figure 1573:  $F_s = 30$  FPS, 61.5 Hz fundamental

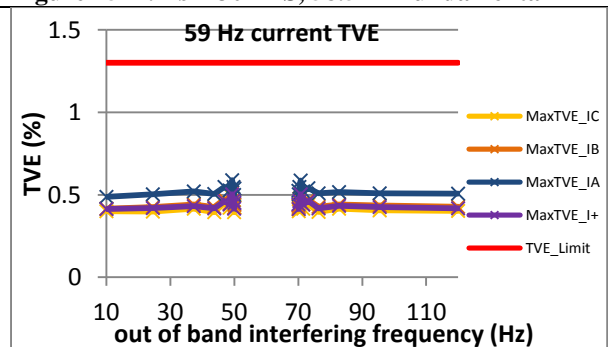


Figure 1574:  $F_s = 20$  FPS, 59 Hz fundamental

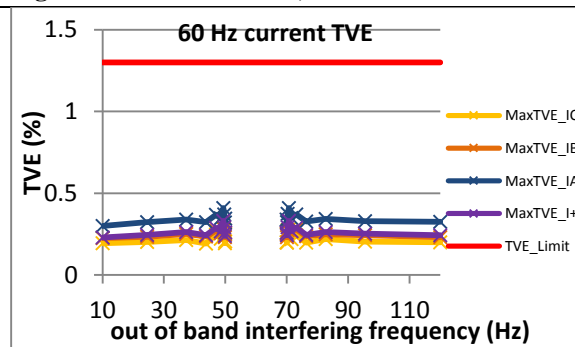


Figure 1575:  $F_s = 20$  FPS, 60 Hz fundamental

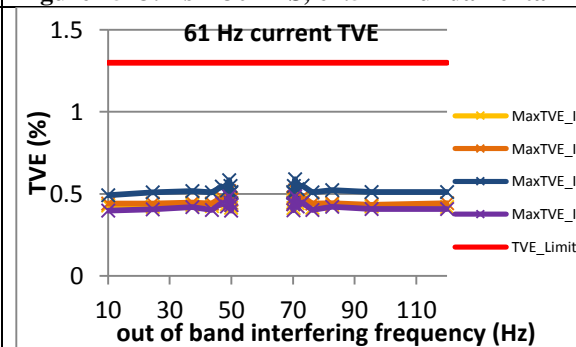
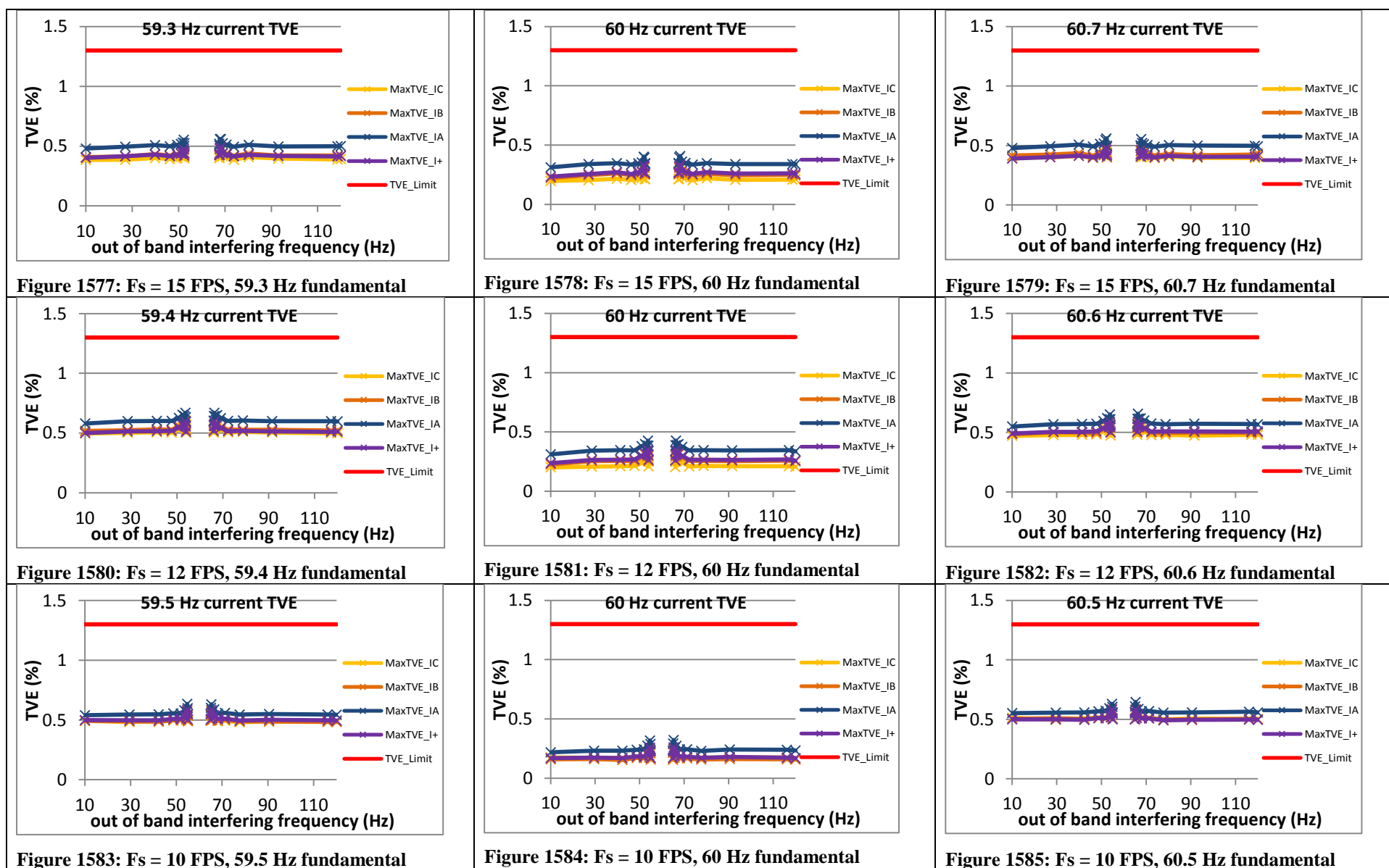


Figure 1576:  $F_s = 20$  FPS, 61 Hz fundamental



### 5.2.3 PMU B out of band interfering signals current TVE: M class

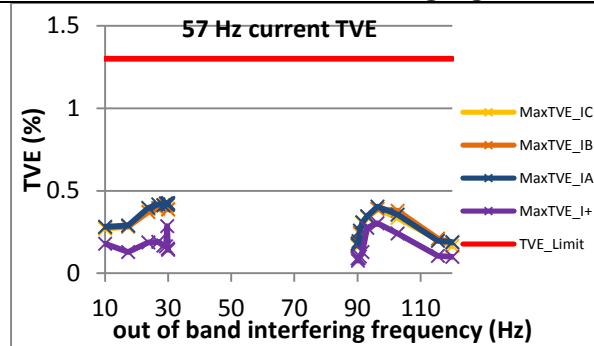


Figure 1586:  $F_s = 60$  FPS, 57 Hz fundamental

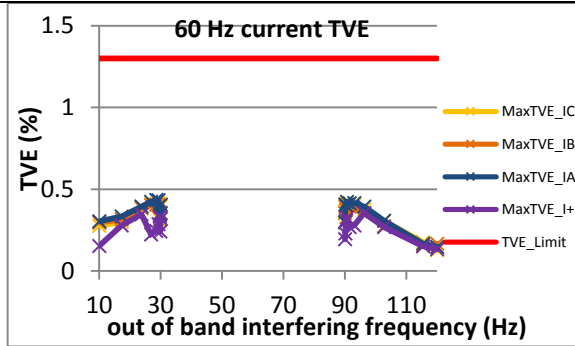


Figure 1587:  $F_s = 60$  FPS, 60 Hz fundamental

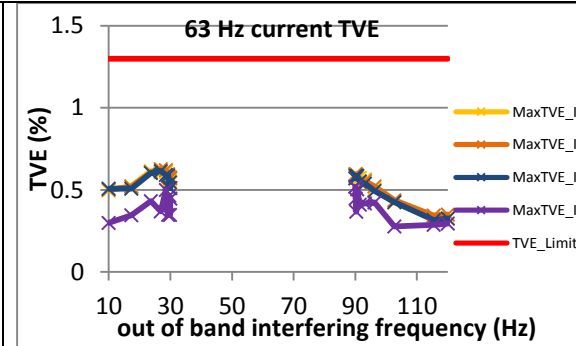


Figure 1588:  $F_s = 60$  FPS, 63 Hz fundamental

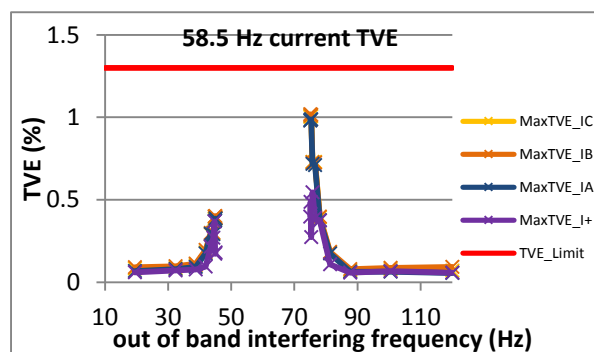


Figure 1589:  $F_s = 30$  FPS, 58.5 Hz fundamental

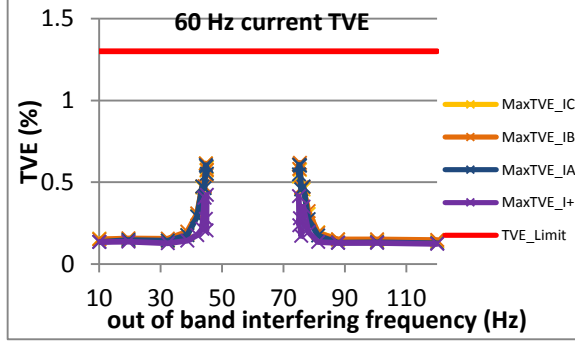


Figure 1590:  $F_s = 30$  FPS, 60 Hz fundamental

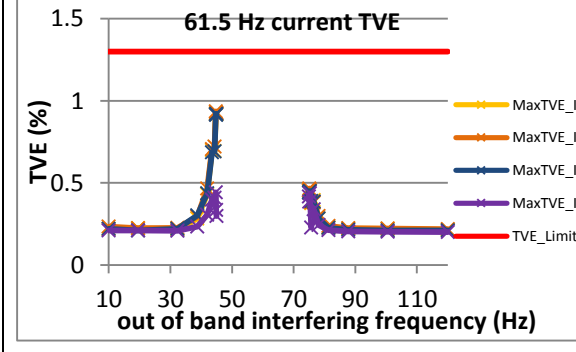


Figure 1591:  $F_s = 30$  FPS, 61.5 Hz fundamental

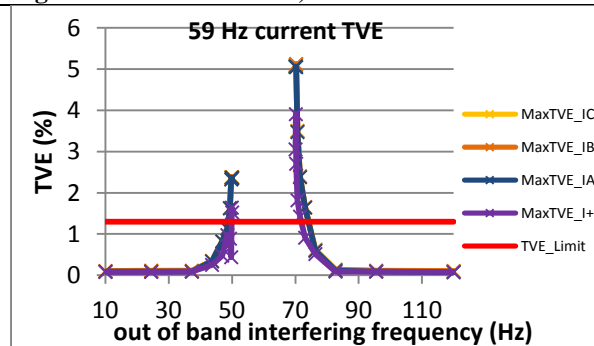


Figure 1592:  $F_s = 20$  FPS, 59 Hz fundamental

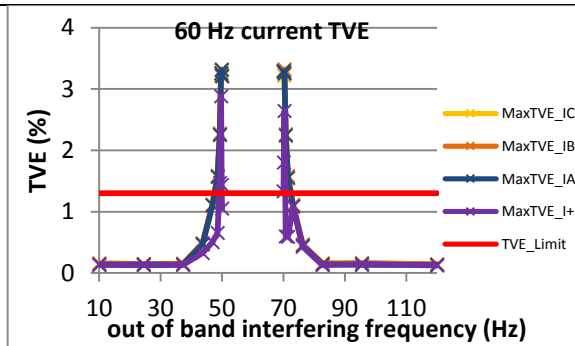


Figure 1593:  $F_s = 20$  FPS, 60 Hz fundamental

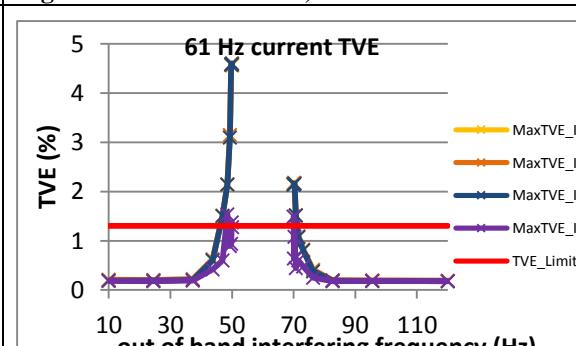
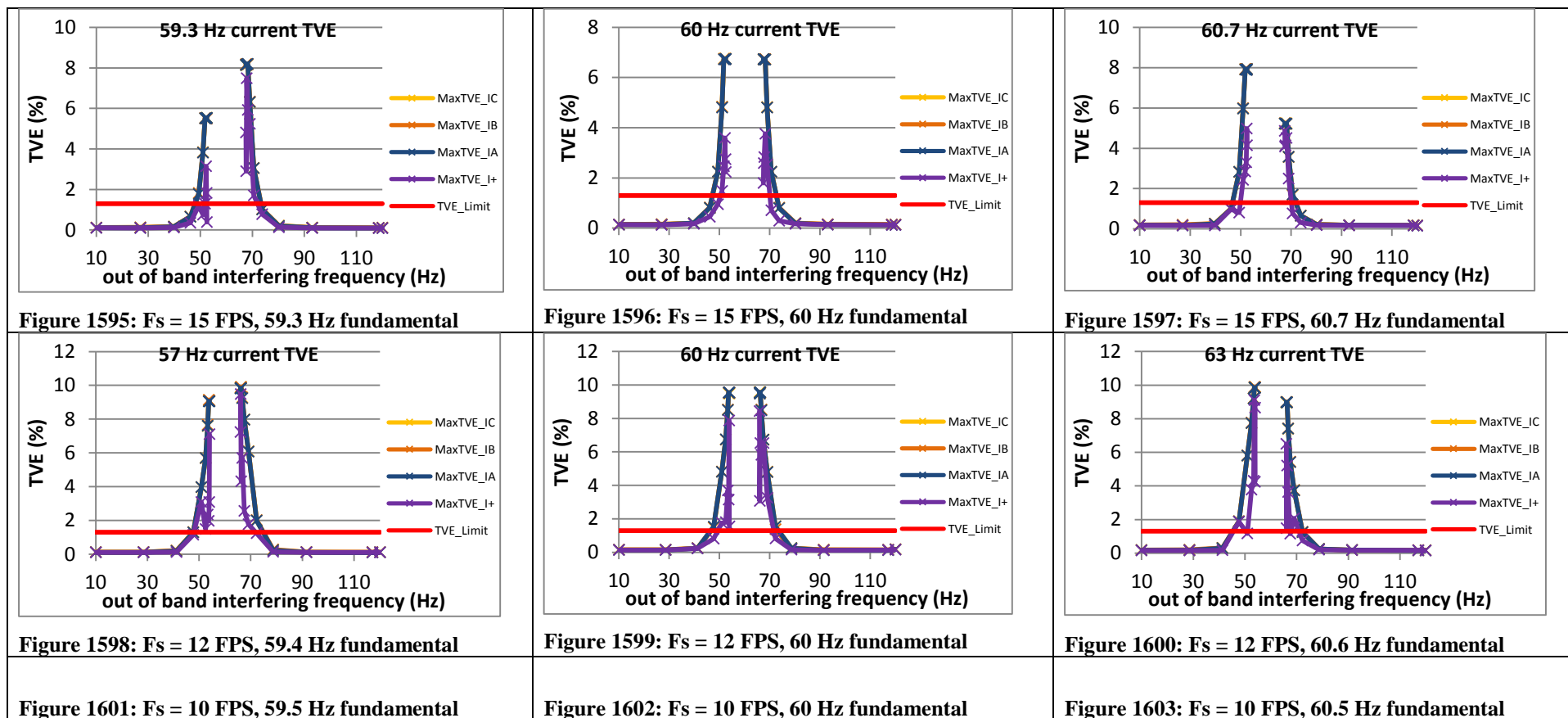
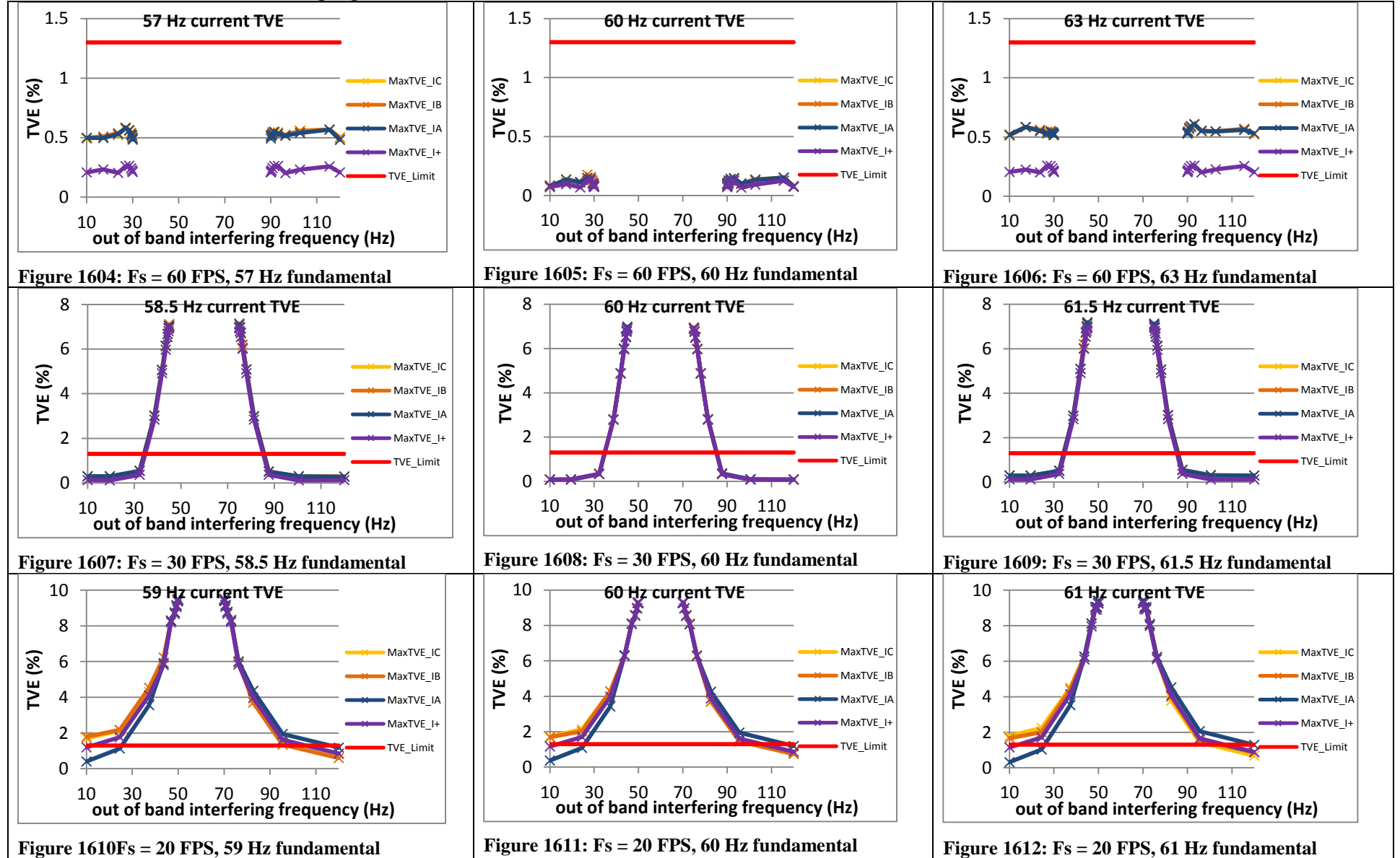
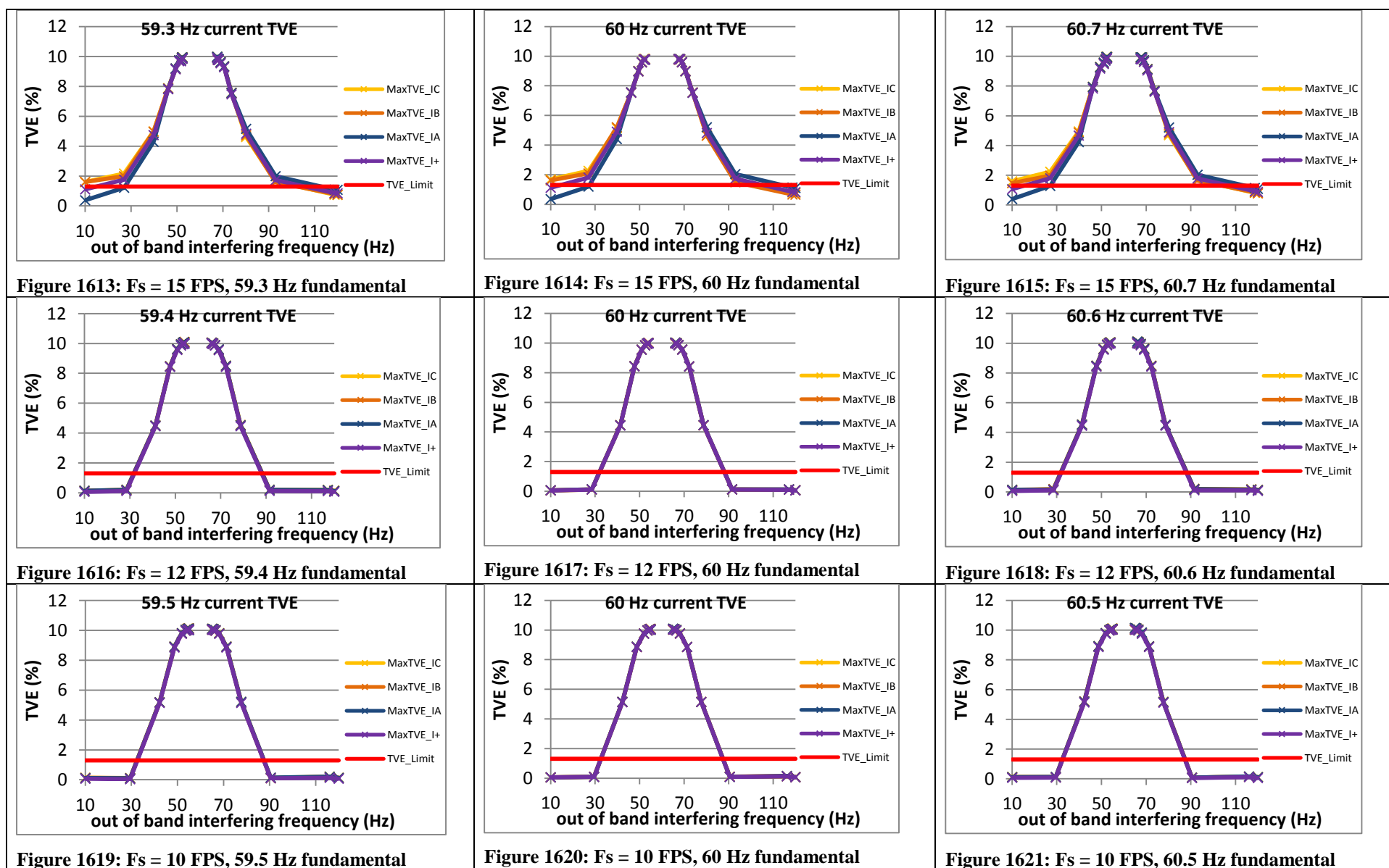


Figure 1594:  $F_s = 20$  FPS, 61 Hz fundamental

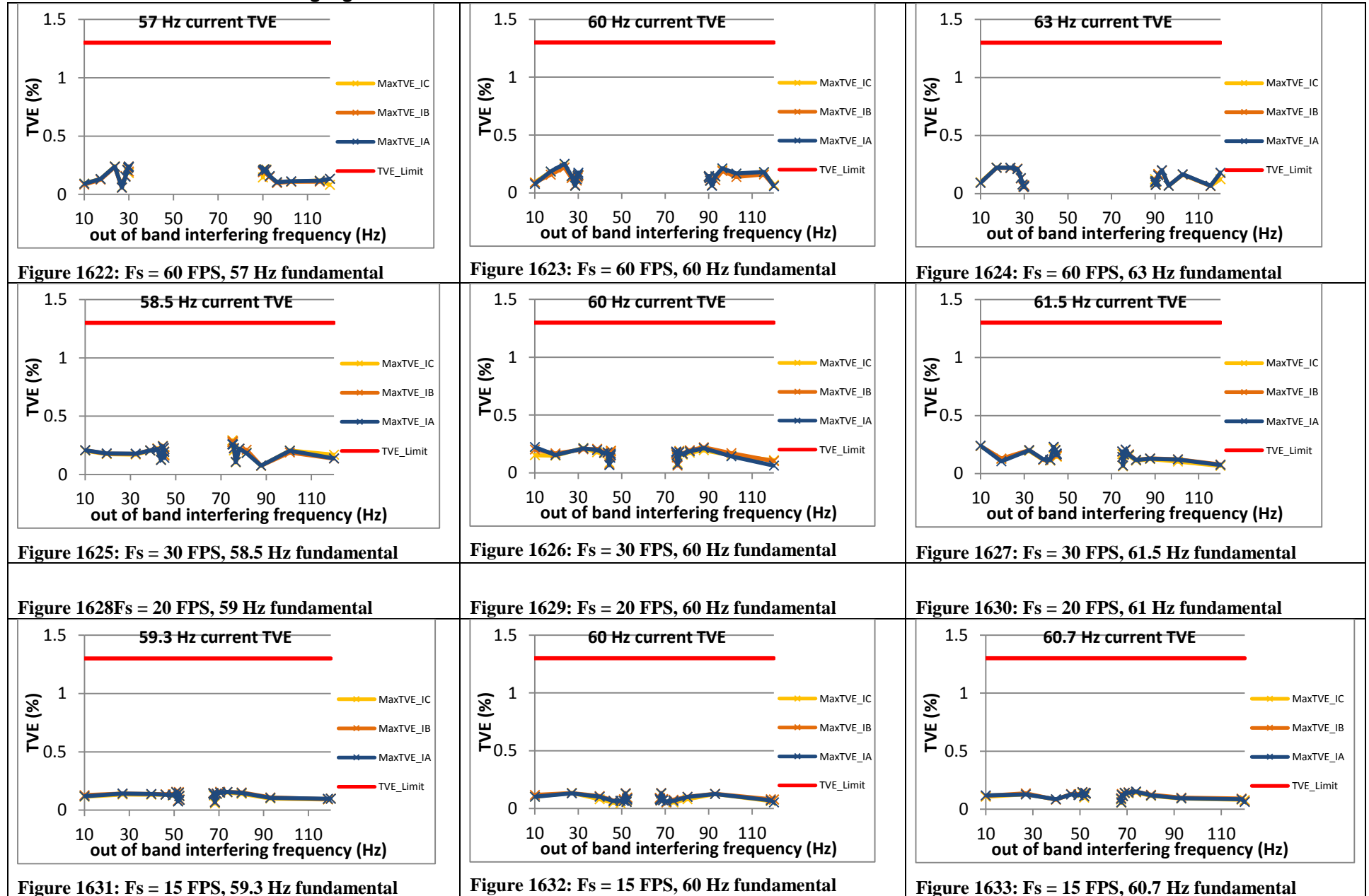


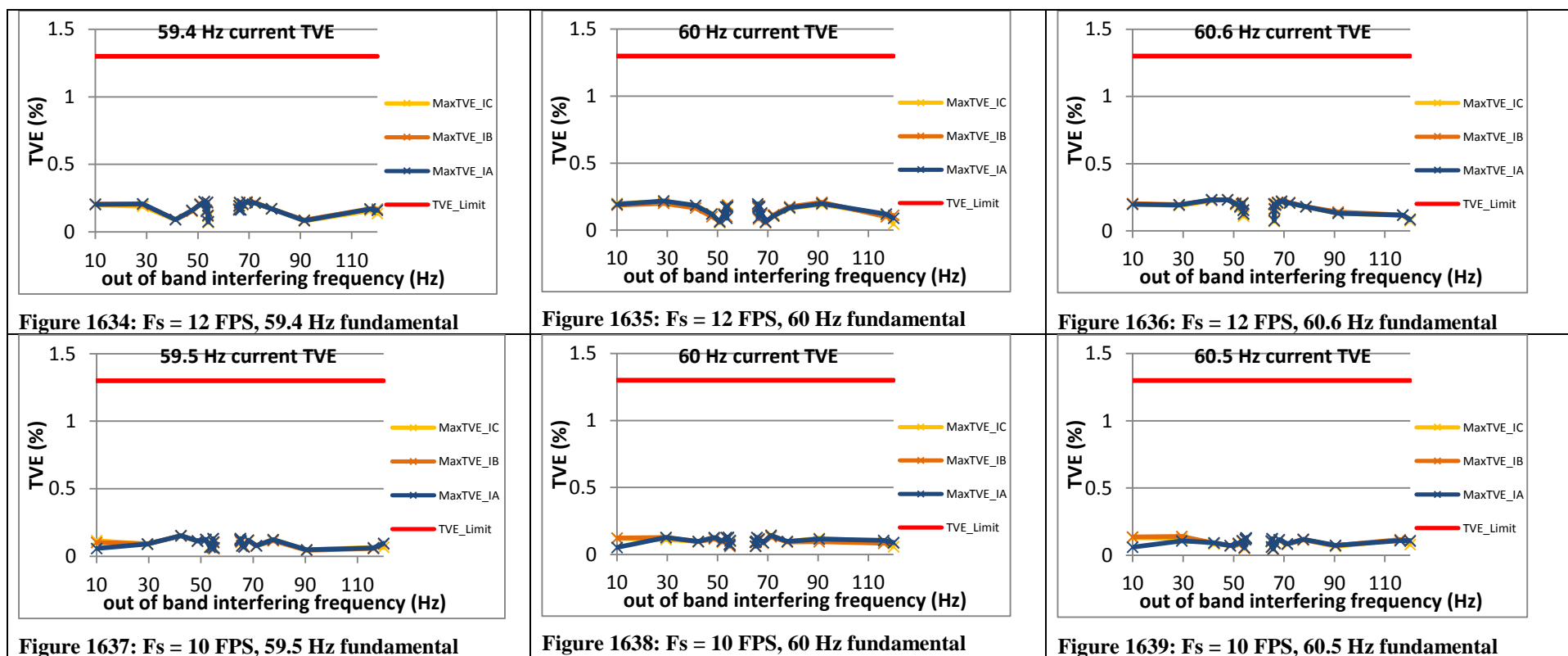
#### 5.2.4 PMU C out of band interfering signals current TVE: M class





### 5.2.5 PMU D out of band interfering signals current TVE: M class







### 5.2.6 PMU E out of band interfering signals current TVE: M class

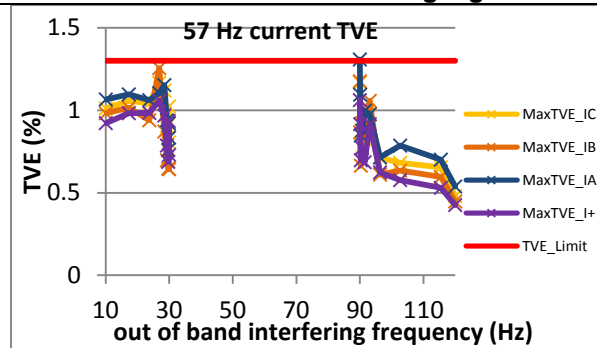


Figure 1640: Fs = 60 FPS, 57 Hz fundamental

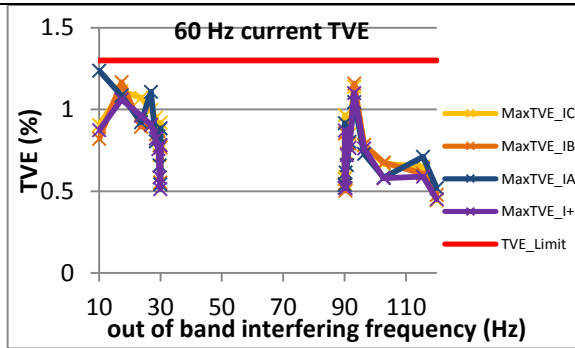


Figure 1641: Fs = 60 FPS, 60 Hz fundamental

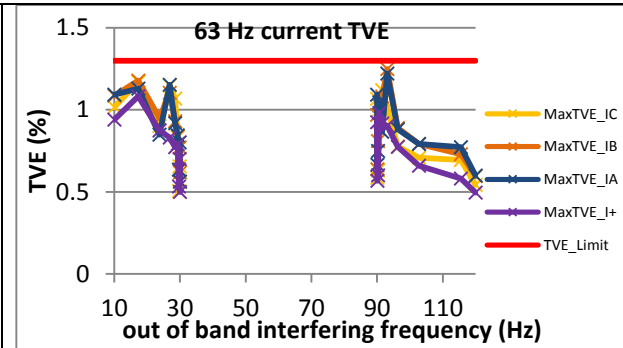


Figure 1642: Fs = 60 FPS, 63 Hz fundamental

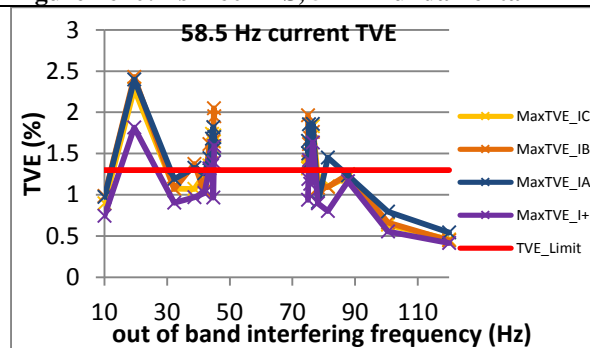


Figure 1643: Fs = 30 FPS, 58.5 Hz fundamental

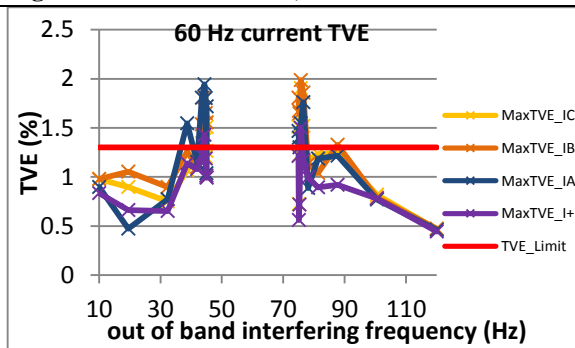


Figure 1644: Fs = 30 FPS, 60 Hz fundamental

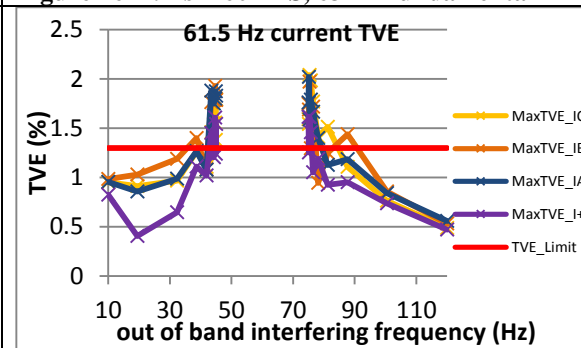


Figure 1645: Fs = 30 FPS, 61.5 Hz fundamental

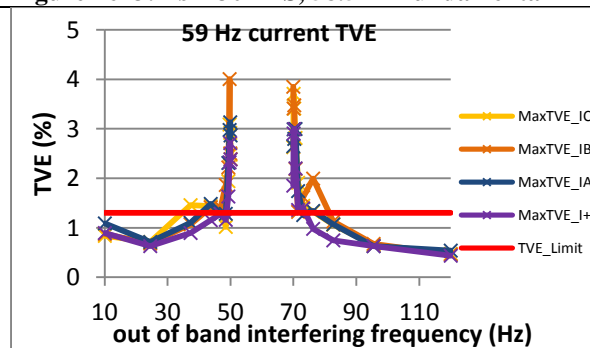


Figure 1646: Fs = 20 FPS, 59 Hz fundamental

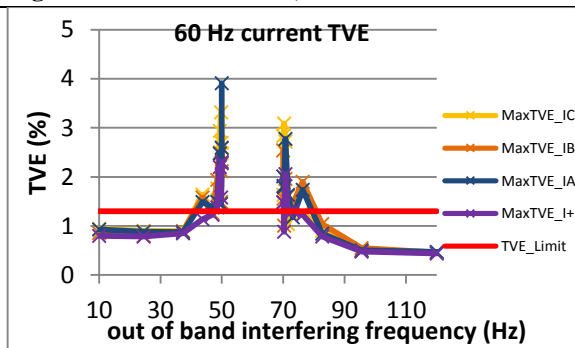


Figure 1647: Fs = 20 FPS, 60 Hz fundamental

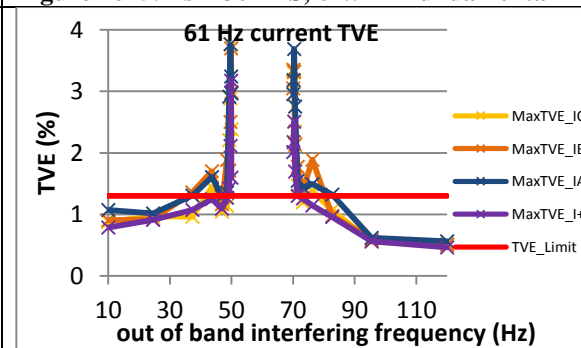


Figure 1648: Fs = 20 FPS, 61 Hz fundamental

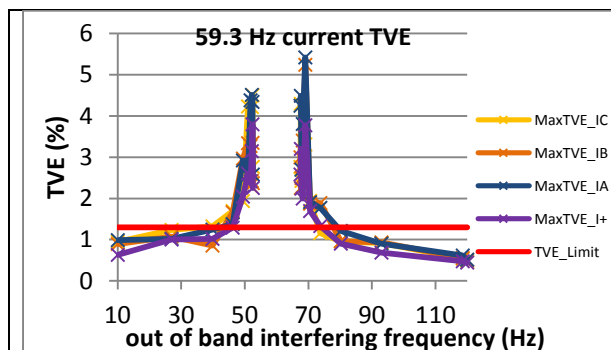


Figure 1649:  $F_s = 15$  FPS, 59.3 Hz fundamental

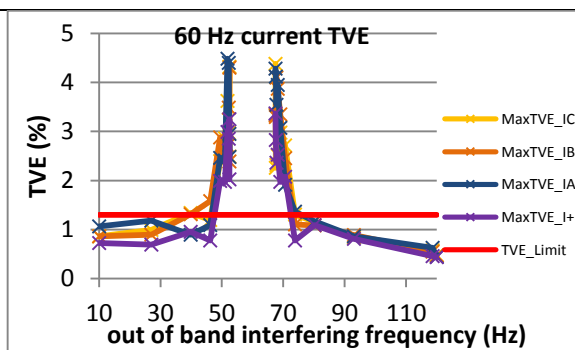


Figure 1650:  $F_s = 15$  FPS, 60 Hz fundamental

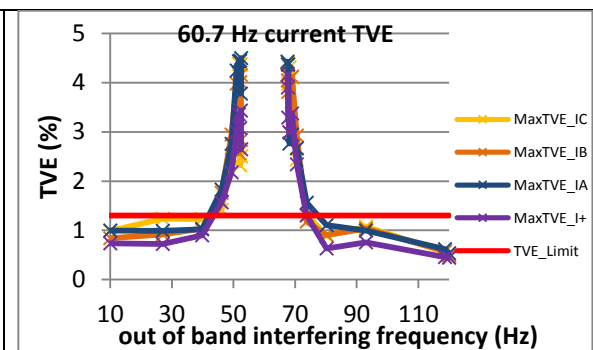


Figure 1651:  $F_s = 15$  FPS, 60.7 Hz fundamental

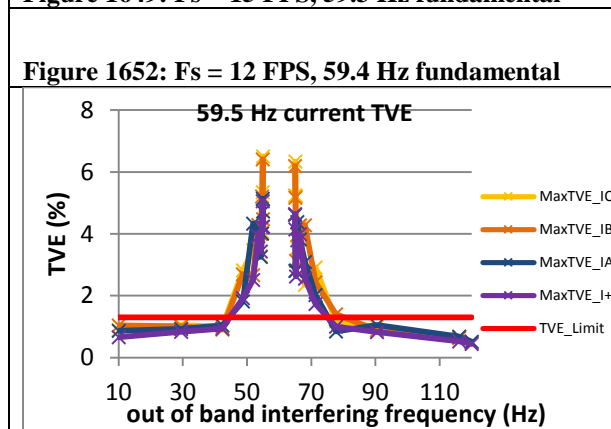


Figure 1652:  $F_s = 12$  FPS, 59.4 Hz fundamental

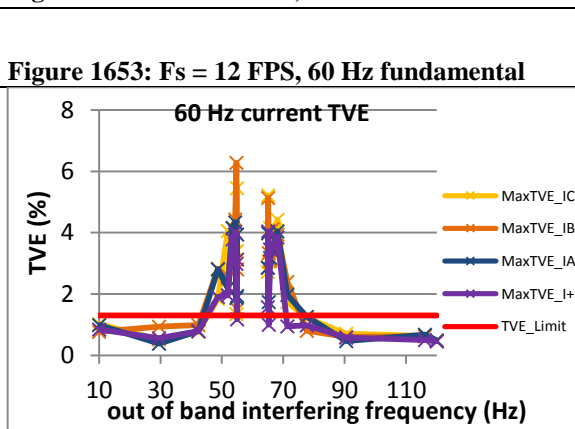


Figure 1653:  $F_s = 12$  FPS, 60 Hz fundamental

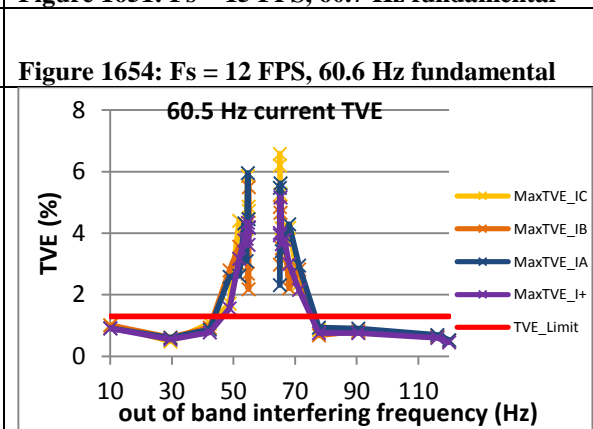


Figure 1654:  $F_s = 12$  FPS, 60.6 Hz fundamental



Figure 1655:  $F_s = 10$  FPS, 59.5 Hz fundamental

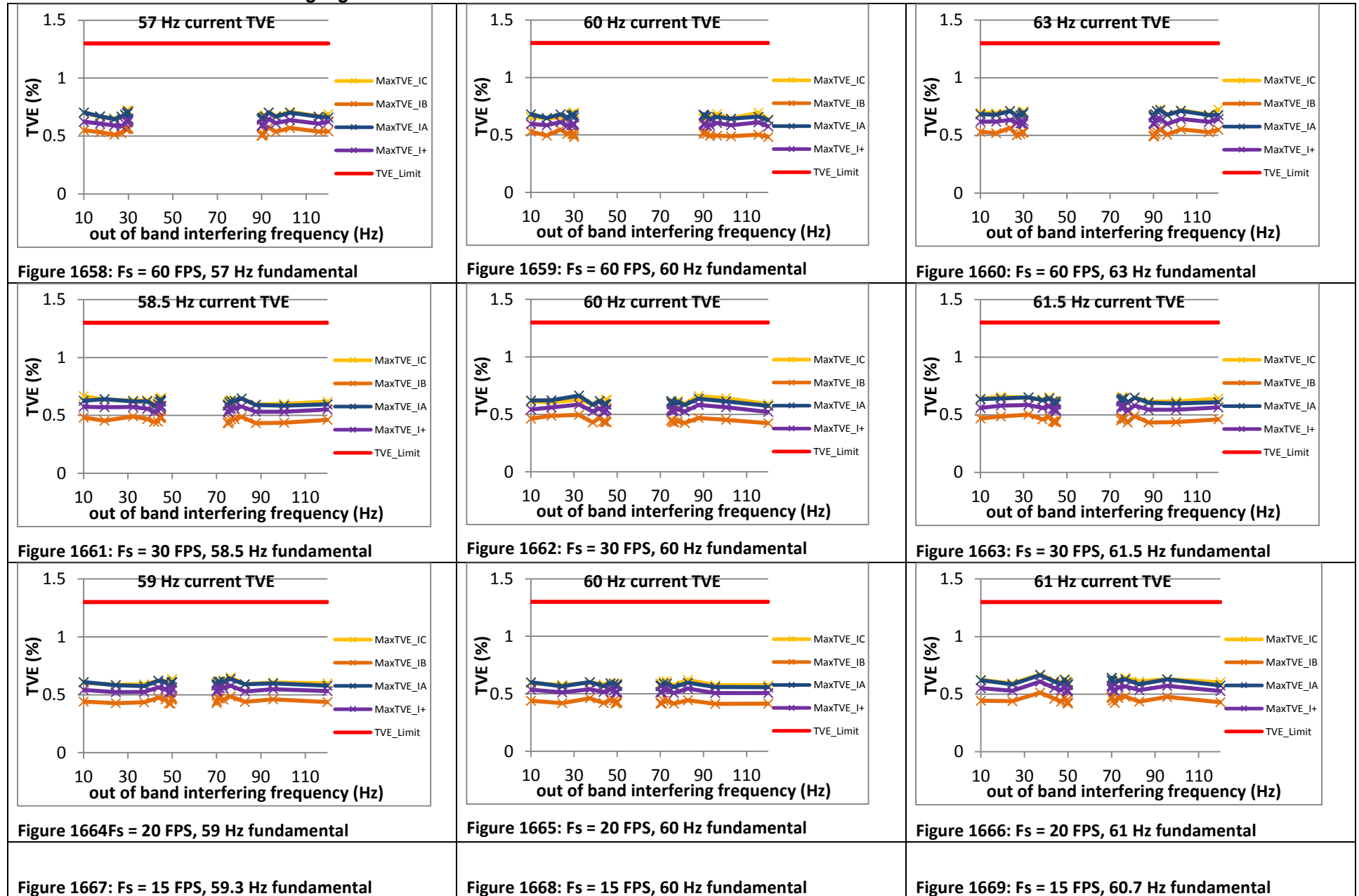


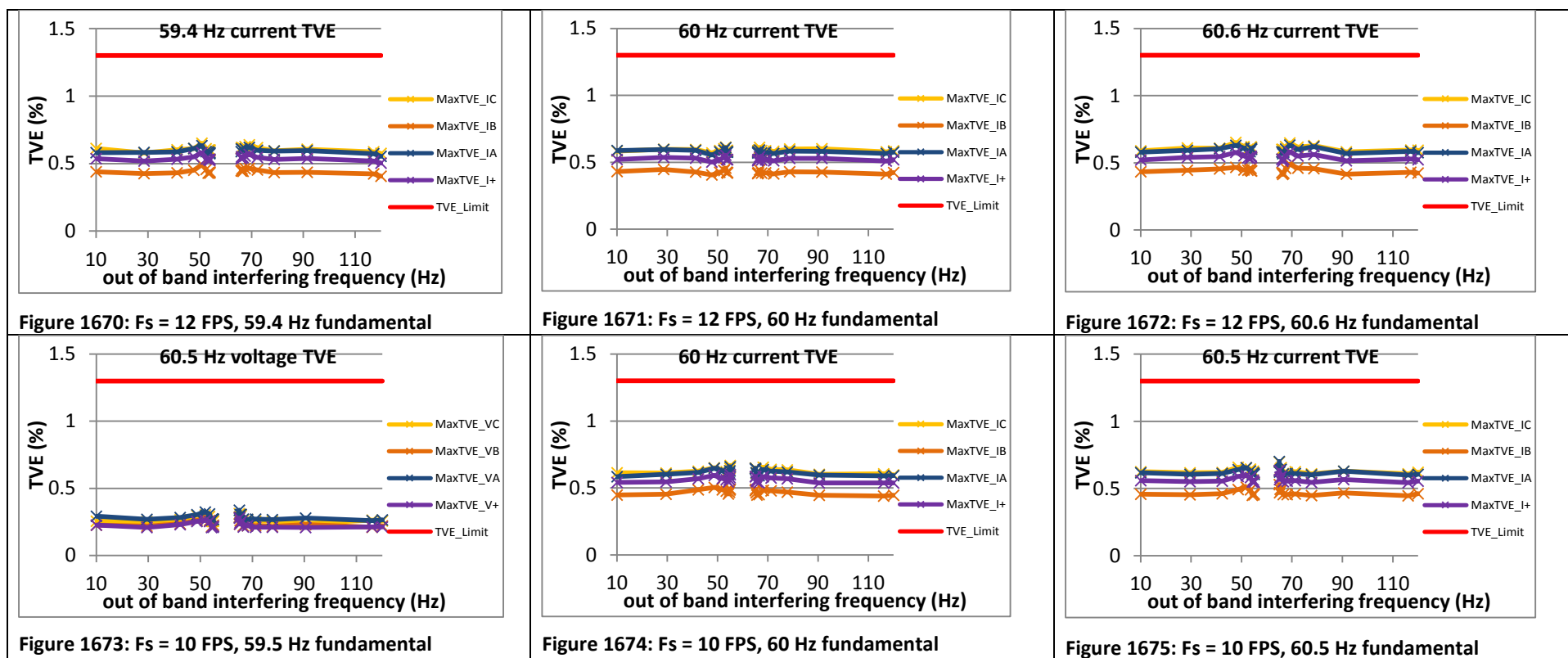
Figure 1656:  $F_s = 10$  FPS, 60 Hz fundamental



Figure 1657:  $F_s = 10$  FPS, 60.5 Hz fundamental

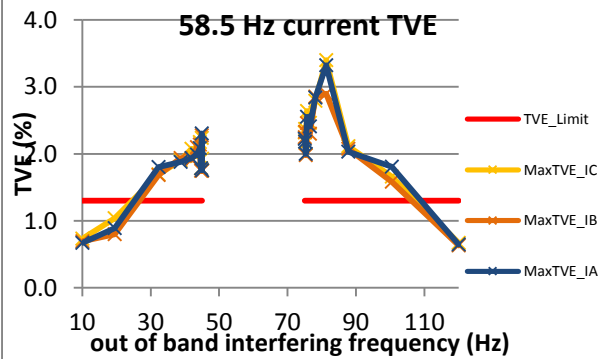
### 5.2.7 PMU F out of band interfering signals current TVE: M class



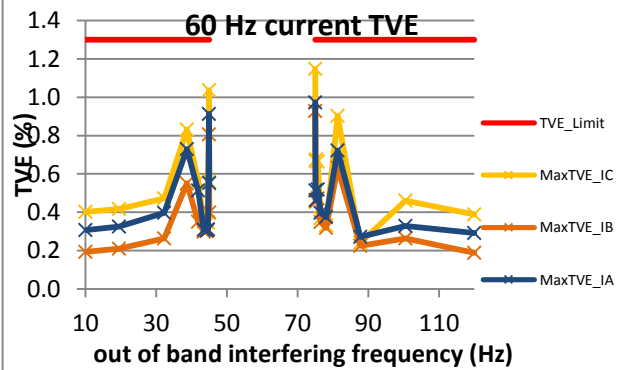


### 5.2.8 PMU G out of band interfering signals current TVE: M class

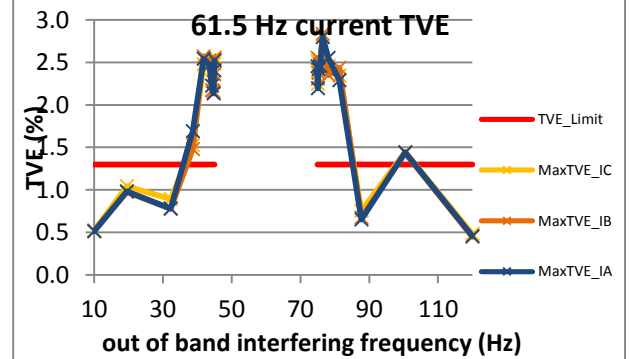
**Figure 1676: Fs = 60 FPS, 57 Hz fundamental**  
PMU G does not support 60 FPS



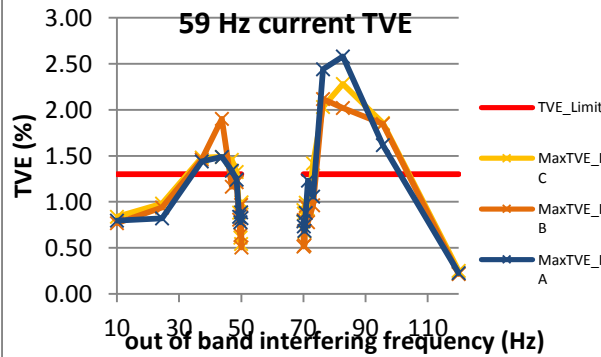
**Figure 1677: Fs = 60 FPS, 60 Hz fundamental**  
PMU G does not support 60 FPS



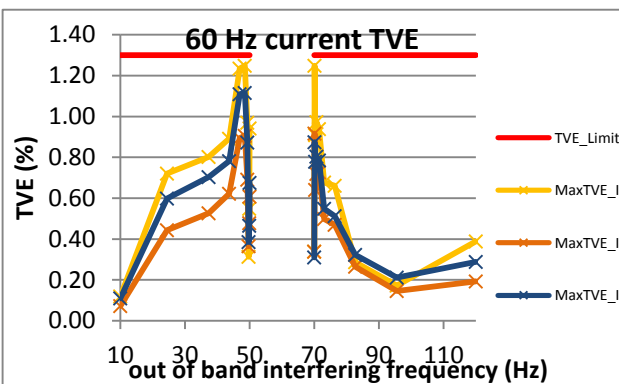
**Figure 1678: Fs = 60 FPS, 63 Hz fundamental**  
PMU G does not support 60 FPS



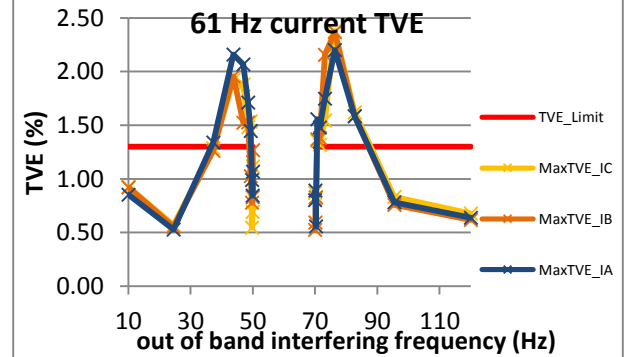
**Figure 1679: Fs = 30 FPS, 58.5 Hz fundamental**



**Figure 1680: Fs = 30 FPS, 60 Hz fundamental**



**Figure 1681: Fs = 30 FPS, 61.5 Hz fundamental**



**Figure 1682: Fs = 20 FPS, 59 Hz fundamental**

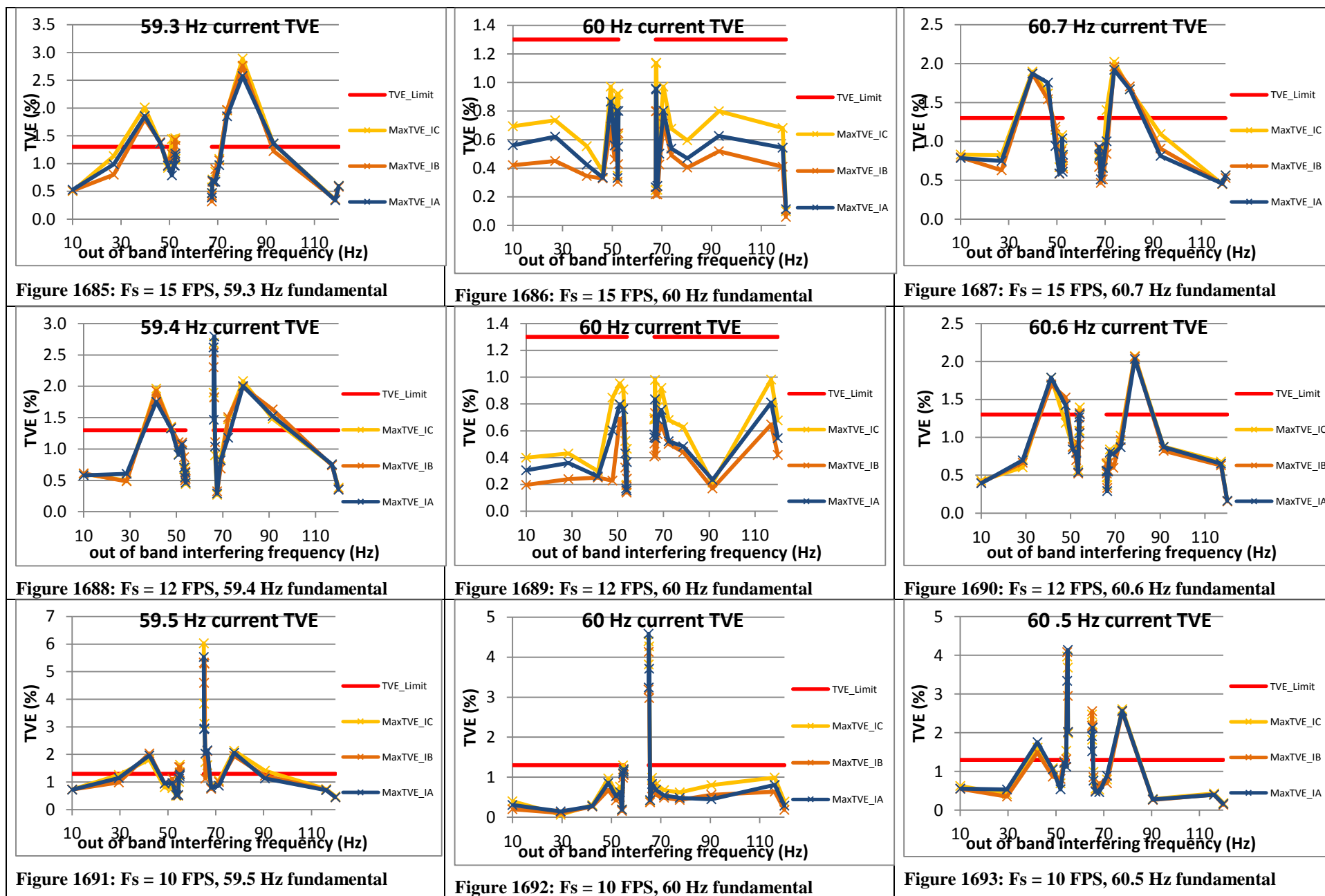


**Figure 1683: Fs = 20 FPS, 60 Hz fundamental**



**Figure 1684: Fs = 20 FPS, 61 Hz fundamental**





### 5.2.9 PMU H out of band interfering signals current TVE: M class

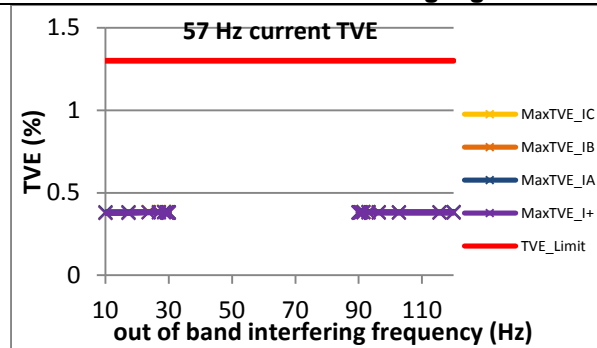


Figure 1694:  $F_s = 60$  FPS, 57 Hz fundamental

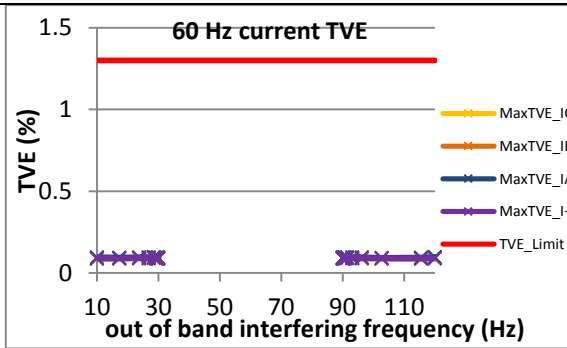


Figure 1695:  $F_s = 60$  FPS, 60 Hz fundamental

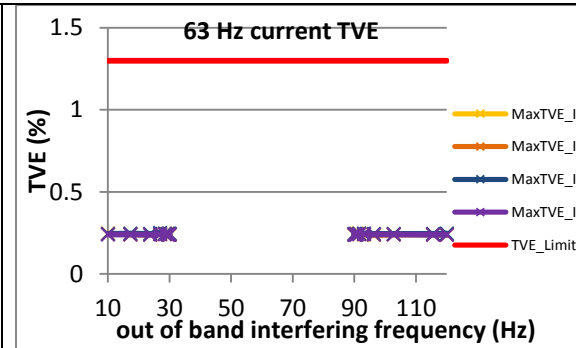


Figure 1696:  $F_s = 60$  FPS, 63 Hz fundamental

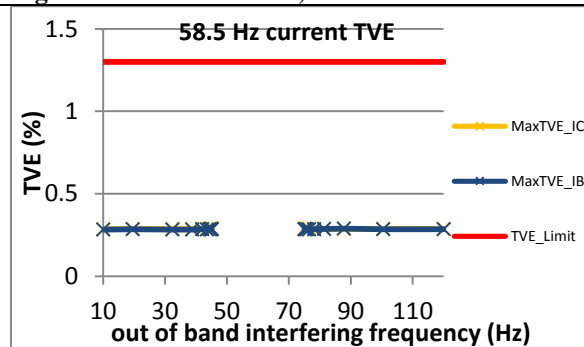


Figure 1697:  $F_s = 30$  FPS, 58.5 Hz fundamental

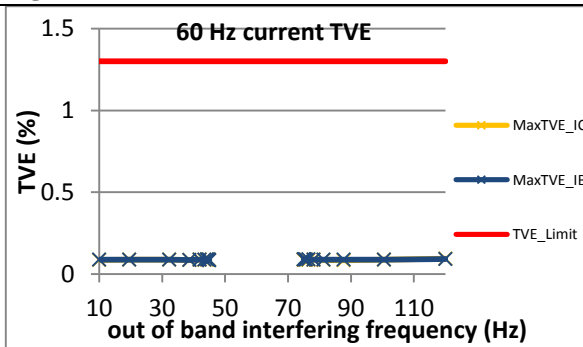


Figure 1698:  $F_s = 30$  FPS, 60 Hz fundamental

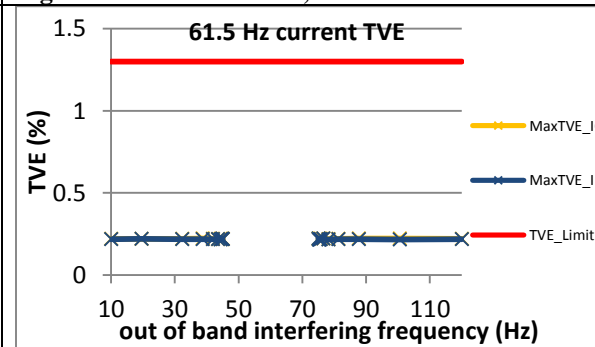


Figure 1699:  $F_s = 30$  FPS, 61.5 Hz fundamental

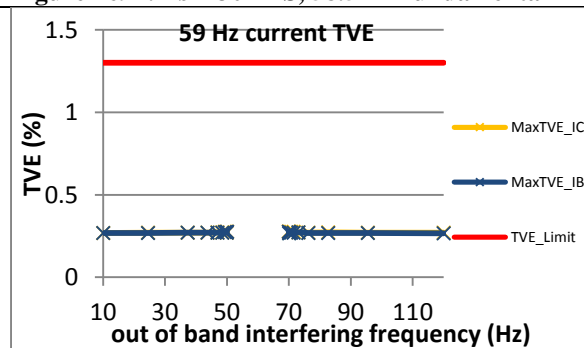


Figure 1700:  $F_s = 20$  FPS, 59 Hz fundamental

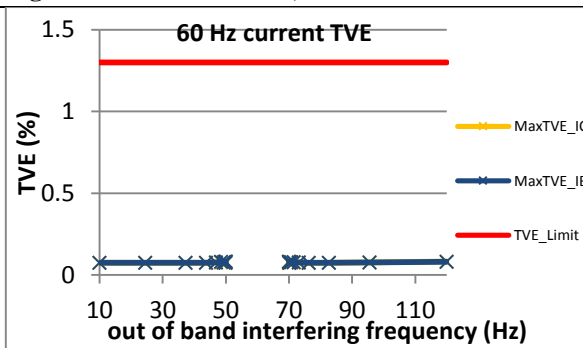


Figure 1701:  $F_s = 20$  FPS, 60 Hz fundamental

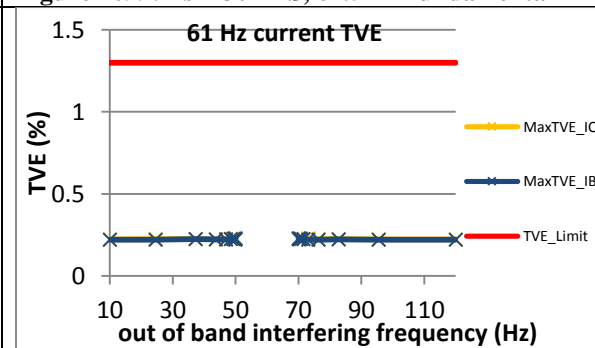
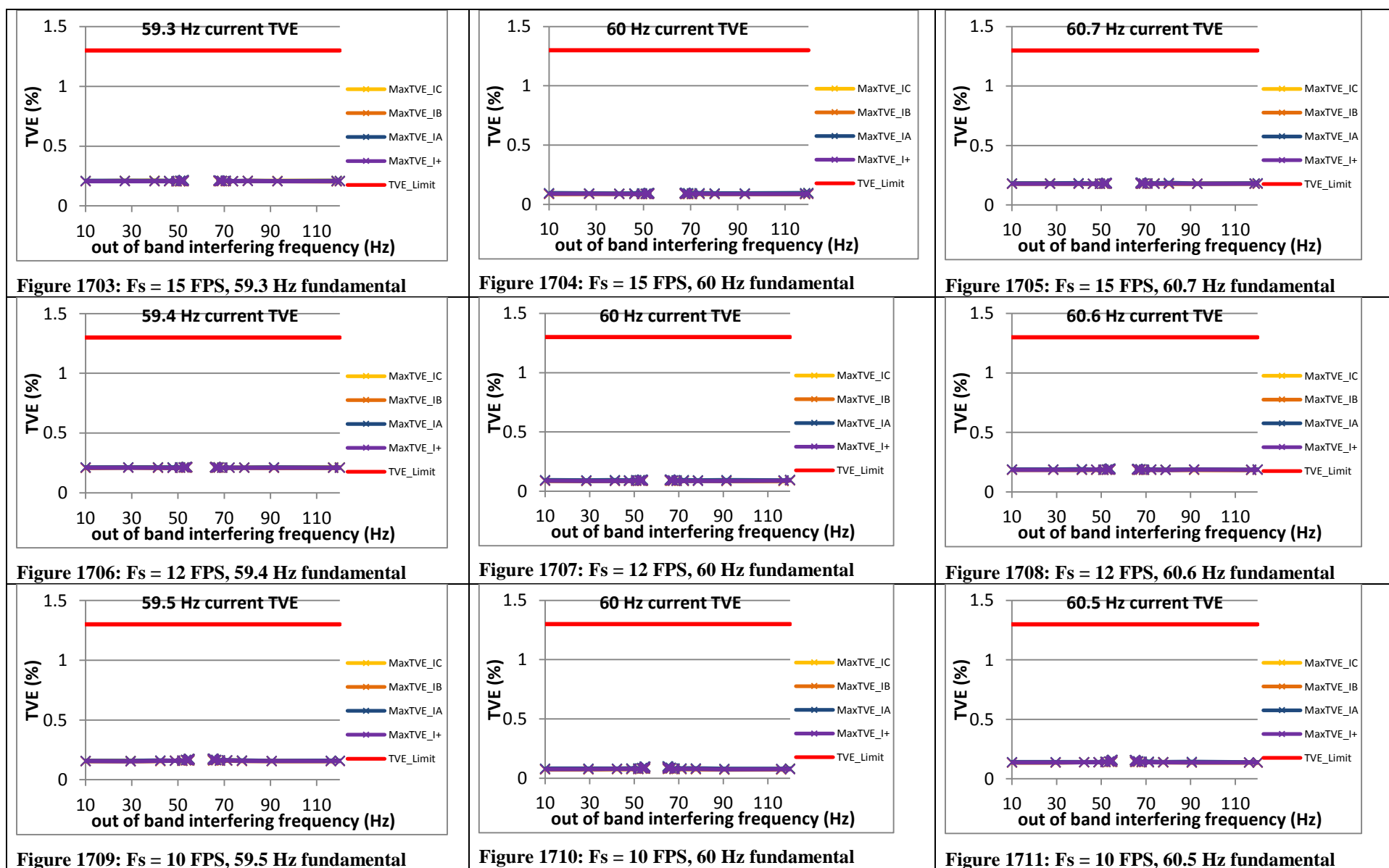
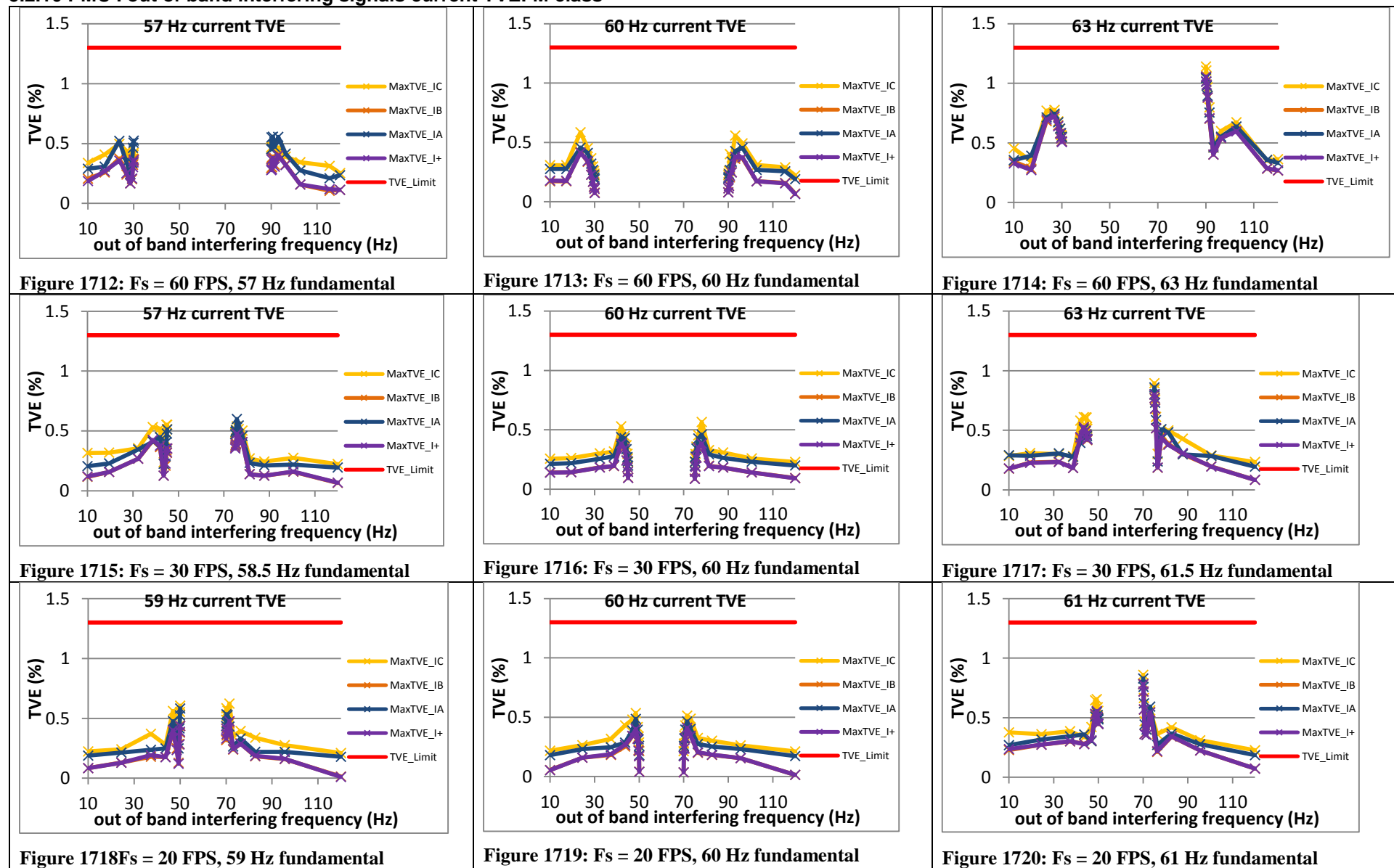


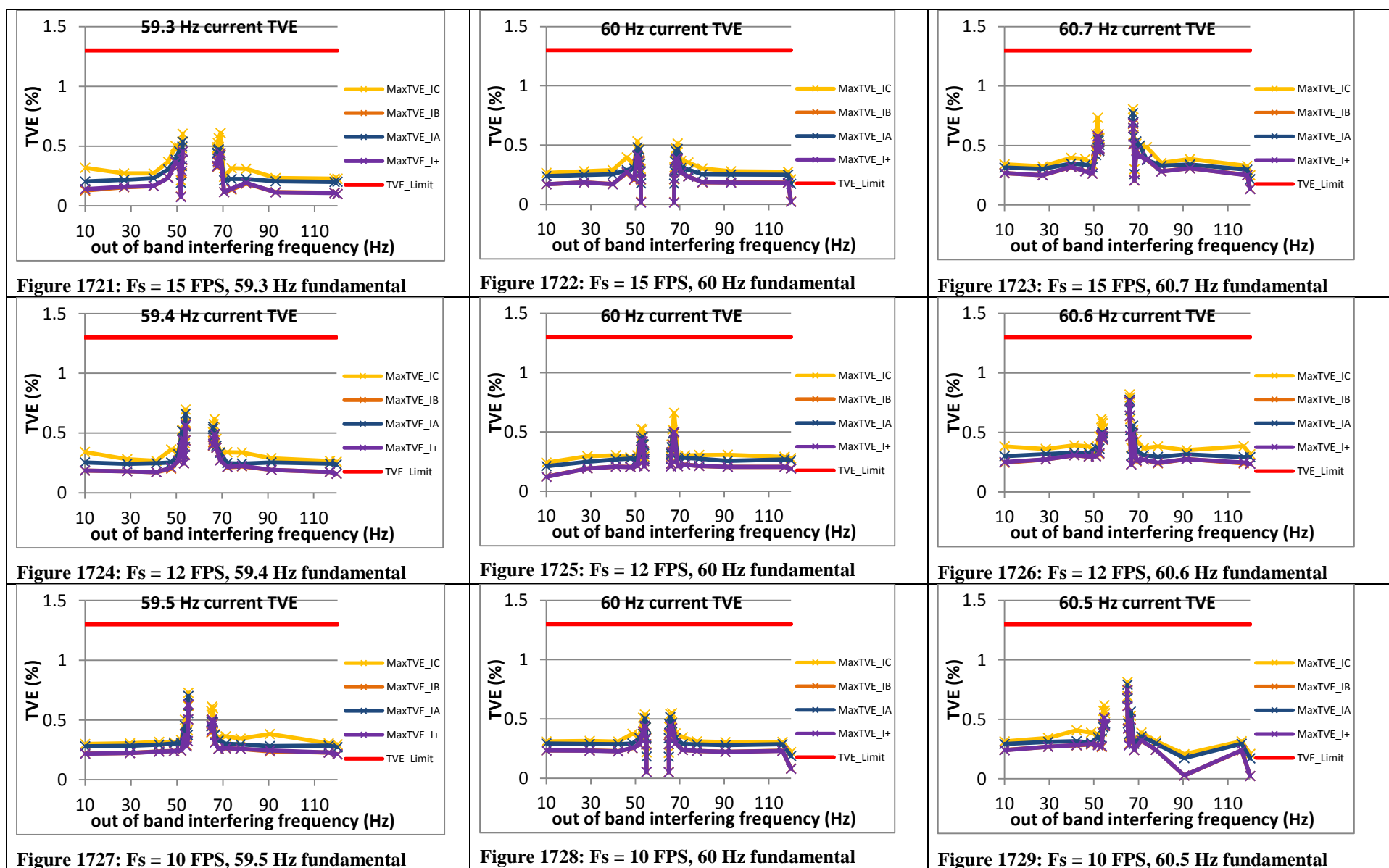
Figure 1702:  $F_s = 20$  FPS, 61 Hz fundamental



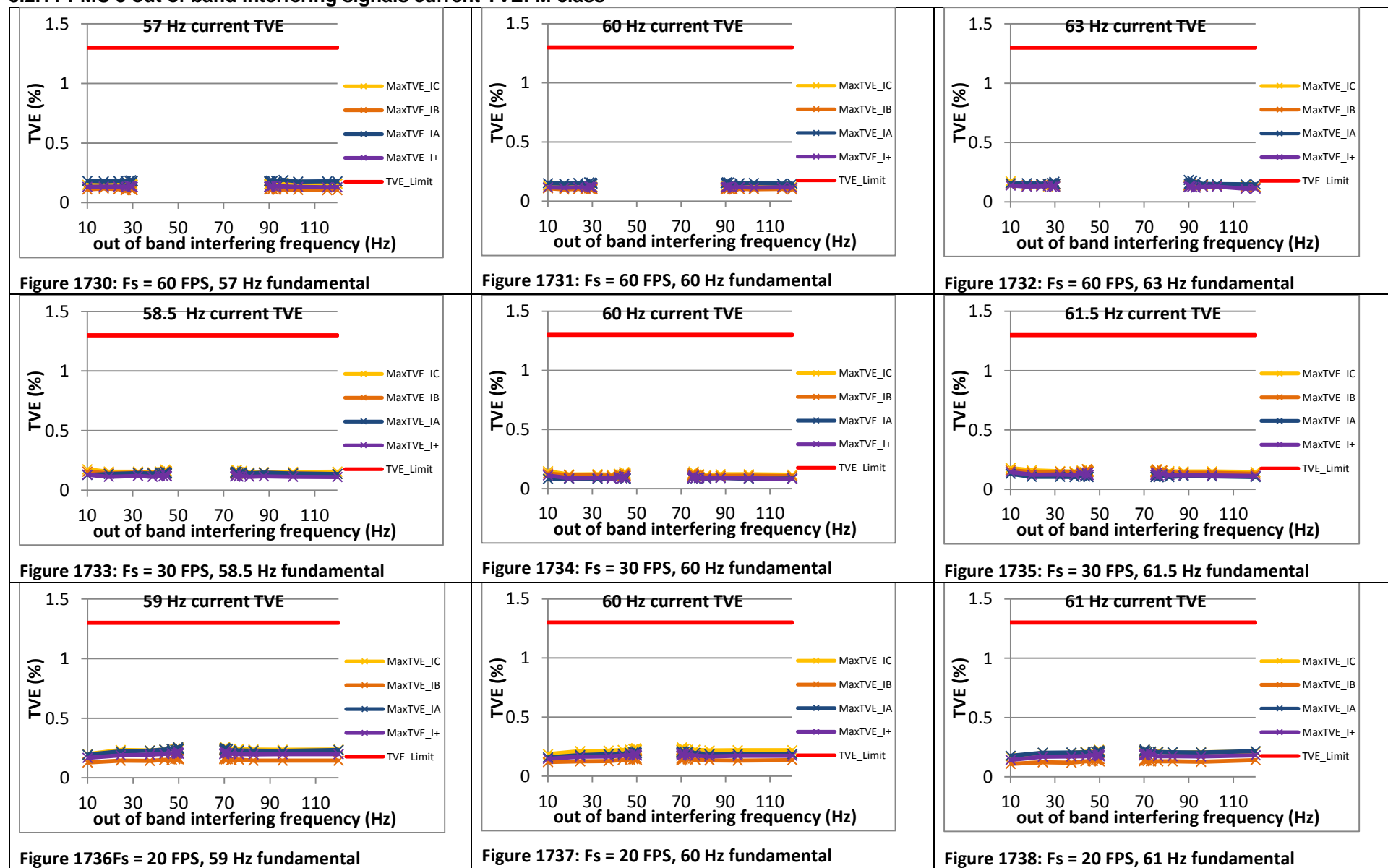


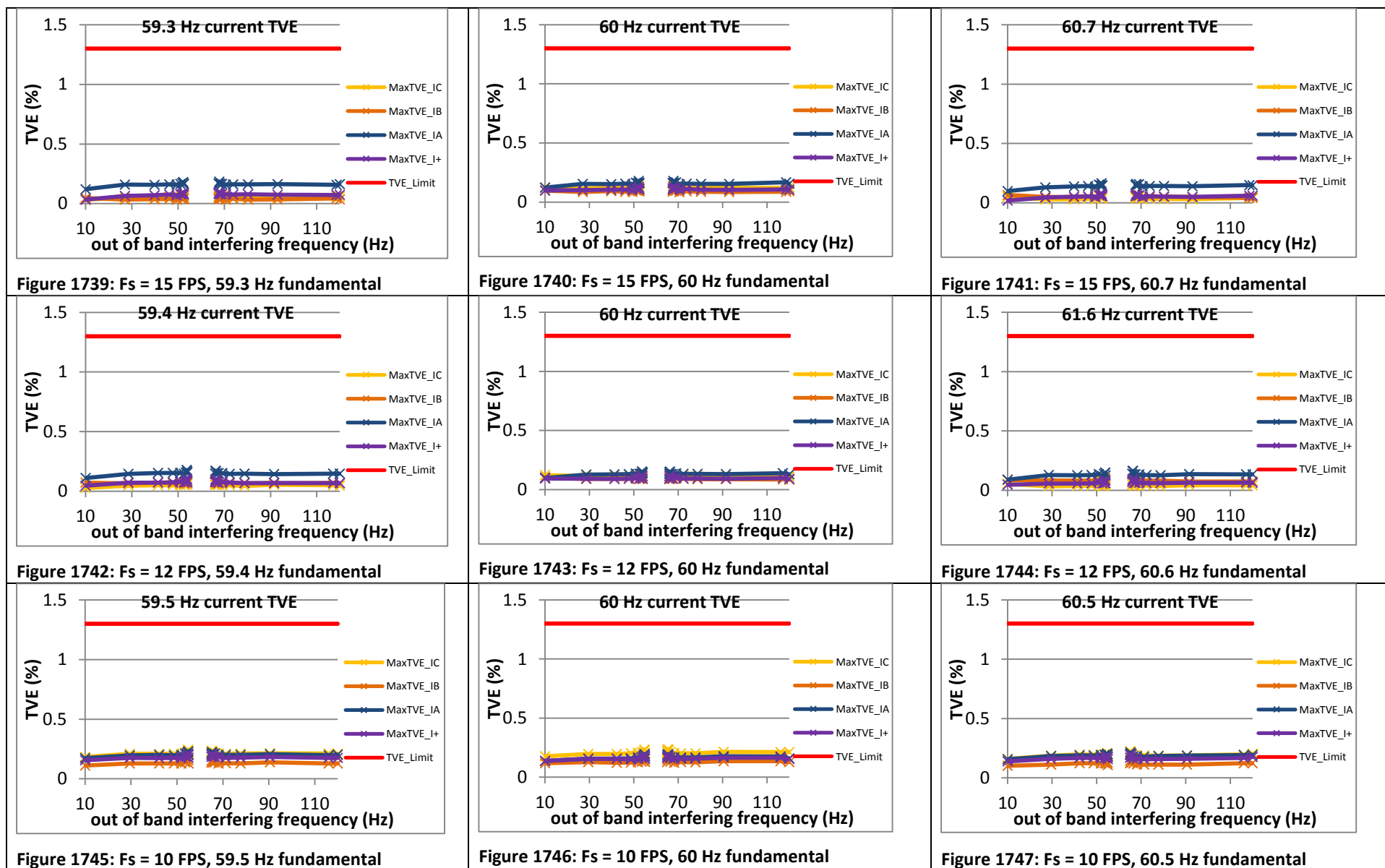
### 5.2.10 PMU I out of band interfering signals current TVE: M class





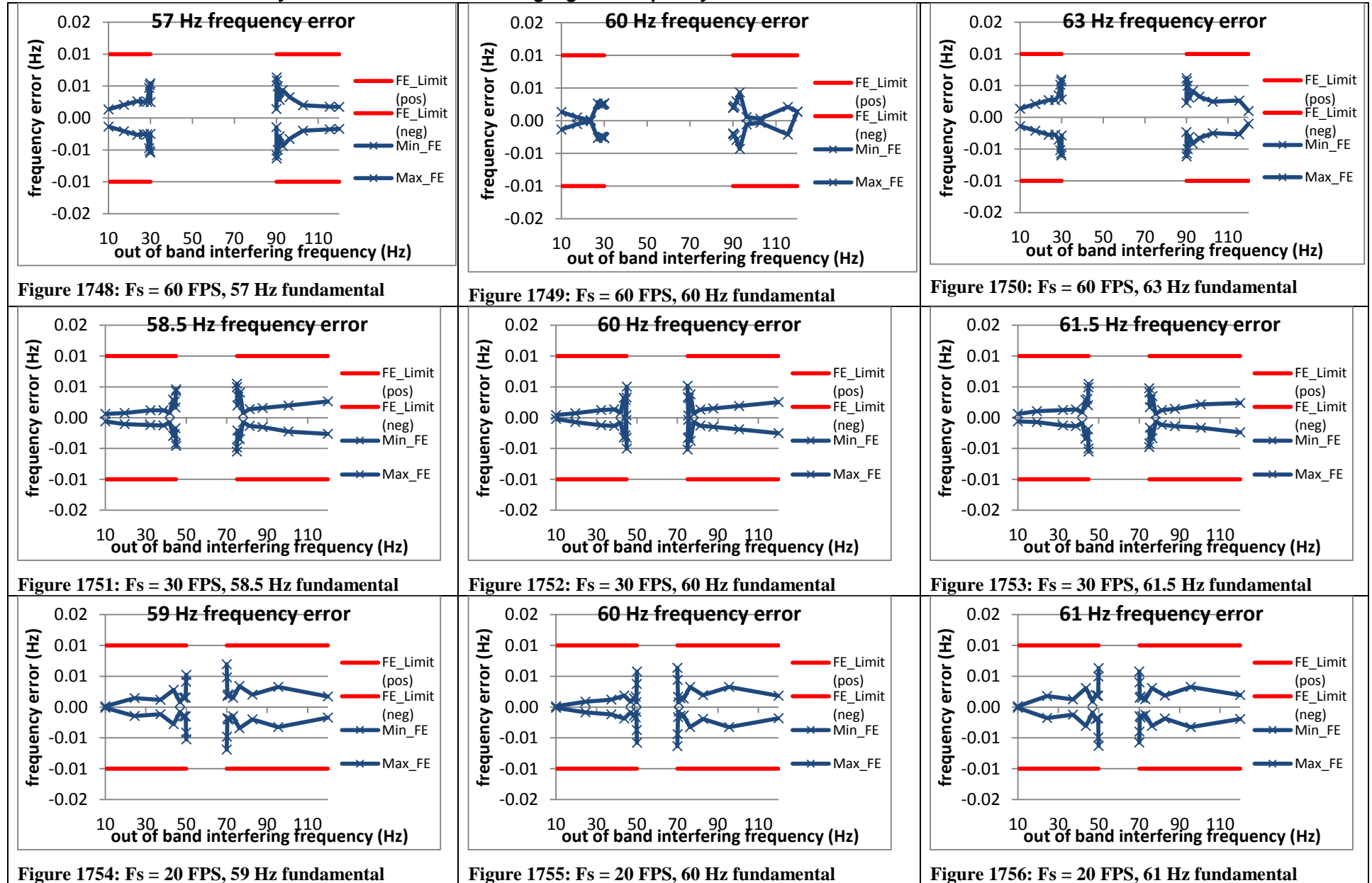
### 5.2.11 PMU J out of band interfering signals current TVE: M class





### 5.3 Steady state out of band interfering signals: frequency error: M class

#### 5.3.1 C37.118.1 Annex C steady state out of band interfering signals frequency error: M class



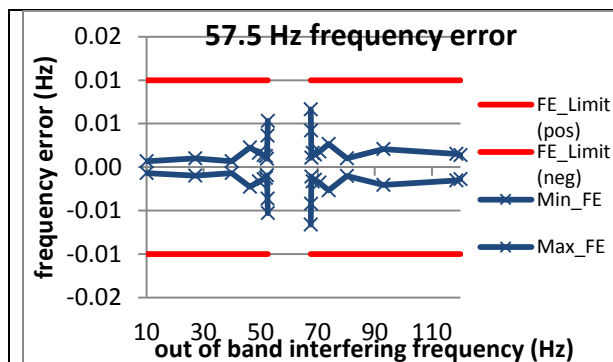


Figure 1757:  $F_s = 15$  FPS, 59.3 Hz fundamental

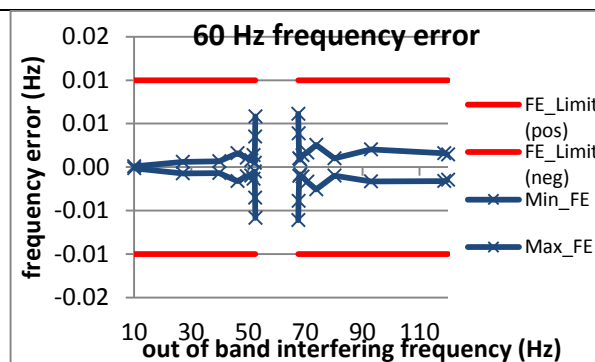


Figure 1758:  $F_s = 15$  FPS, 60 Hz fundamental

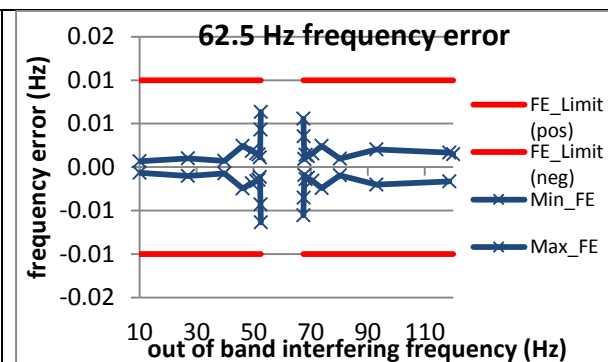


Figure 1759:  $F_s = 15$  FPS, 60.7 Hz fundamental

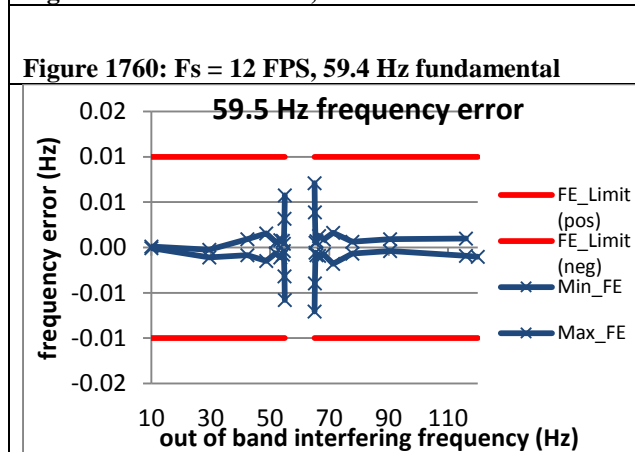


Figure 1760:  $F_s = 12$  FPS, 59.4 Hz fundamental

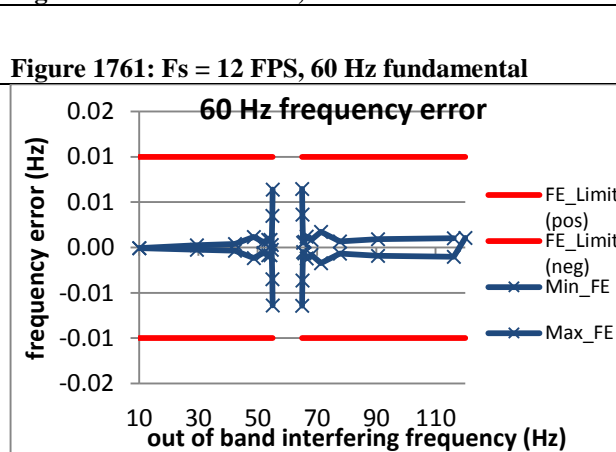


Figure 1761:  $F_s = 12$  FPS, 60 Hz fundamental

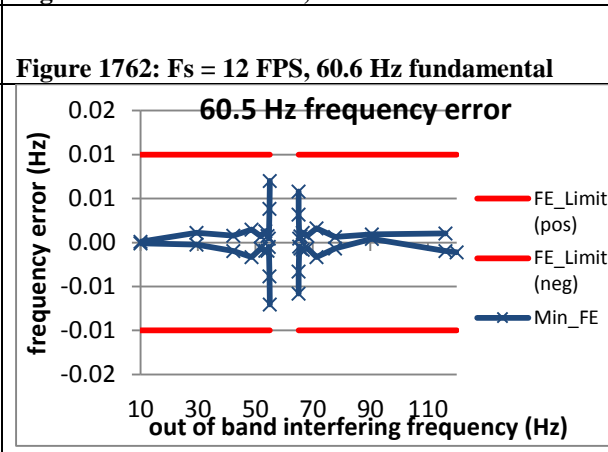


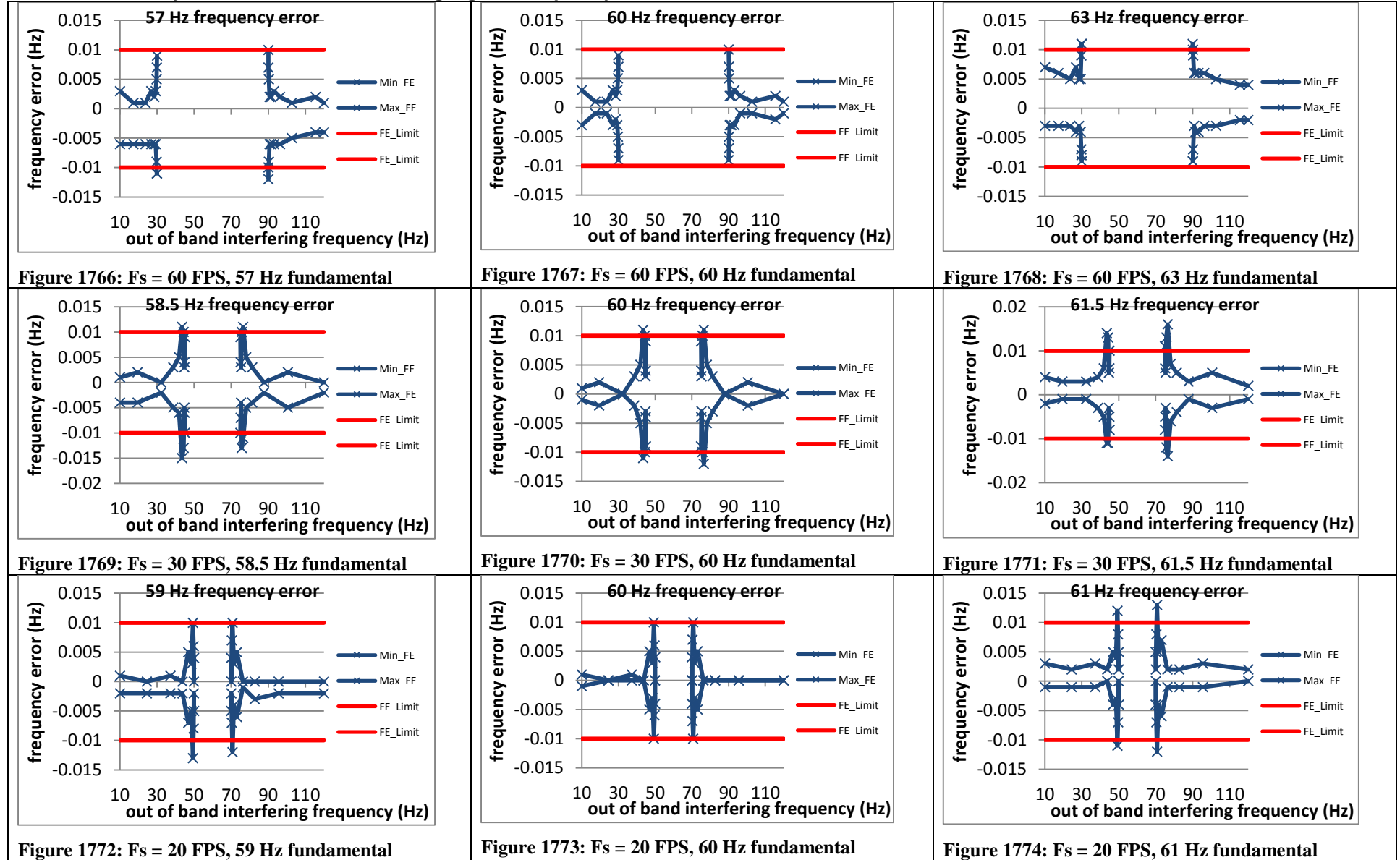
Figure 1762:  $F_s = 12$  FPS, 60.6 Hz fundamental

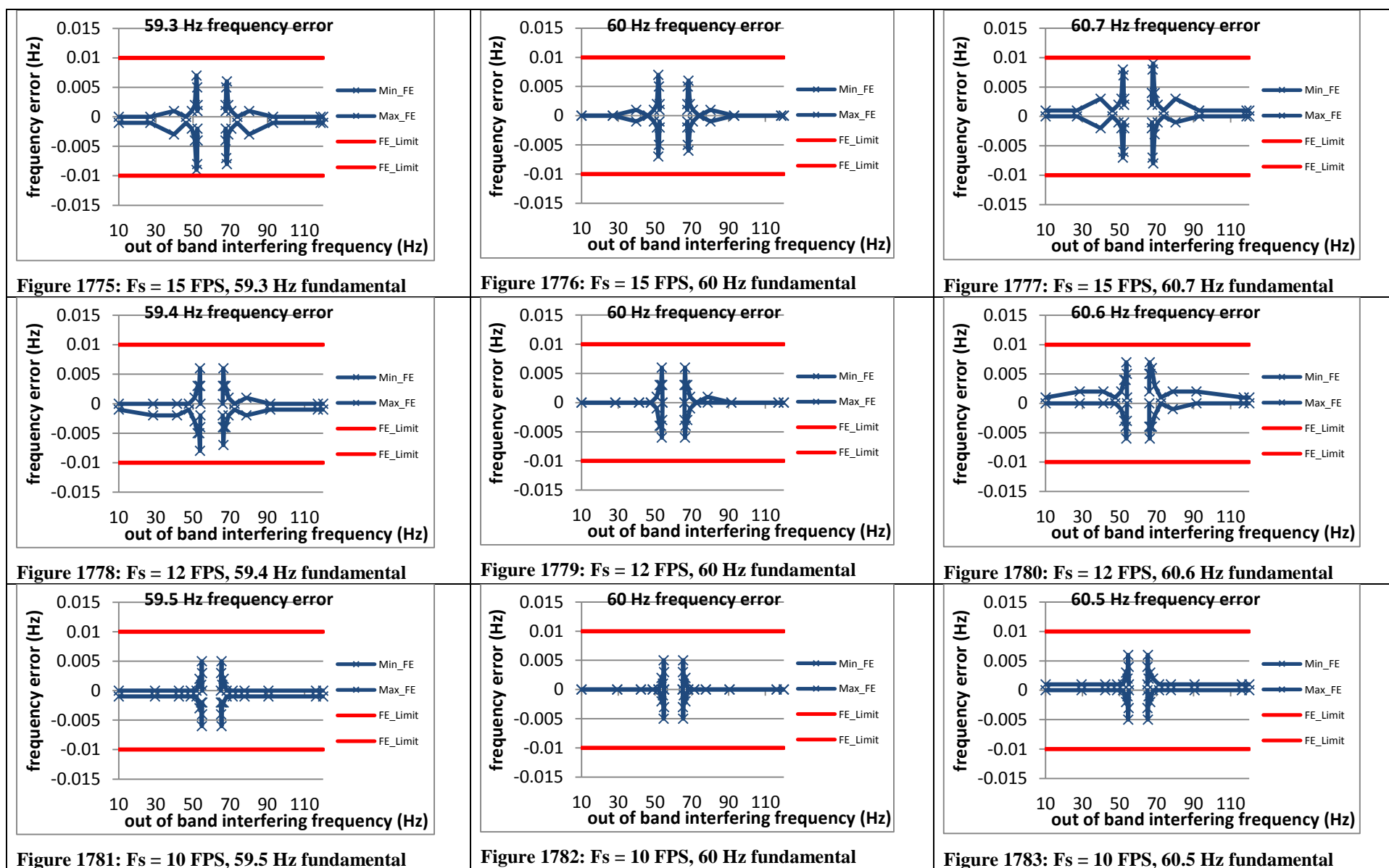
Figure 1763:  $F_s = 10$  FPS, 59.5 Hz fundamental

Figure 1764:  $F_s = 10$  FPS, 60 Hz fundamental

Figure 1765:  $F_s = 10$  FPS, 60.5 Hz fundamental

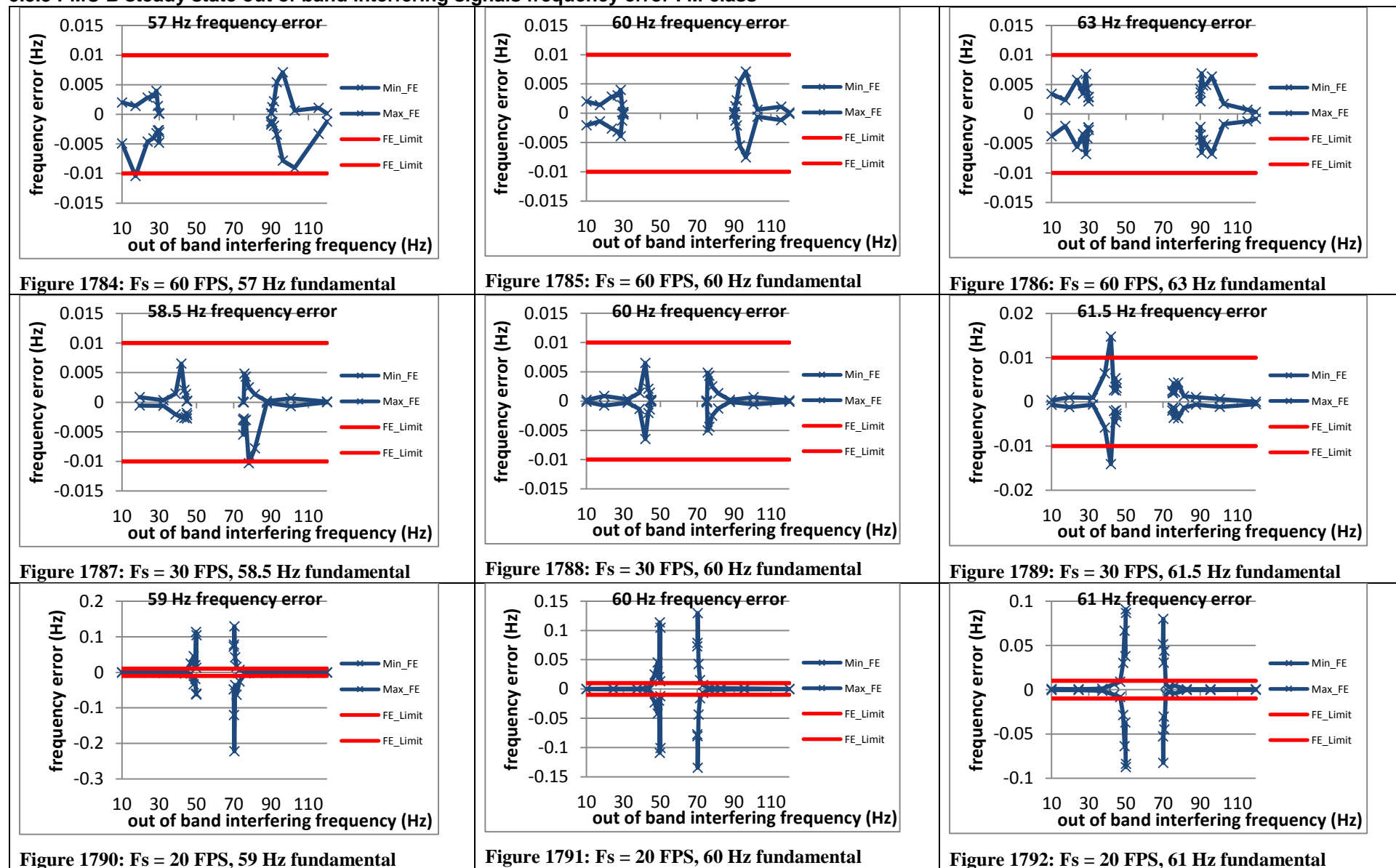
### 5.3.2 PMU A steady state out of band interfering signals frequency error : M class

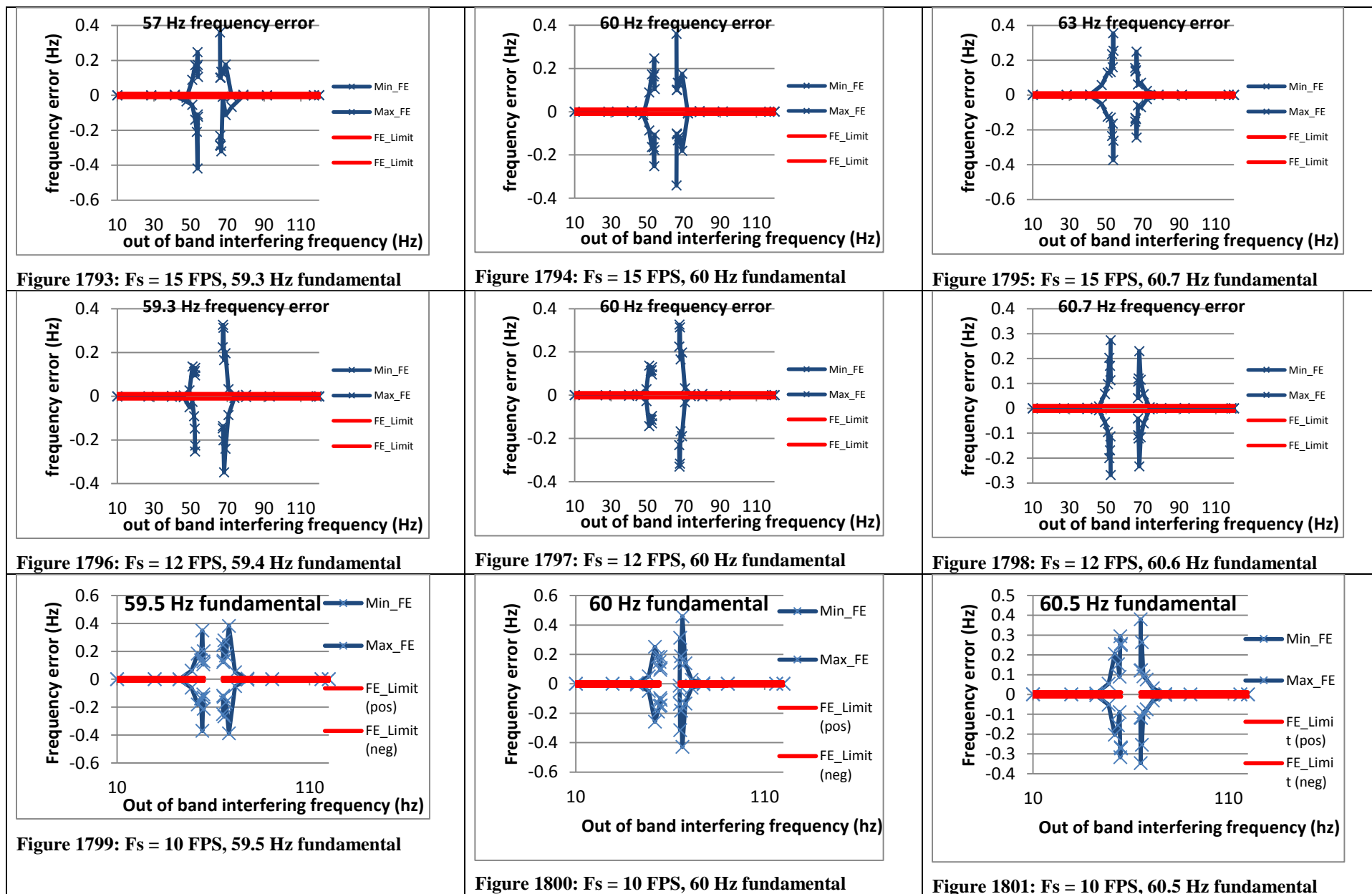




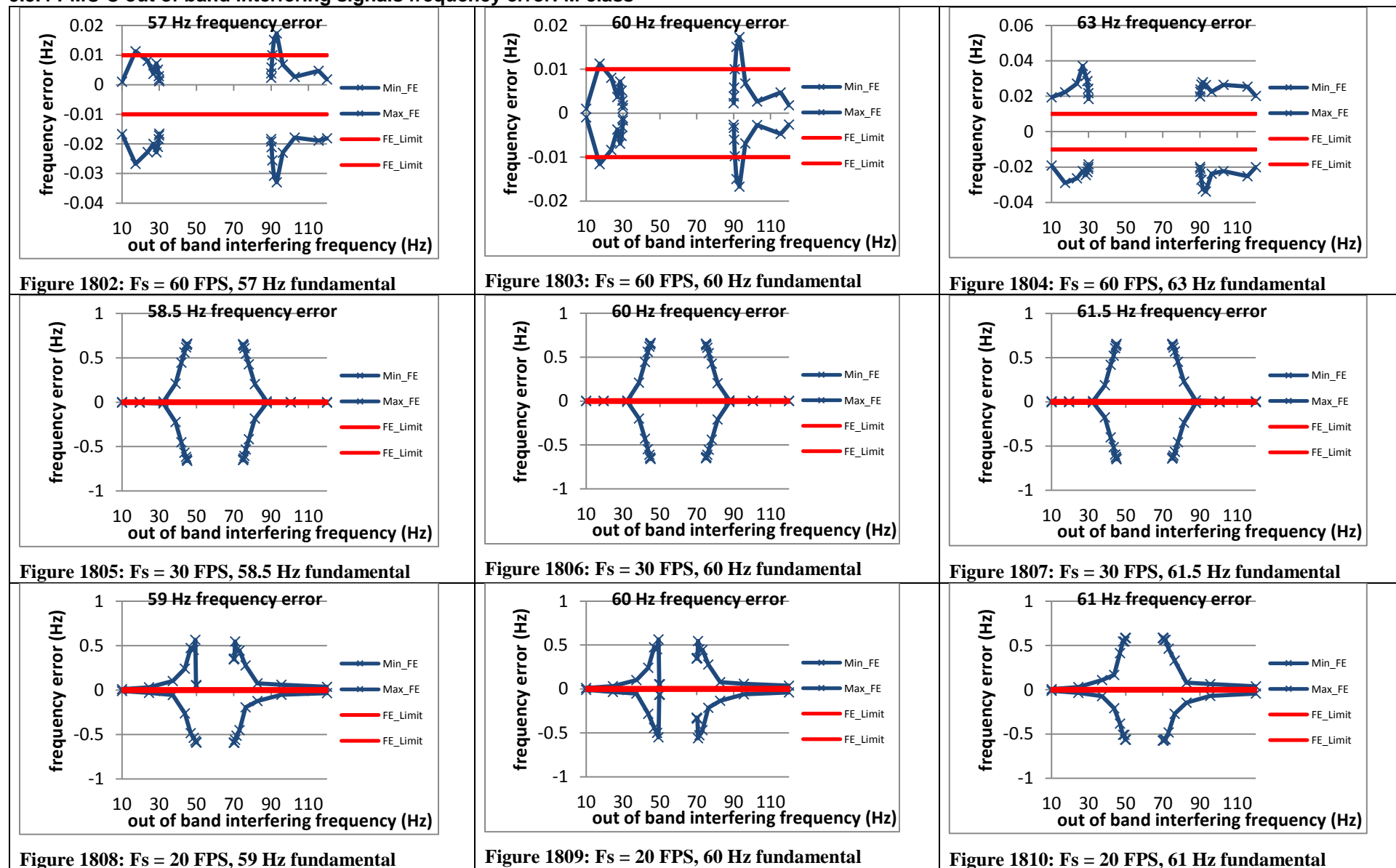


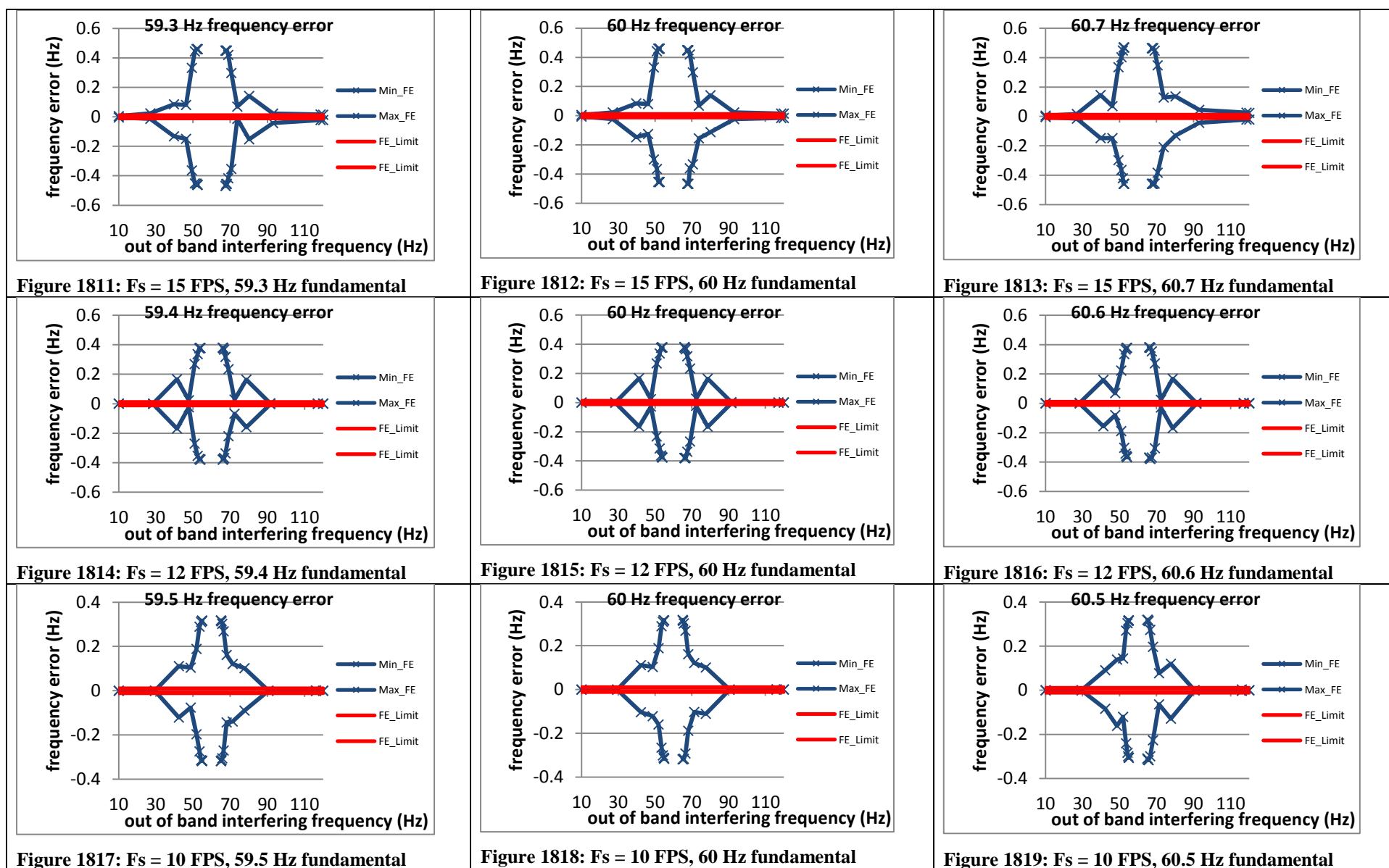
### 5.3.3 PMU B steady state out of band interfering signals frequency error : M class



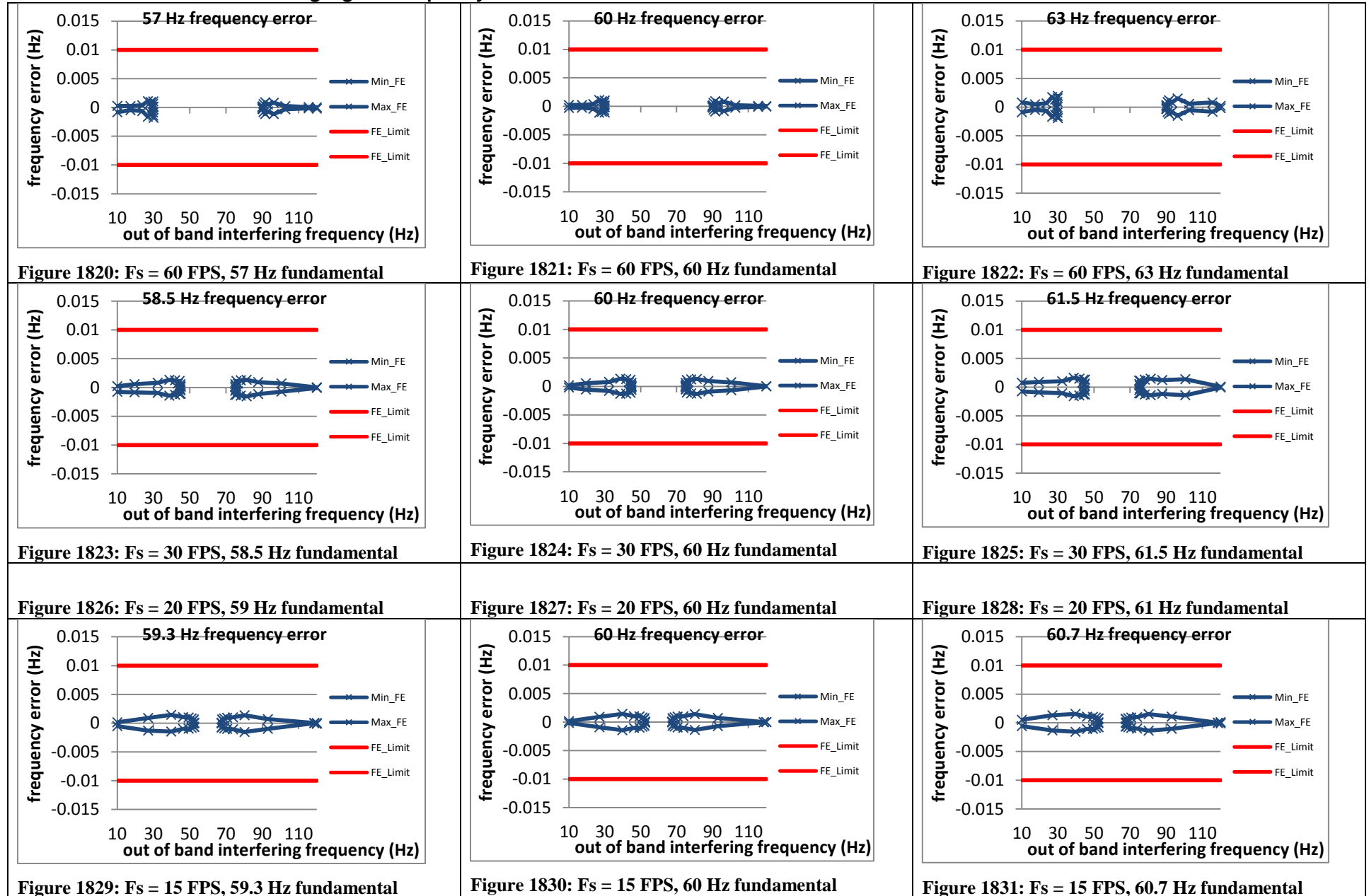


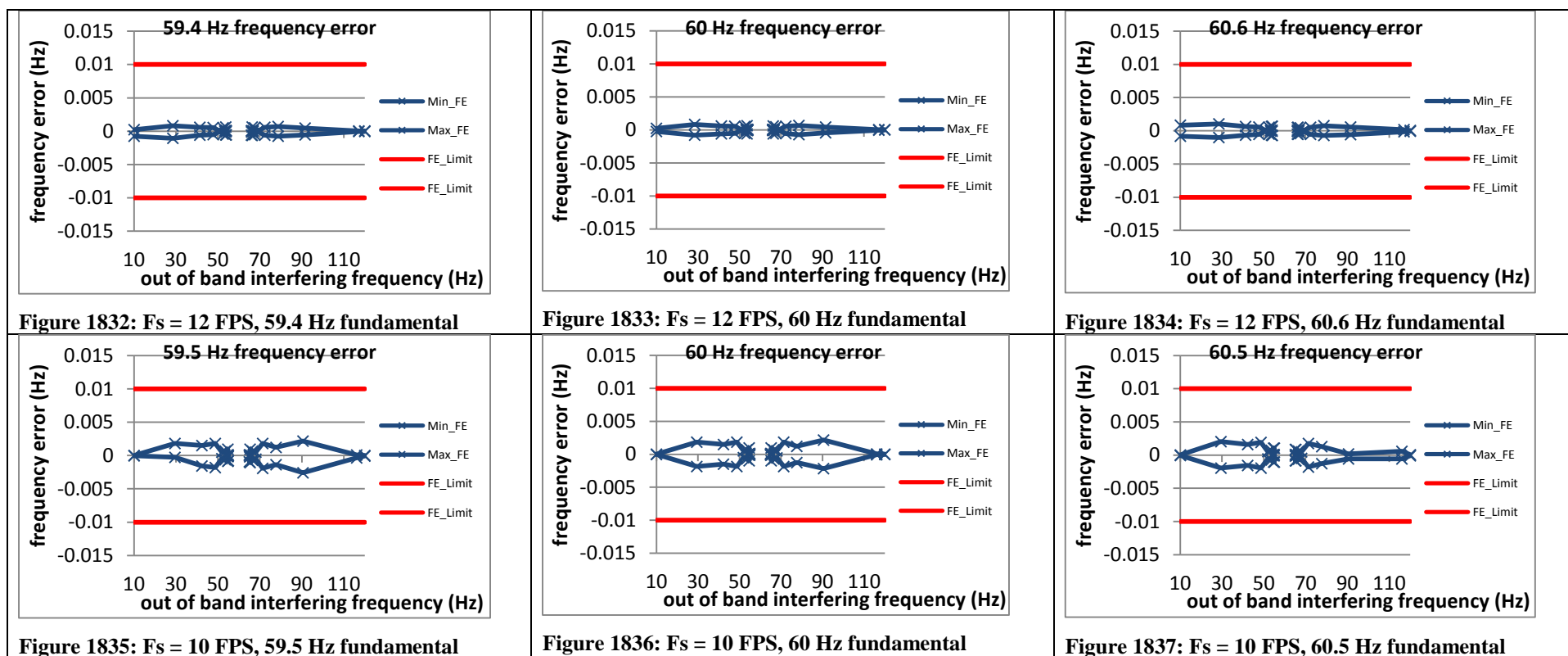
### 5.3.4 PMU C out of band interfering signals frequency error: M class





### 5.3.5 PMU D out of band interfering signals frequency error: M class





### 5.3.6 PMU E out of band interfering signals frequency error: M class

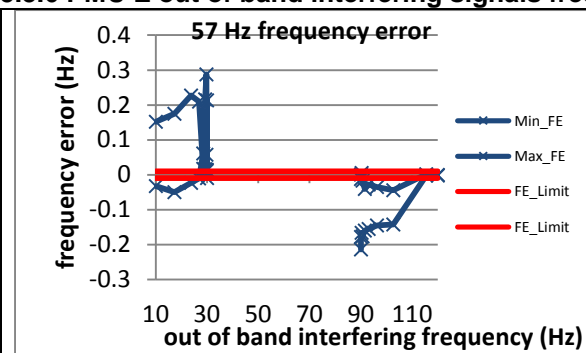


Figure 1838:  $F_s = 60$  FPS, 57 Hz fundamental

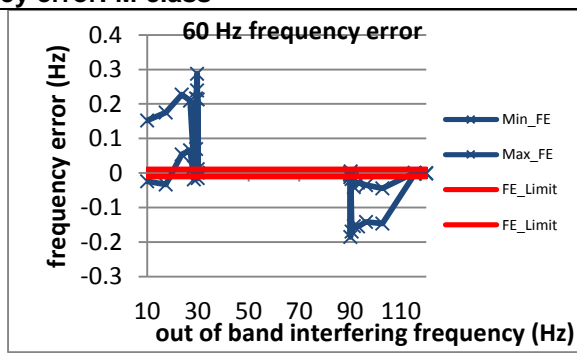


Figure 1839:  $F_s = 60$  FPS, 60 Hz fundamental

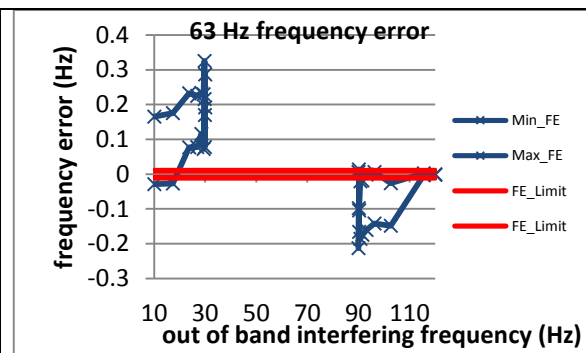


Figure 1840:  $F_s = 60$  FPS, 63 Hz fundamental

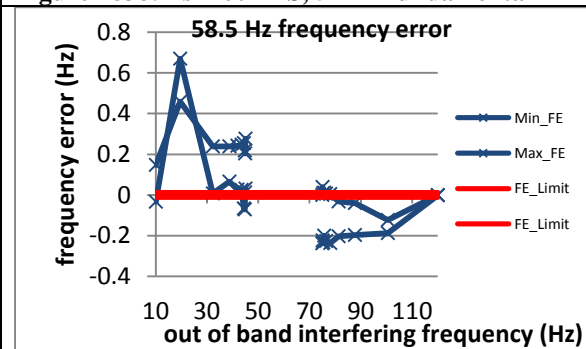


Figure 1841:  $F_s = 30$  FPS, 58.5 Hz fundamental

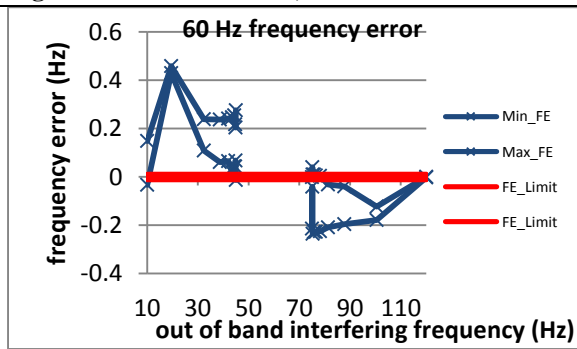


Figure 1842:  $F_s = 30$  FPS, 60 Hz fundamental

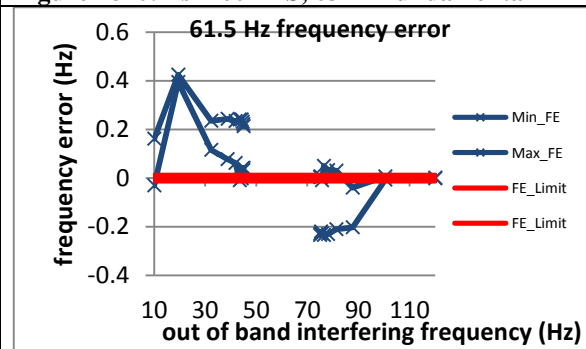


Figure 1843:  $F_s = 30$  FPS, 61.5 Hz fundamental

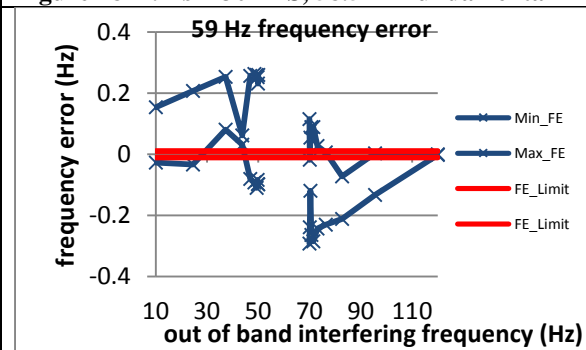


Figure 1844:  $F_s = 20$  FPS, 59 Hz fundamental

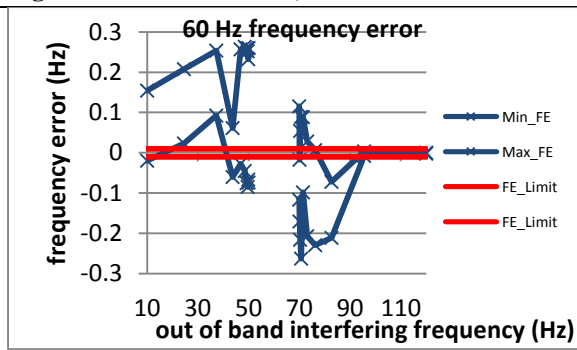


Figure 1845:  $F_s = 20$  FPS, 60 Hz fundamental

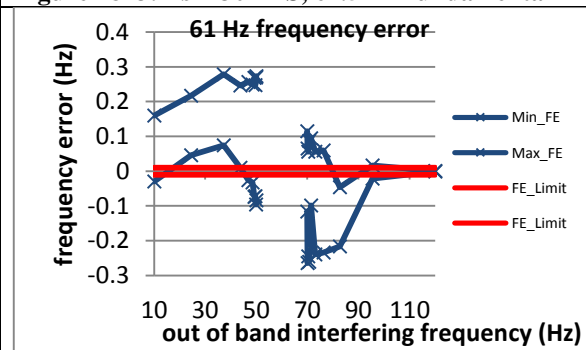


Figure 1846:  $F_s = 20$  FPS, 61 Hz fundamental

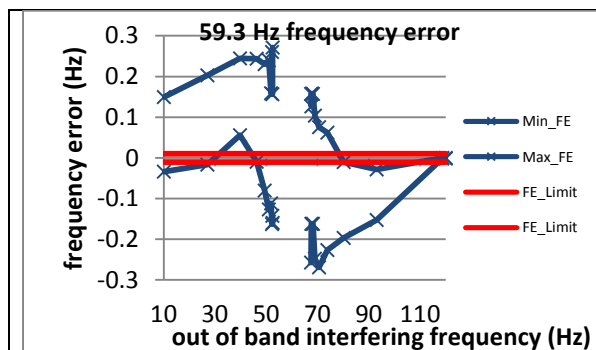


Figure 1847:  $F_s = 15$  FPS, 59.3 Hz fundamental

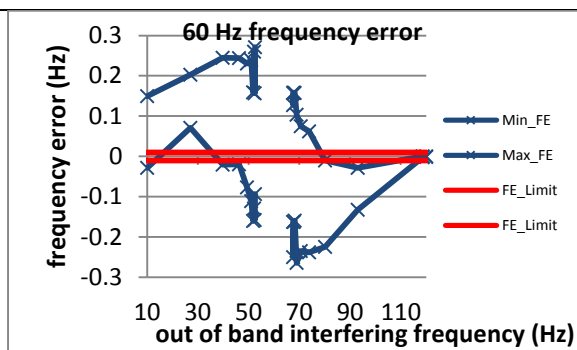


Figure 1848:  $F_s = 15$  FPS, 60 Hz fundamental

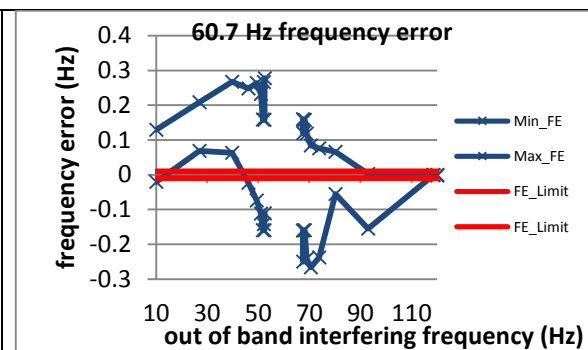


Figure 1849:  $F_s = 15$  FPS, 60.7 Hz fundamental

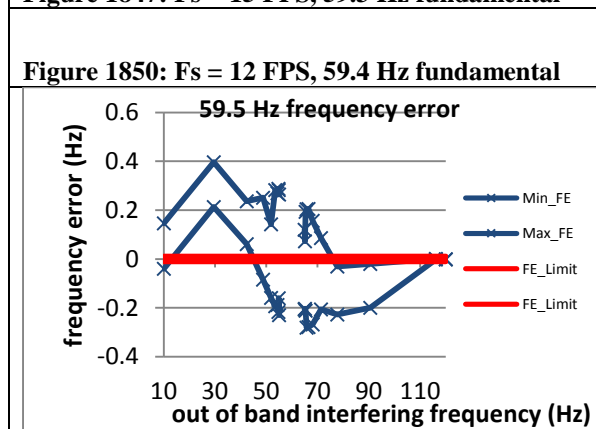


Figure 1850:  $F_s = 12$  FPS, 59.4 Hz fundamental

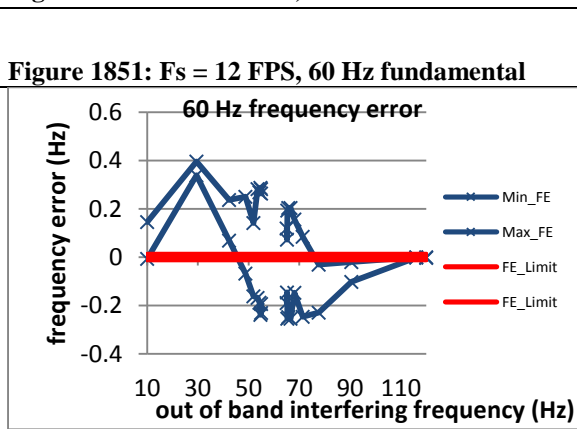


Figure 1851:  $F_s = 12$  FPS, 60 Hz fundamental

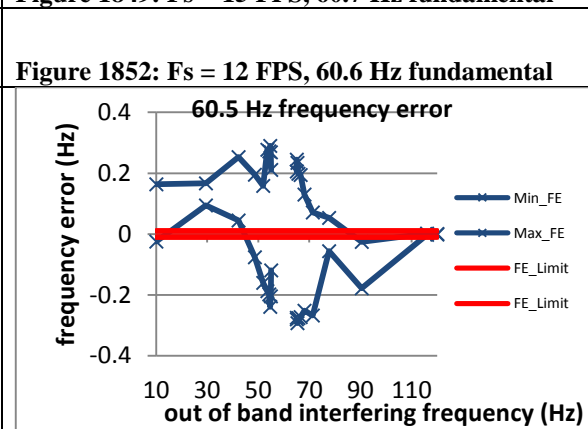


Figure 1852:  $F_s = 12$  FPS, 60.6 Hz fundamental



Figure 1853:  $F_s = 10$  FPS, 59.5 Hz fundamental



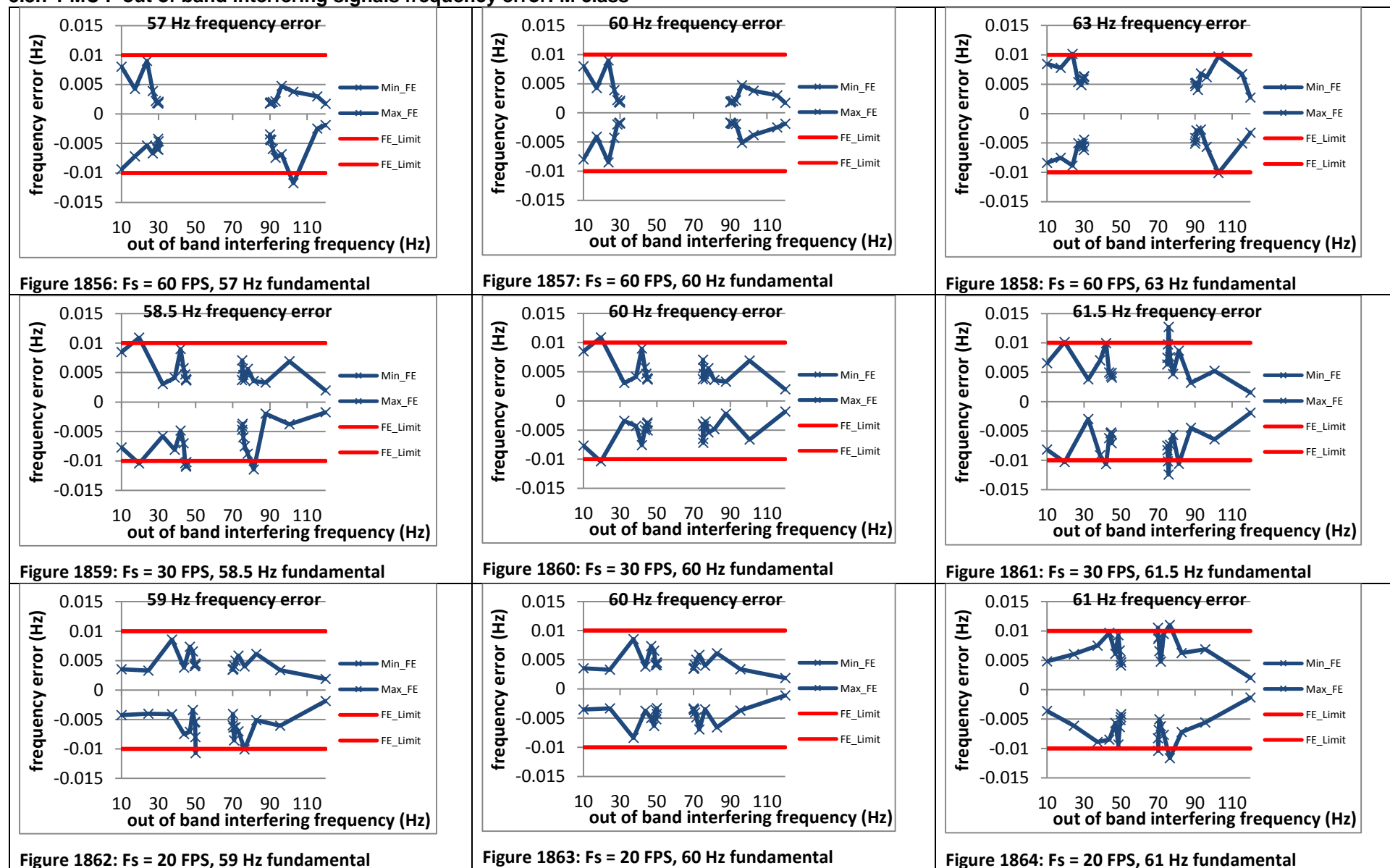
Figure 1854:  $F_s = 10$  FPS, 60 Hz fundamental

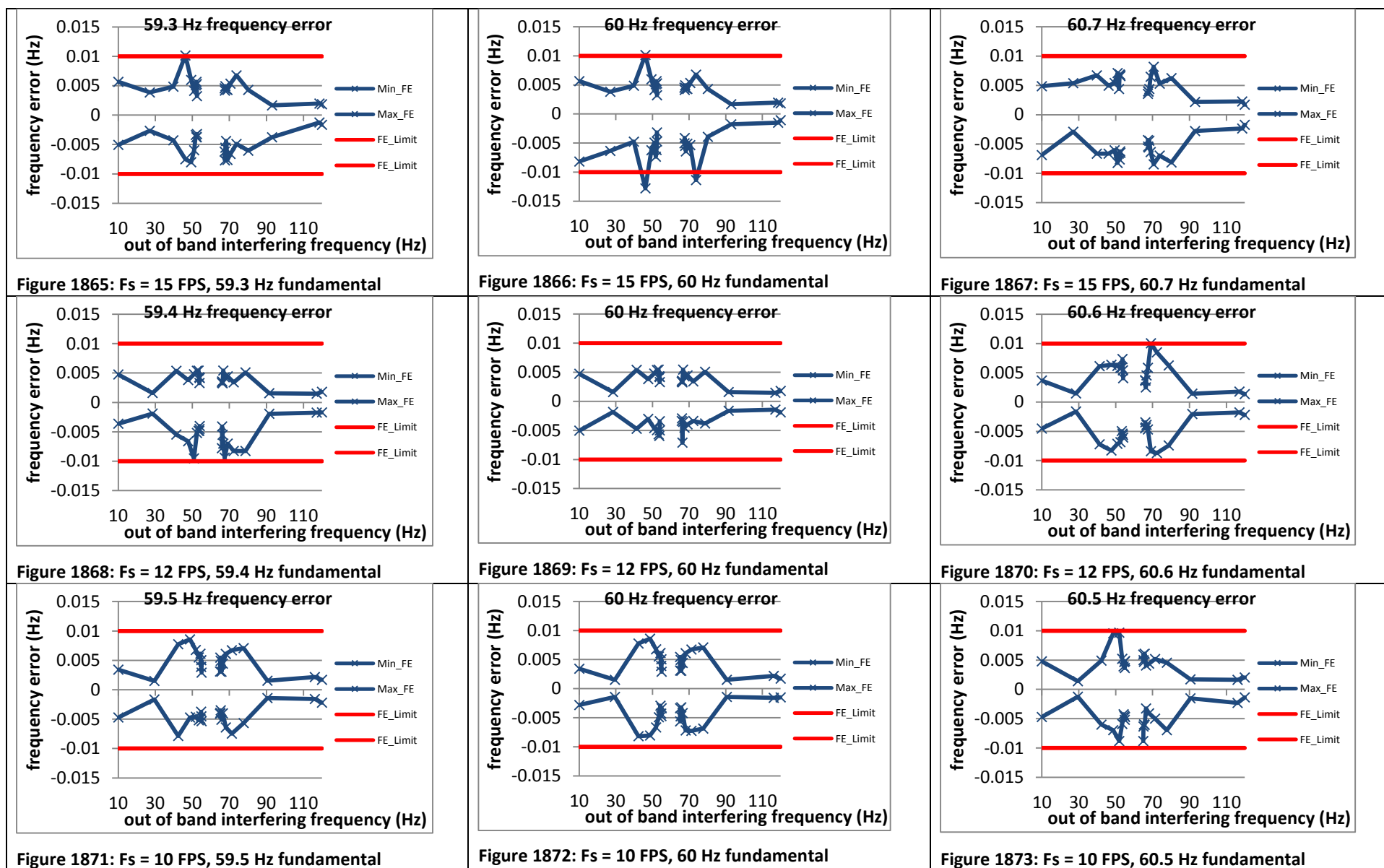


Figure 1855:  $F_s = 10$  FPS, 60.5 Hz fundamental

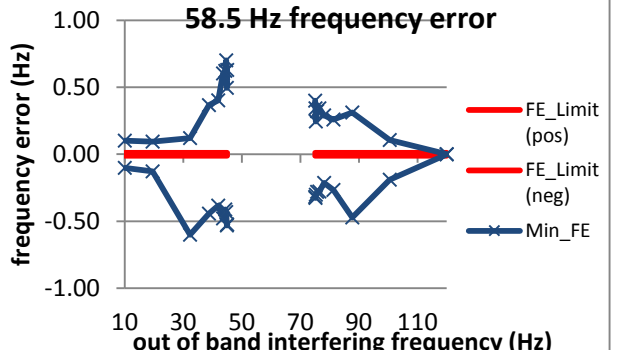
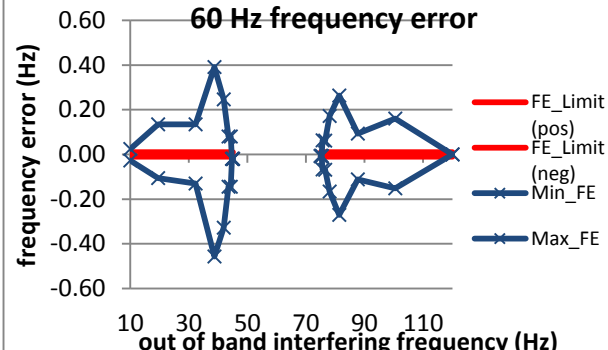
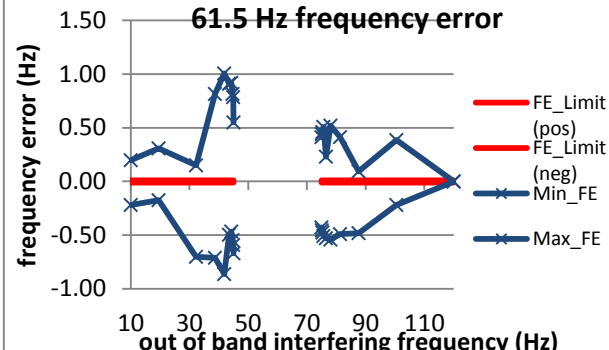
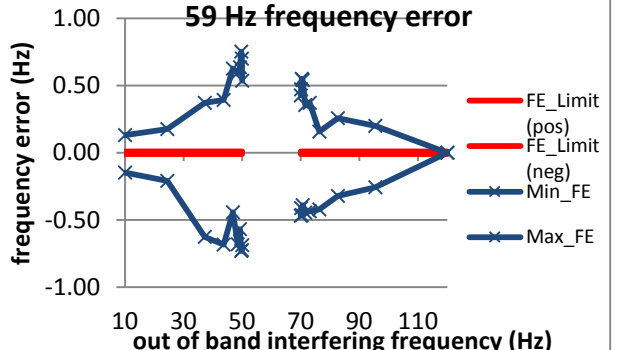
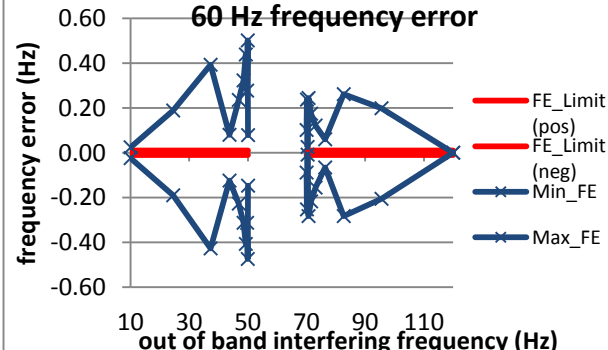
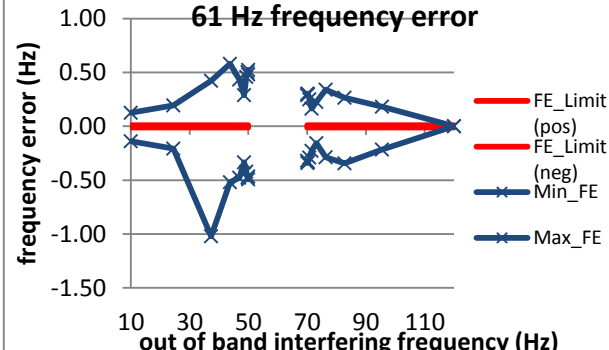


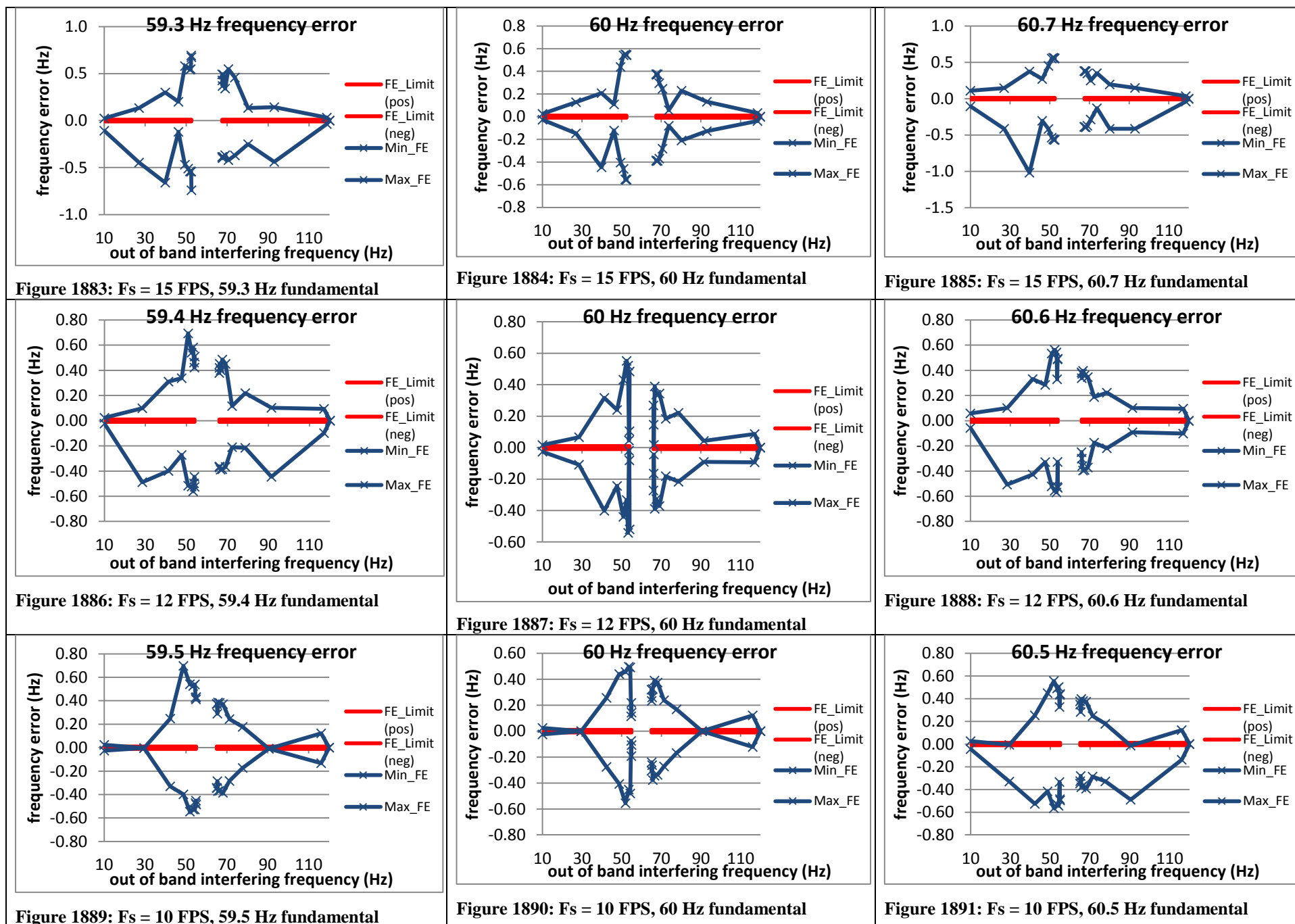
### 5.3.7 PMU F out of band interfering signals frequency error: M class



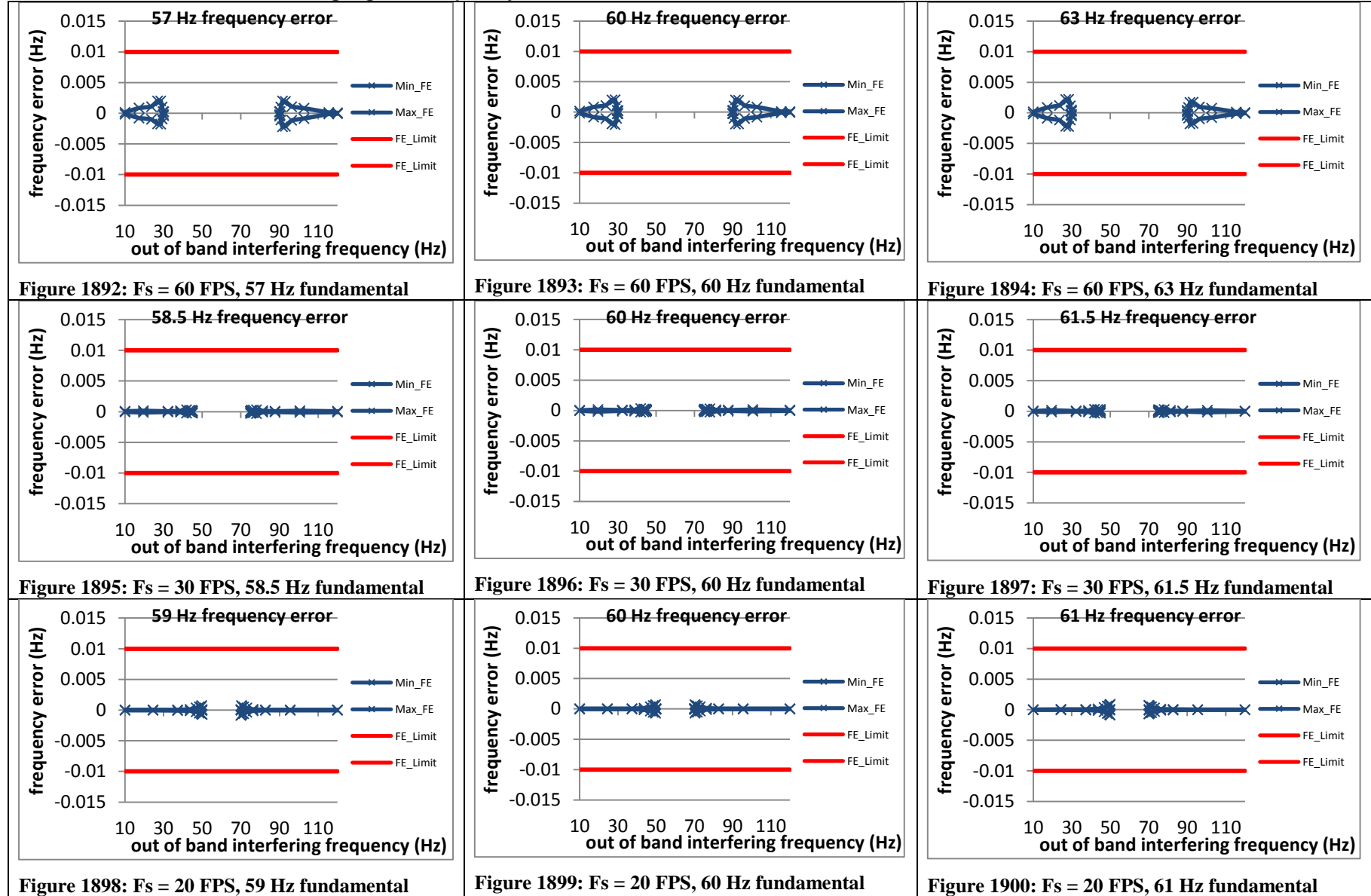


### 5.3.8 PMU G out of band interfering signals frequency error: M class

<p>60 FPS is not supported by this PMU</p> <p><b>Figure 1874: <math>F_s = 60</math> FPS, 57 Hz fundamental</b></p>	<p>60 FPS is not supported by this PMU</p> <p><b>Figure 1875: <math>F_s = 60</math> FPS, 60 Hz fundamental</b></p>	<p>60 FPS is not supported by this PMU</p> <p><b>Figure 1876: <math>F_s = 60</math> FPS, 63 Hz fundamental</b></p>
		
<p><b>Figure 1877: <math>F_s = 30</math> FPS, 58.5 Hz fundamental</b></p>	<p><b>Figure 1878: <math>F_s = 30</math> FPS, 60 Hz fundamental</b></p>	<p><b>Figure 1879: <math>F_s = 30</math> FPS, 61.5 Hz fundamental</b></p>
		
<p><b>Figure 1880: <math>F_s = 20</math> FPS, 59 Hz fundamental</b></p>	<p><b>Figure 1881: <math>F_s = 20</math> FPS, 60 Hz fundamental</b></p>	<p><b>Figure 1882: <math>F_s = 20</math> FPS, 61 Hz fundamental</b></p>



### 5.3.9 PMU H out of band interfering signals frequency error: M class



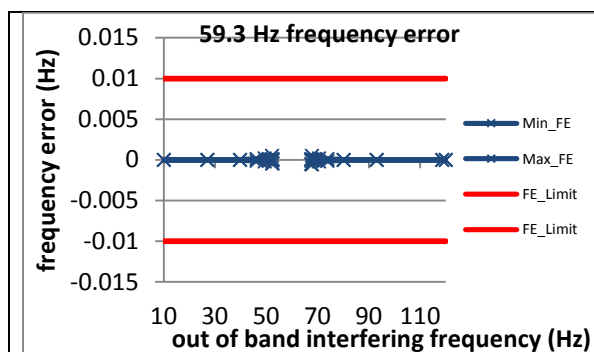


Figure 1901:  $F_s = 15$  FPS, 59.3 Hz fundamental

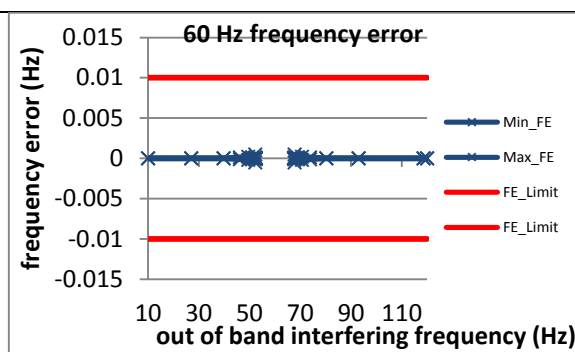


Figure 1902:  $F_s = 15$  FPS, 60 Hz fundamental

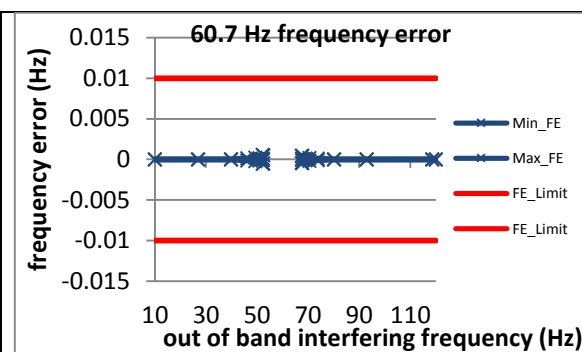


Figure 1903:  $F_s = 15$  FPS, 60.7 Hz fundamental

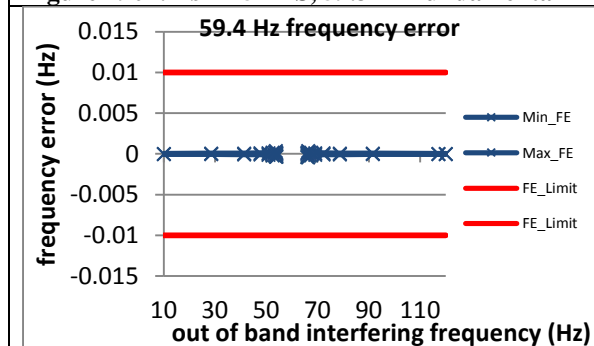


Figure 1904:  $F_s = 12$  FPS, 59.4 Hz fundamental

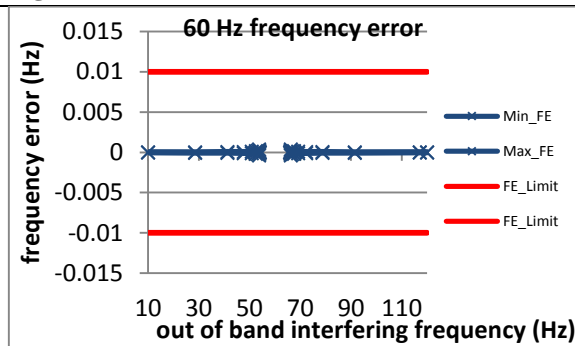


Figure 1905:  $F_s = 12$  FPS, 60 Hz fundamental

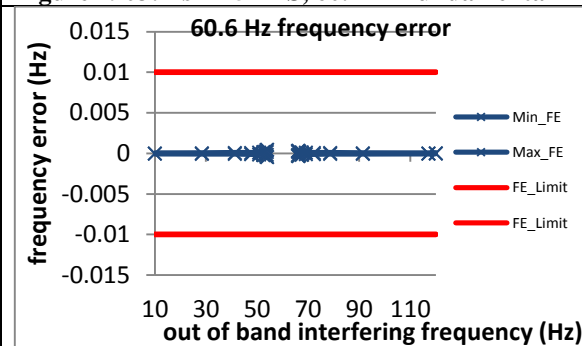


Figure 1906:  $F_s = 12$  FPS, 60.6 Hz fundamental

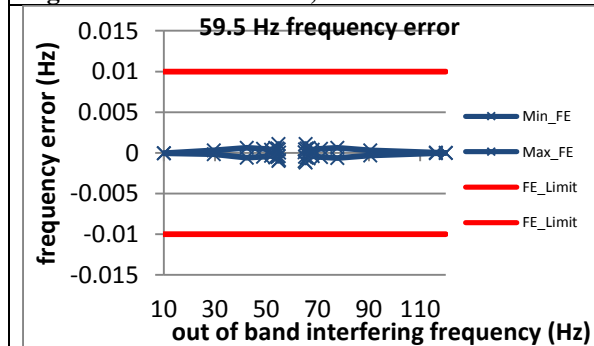


Figure 1907:  $F_s = 10$  FPS, 59.5 Hz fundamental

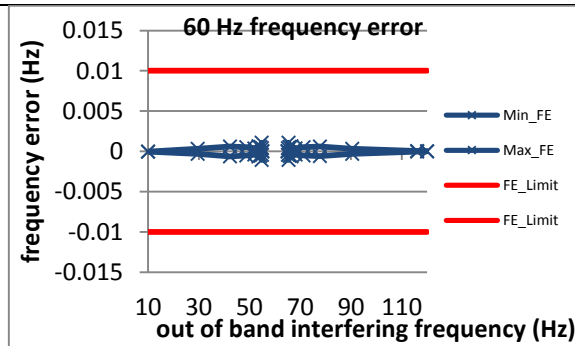


Figure 1908:  $F_s = 10$  FPS, 60 Hz fundamental

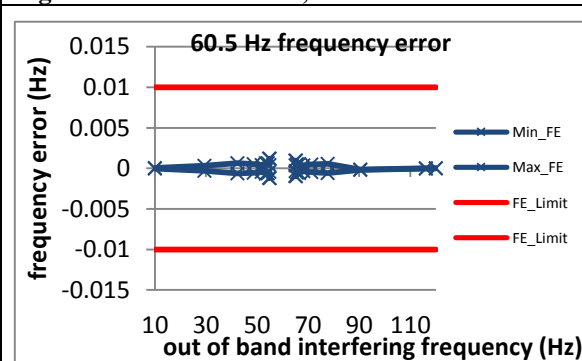
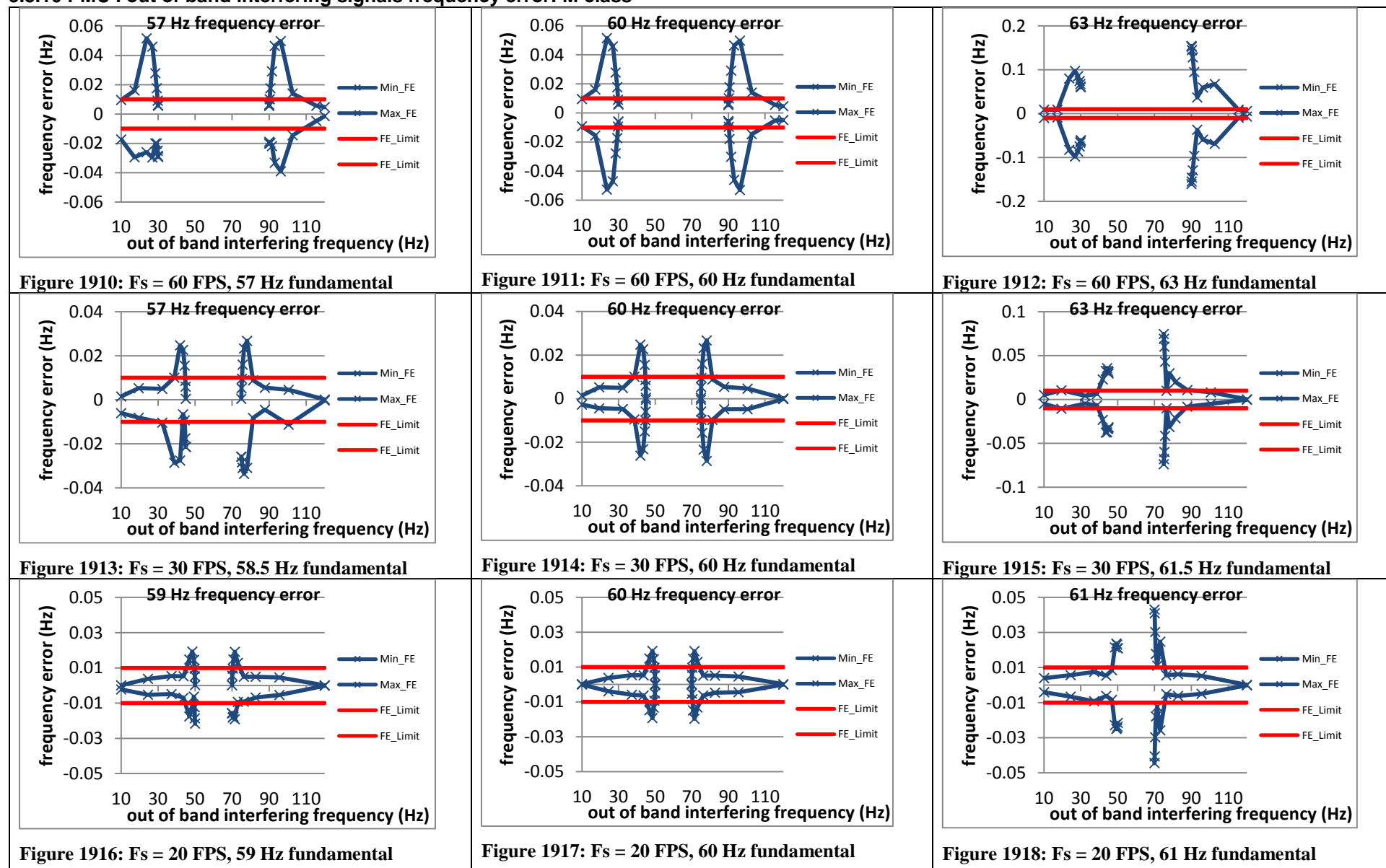
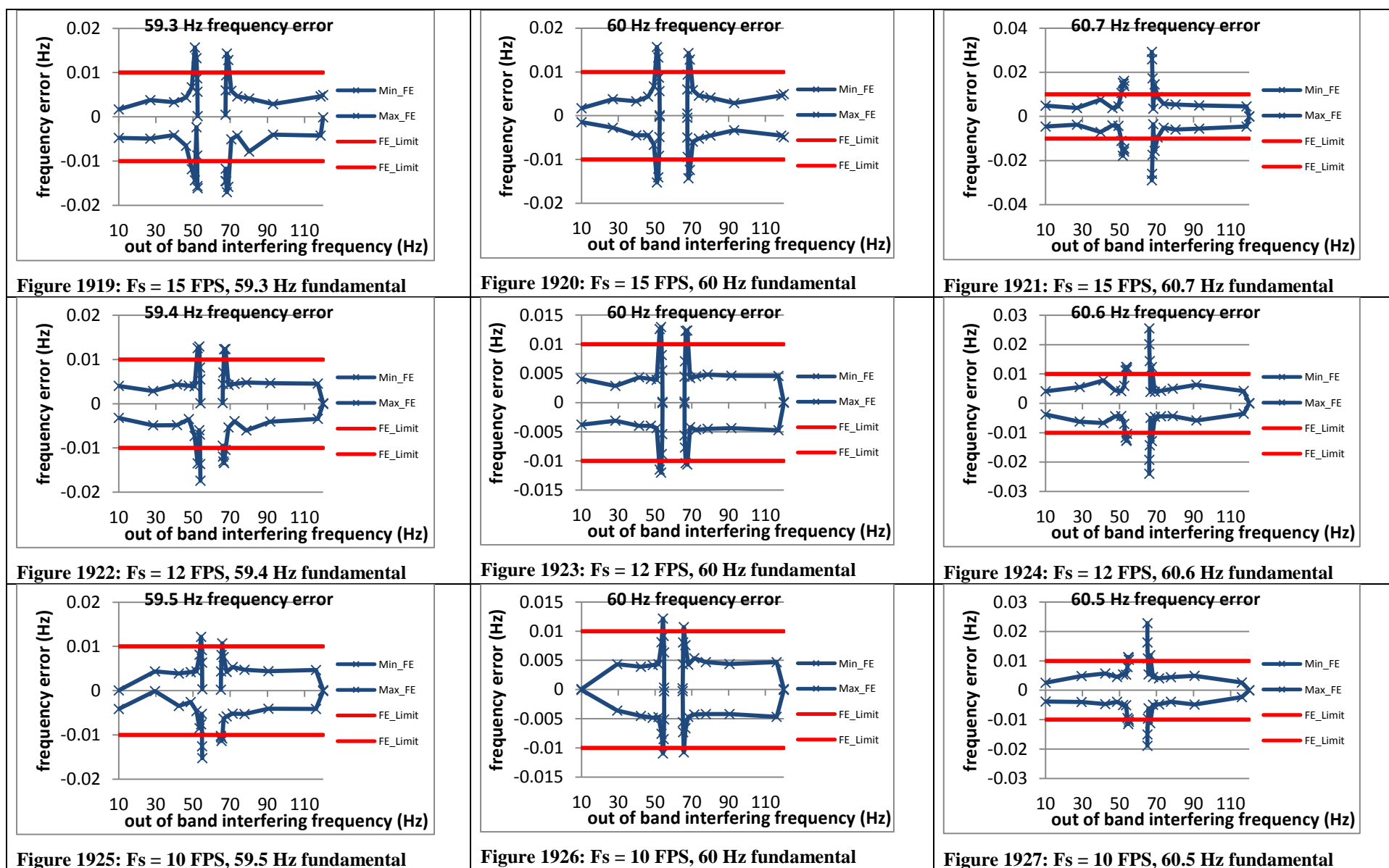


Figure 1909:  $F_s = 10$  FPS, 60.5 Hz fundamental

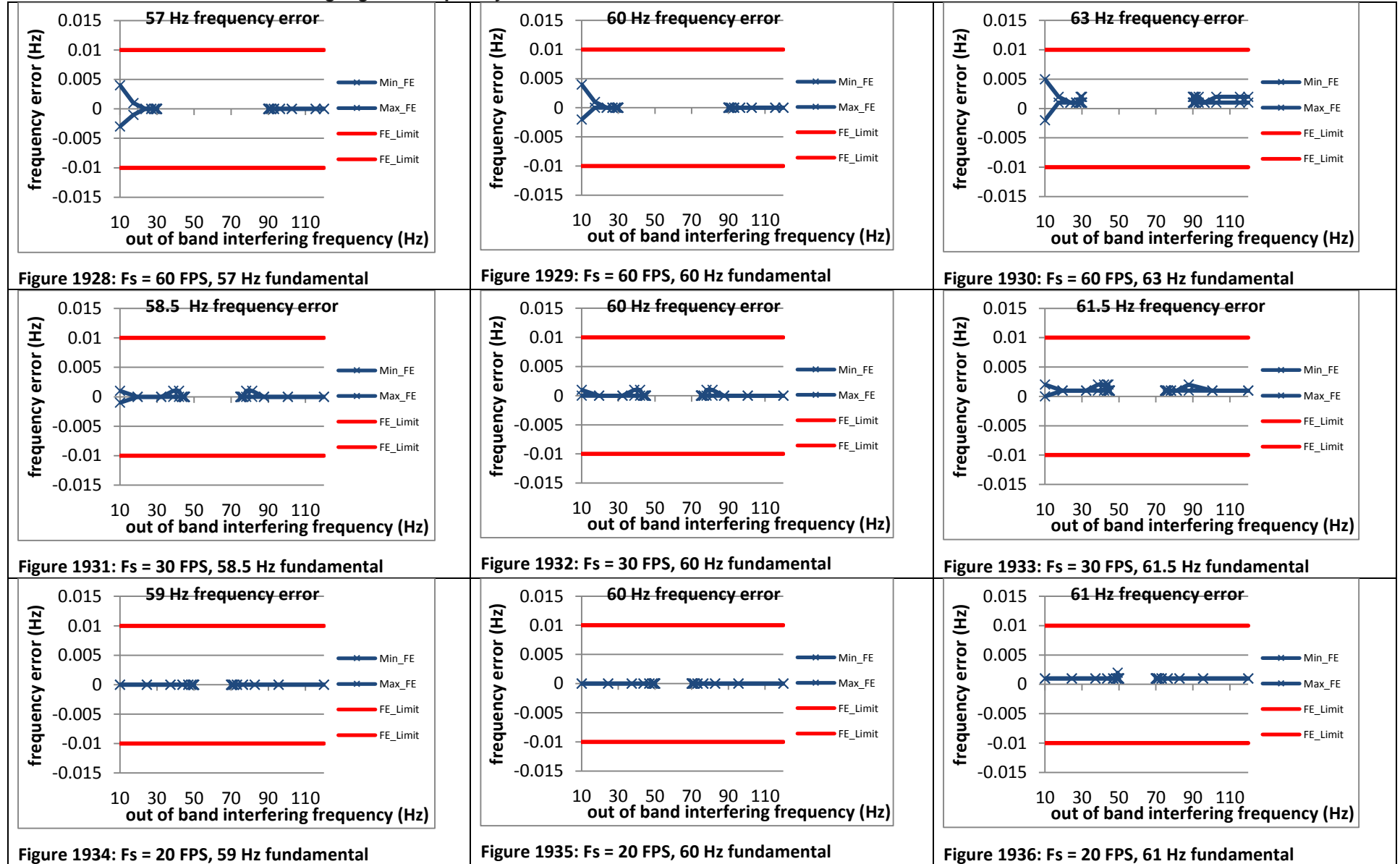
### 5.3.10 PMU I out of band interfering signals frequency error: M class

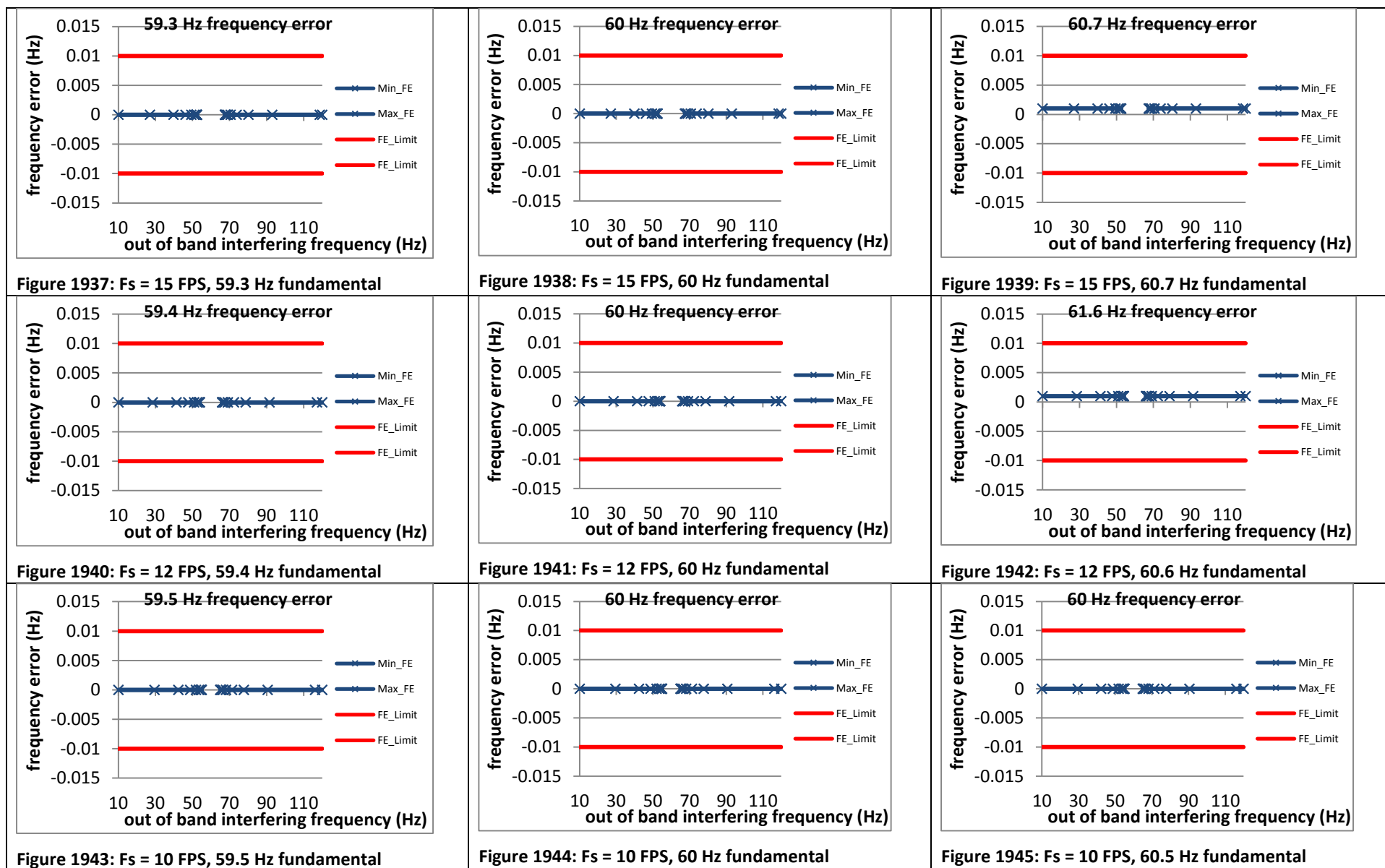






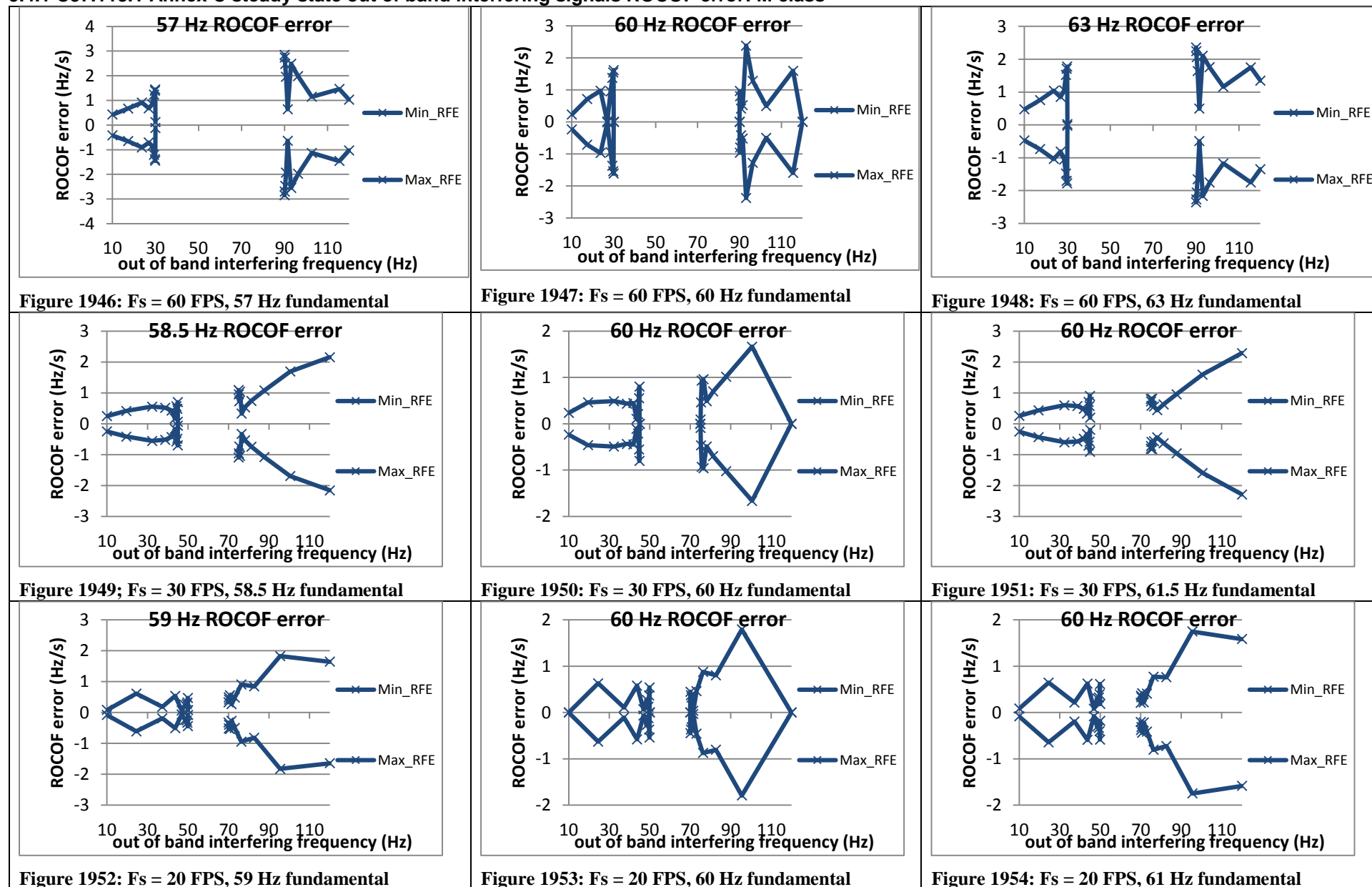
### 5.3.11 PMU J out of band interfering signals frequency error: M class





## 5.4 Steady state out of band interfering signals: ROCOF error: M class

### 5.4.1 C37.118.1 Annex C steady state out of band interfering signals ROCOF error: M class



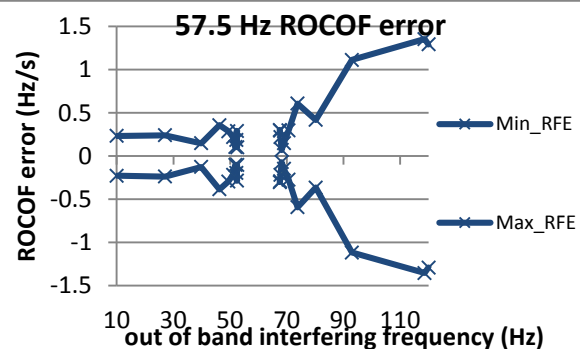


Figure 1955:  $F_s = 15$  FPS, 59.3 Hz fundamental

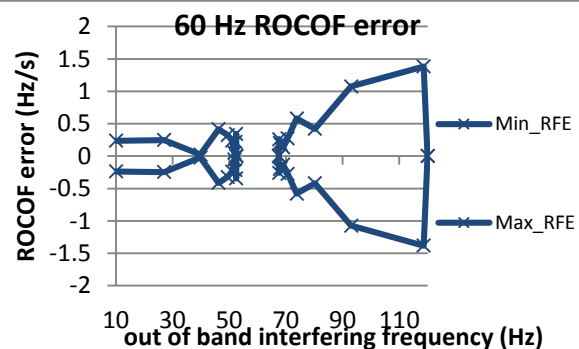


Figure 1956:  $F_s = 15$  FPS, 60 Hz fundamental

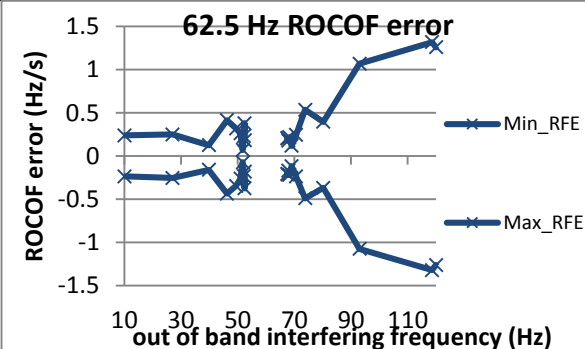


Figure 1957:  $F_s = 15$  FPS, 60.7 Hz fundamental

Figure 1958:  $F_s = 12$  FPS, 59.4 Hz fundamental

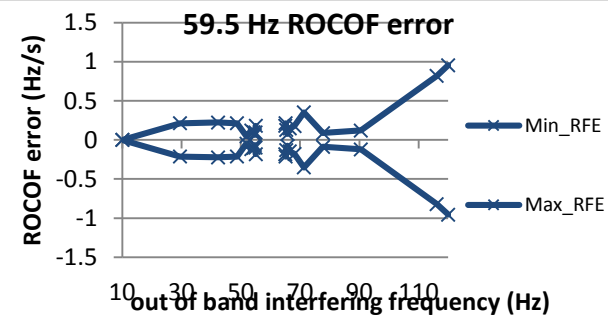


Figure 1961:  $F_s = 10$  FPS, 59.5 Hz fundamental

Figure 1959:  $F_s = 12$  FPS, 60 Hz fundamental

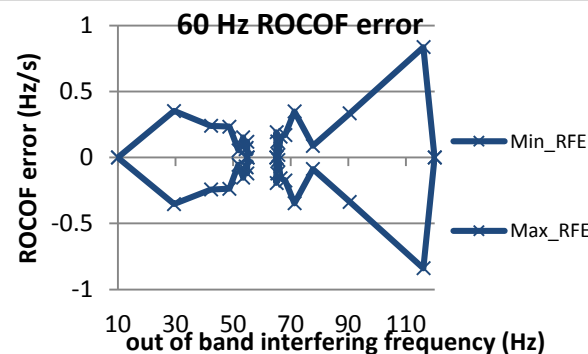


Figure 1962:  $F_s = 10$  FPS, 60 Hz fundamental

Figure 1960:  $F_s = 12$  FPS, 60.6 Hz fundamental

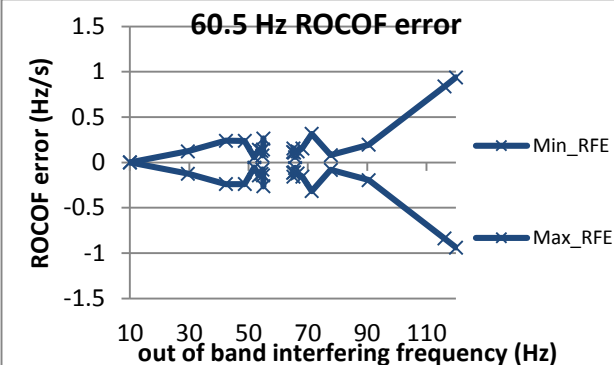
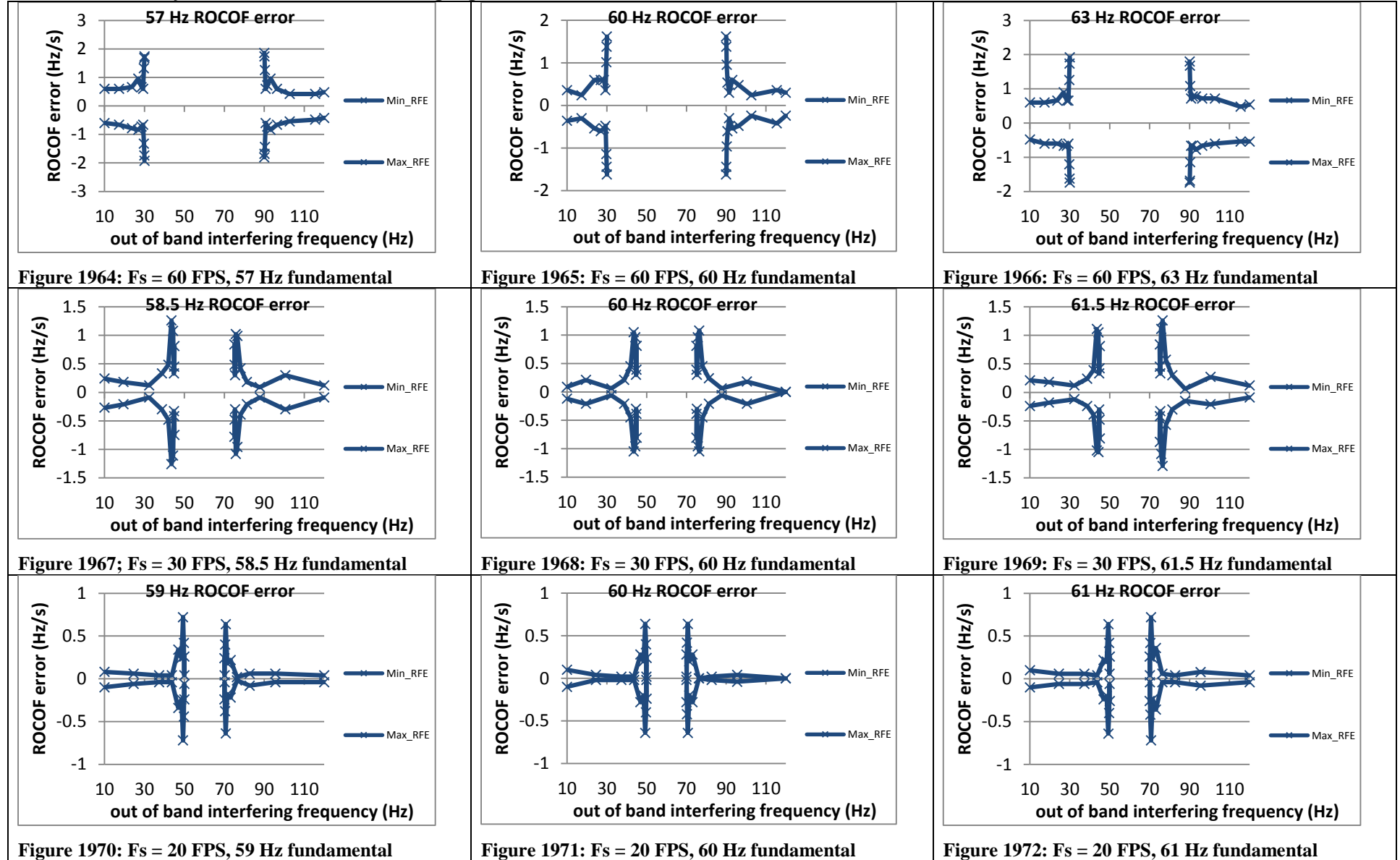
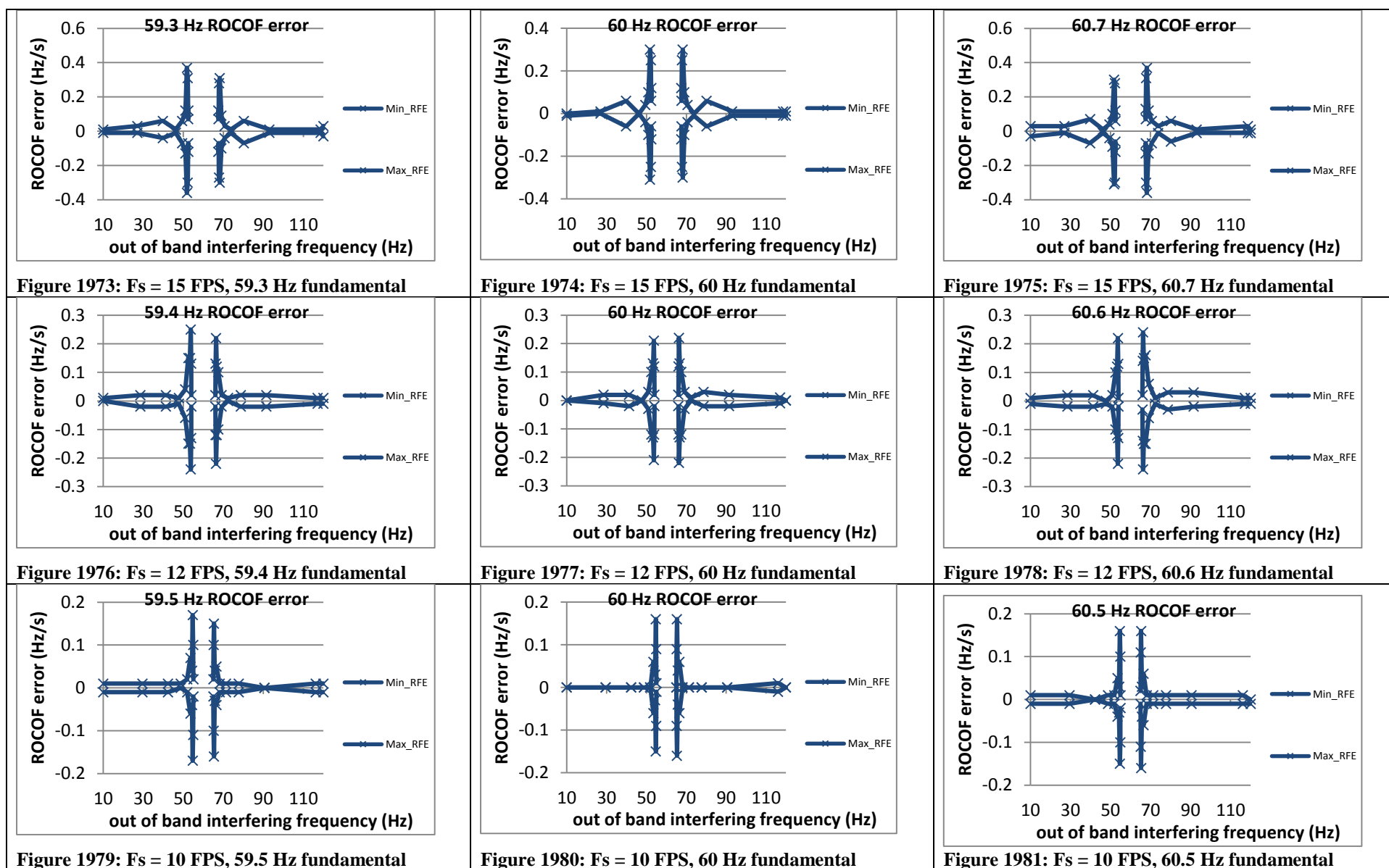


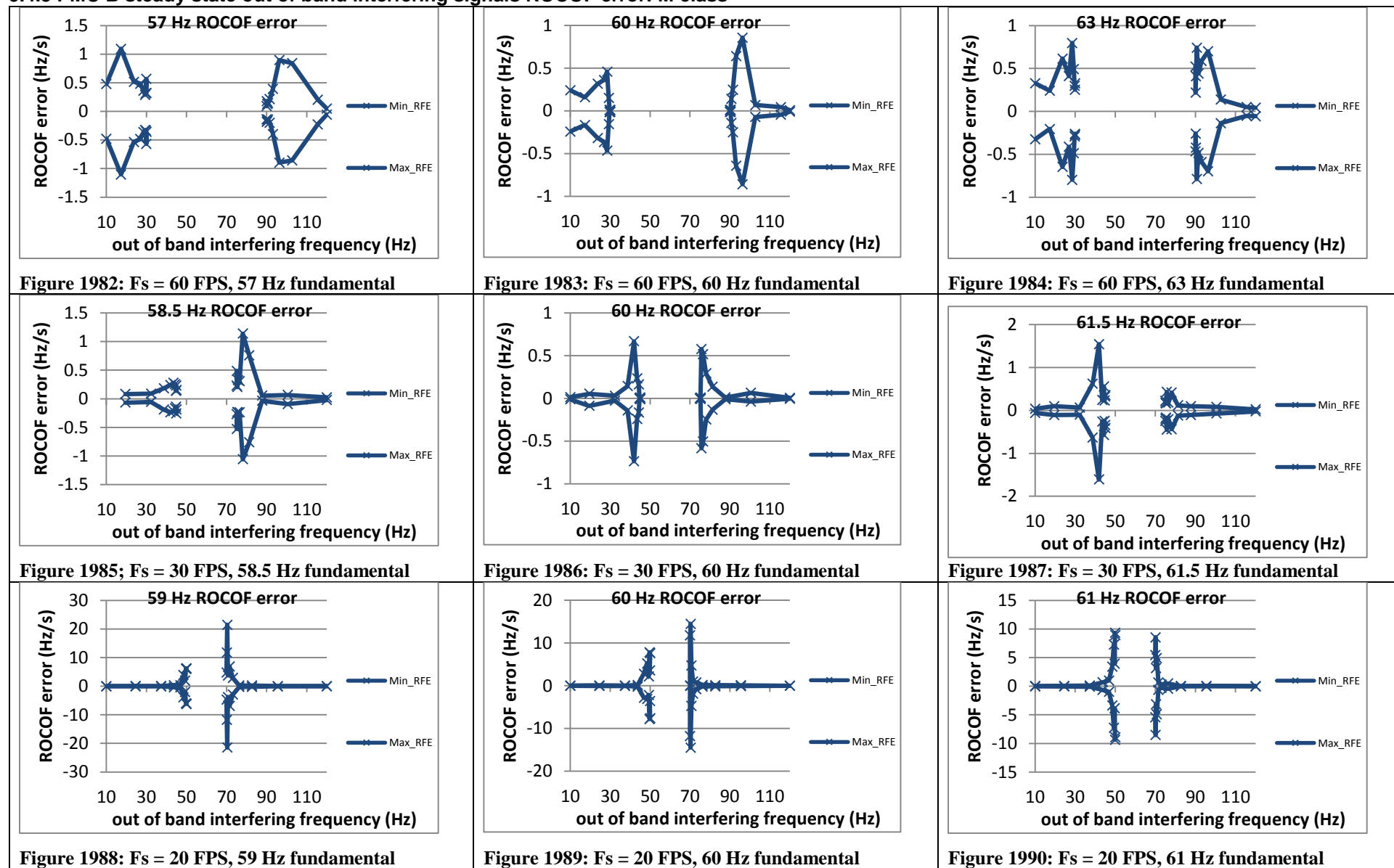
Figure 1963:  $F_s = 10$  FPS, 60.5 Hz fundamental

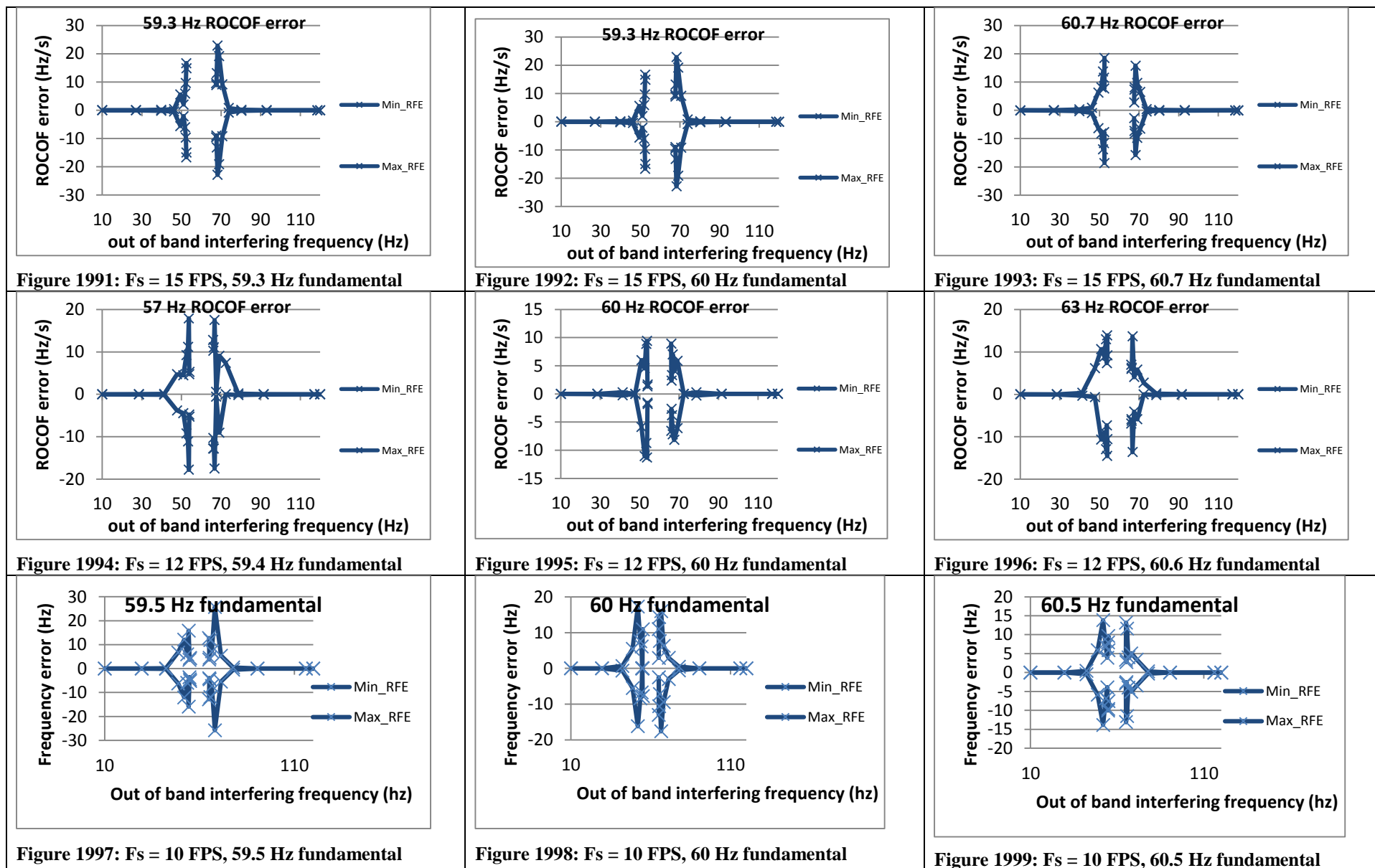
#### 5.4.2 PMU A steady state out of band interfering signals ROCOF error: M class





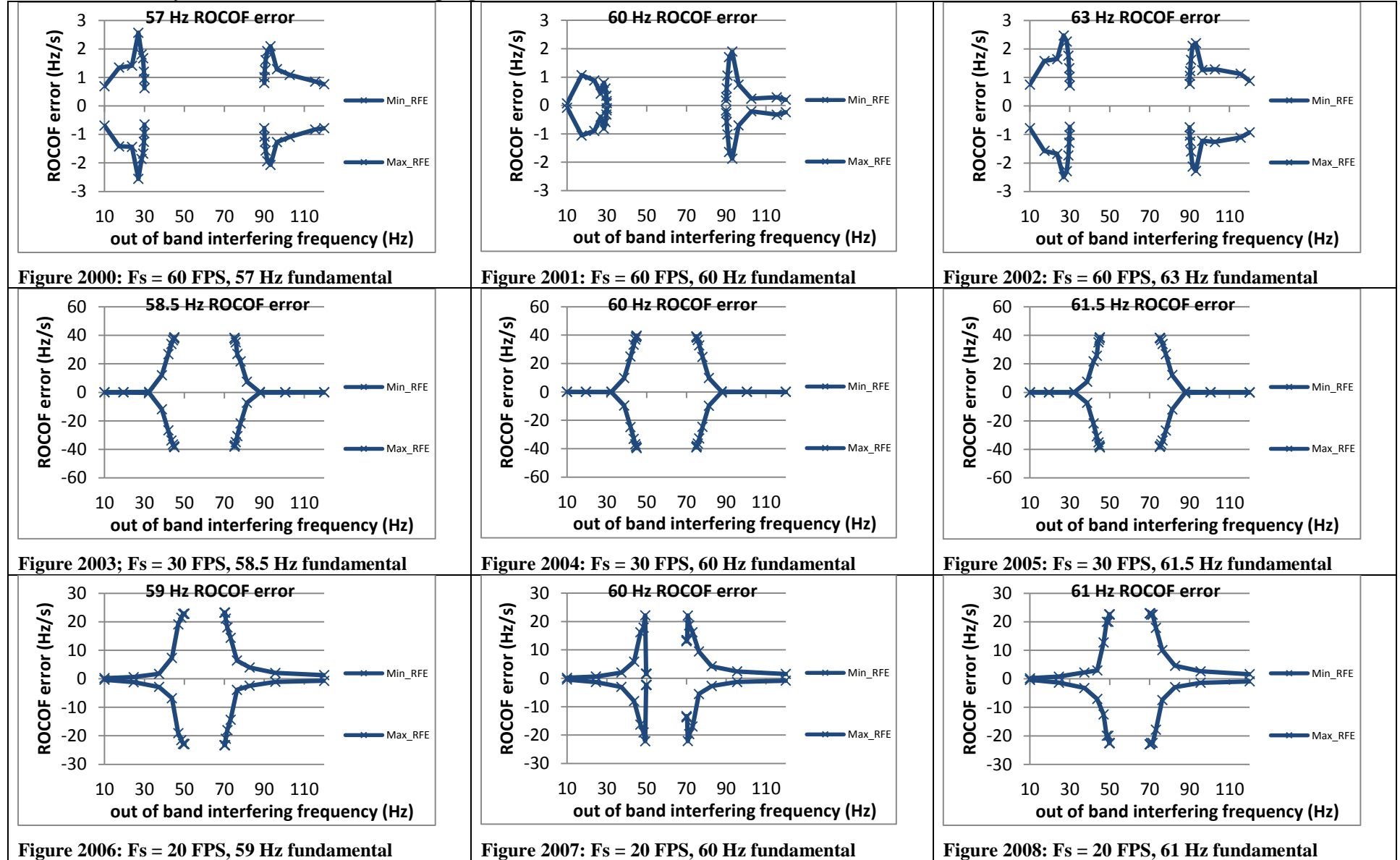
### 5.4.3 PMU B steady state out of band interfering signals ROCOF error: M class

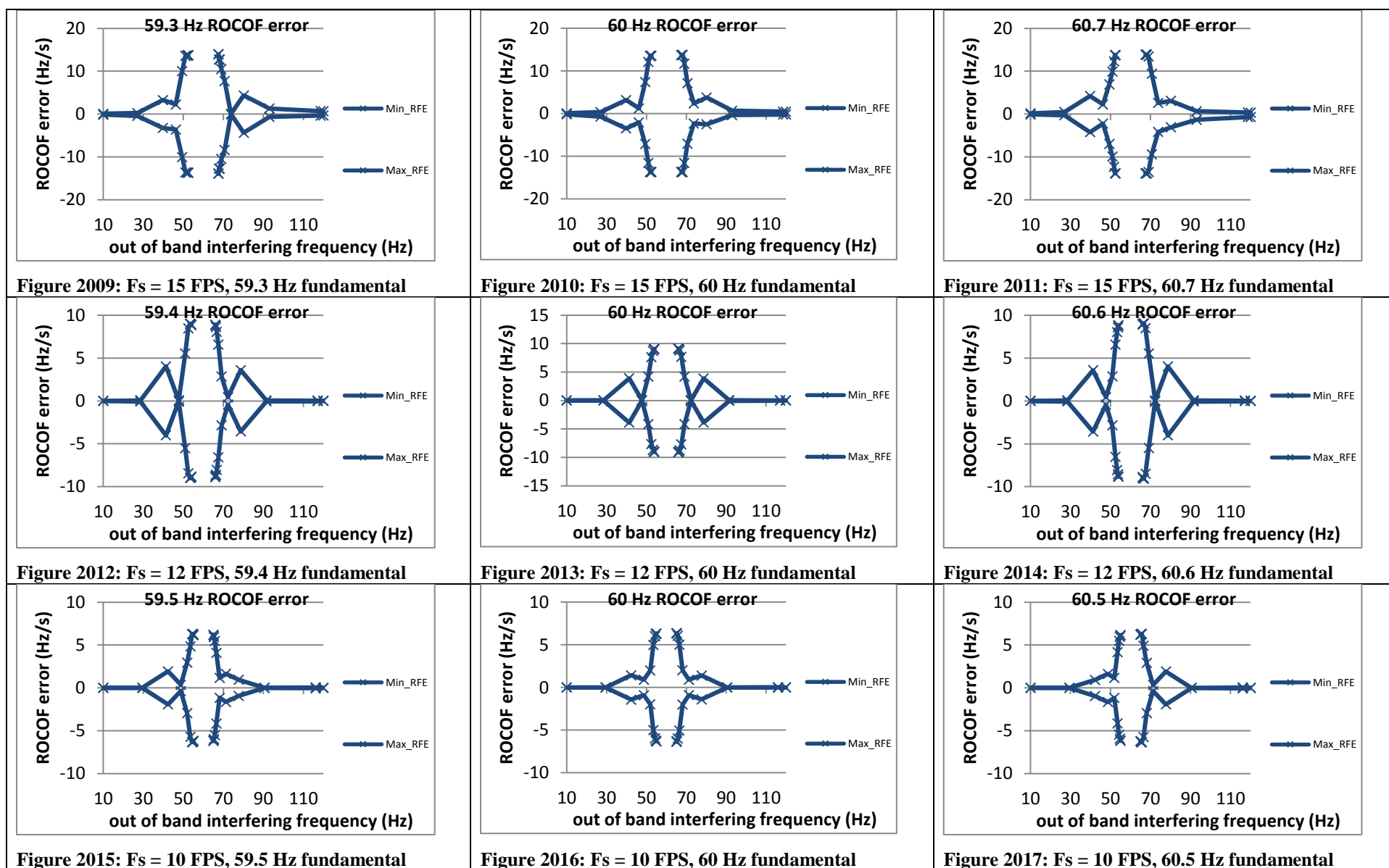




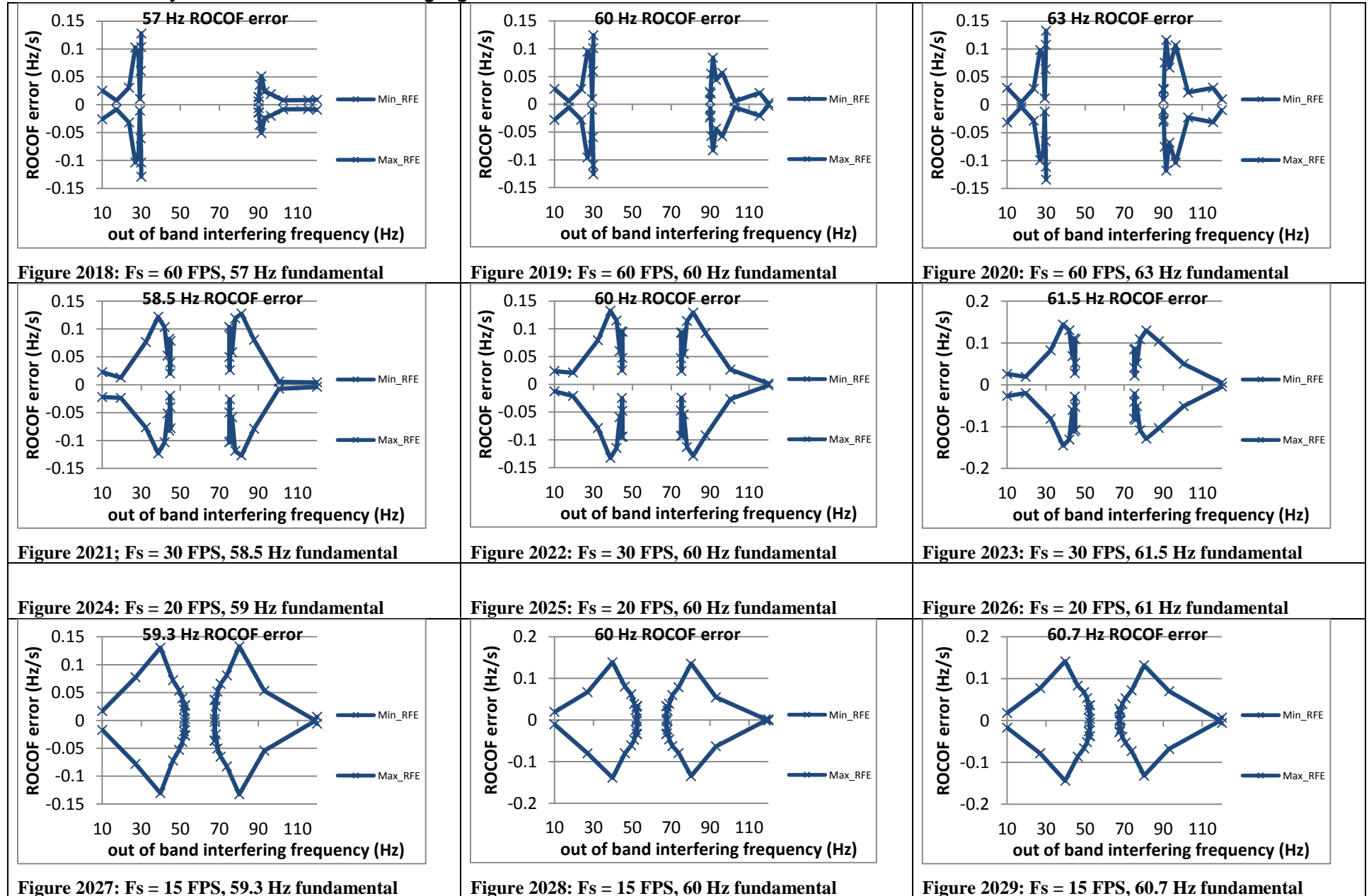


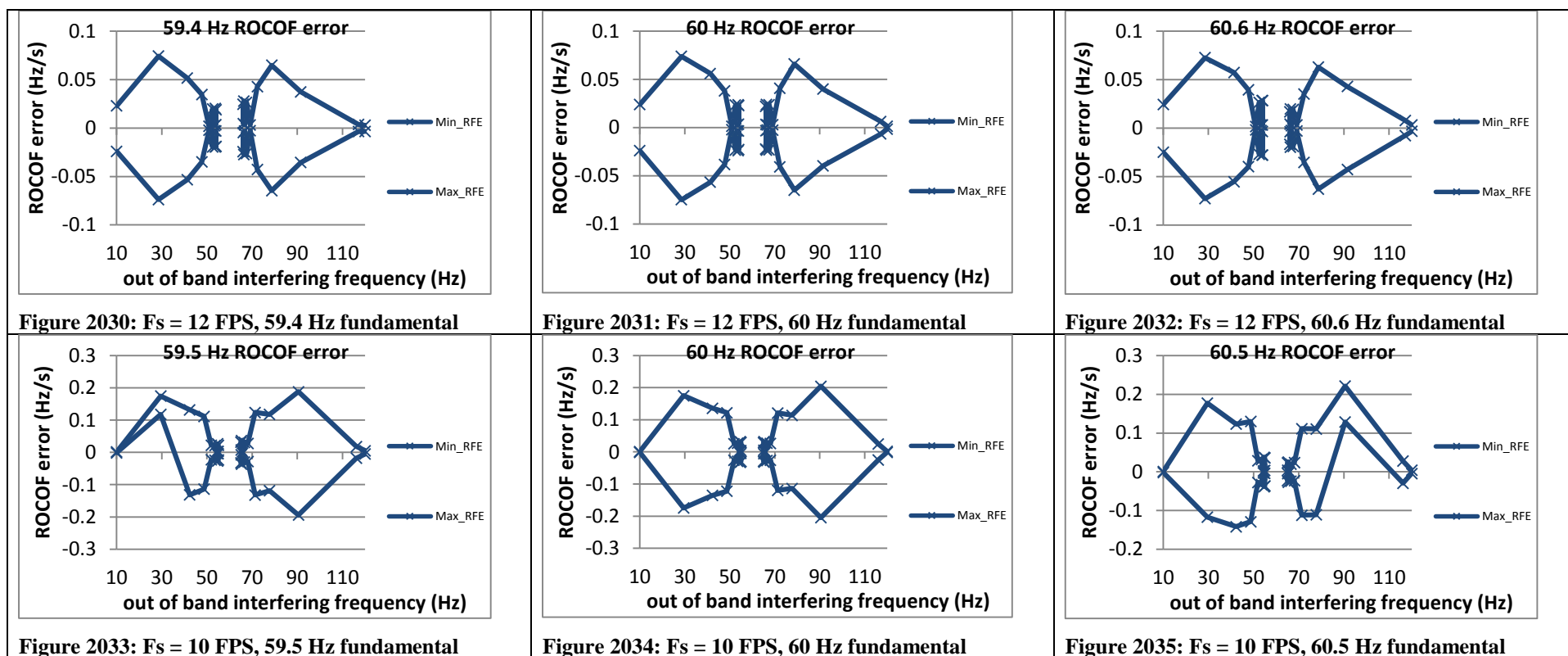
#### 5.4.4 PMU C steady state out of band interfering signals ROCOF error: M class



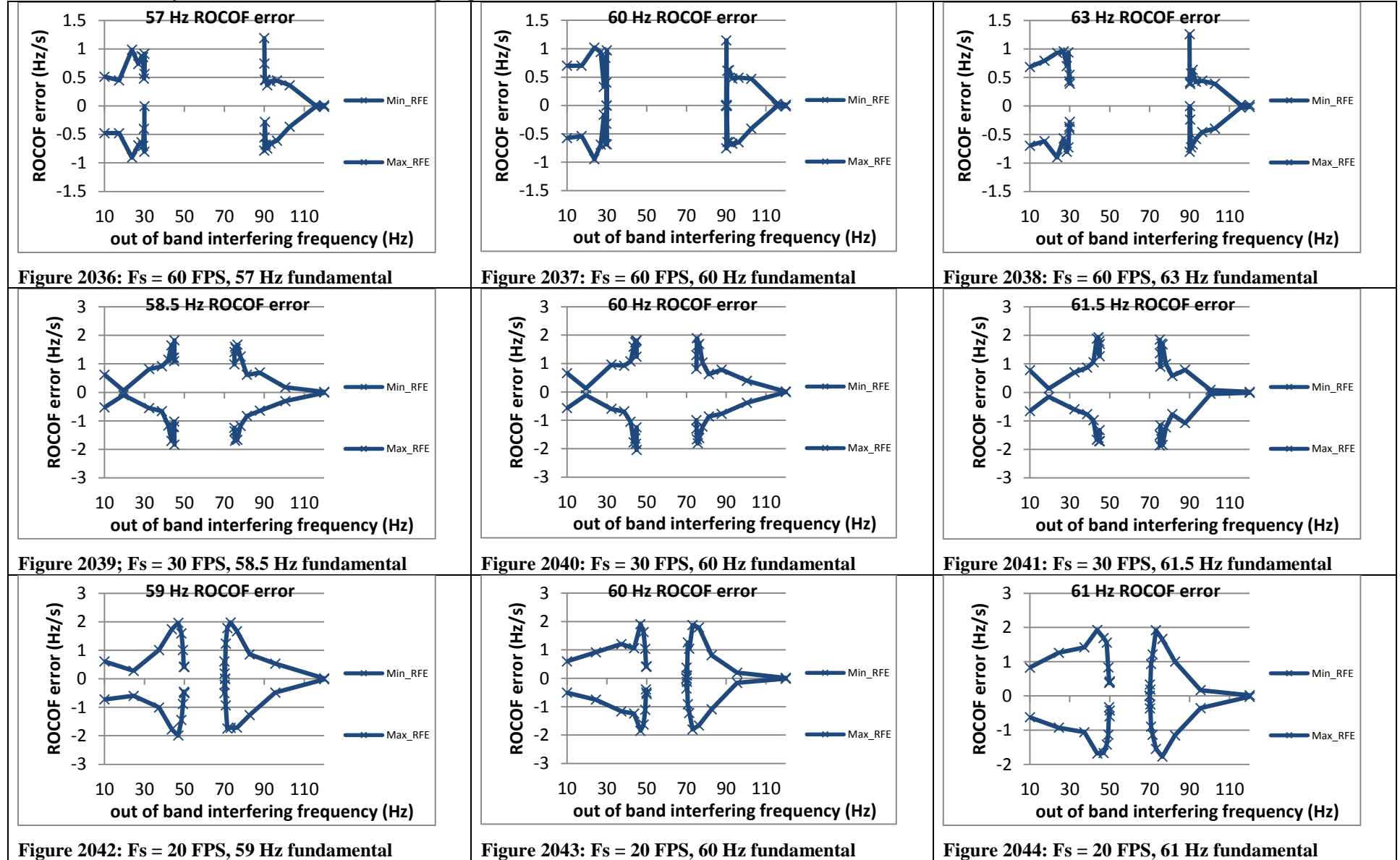


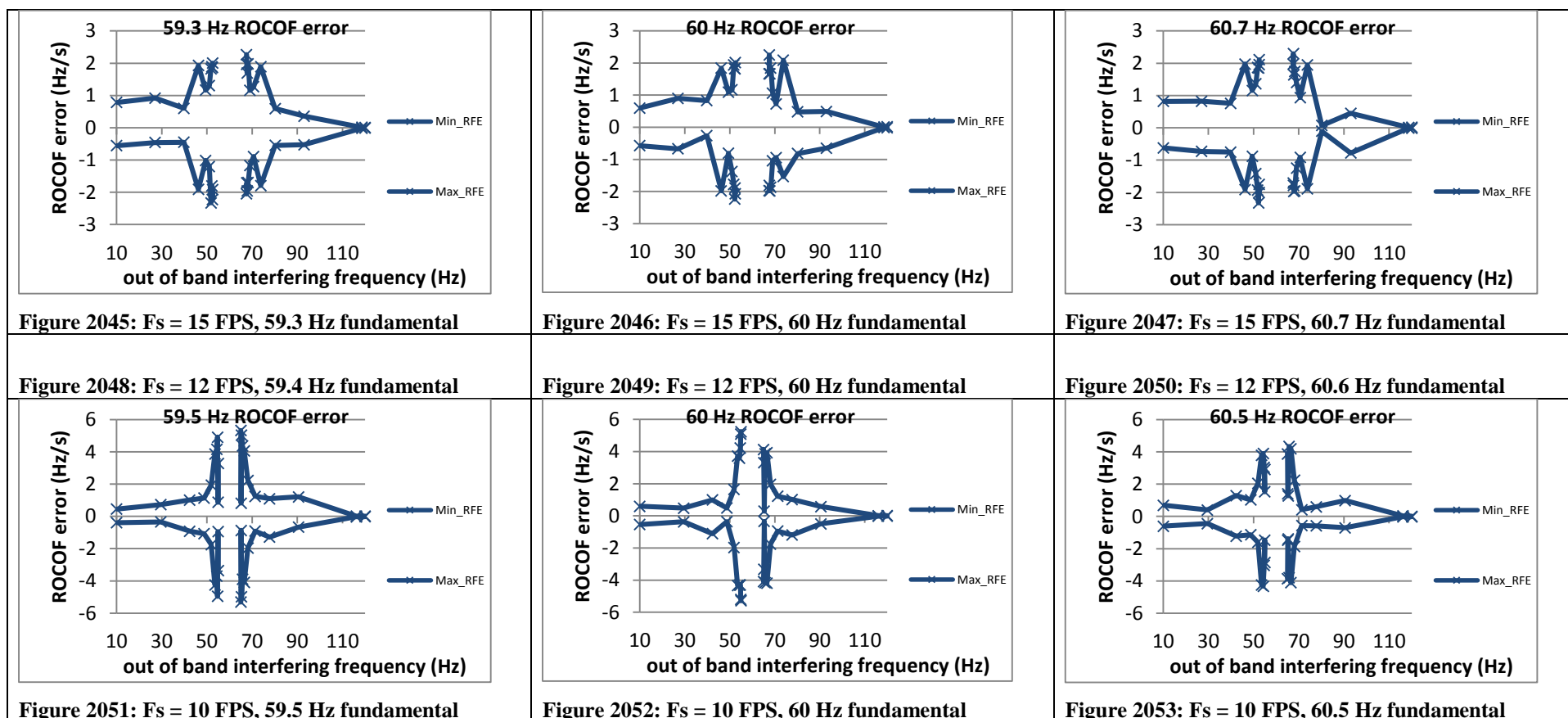
#### 5.4.5 PMU D steady state out of band interfering signals ROCOF error: M class



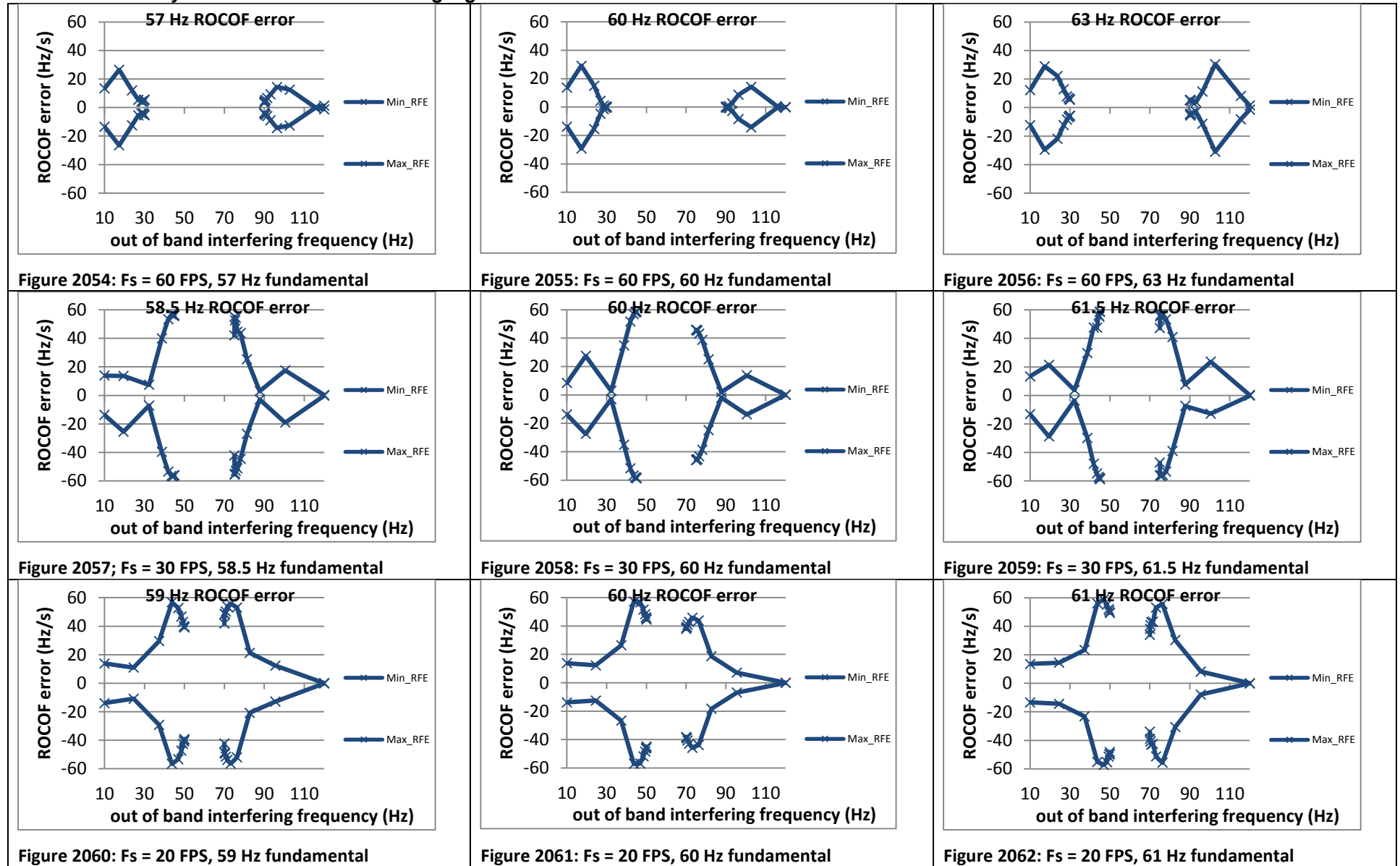


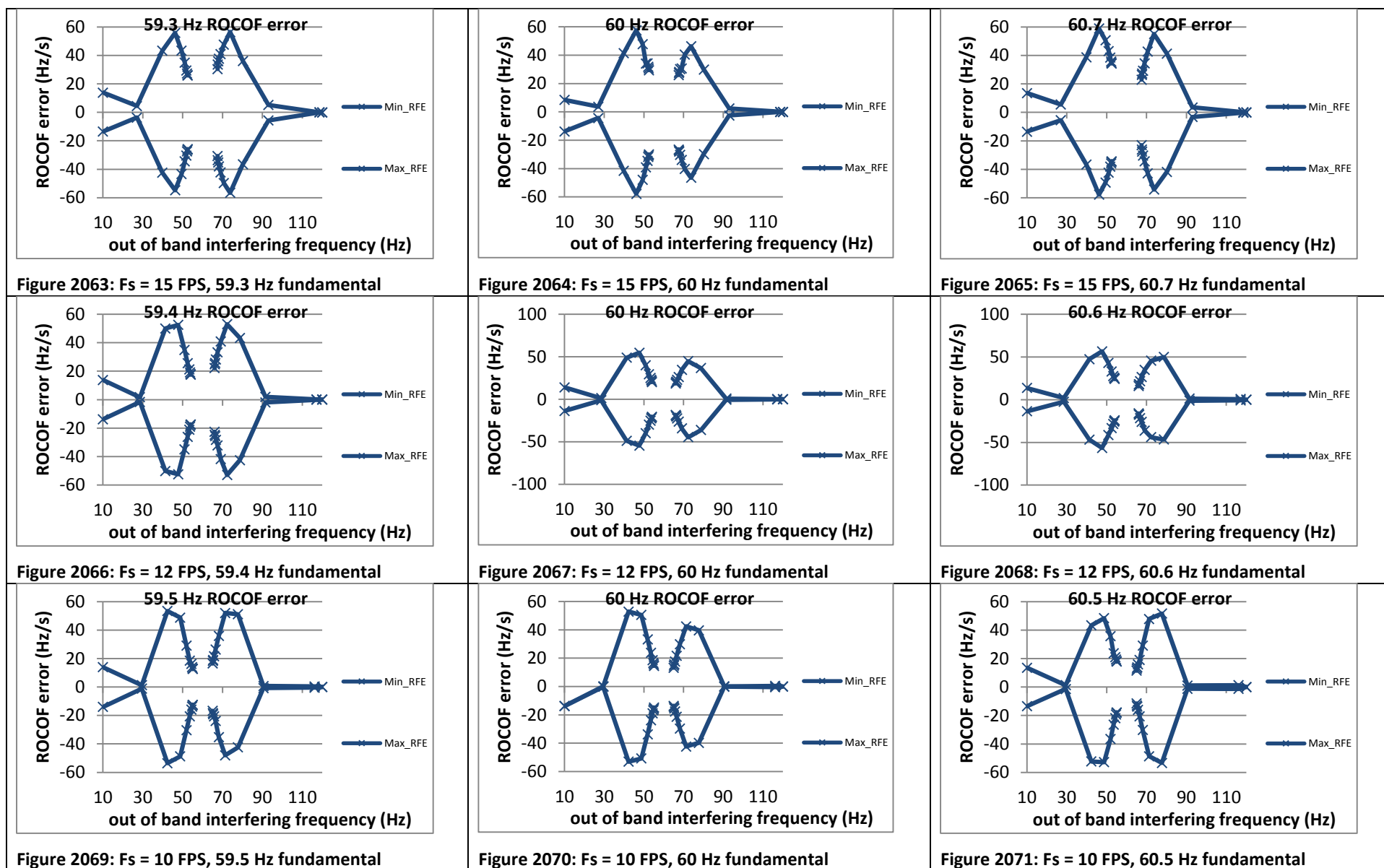
#### 5.4.6 PMU E steady state out of band interfering signals ROCOF error: M class





#### 5.4.7 PMU F steady state out of band interfering signals ROCOF error: M class







#### 5.4.8 PMU G\* steady state out of band interfering signals ROCOF error: M class

Figure 2072:  $F_s = 60$  FPS is not supported by this PMU

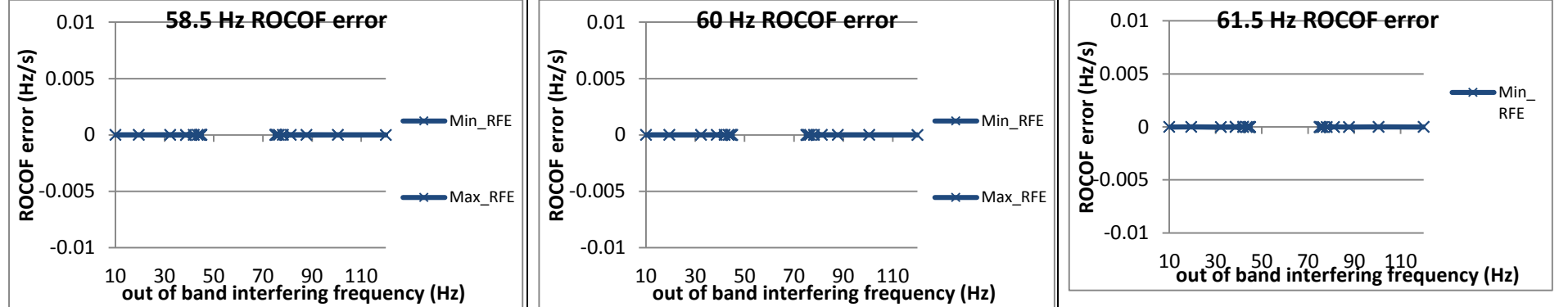


Figure 2073:  $F_s = 30$  FPS, 58.5 Hz fundamental

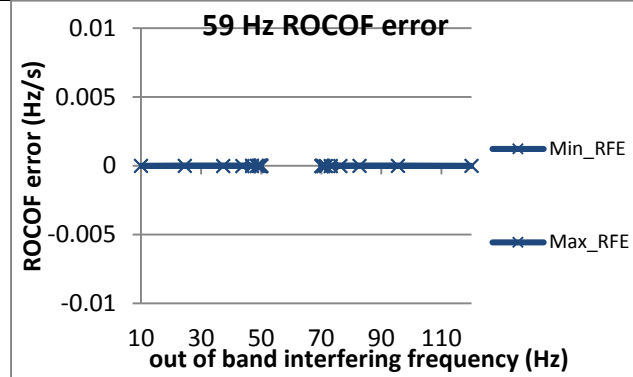


Figure 2074:  $F_s = 30$  FPS, 60 Hz fundamental

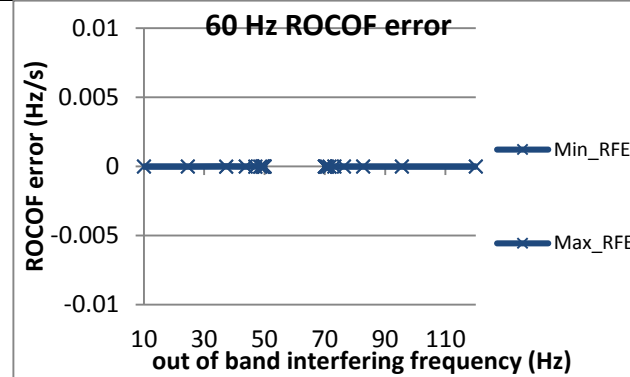


Figure 2075:  $F_s = 30$  FPS, 61.5 Hz fundamental

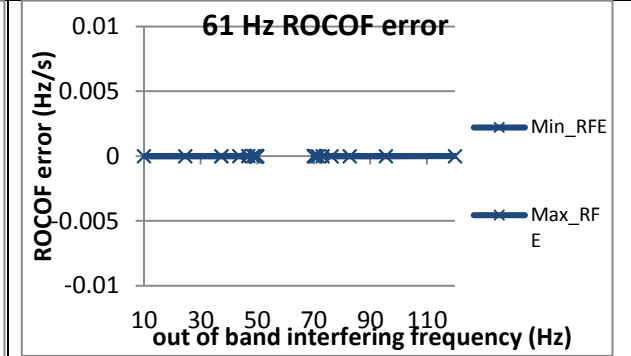


Figure 2076:  $F_s = 20$  FPS, 59 Hz fundamental

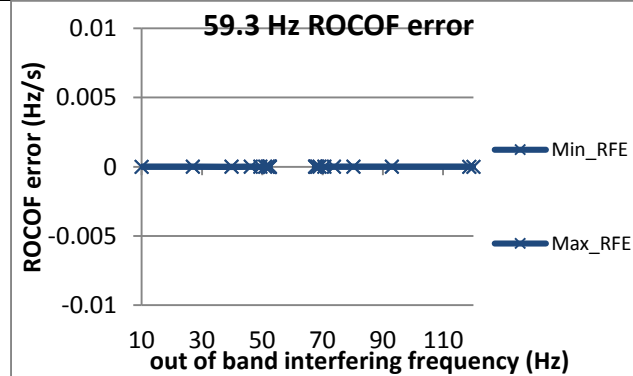


Figure 2077:  $F_s = 20$  FPS, 60 Hz fundamental

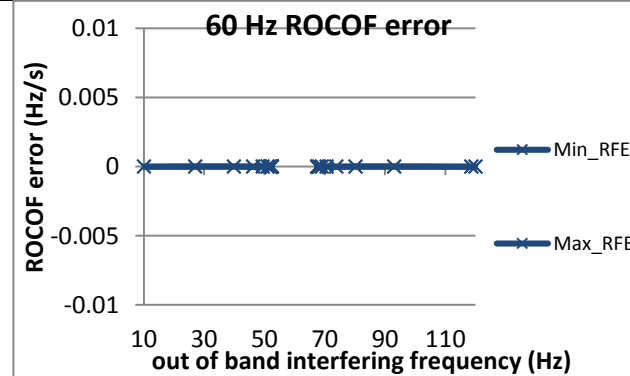
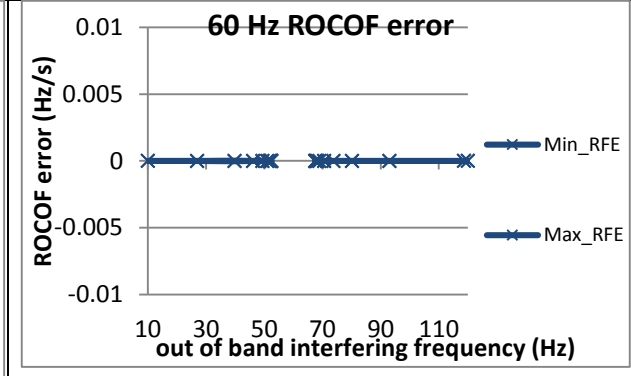
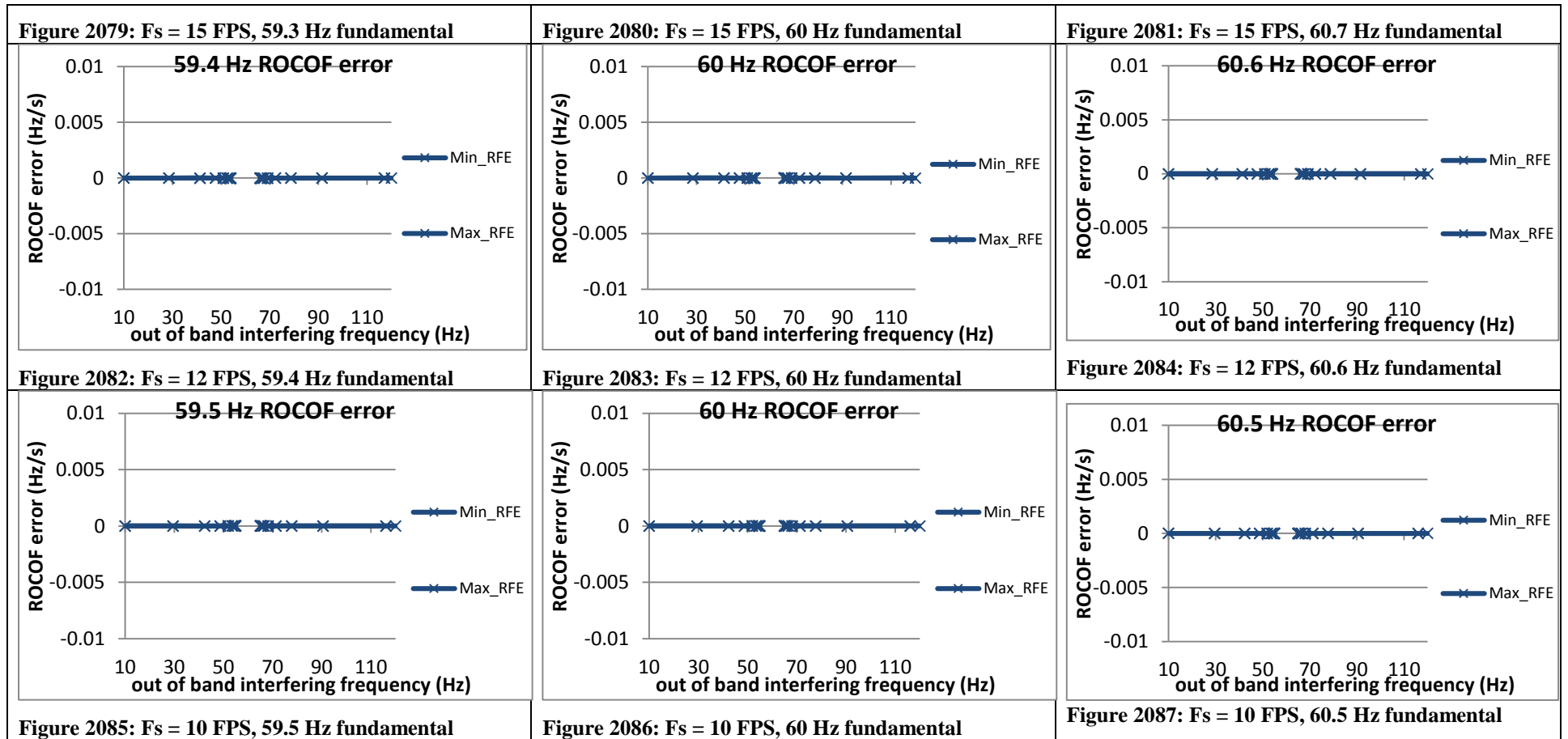


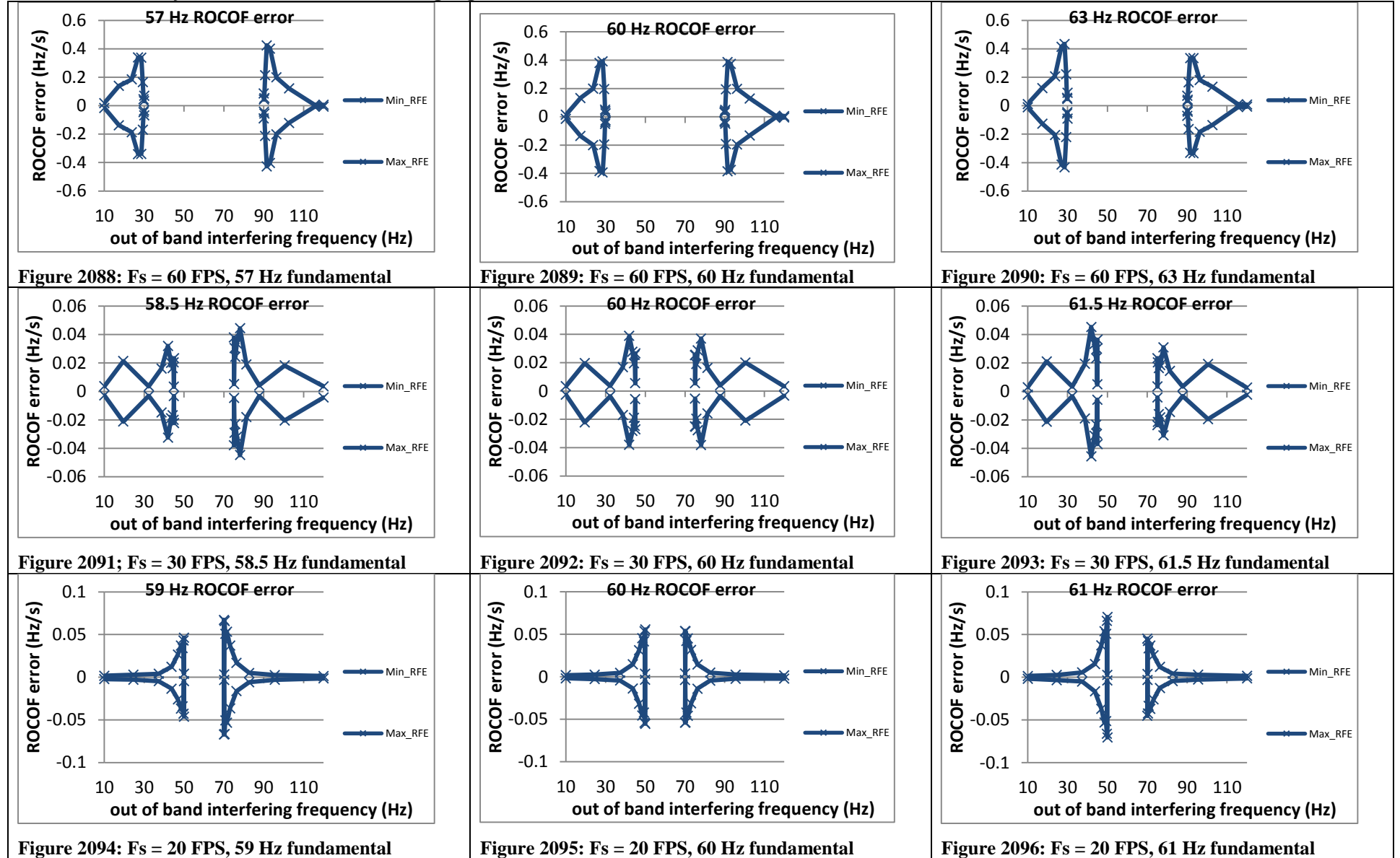
Figure 2078:  $F_s = 20$  FPS, 61 Hz fundamental

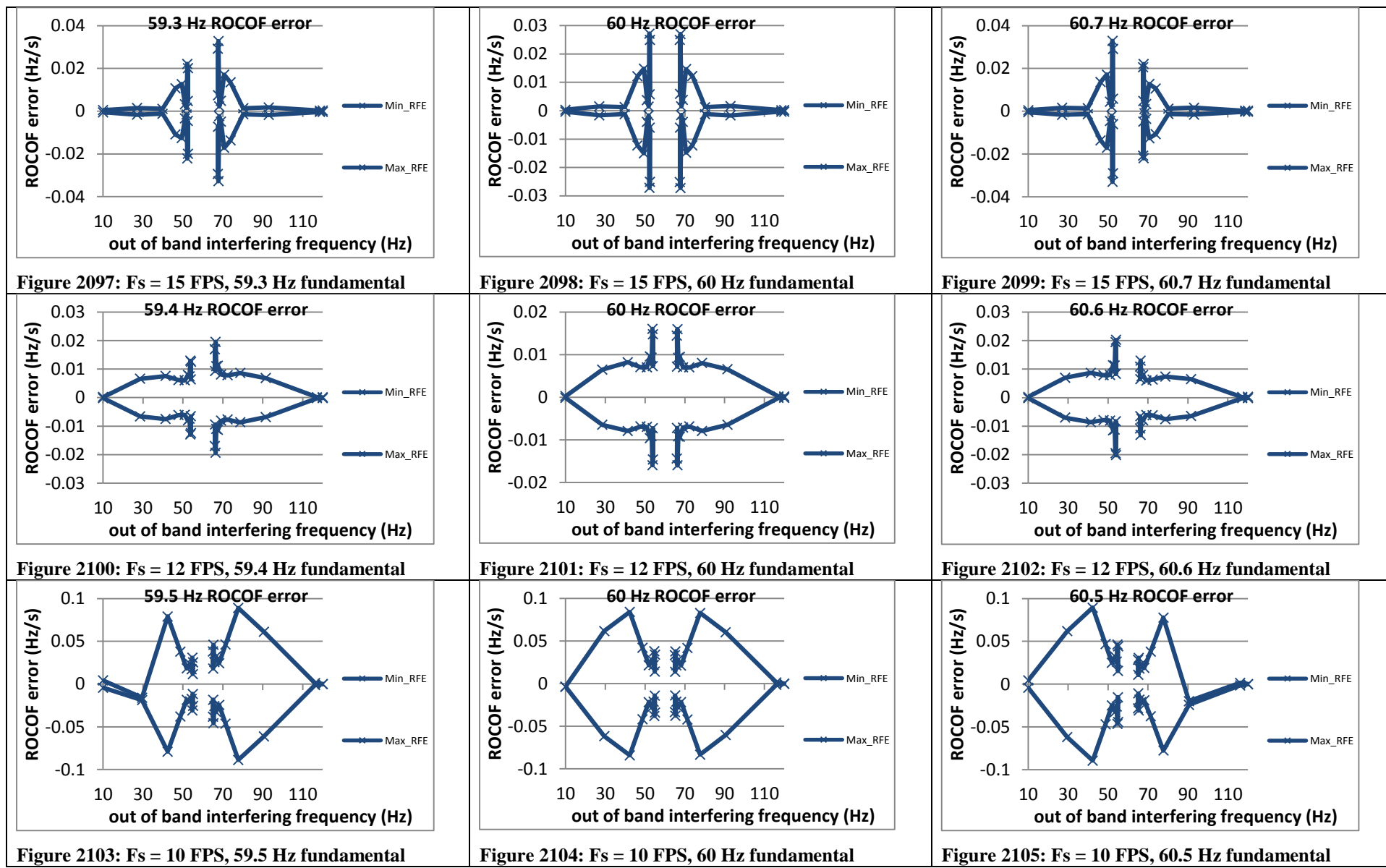




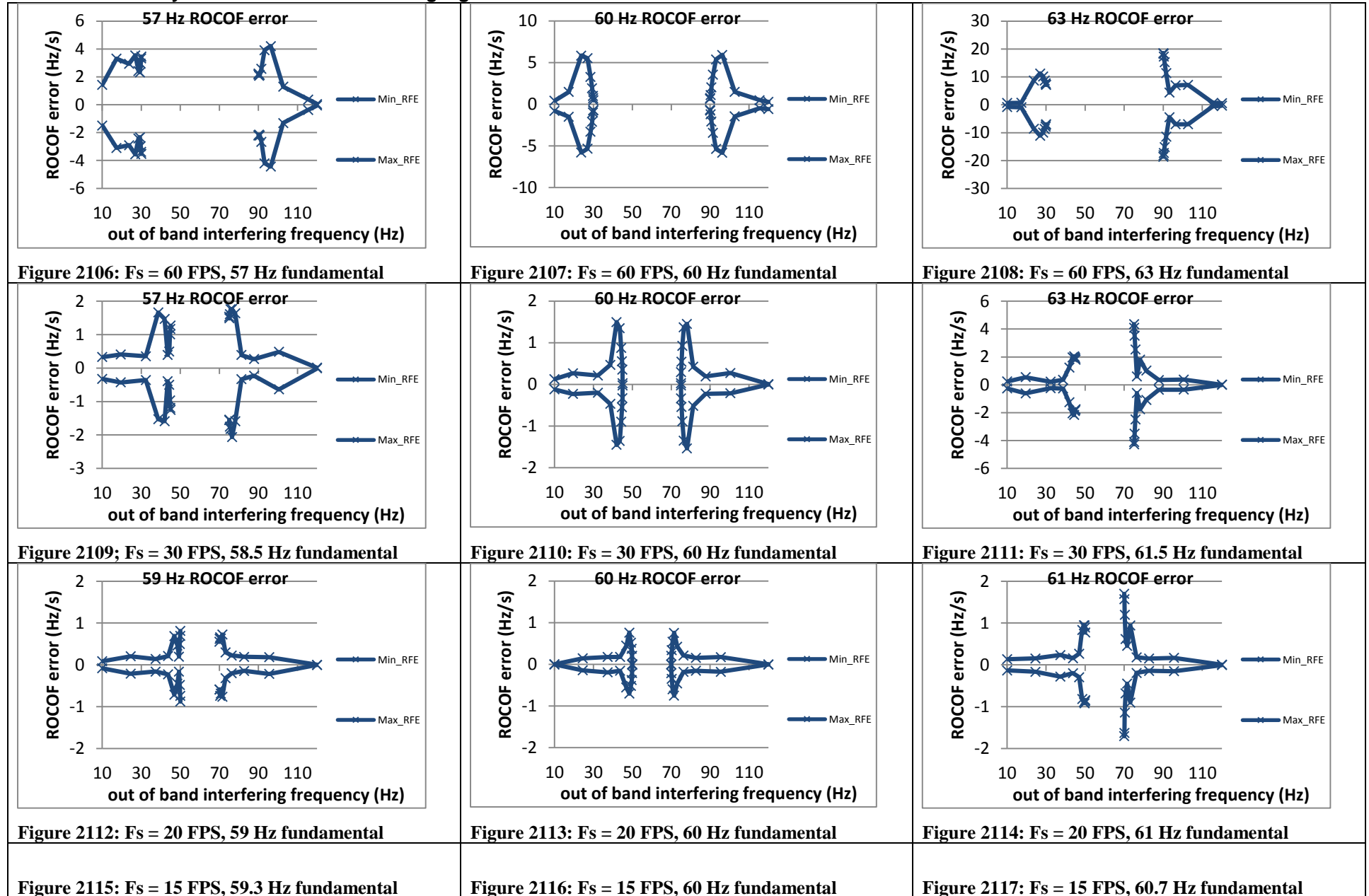
\* PMU G always outputs ROCOF = 0

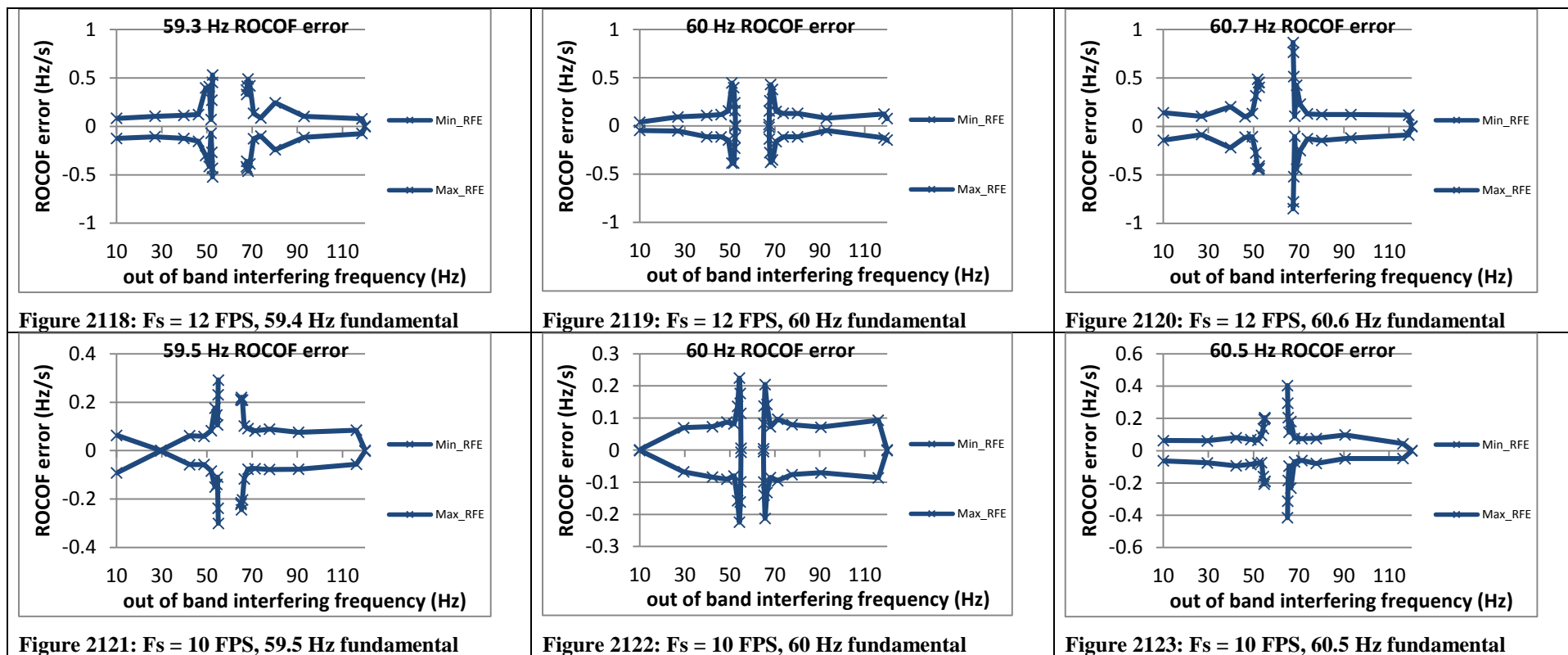
#### 5.4.9 PMU H steady state out of band interfering signals ROCOF error: M class



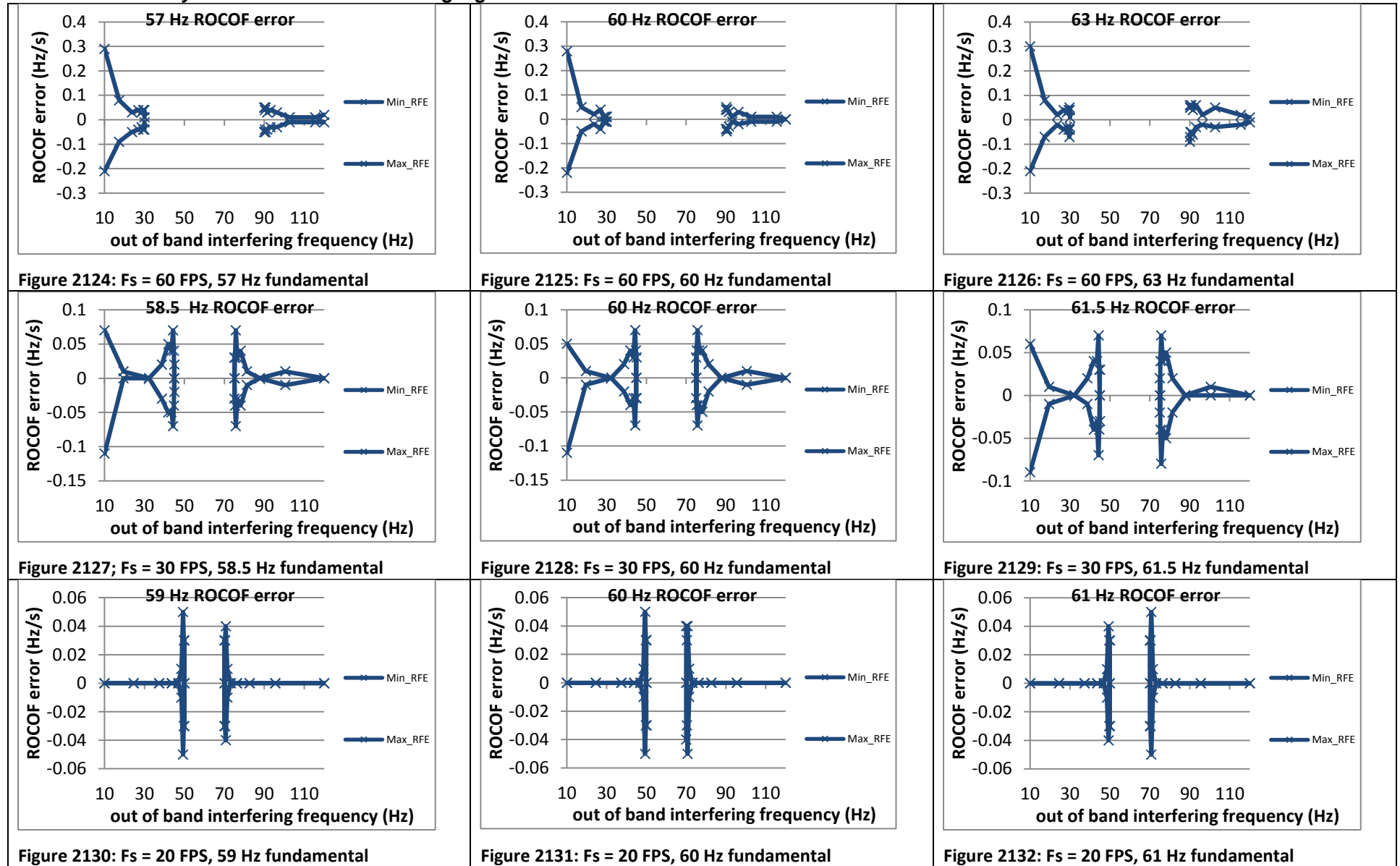


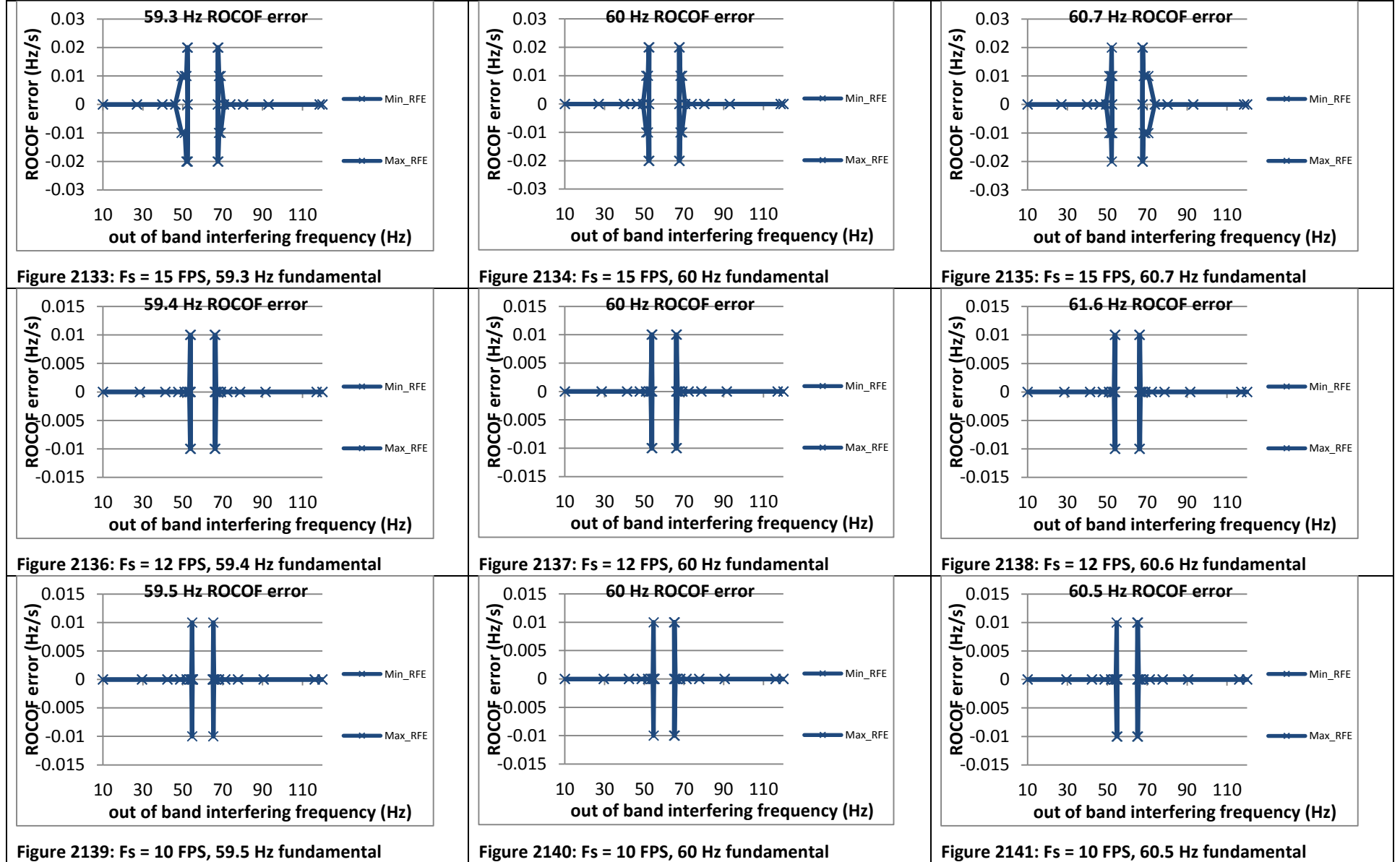
#### 5.4.10 PMU I steady state out of band interfering signals ROCOF error: M class





#### 5.4.11 PMU J steady state out of band interfering signals ROCOF error: M class







## 6. Dynamic ramp of system frequency

### Table of Contents

6. Dynamic ramp of system frequency .....	352
6.1 Dynamic ramp of system frequency voltage TVE, M class.....	357
6.1.1 C37.118.1 Annex C dynamic ramp of system frequency voltage TVE: F0 = 60, M class .....	357
6.1.2 PMU A dynamic ramp of system frequency voltage TVE: M class .....	359
6.1.3 PMU B dynamic ramp of system frequency voltage TVE: M class .....	361
6.1.4 PMU C dynamic ramp of system frequency voltage TVE: M class.....	363
6.1.5 PMU D dynamic ramp of system frequency voltage TVE: M class .....	365
6.1.6 PMU E dynamic ramp of system frequency voltage TVE: M class.....	367
6.1.7 PMU F dynamic ramp of system frequency voltage TVE: M class.....	369
6.1.8 PMU G dynamic ramp of system frequency voltage TVE: M class .....	371
6.1.9 PMU H dynamic ramp of system frequency voltage TVE: M class .....	373
6.1.10 PMU I dynamic ramp of system frequency voltage TVE: M class.....	375
6.1.11 PMU J dynamic ramp of system frequency voltage TVE: M class .....	377
6.2 Dynamic ramp of system frequency current TVE, M class.....	379
6.2.1 C37.118.1 Annex C dynamic ramp of system frequency current TVE, M class .....	379
6.2.2 PMU A dynamic ramp of system frequency current TVE, M class .....	381
6.2.3 PMU B dynamic ramp of system frequency current TVE, M class .....	383
6.2.4 PMU C dynamic ramp of system frequency current TVE, M class.....	385
6.2.5 PMU D dynamic ramp of system frequency current TVE, M class .....	387
6.2.6 PMU E dynamic ramp of system frequency current TVE, M class.....	389
6.2.7 PMU F dynamic ramp of system frequency current TVE, M class.....	391
6.2.8 PMU G dynamic ramp of system frequency current TVE, M class .....	393
6.2.9 PMU H dynamic ramp of system frequency current TVE, M class .....	395
6.2.10 PMU I dynamic ramp of system frequency current TVE, M class.....	397
6.2.11 PMU J dynamic ramp of system frequency current TVE, M class .....	399
6.3 Dynamic ramp of system frequency frequency error, M class .....	401
6.3.1 C367.118.1 Annex C dynamic ramp of system frequency frequency error: M class .....	401
6.3.2 C37.118.1 PMU A dynamic ramp of system frequency frequency error: M class.....	403
6.3.3 PMU B dynamic ramp of system frequency frequency error: M class .....	405
6.3.4 PMU C dynamic ramp of system frequency frequency error: M class .....	407
6.3.5 PMU D dynamic ramp of system frequency frequency error: M class.....	409
6.3.6 PMU E dynamic ramp of system frequency frequency error: M class .....	411
6.3.7 PMU F dynamic ramp of system frequency frequency error: M class .....	413

6.3.8 PMU G dynamic ramp of system frequency frequency error: M class.....	415
6.3.9 PMU H dynamic ramp of system frequency frequency error: M class.....	417
6.3.10 PMU I dynamic ramp of system frequency frequency error: M class .....	419
6.3.11 PMU J dynamic ramp of system frequency frequency error: M class.....	421
6.4 Dynamic ramp of system frequency ROCOF error .....	423
6.4.1 C37.118.1 Annex C dynamic ramp of system frequency ROCOF error: M class.....	423
6.4.2 PMU A dynamic ramp of system frequency ROCOF error: M class.....	425
6.4.3 PMU B dynamic ramp of system frequency ROCOF error: M class.....	427
6.4.4 PMU C dynamic ramp of system frequency ROCOF error: M class .....	429
6.4.5 PMU D dynamic ramp of system frequency ROCOF error: M class.....	431
6.4.6 PMU E dynamic ramp of system frequency ROCOF error: M class .....	433
6.4.7 PMU F dynamic ramp of system frequency ROCOF error: M class .....	435
6.4.8 PMU G* dynamic ramp of system frequency ROCOF error: M class.....	437
6.4.9 PMU H dynamic ramp of system frequency ROCOF error: M class.....	439
6.4.10 PMU I dynamic ramp of system frequency ROCOF error: M class .....	441
6.4.11 PMU J dynamic ramp of system frequency ROCOF error: M class.....	443
6.5 Dynamic ramp of system frequency voltage TVE, P class .....	445
6.5.1 C37.118.1 Annex C dynamic ramp of system frequency voltage TVE, P class.....	445
6.5.2 PMU A dynamic ramp of system frequency voltage TVE, P class.....	447
6.5.3 PMU B dynamic ramp of system frequency voltage TVE, P class.....	449
6.5.4 PMU C dynamic ramp of system frequency voltage TVE, P class.....	451
6.5.5 PMU D dynamic ramp of system frequency voltage TVE, P class.....	453
6.5.6 PMU E dynamic ramp of system frequency voltage TVE, P class .....	455
6.5.7 PMU F dynamic ramp of system frequency voltage TVE, P class .....	455
6.5.8 PMU G dynamic ramp of system frequency voltage TVE, P class.....	457
6.5.9 PMU H dynamic ramp of system frequency voltage TVE, P class.....	457
6.5.10 PMU I dynamic ramp of system frequency voltage TVE, P class .....	460
6.5.11 PMU J dynamic ramp of system frequency voltage TVE, P class.....	460
6.6 Dynamic ramp of system frequency current TVE, P class .....	462
6.6.1 C37.118.1 Annex C dynamic ramp of system frequency current TVE, P class.....	462
6.6.2 PMU A dynamic ramp of system frequency current TVE, P class.....	464
6.6.3 PMU B dynamic ramp of system frequency current TVE, P class.....	466
6.6.4 PMU C dynamic ramp of system frequency current TVE, P class.....	468
6.6.5 PMU D dynamic ramp of system frequency current TVE, P class.....	470
6.6.6 PMU E dynamic ramp of system frequency current TVE, P class .....	472
6.6.7 PMU F dynamic ramp of system frequency current TVE, P class .....	472
6.6.8 PMU G dynamic ramp of system frequency current TVE, P class .....	474
6.6.9 PMU H dynamic ramp of system frequency current TVE, P class .....	474
6.6.10 PMU I dynamic ramp of system frequency current TVE, P class.....	476
6.6.11 PMU J dynamic ramp of system frequency current TVE, P class.....	476

6.7 Dynamic ramp of system frequency frequency, P class.....	478
6.7.1 C37.118.1 Annex C dynamic ramp of system frequency frequency error, P class .....	478
6.7.2 PMU A dynamic ramp of system frequency frequency error, P class .....	480
6.7.3 PMU B dynamic ramp of system frequency frequency error, P class .....	482
6.7.4 PMU C dynamic ramp of system frequency frequency error, P class .....	484
6.7.5 PMU D dynamic ramp of system frequency frequency error, P class .....	486
6.7.6 PMU E dynamic ramp of system frequency frequency error, P class.....	488
6.7.7 PMU F dynamic ramp of system frequency frequency error, P class.....	488
6.7.8 PMU G dynamic ramp of system frequency frequency error, P class .....	490
6.7.9 PMU H dynamic ramp of system frequency frequency error, P class .....	490
6.7.10 PMU I dynamic ramp of system frequency frequency error, P class.....	492
6.7.11 PMU J dynamic ramp of system frequency frequency error, P class .....	492
6.8 Dynamic ramp of system frequency ROCOF, P class.....	494
6.8.1 C37.118.1 Annex C dynamic ramp of system frequency ROCOF error, P class .....	494
6.8.2 PMU A dynamic ramp of system frequency ROCOF error, P class .....	496
6.8.3 PMU B dynamic ramp of system frequency ROCOF error, P class .....	498
6.8.4 PMU C dynamic ramp of system frequency ROCOF error, P class .....	500
6.8.5 PMU D dynamic ramp of system frequency ROCOF error, P class .....	502
6.8.6 PMU E dynamic ramp of system frequency ROCOF error, P class.....	504
6.8.7 PMU F dynamic ramp of system frequency ROCOF error, P class.....	504
6.8.8 PMU G dynamic ramp of system frequency ROCOF error, P class .....	506
6.8.9 PMU H dynamic ramp of system frequency ROCOF error, P class .....	506
6.8.10 PMU I dynamic ramp of system frequency ROCOF error, P class .....	508
6.8.11 PMU J dynamic ramp of system frequency ROCOF error, P class .....	508

IEEE Std. C37.118.1-2011 table 7 specifies the minimum range of influence quantity over which PMU shall be within given TVE limit:

For M class the range is the lesser of:

- $F_0 \pm F_s/5$  Hz
- $F_0 \pm 5$  Hz

For P class the range is  $F_0 \pm 2$ Hz.

IEEE Std. C37.118.1a states that the error calculation shall exclude measurements during the first seven sample periods for M class and two sample periods for P class before and after a change in the test ROCOF. In the tests below; the ramp of system frequency test is performed by first applying a beginning steady state frequency at the required range. The standard requires two transition time samples ( $N_t$ ) and a ramp rate ( $R$ ) of  $\pm 1$  Hz/second. The beginning frequency is:

Test plan:

- a) Begin with input at nominal magnitude and lower frequency range.
- b) Wait for the system to settle.
- c) Begin ramping the frequency with a positive ramp rate of 1 Hz/s, ramp until the upper frequency range is reached and hold at that frequency for at least the settling period.
- d) Calculate the errors: TVE, FE, and RFE for each report.
- e) Calculate the max TVE, FE, and RFE excluding data during the exclusion intervals as required by the standard.
- f) Hold the frequency constant for at least the settling period, and then begin ramping the frequency at the negative ramp rate.
- g) Calculate the max TVE, FE, and RFE excluding data during the exclusion intervals as required by the standard.

The ramp test is performed twice, once with ramp rates = +1 Hz/s and again with -1 Hz/s. The plots below show the TVE, Fe and RFe for individual test runs in columns showing the positive and negative ramp, and rows showing the PMU response at various reporting rates. The X axis of the plots are the ramp time and the Y axis are TVE, Fe and RFe respectively. The excluded measurements are not shown in the plots.

M class limits:

- TVE: 1%
- Fe: 0.01 Hz
- RFe: 0.2 Hz/s

P class limits:

- TVE: 1%
- Fe: 0.01 Hz
- RFe: 0.4 Hz/s

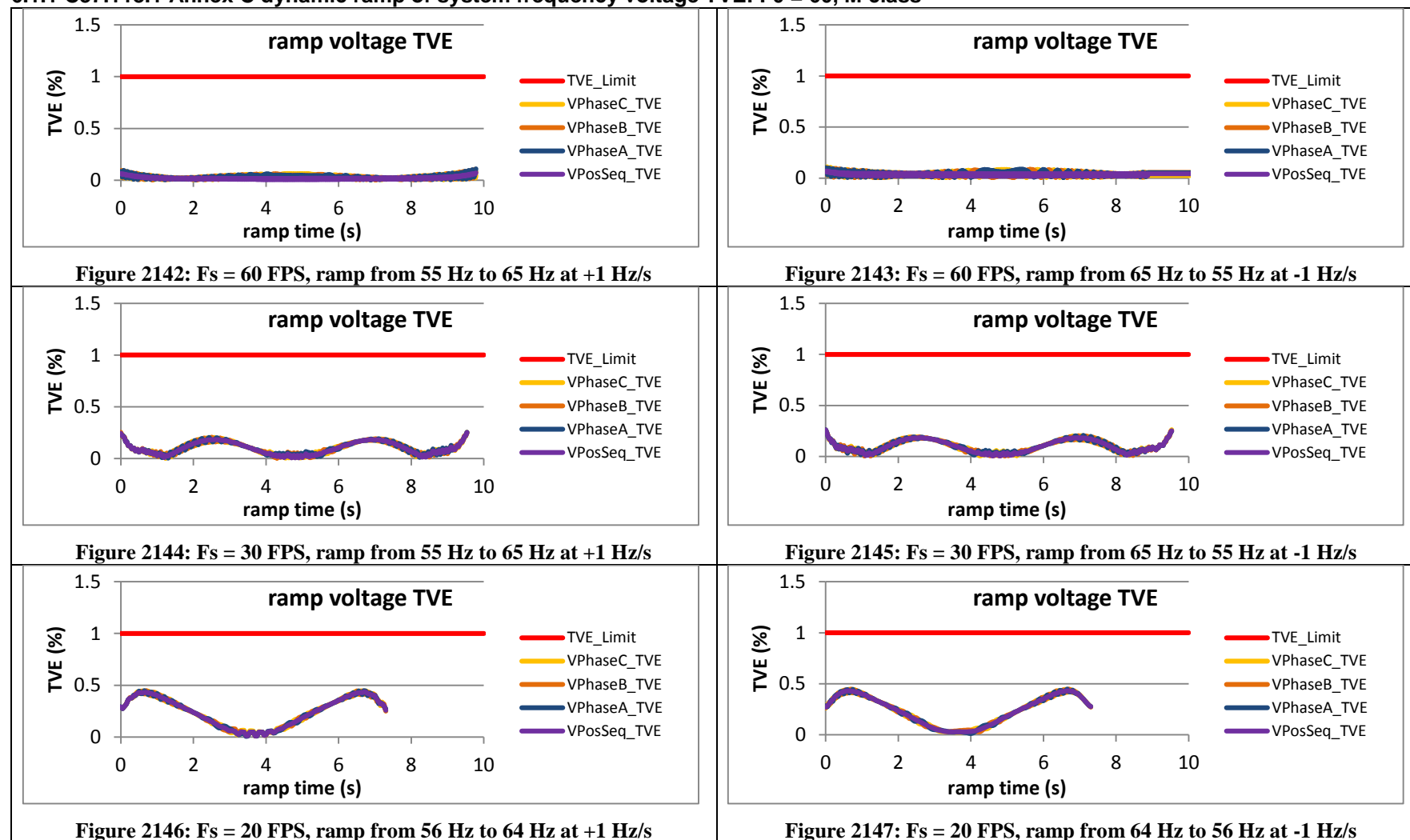
Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T V E	FE	RF E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E	T V E	F E	R F E			
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
PMU A	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	F	P	P	F
PMU B	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	F
PMU C	P	F	P	P	F	P	P	F	P	P	F	P	P	F	F	P	F	F	P	F	F	P	F	P	P	F	F	P	F	P	P	F	F	P	F	F
PMU D	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
PMU E	P	F	P	-	-	-	-	-	-	-	-	-	P	F	P	-	-	-	P	F	P	-	-	-	P	F	P	-	-	-	P	F	P	-	-	-
PMU F	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	I
PMU G*	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	-	-	-	-	-	-
PMU H	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
PMU I	F	F	P	-	-	-	F	F	P	-	-	-	F	F	P	-	-	-	F	F	F	-	-	-	P	F	P	-	-	-	P	F	F	-	-	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	

P = Pass, F = Fail, I = Indeterminate

\* PMU G always outputs ROCOF = 0

## 6.1 Dynamic ramp of system frequency voltage TVE, M class

### 6.1.1 C37.118.1 Annex C dynamic ramp of system frequency voltage TVE: $F_0 = 60$ , M class



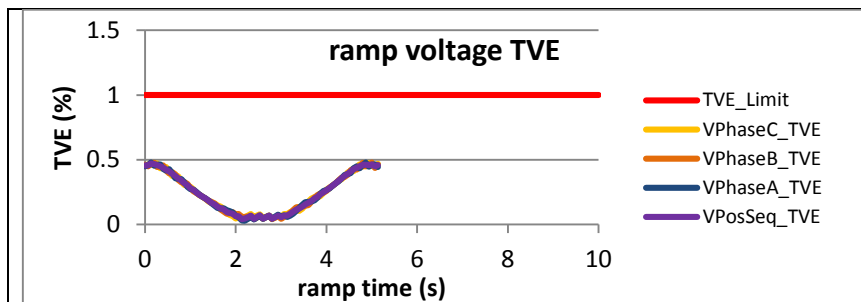


Figure 2148:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

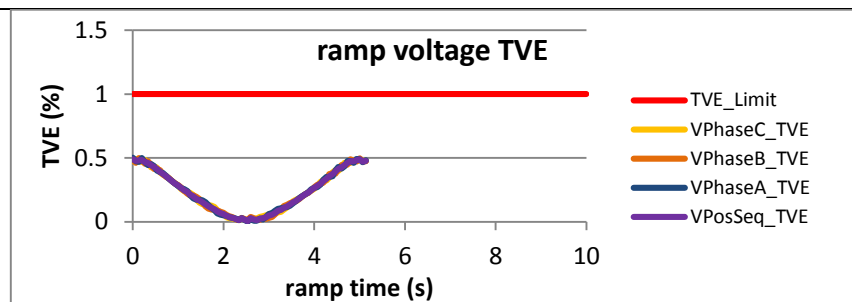


Figure 2149:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

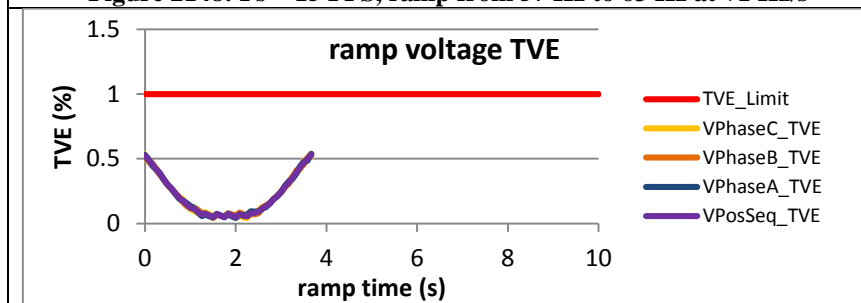


Figure 2150:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

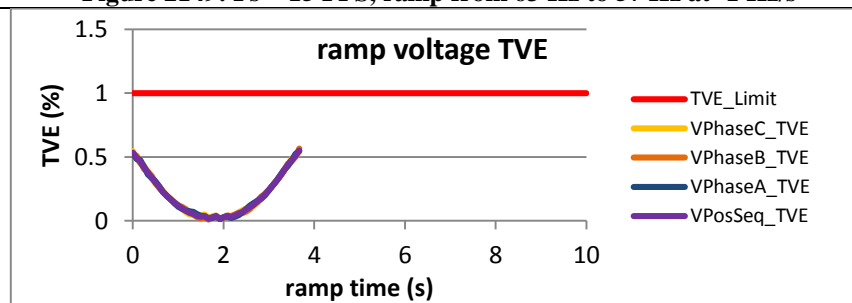


Figure 2151:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

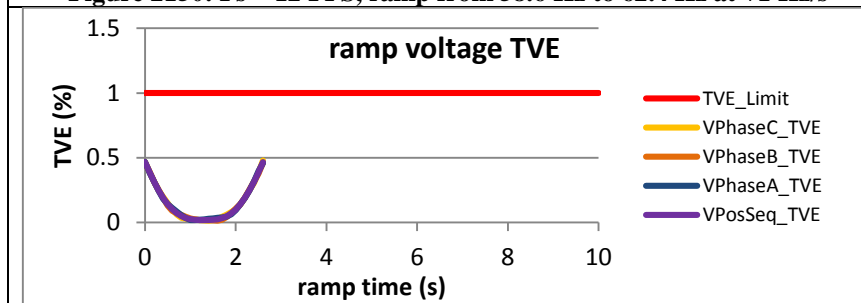


Figure 2152:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

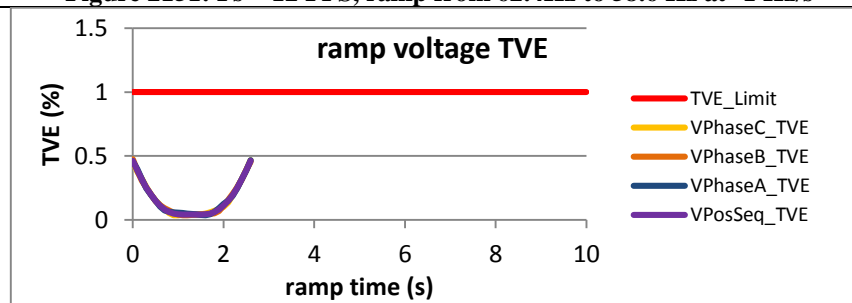
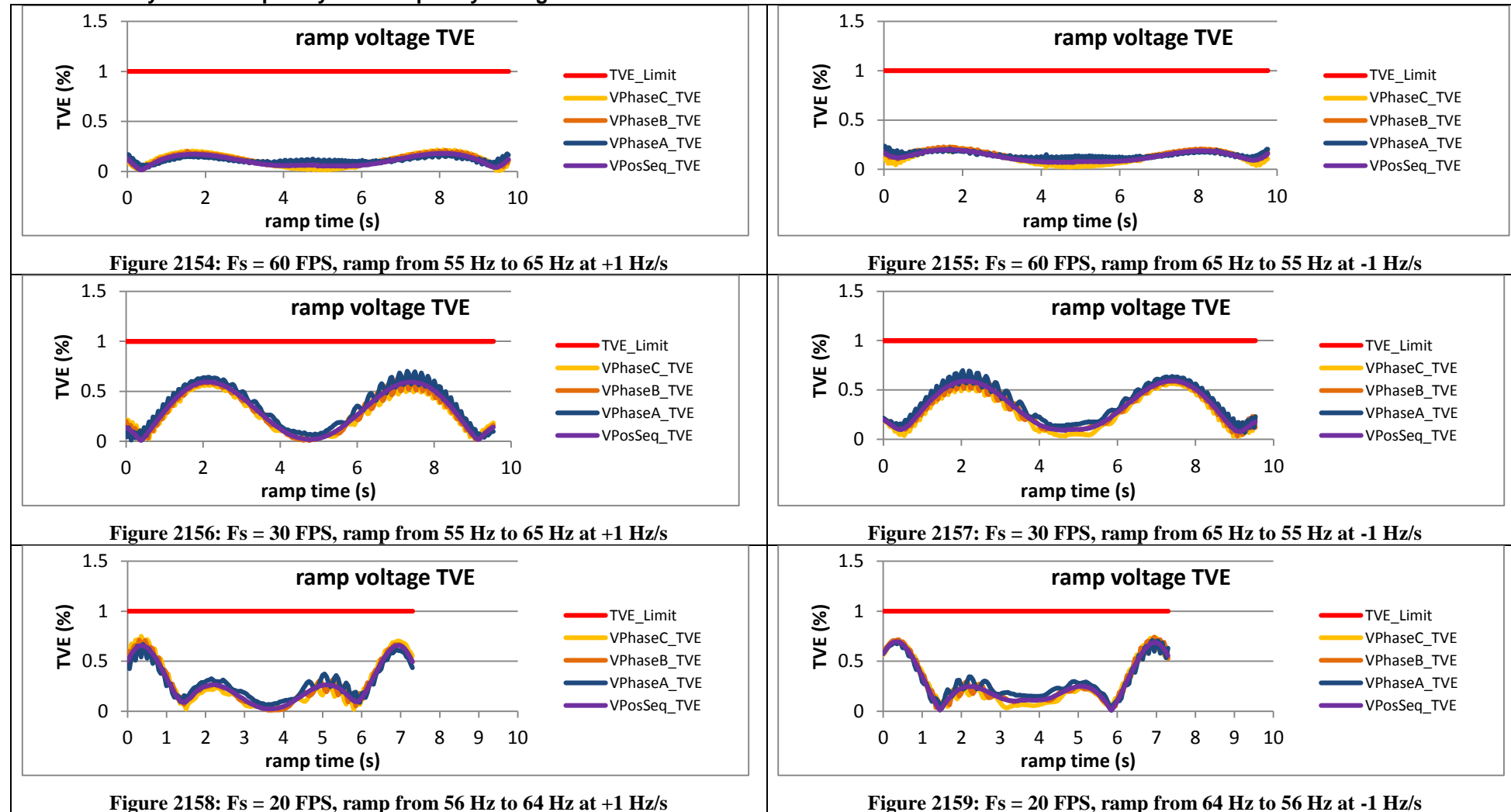


Figure 2153:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.1.2 PMU A dynamic ramp of system frequency voltage TVE: M class





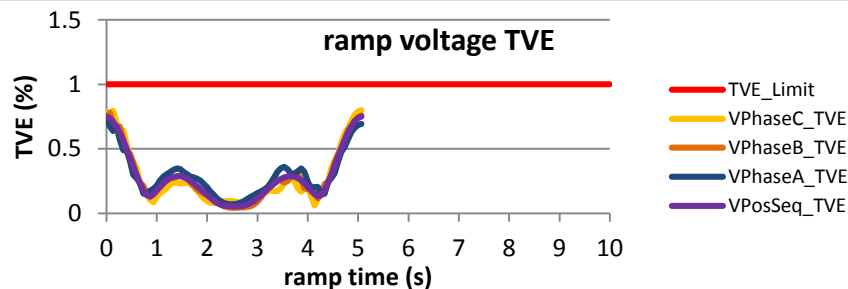


Figure 2160:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

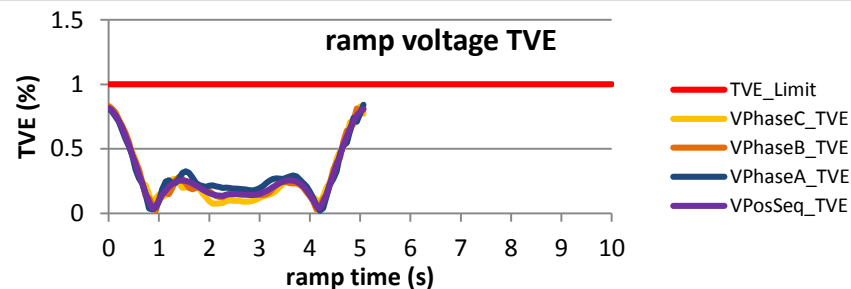


Figure 2161:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

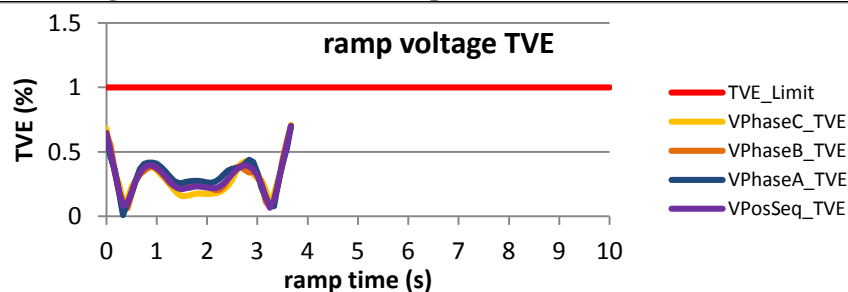


Figure 2162:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

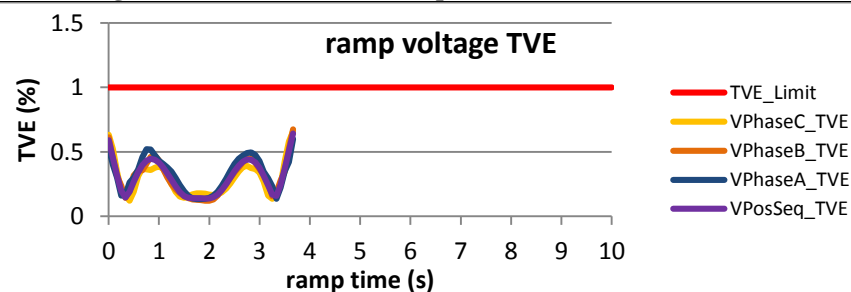


Figure 2163:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

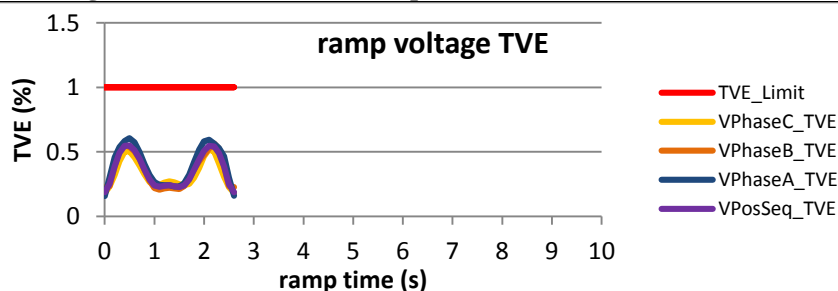


Figure 2164:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

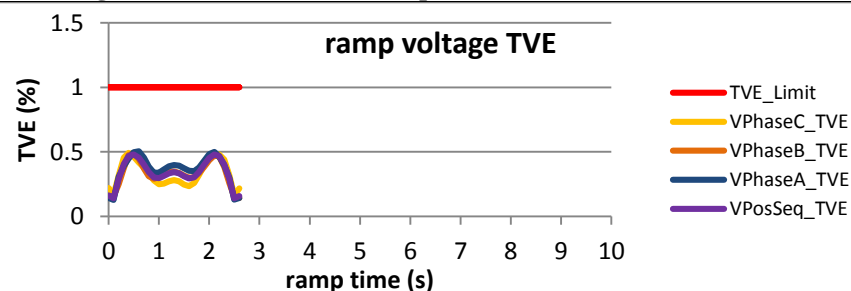


Figure 2165:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.1.3 PMU B dynamic ramp of system frequency voltage TVE: M class

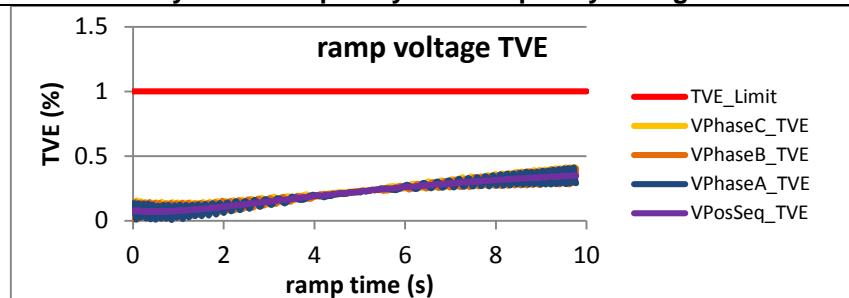


Figure 2166:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

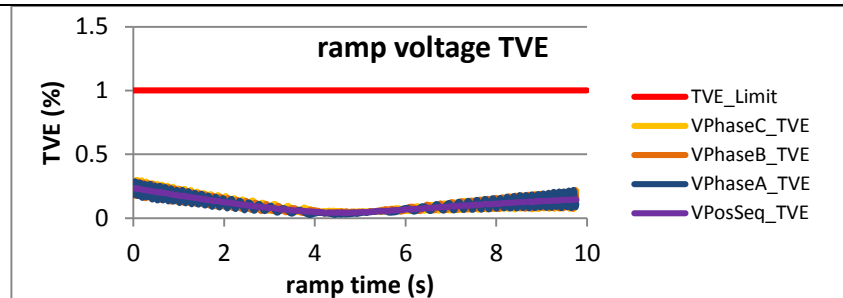


Figure 2167:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

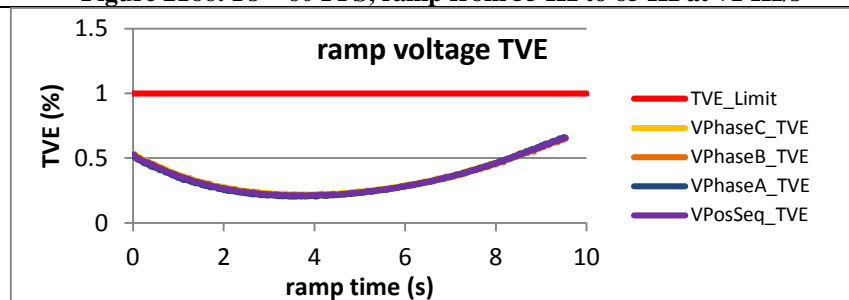


Figure 2168:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

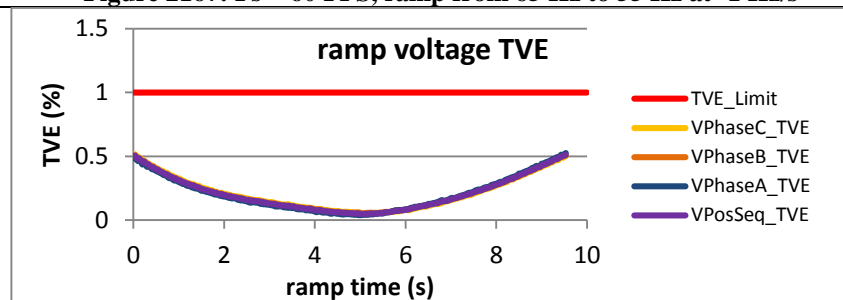


Figure 2169:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

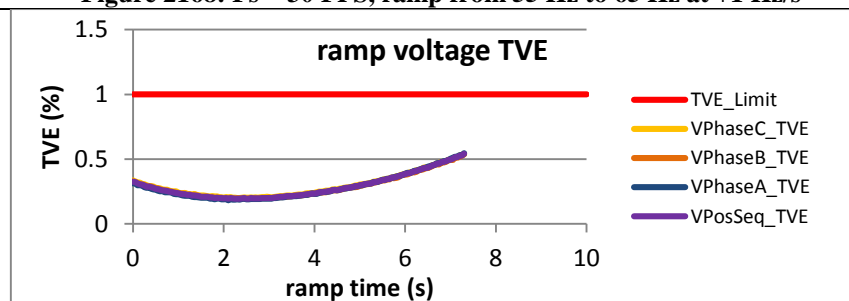


Figure 2170:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

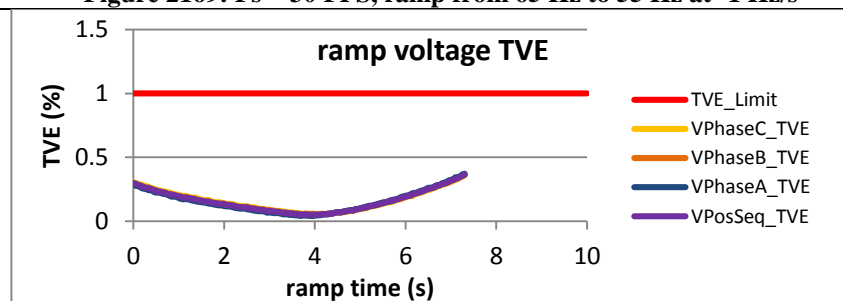
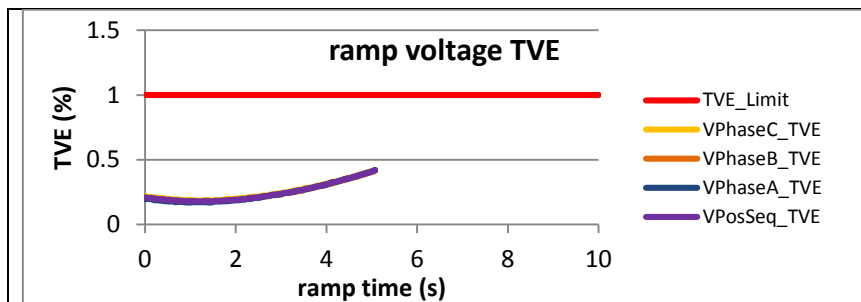
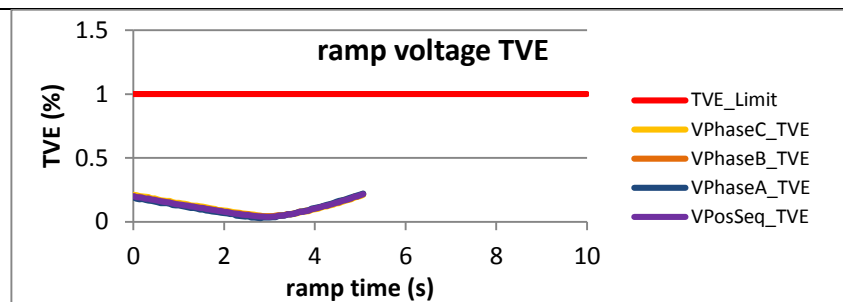


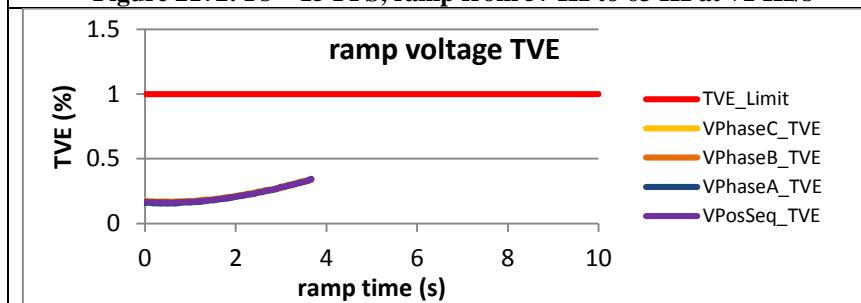
Figure 2171:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s



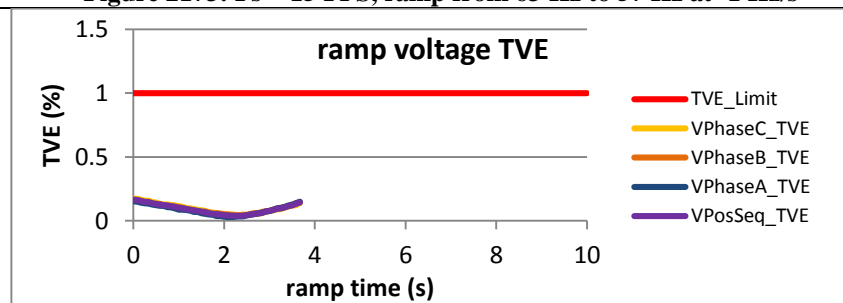
**Figure 2172:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s**



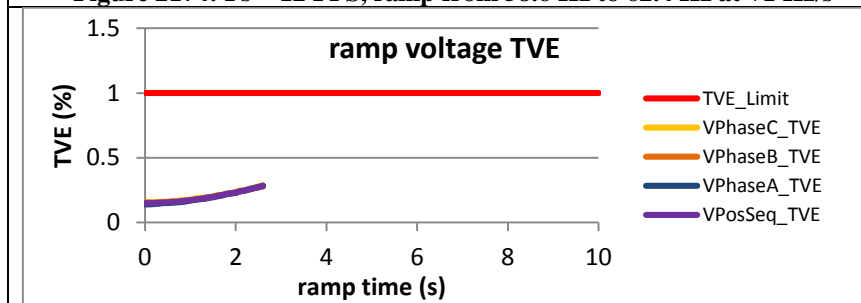
**Figure 2173:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s**



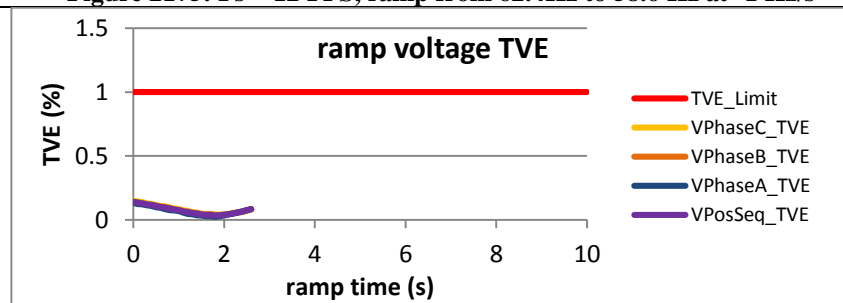
**Figure 2174:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s**



**Figure 2175:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s**



**Figure 2176:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s**



**Figure 2177:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s**

#### 6.1.4 PMU C dynamic ramp of system frequency voltage TVE: M class

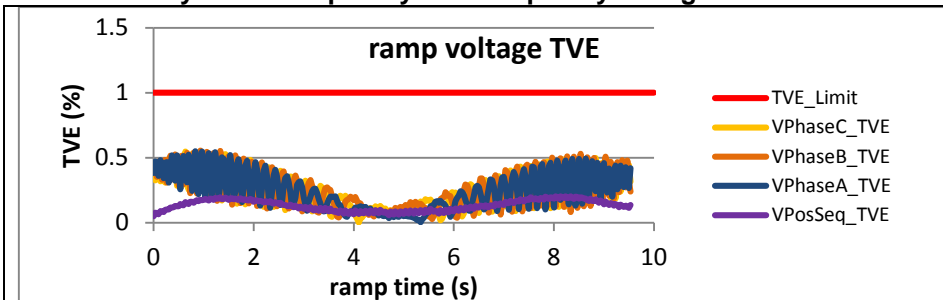


Figure 2178:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

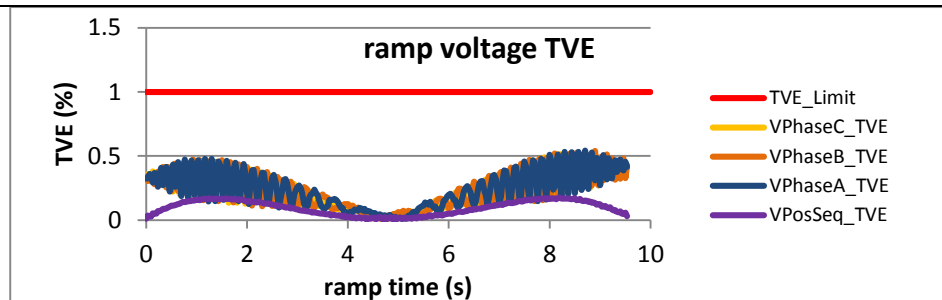


Figure 2179:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

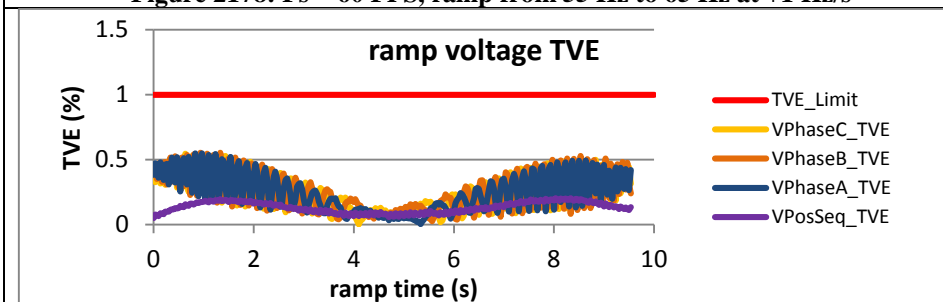


Figure 2180:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

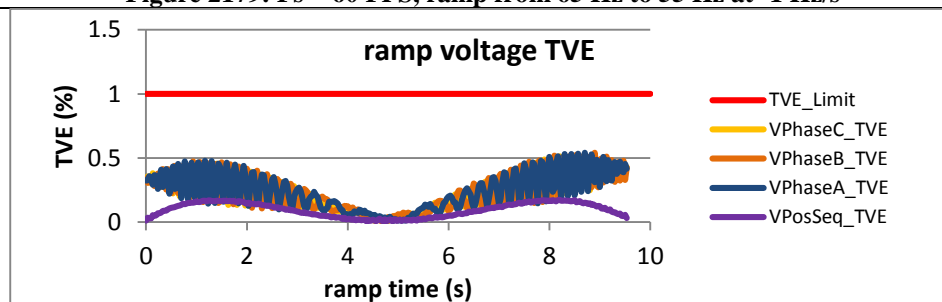


Figure 2181:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

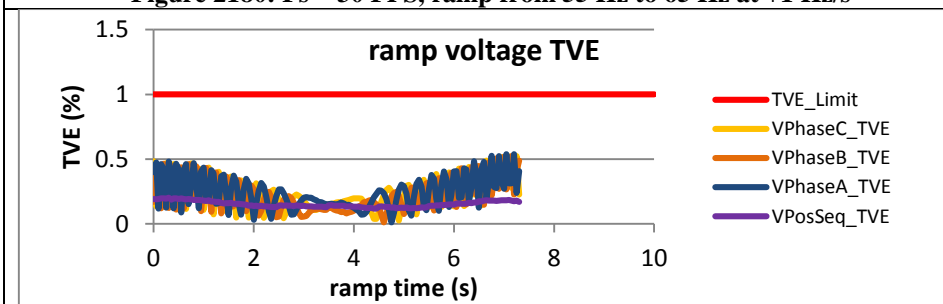


Figure 2182:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

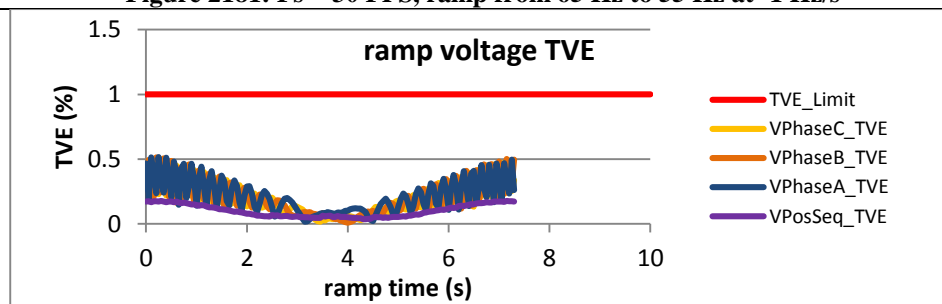


Figure 2183:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

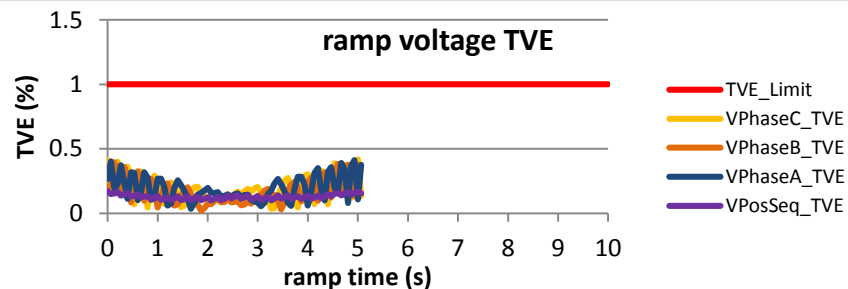


Figure 2184:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

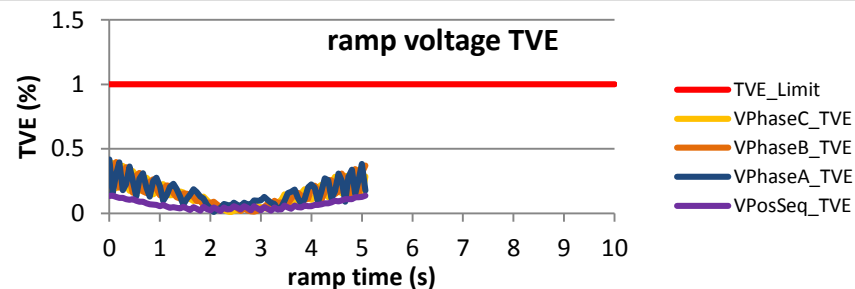


Figure 2185:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

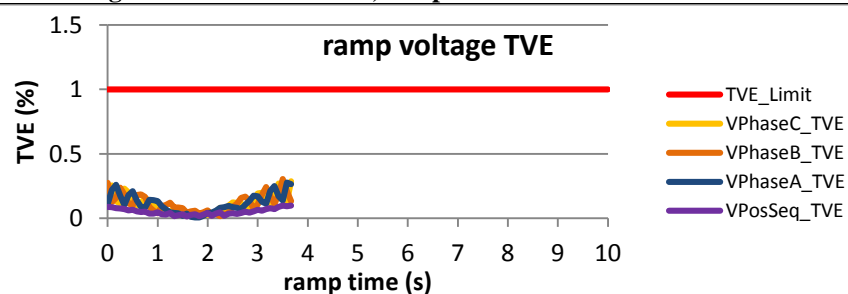


Figure 2186:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

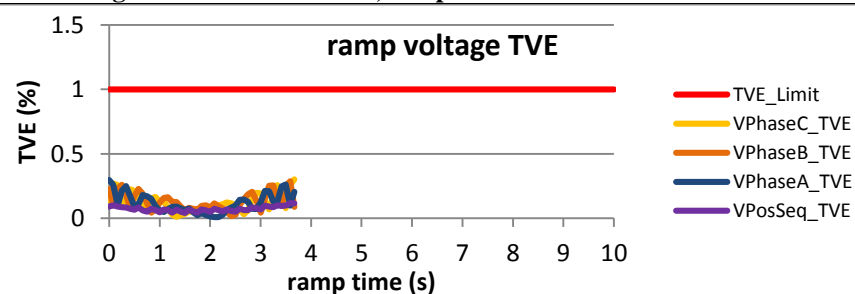


Figure 2187:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

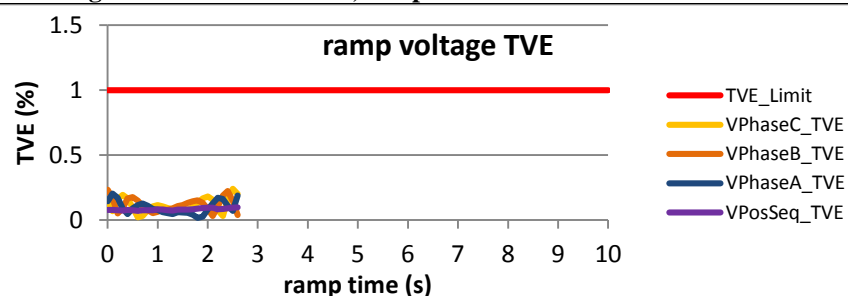


Figure 2188:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

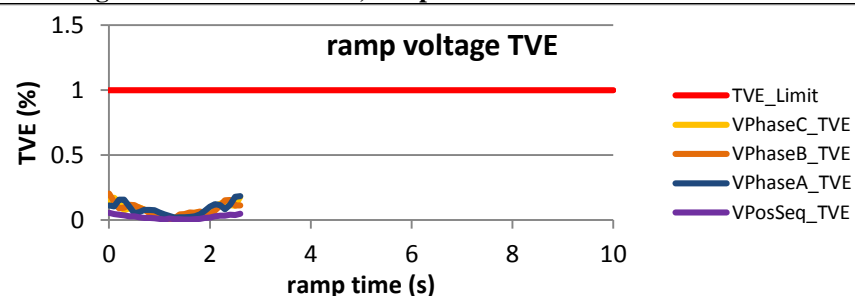


Figure 2189:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.1.5 PMU D dynamic ramp of system frequency voltage TVE: M class

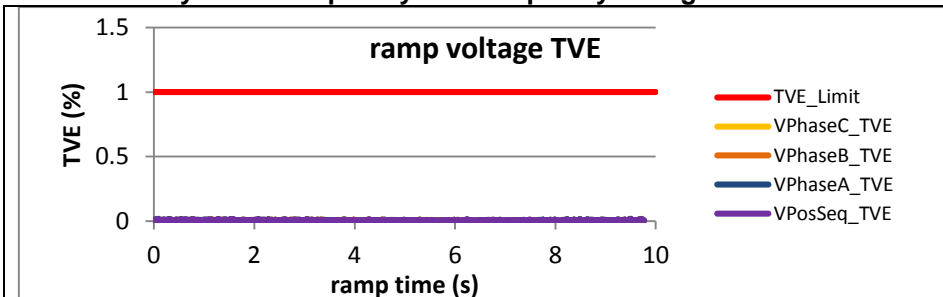


Figure 2190:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

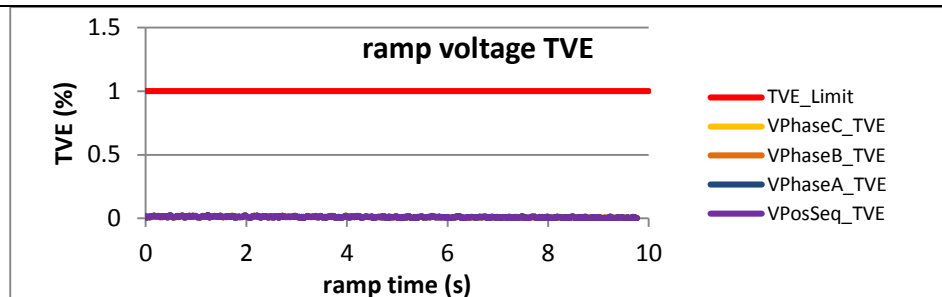


Figure 2191:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

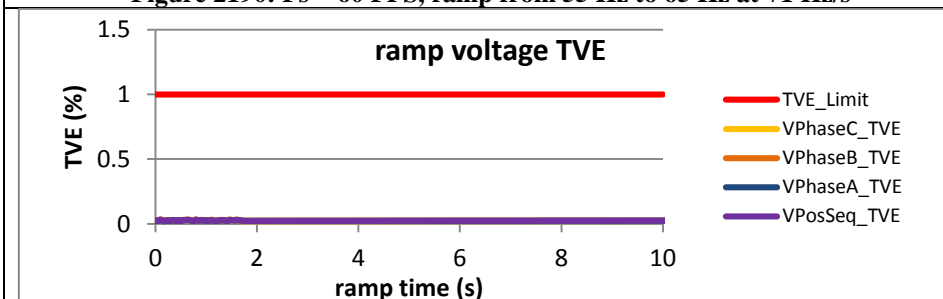


Figure 2192:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

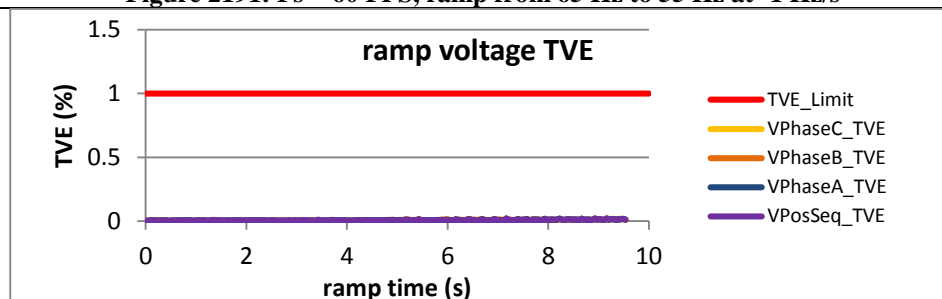


Figure 2193:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

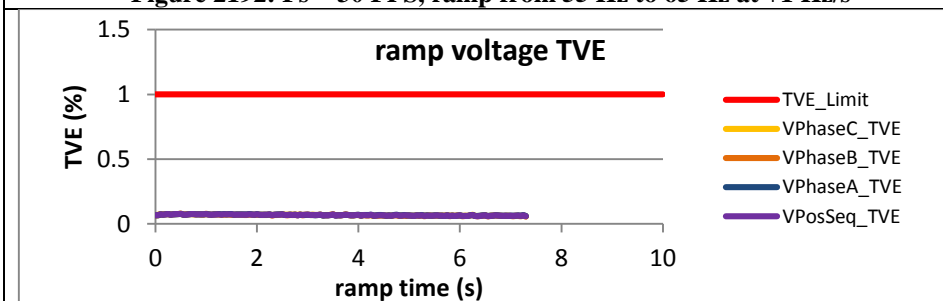


Figure 2194:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

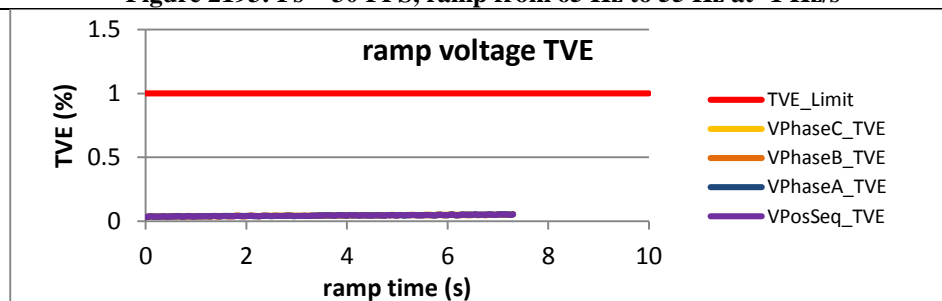


Figure 2195:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

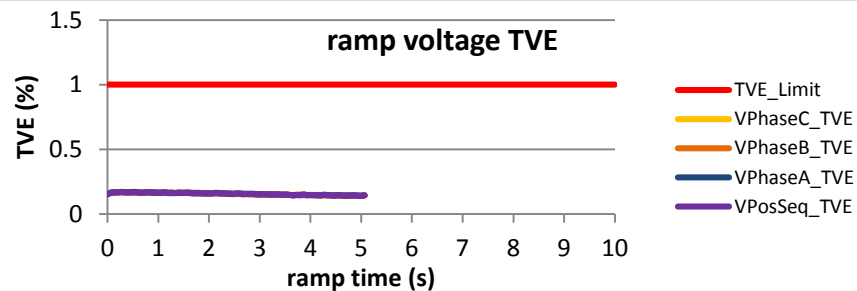


Figure 2196:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

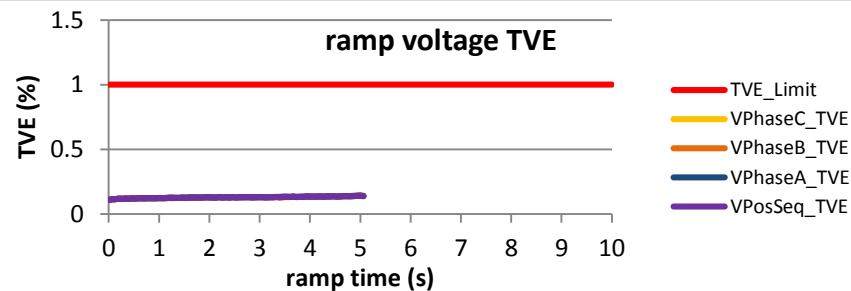


Figure 2197:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

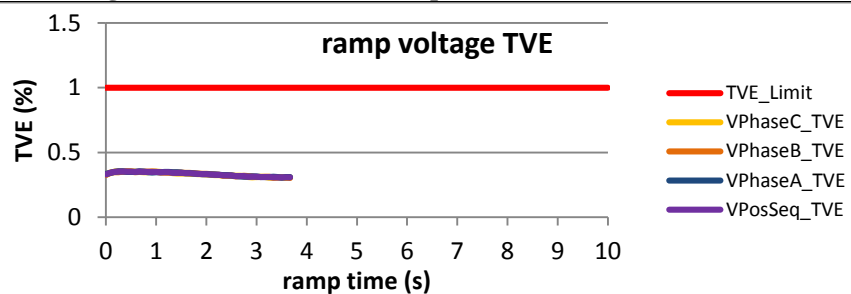


Figure 2198:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

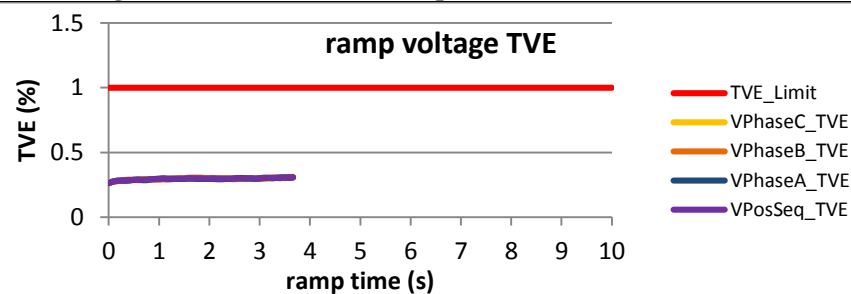


Figure 2199:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

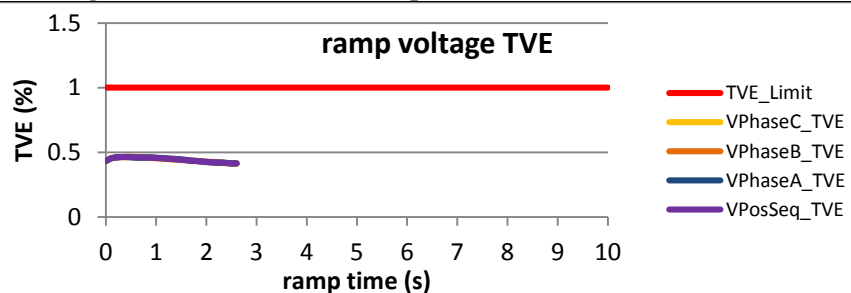


Figure 2200:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

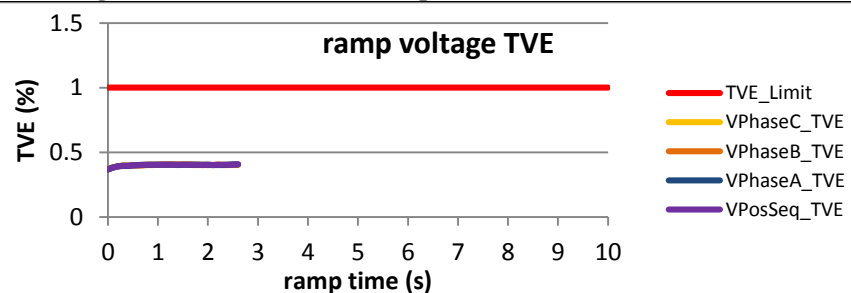
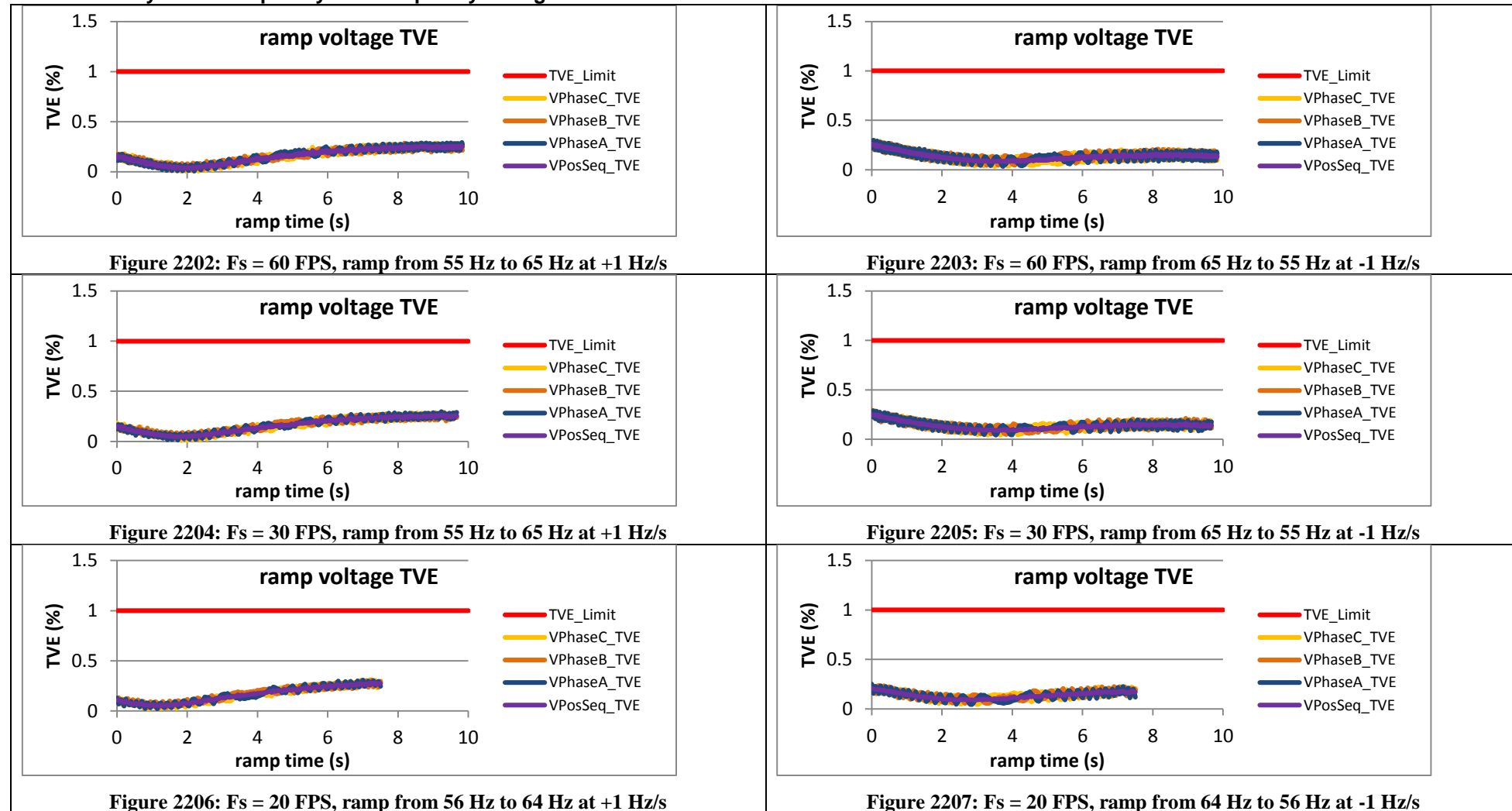


Figure 2201:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.1.6 PMU E dynamic ramp of system frequency voltage TVE: M class





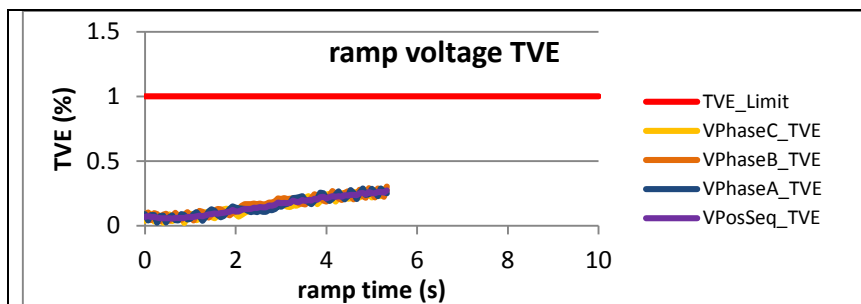


Figure 2208:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

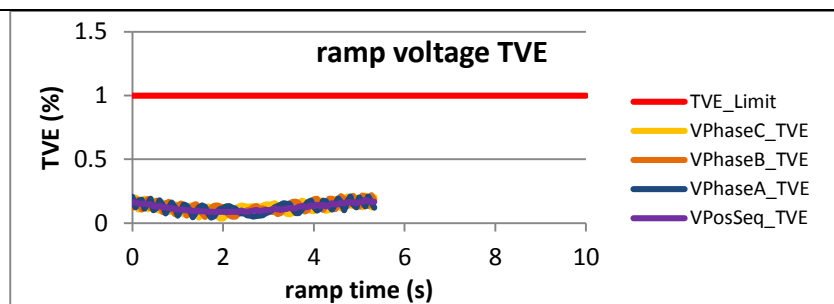


Figure 2209:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

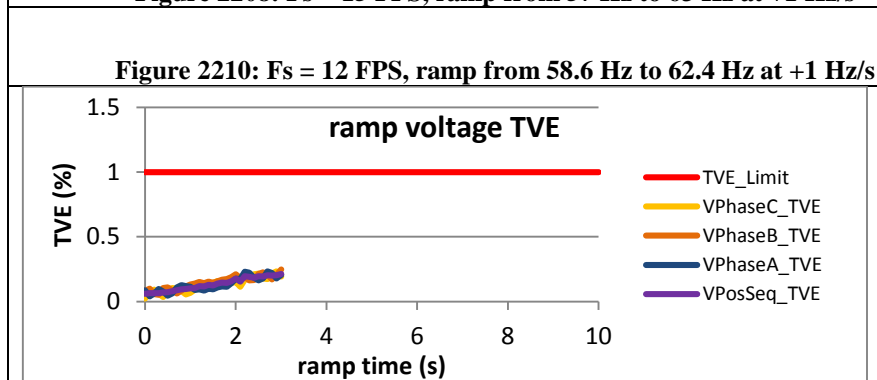


Figure 2210:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

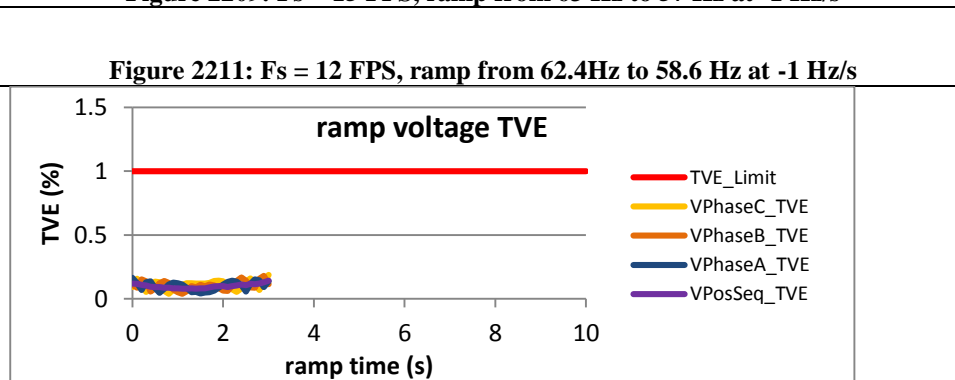


Figure 2211:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

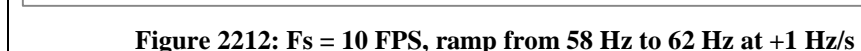


Figure 2212:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s



Figure 2213:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.1.7 PMU F dynamic ramp of system frequency voltage TVE: M class

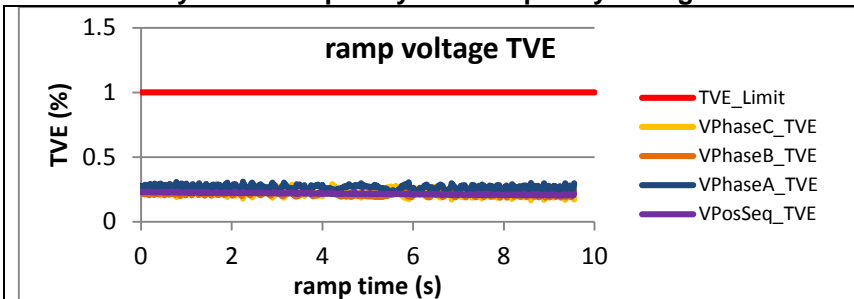


Figure 2214:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

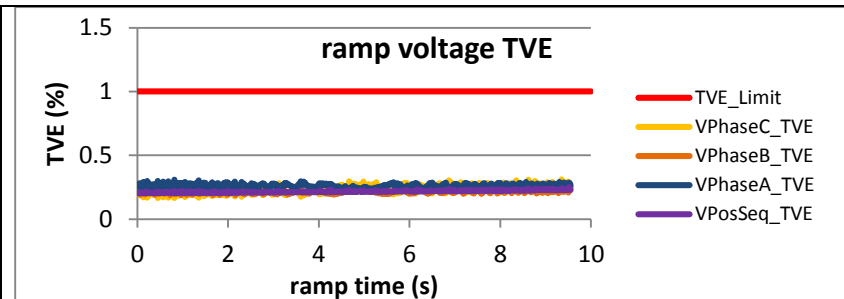


Figure 2215:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

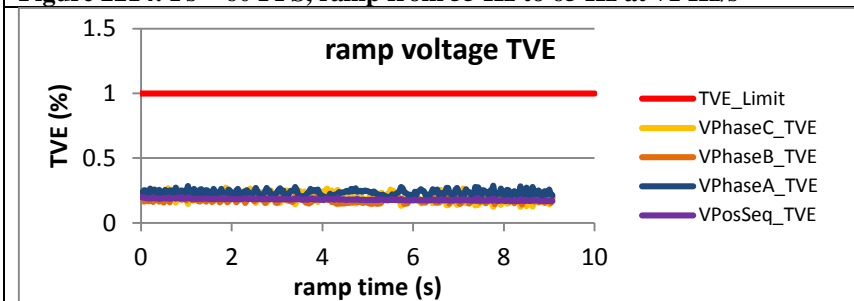


Figure 2216:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

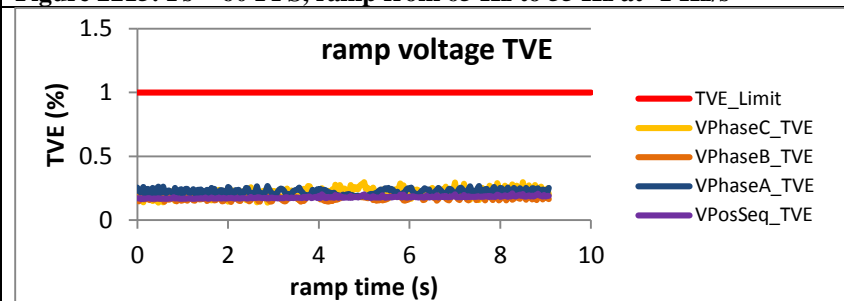


Figure 2217:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

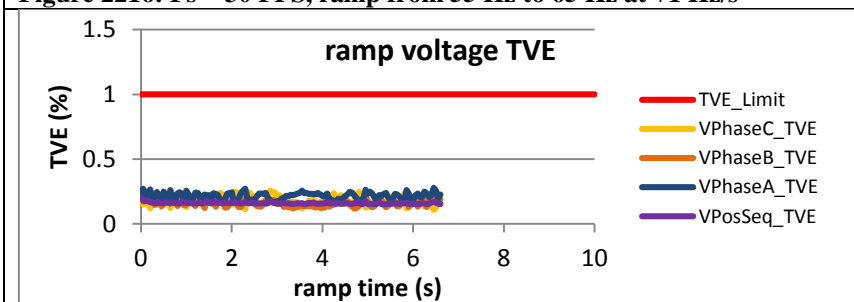


Figure 2218:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

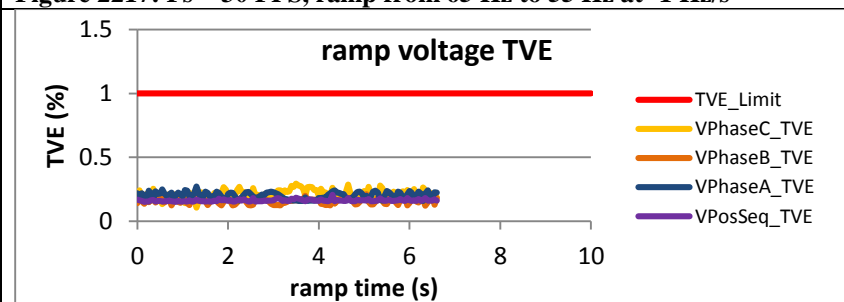


Figure 2219:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

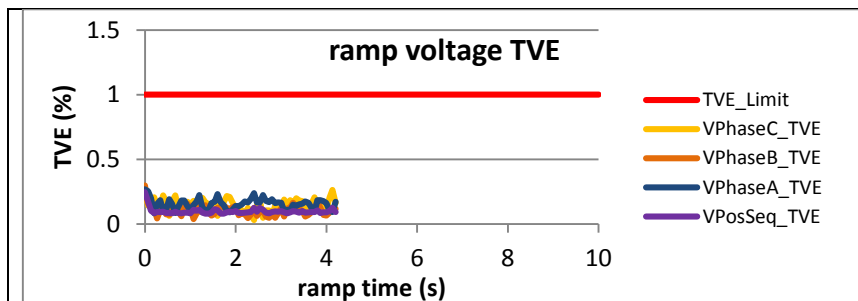


Figure 2220:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

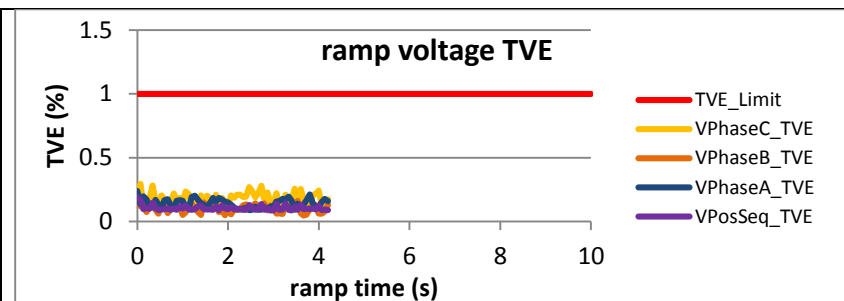


Figure 2221:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

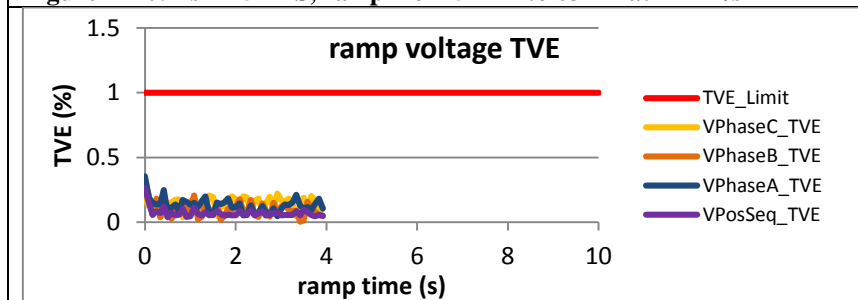


Figure 2222:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

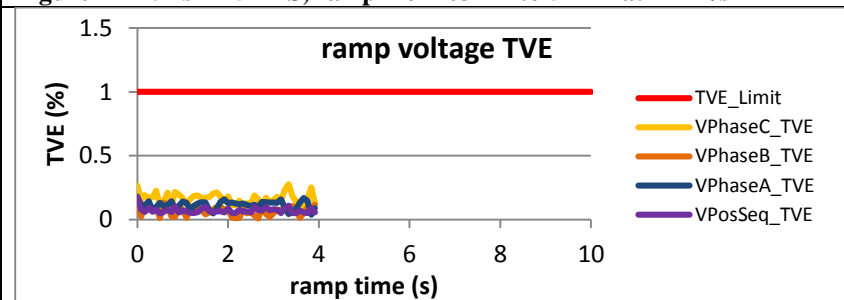


Figure 2223:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

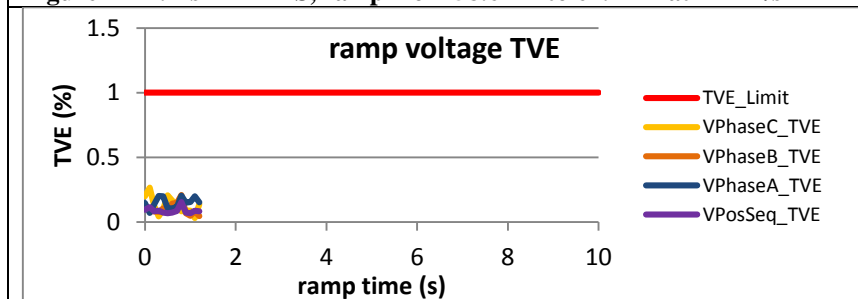


Figure 2224:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

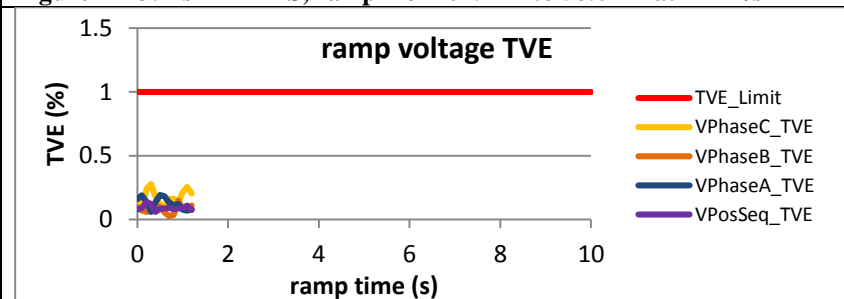


Figure 2225:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

# 6.1.8 PMU G dynamic ramp of system frequency voltage TVE: M class

Figure 2226:  $F_s = 60$  FPS is not supported by this PMU

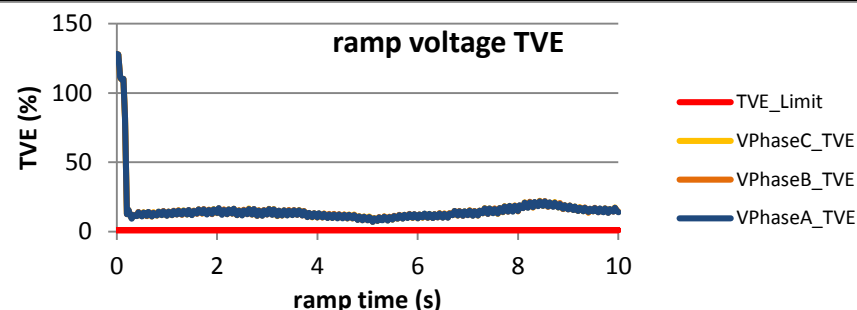
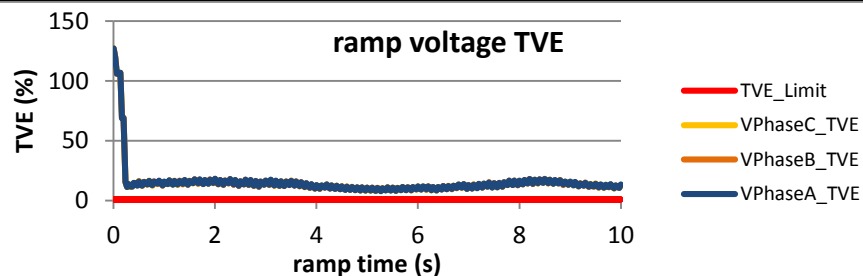


Figure 2227:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

Figure 2228:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

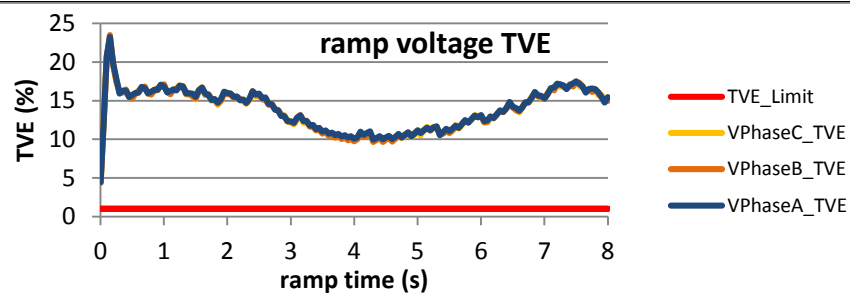


Figure 2229:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

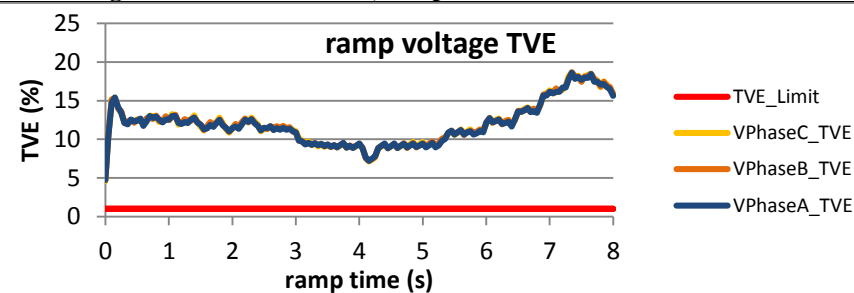


Figure 2230:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

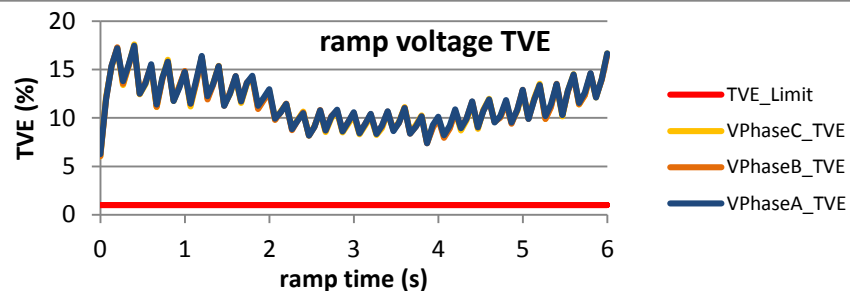


Figure 2231:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

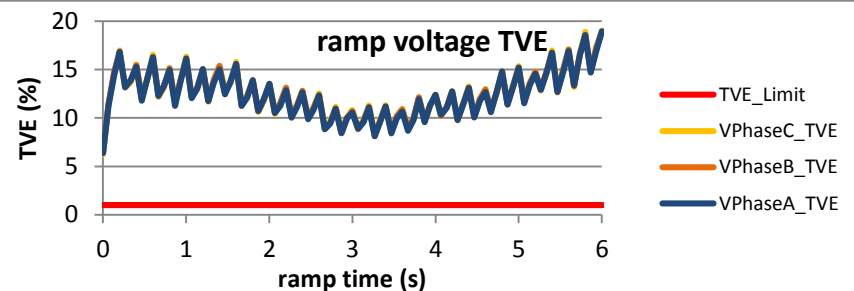


Figure 2232:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

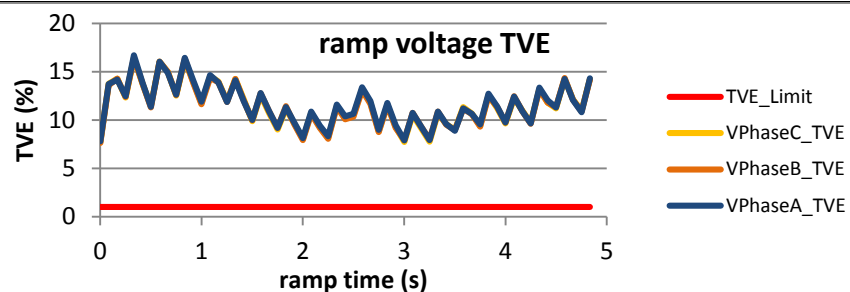


Figure 2233:  $F_s = 12$  FPS, ramp from 57.6 Hz to 62.4 Hz at +1 Hz/s

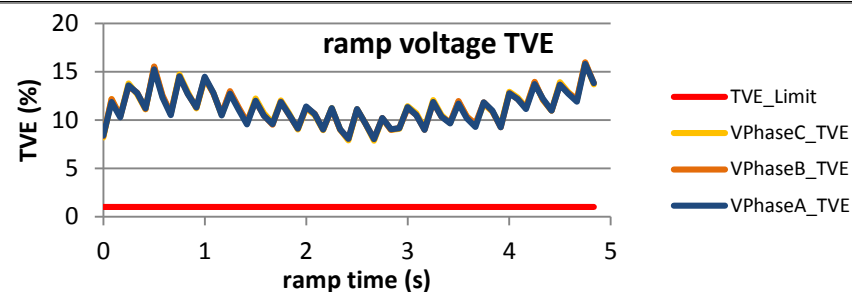


Figure 2234:  $F_s = 12$  FPS, ramp from 62.4 Hz to 57.6 Hz at -1 Hz/s

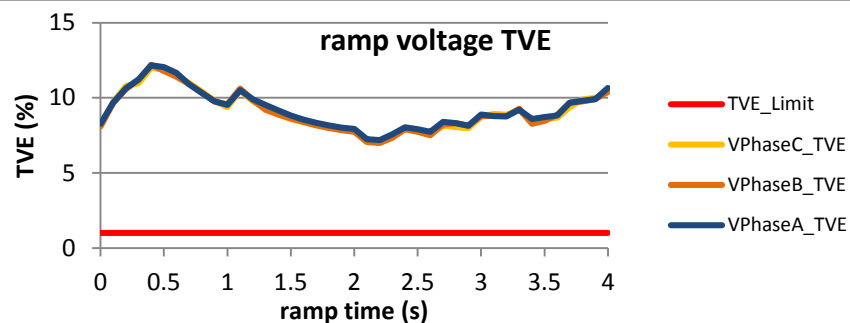


Figure 2235:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

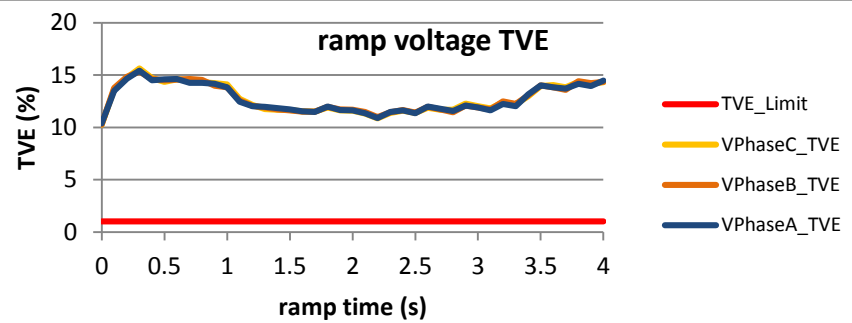
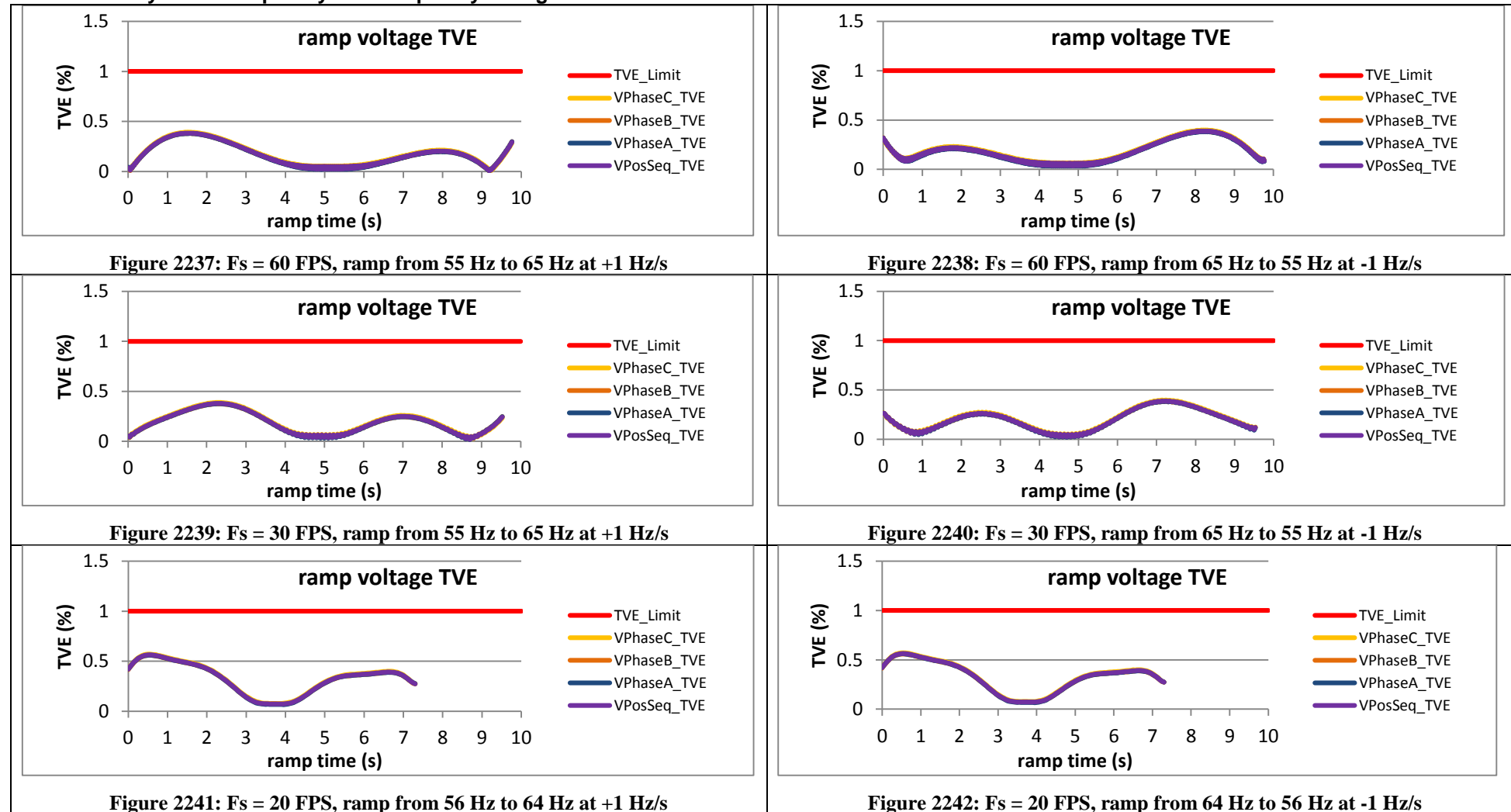


Figure 2236:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.1.9 PMU H dynamic ramp of system frequency voltage TVE: M class



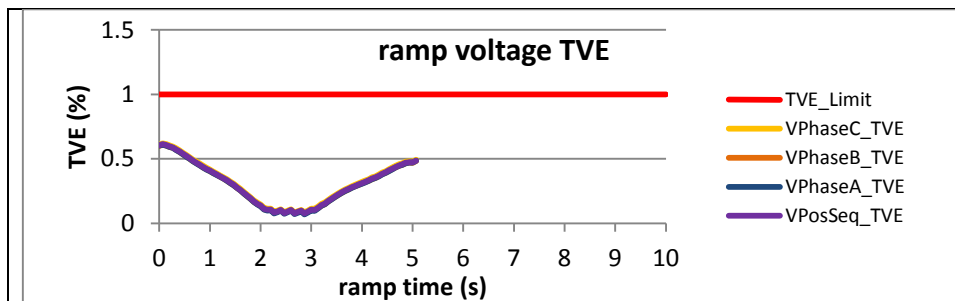


Figure 2243:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

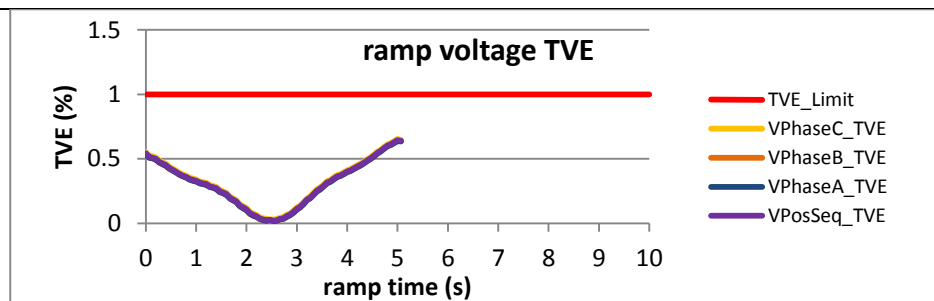


Figure 2244:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

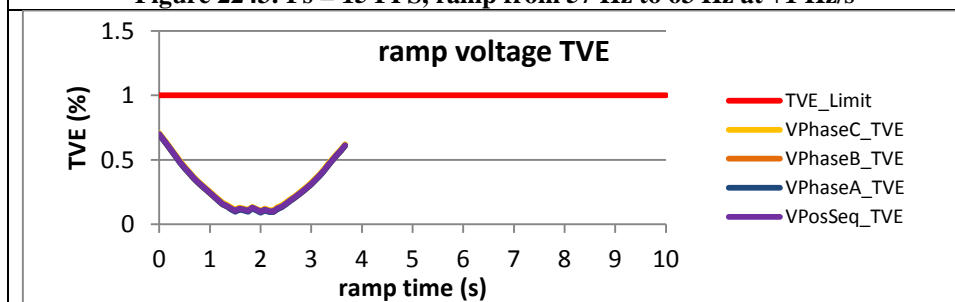


Figure 2245:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

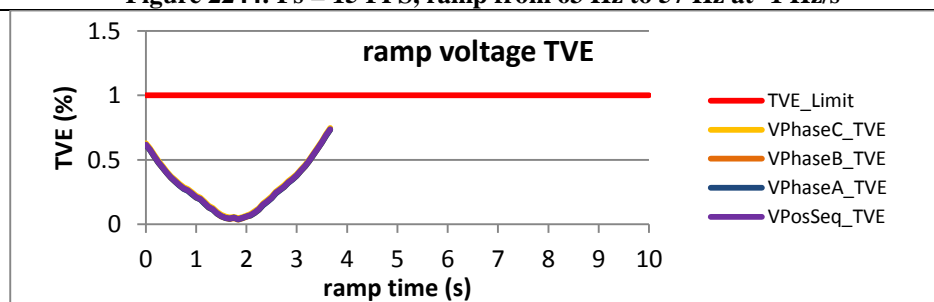


Figure 2246:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

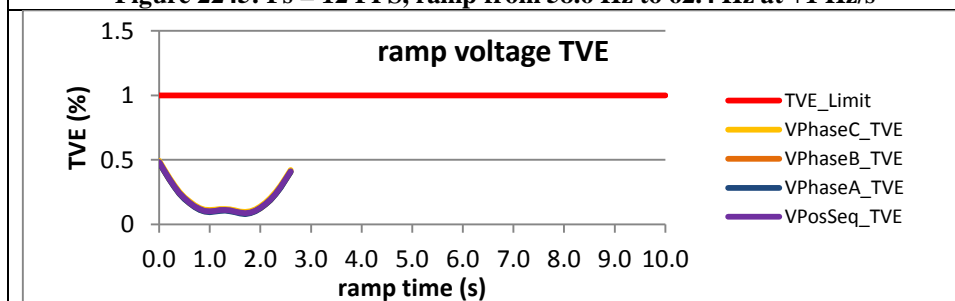


Figure 2247:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

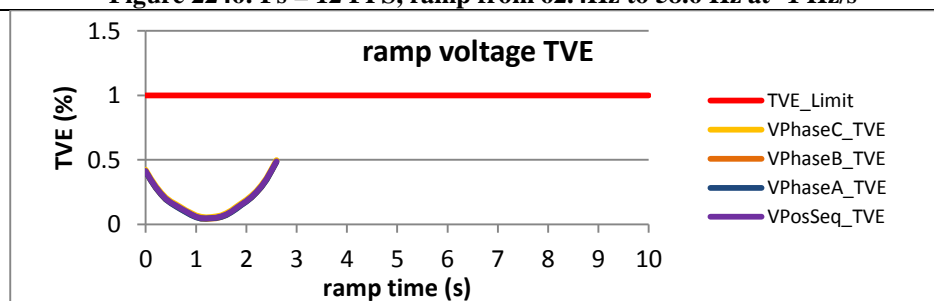
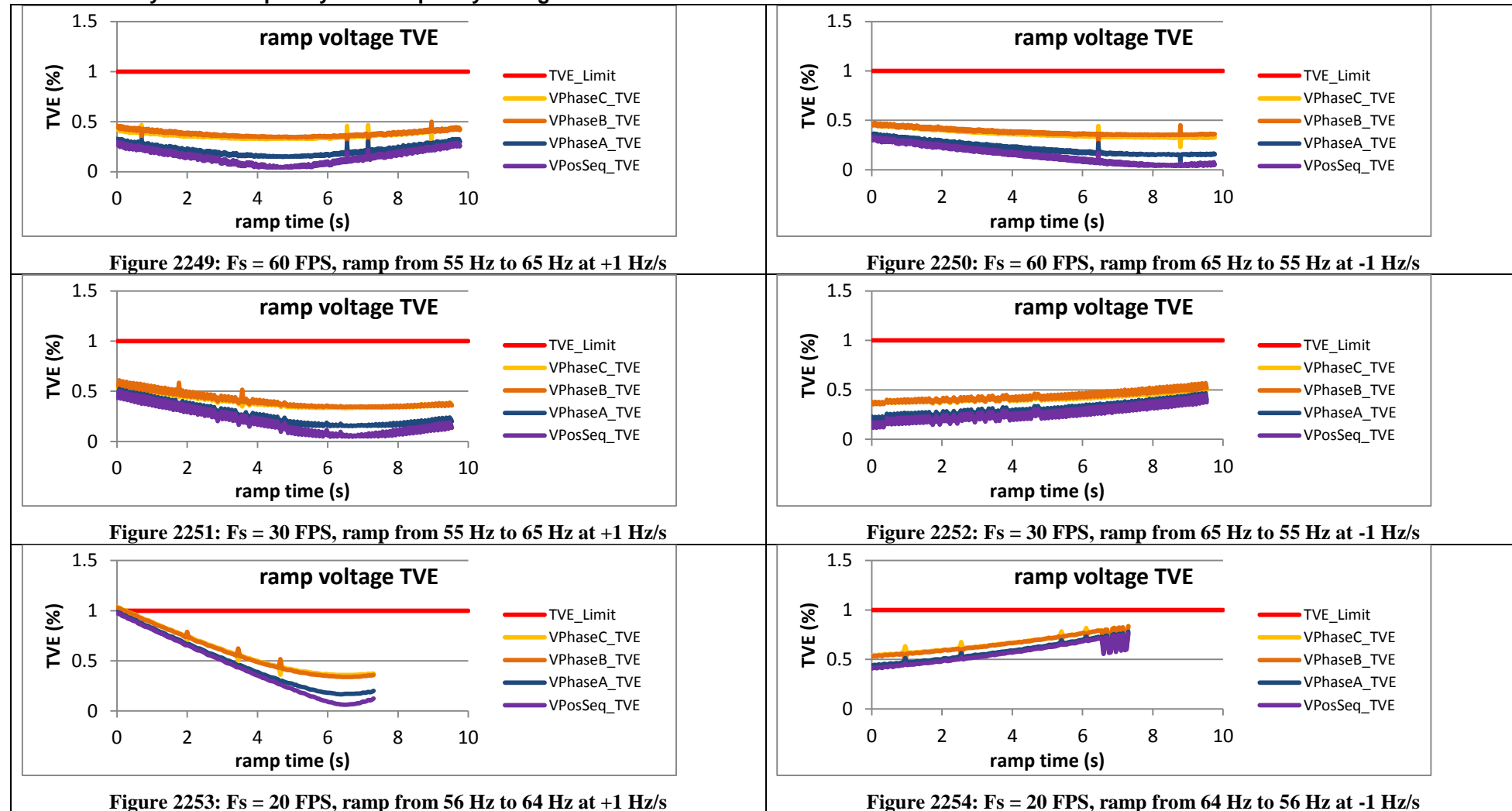


Figure 2248:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

# 6.1.10 PMU I dynamic ramp of system frequency voltage TVE: M class





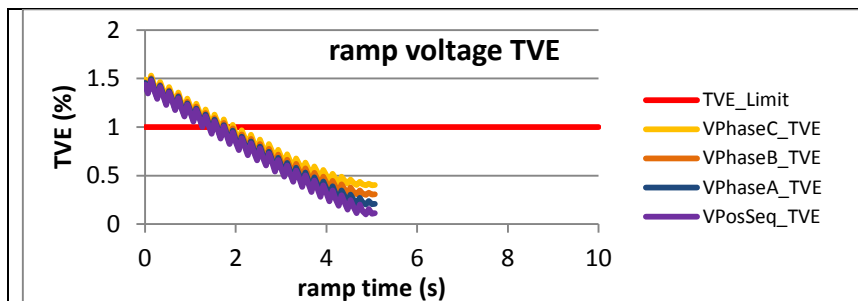


Figure 2255:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

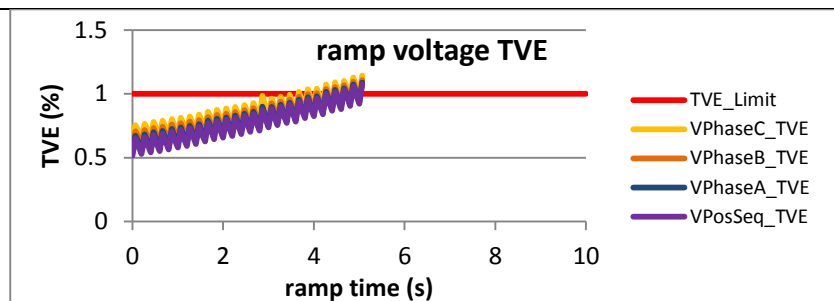


Figure 2256:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

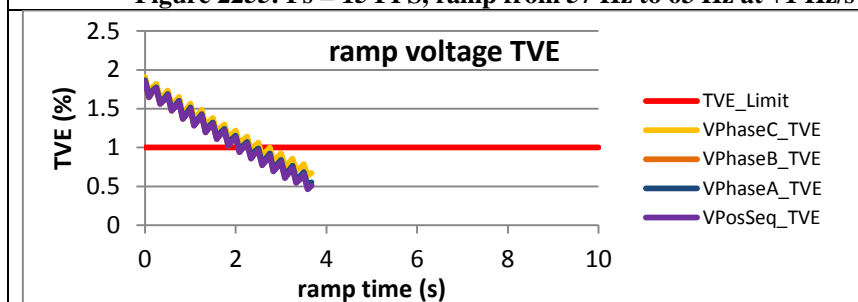


Figure 2257:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

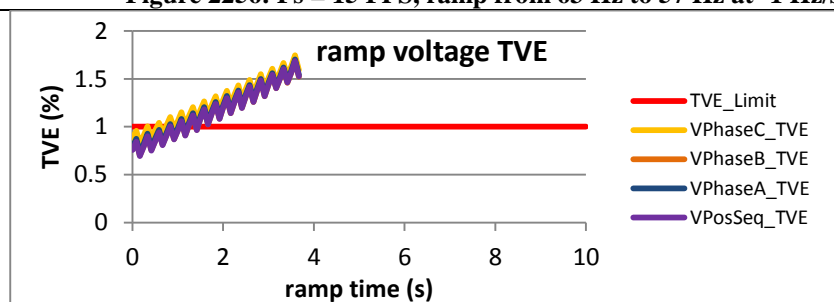


Figure 2258:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

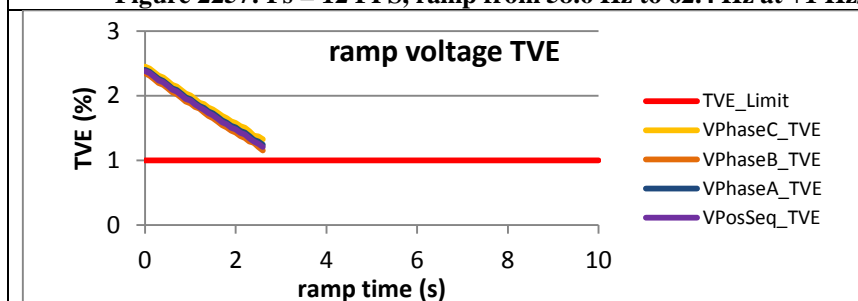


Figure 2259:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

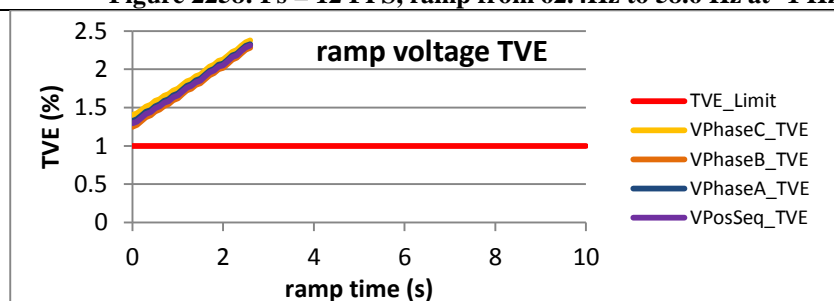


Figure 2260:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.1.11 PMU J dynamic ramp of system frequency voltage TVE: M class

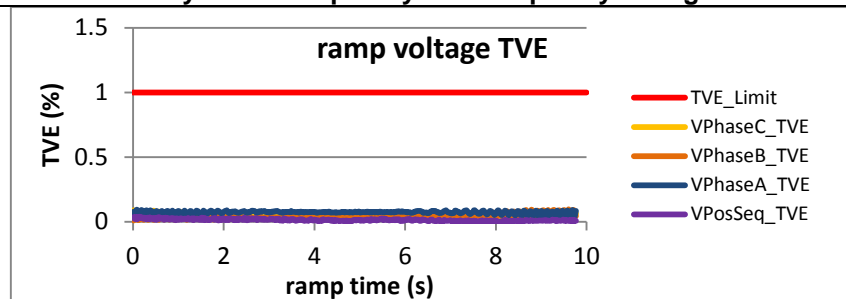


Figure 2261: Fs = 60 FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

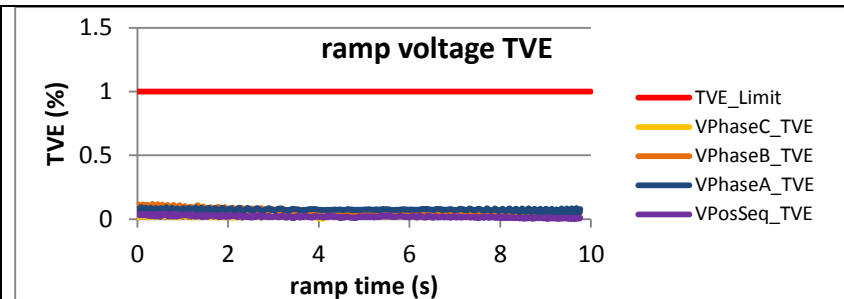


Figure 2262: Fs = 60 FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

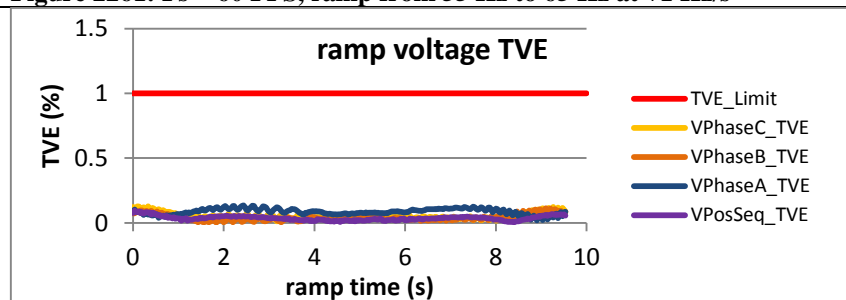


Figure 2263: Fs = 30 FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

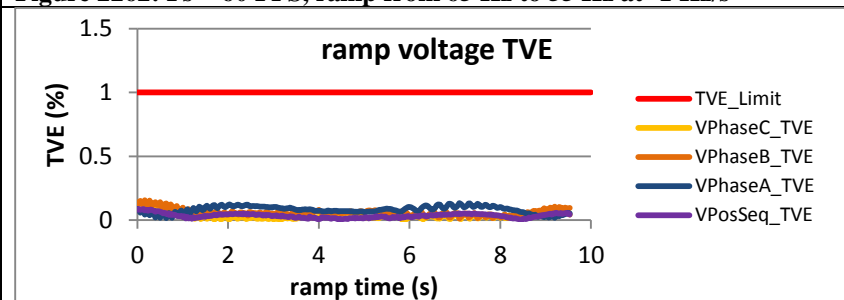


Figure 2264: Fs = 30 FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

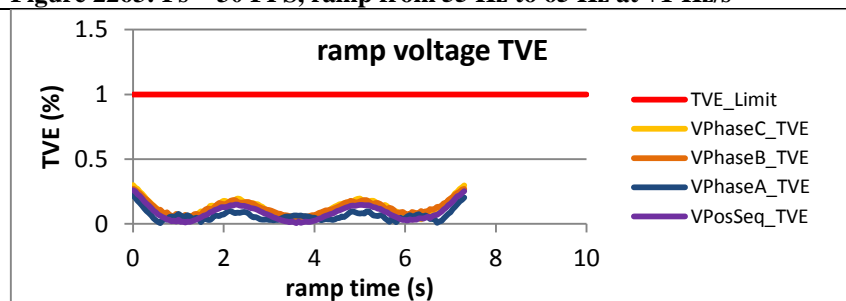


Figure 2265: Fs = 20 FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

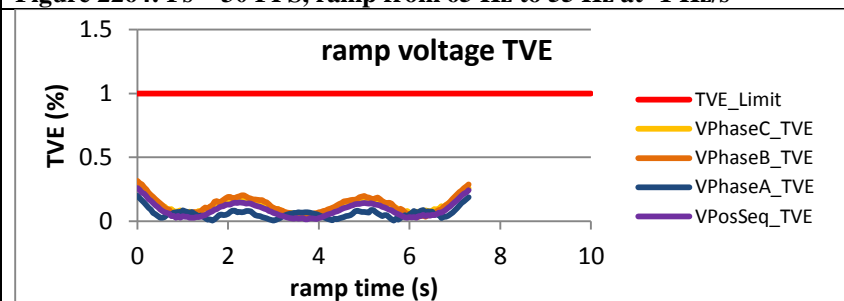


Figure 2266: Fs = 20 FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

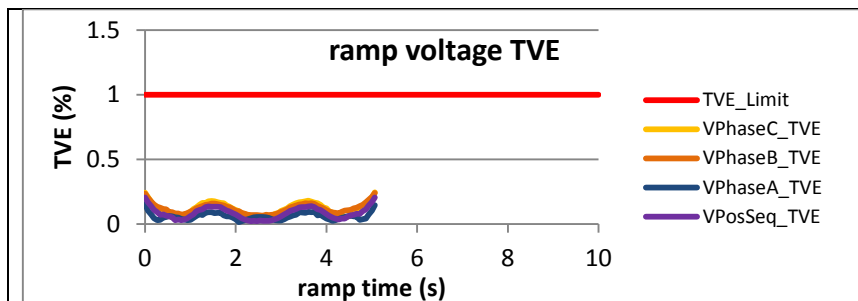


Figure 2267:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

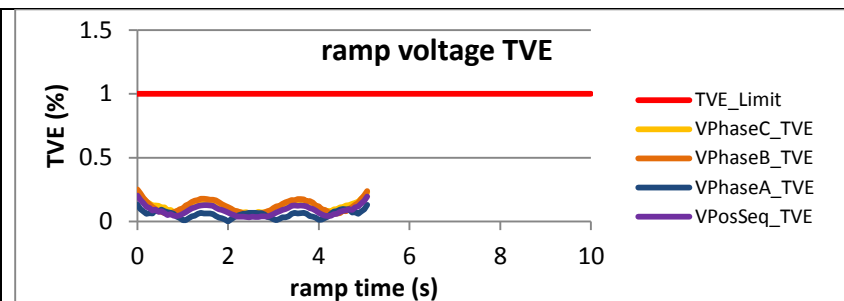


Figure 2268:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

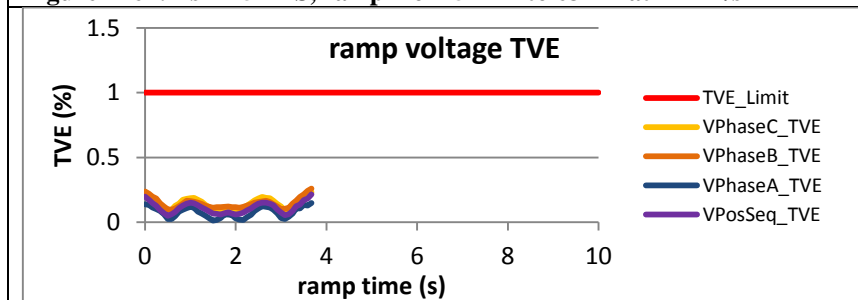


Figure 2269:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

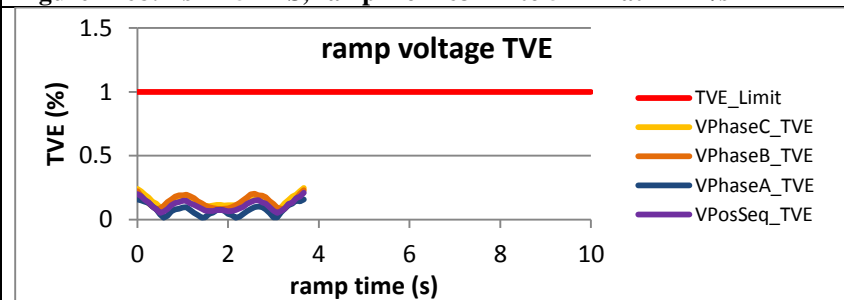


Figure 2270:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

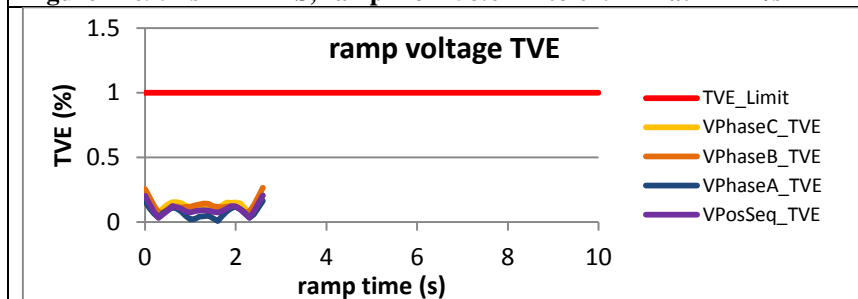


Figure 2271:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

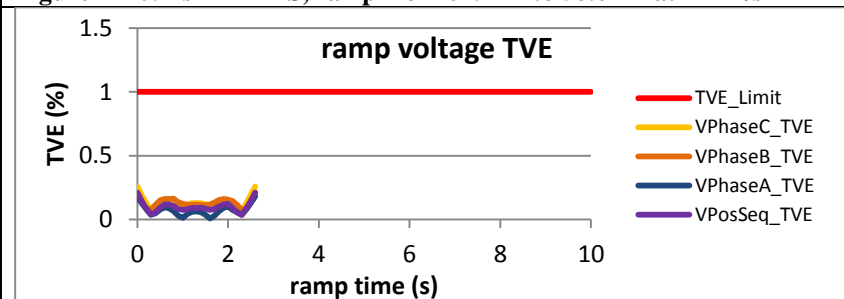


Figure 2272:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.2 Dynamic ramp of system frequency current TVE, M class

### 6.2.1 C37.118.1 Annex C dynamic ramp of system frequency current TVE, M class

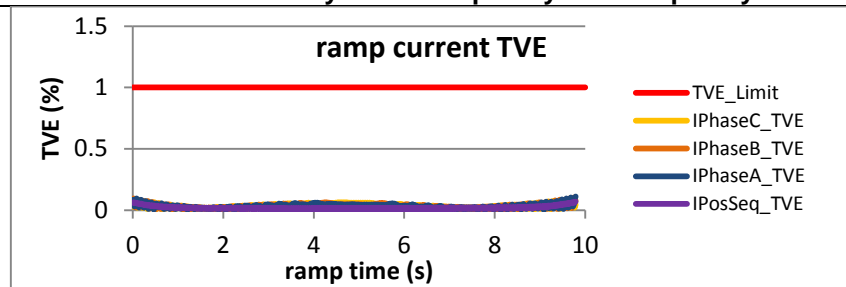


Figure 2273:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

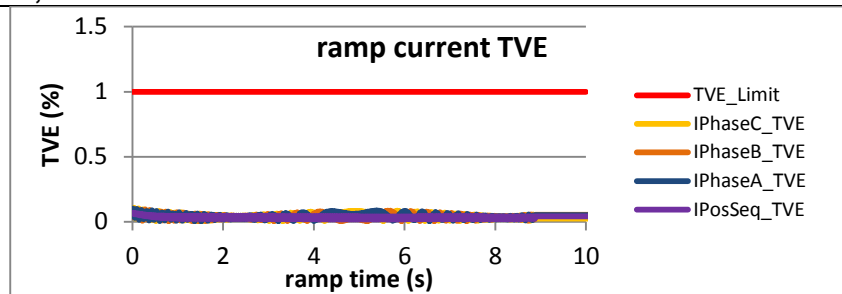


Figure 2274:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

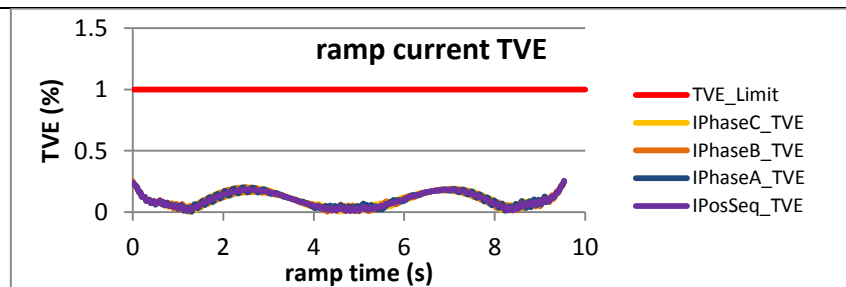


Figure 2275:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

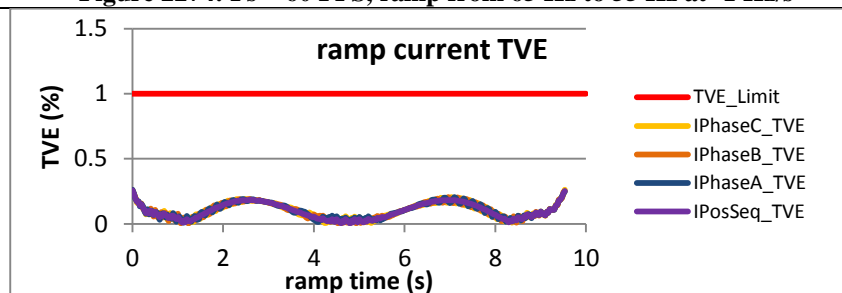


Figure 2276:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

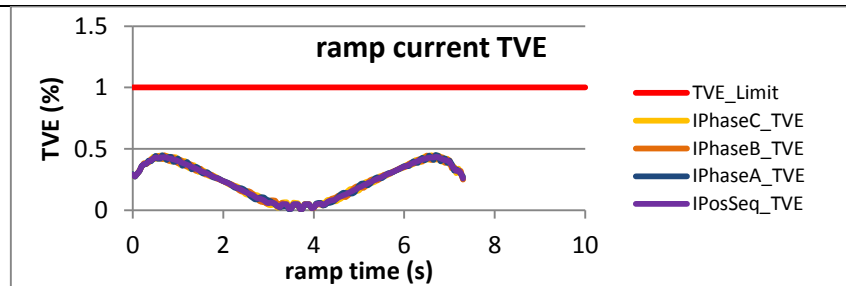


Figure 2277:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

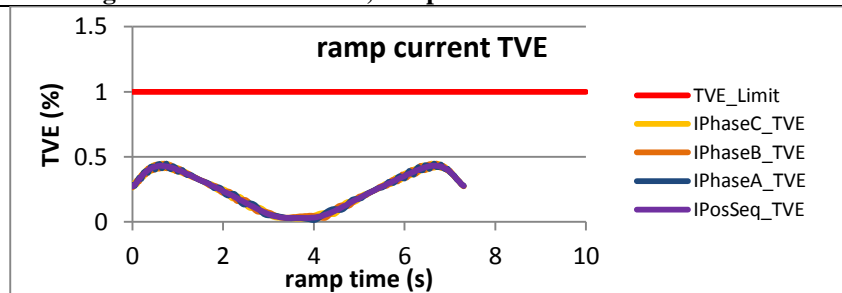


Figure 2278:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

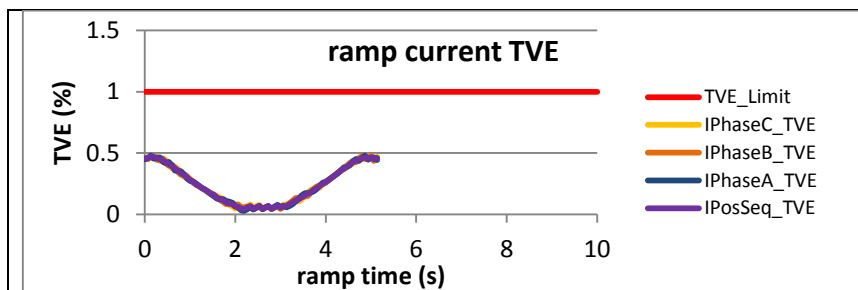


Figure 2279:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

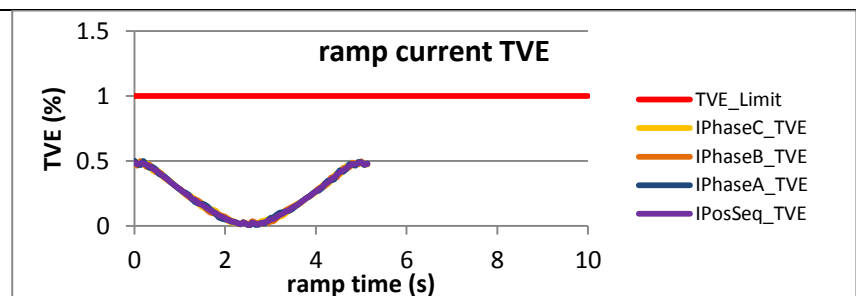


Figure 2280:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

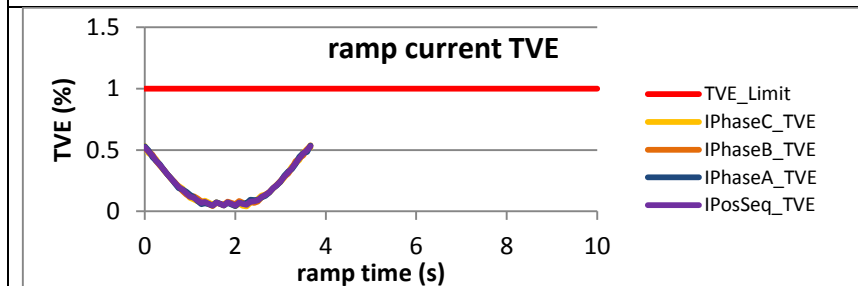


Figure 2281:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

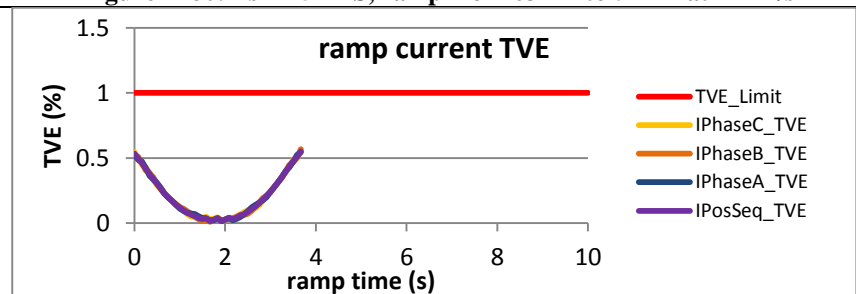


Figure 2282:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

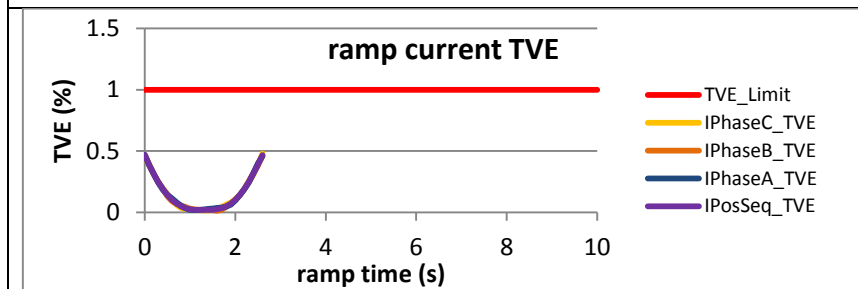


Figure 2283:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

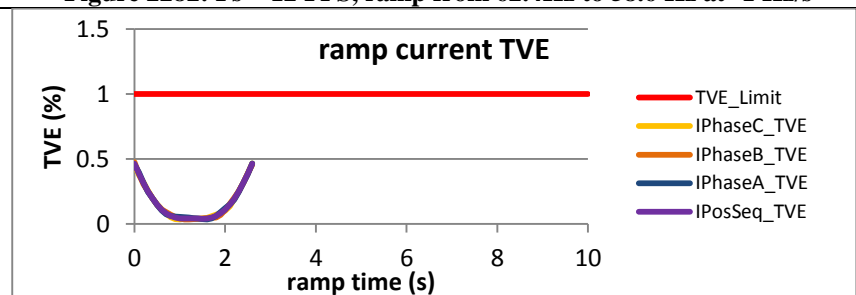
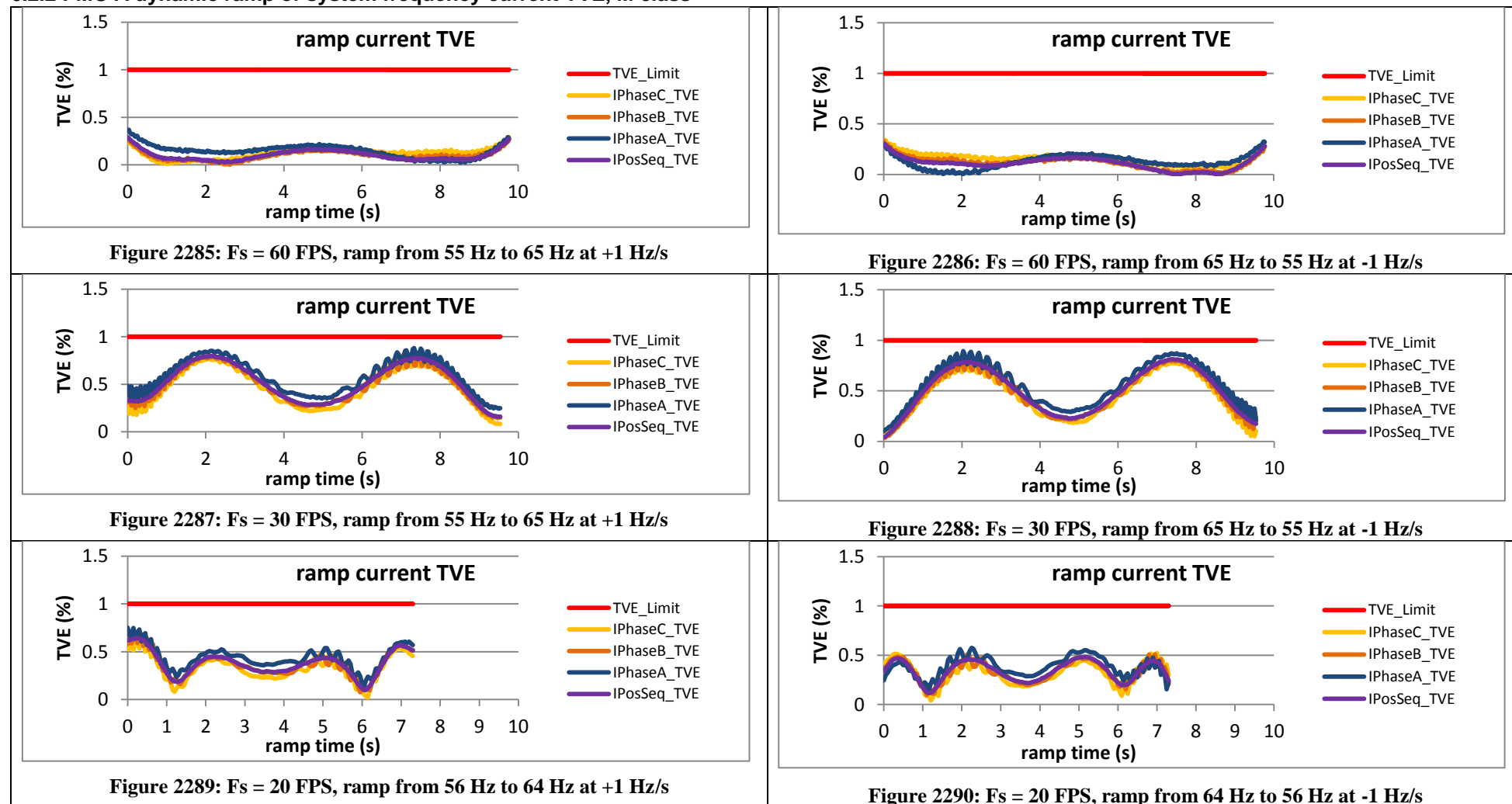


Figure 2284:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.2.2 PMU A dynamic ramp of system frequency current TVE, M class



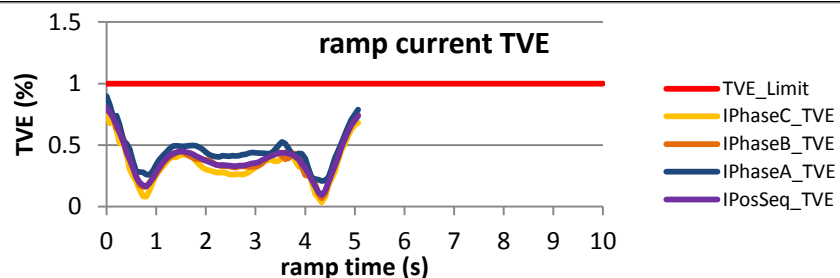


Figure 2291:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

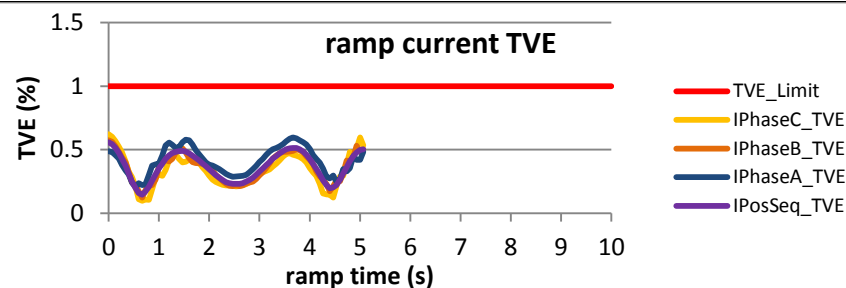


Figure 2292:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

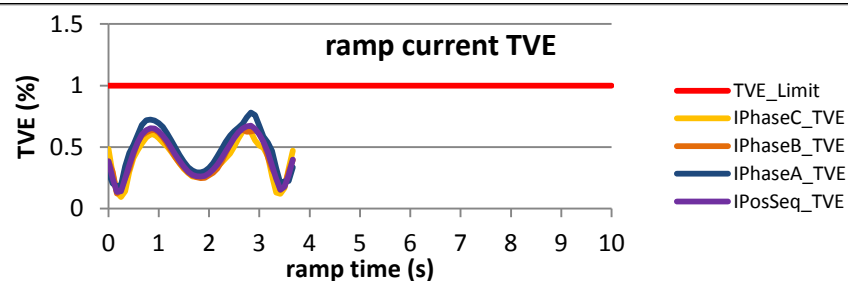


Figure 2293:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

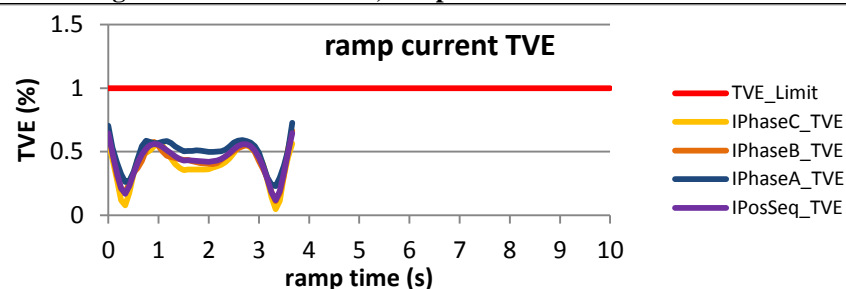


Figure 2294:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

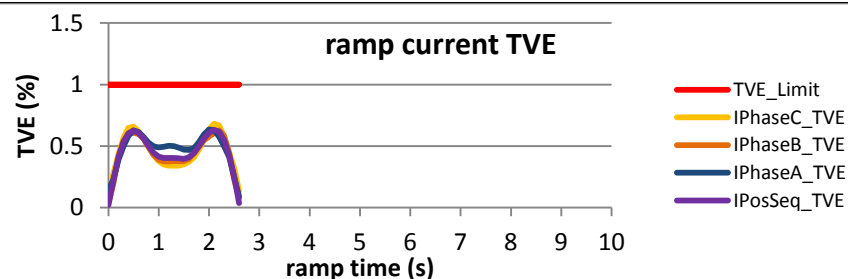


Figure 2295:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

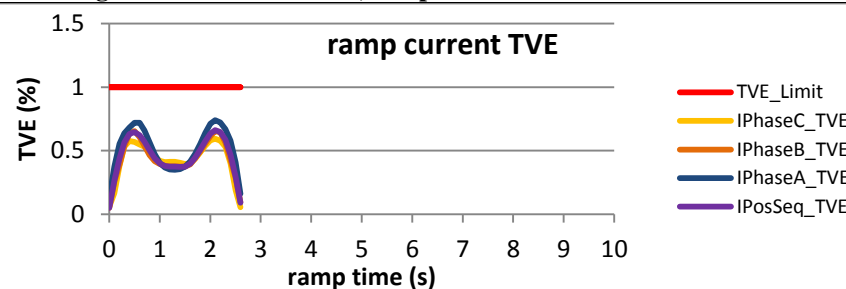


Figure 2296:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.2.3 PMU B dynamic ramp of system frequency current TVE, M class

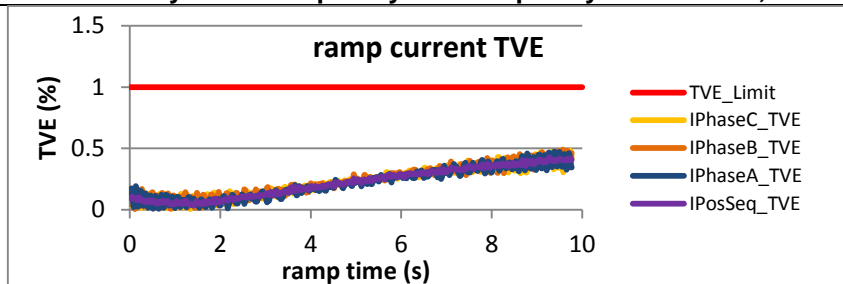


Figure 2297:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

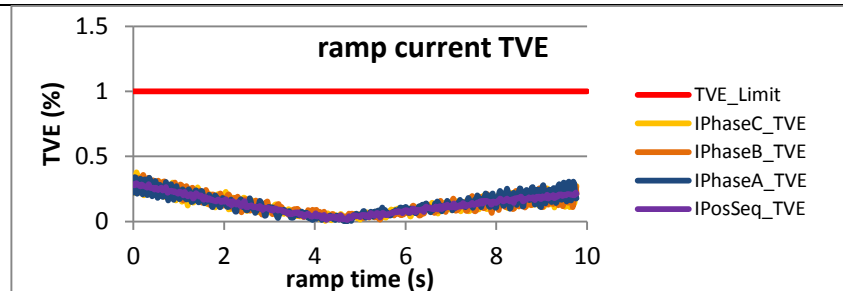


Figure 2298:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

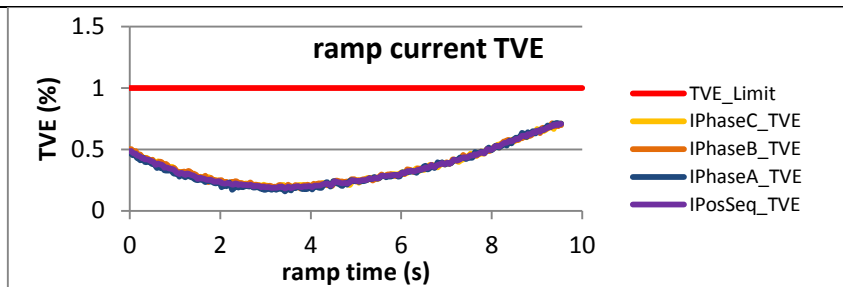


Figure 2299:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

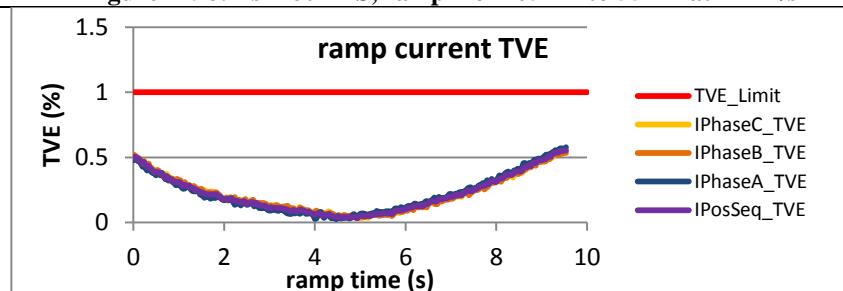


Figure 2300:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

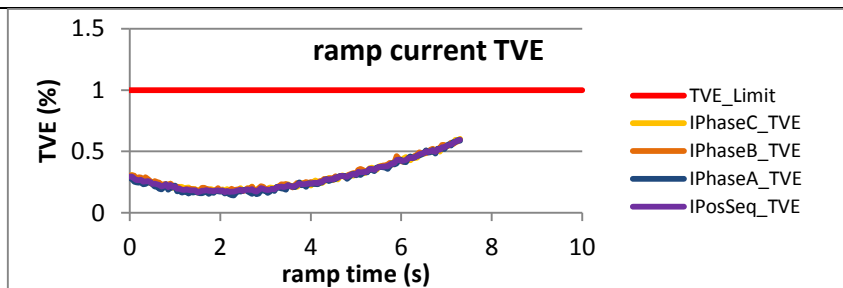


Figure 2301:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

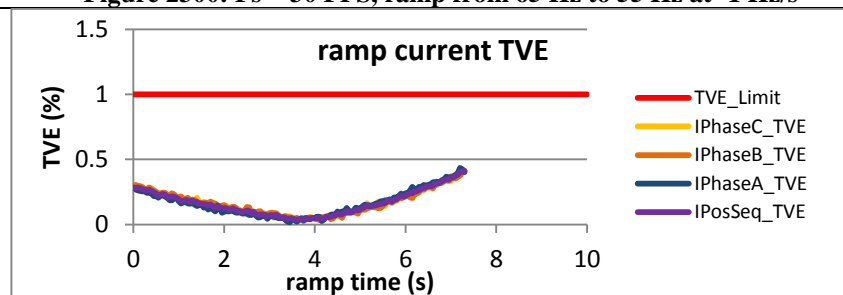


Figure 2302:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s



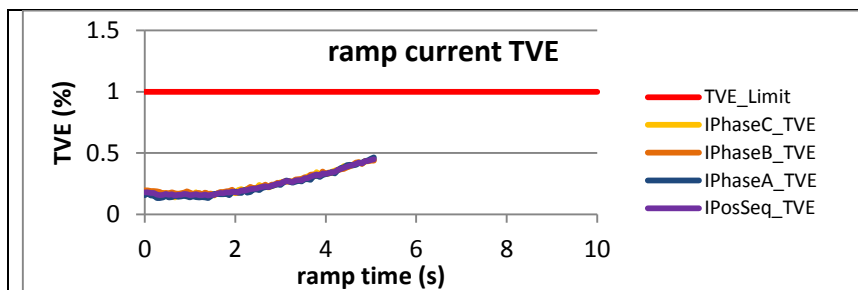


Figure 2303:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

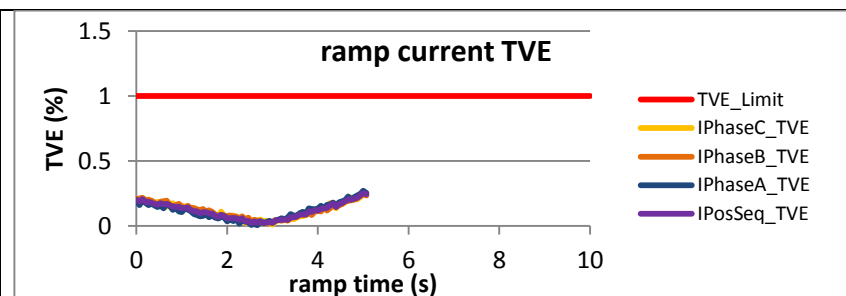


Figure 2304:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

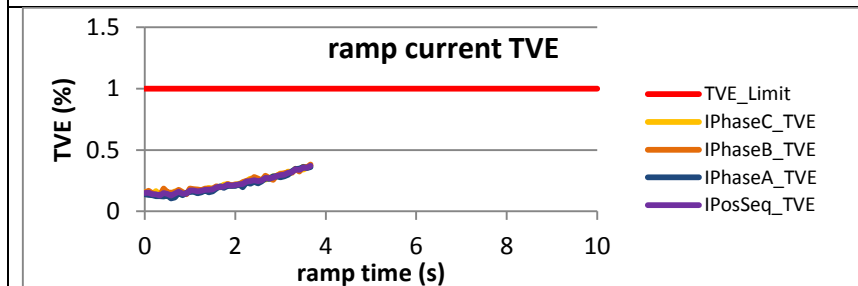


Figure 2305:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

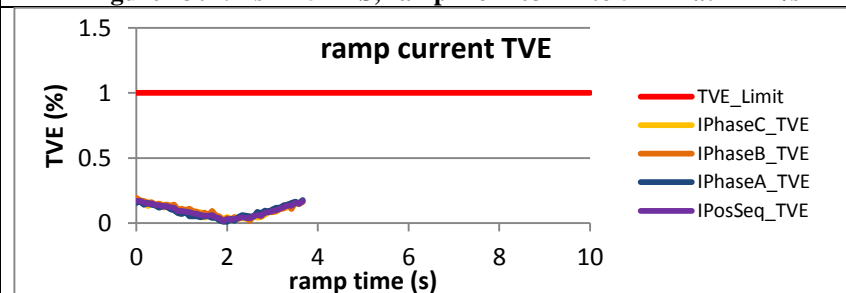


Figure 2306:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

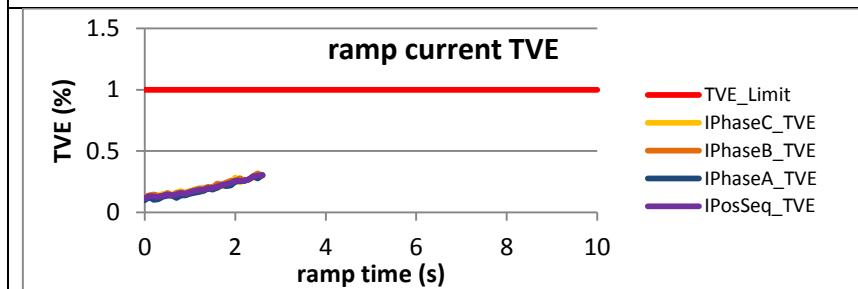


Figure 2307:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

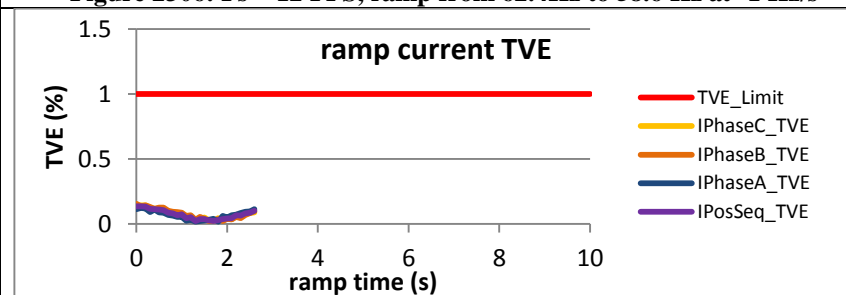


Figure 2308:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.2.4 PMU C dynamic ramp of system frequency current TVE, M class

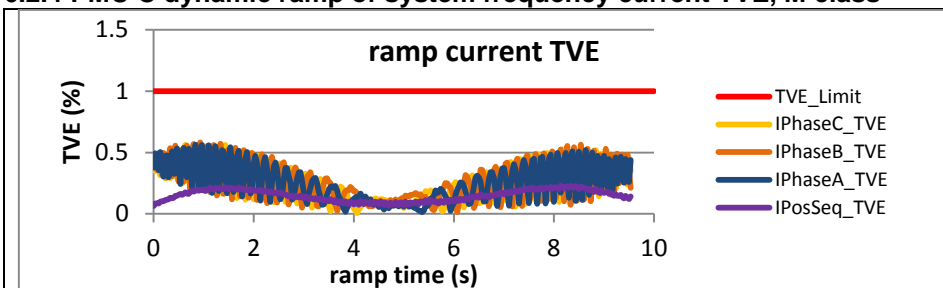


Figure 2309:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

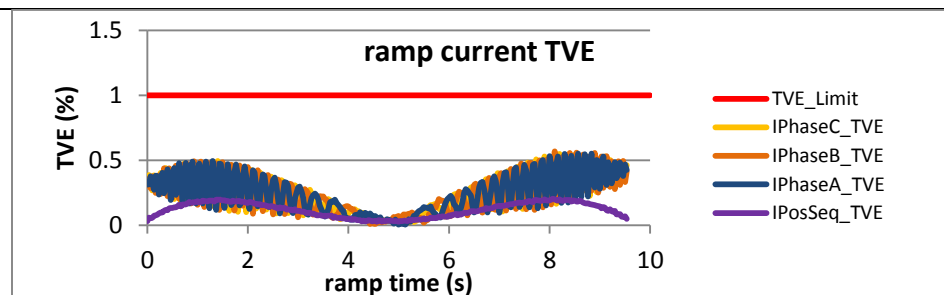


Figure 2310:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

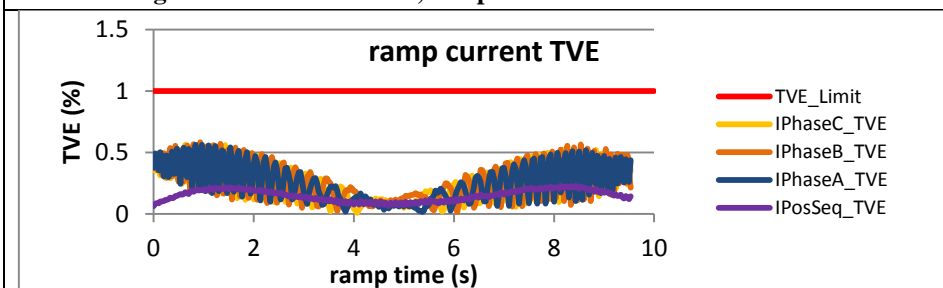


Figure 2311:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

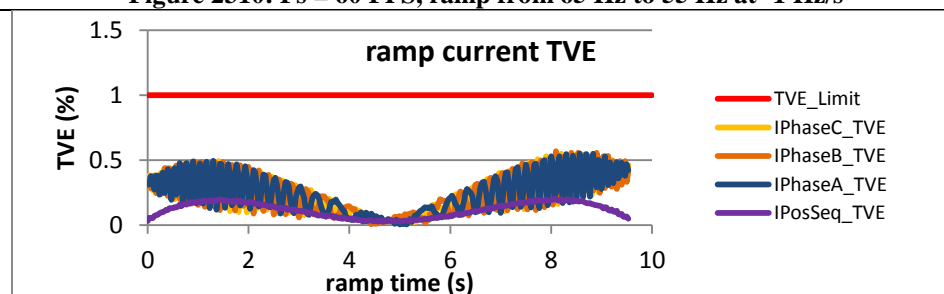


Figure 2312:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

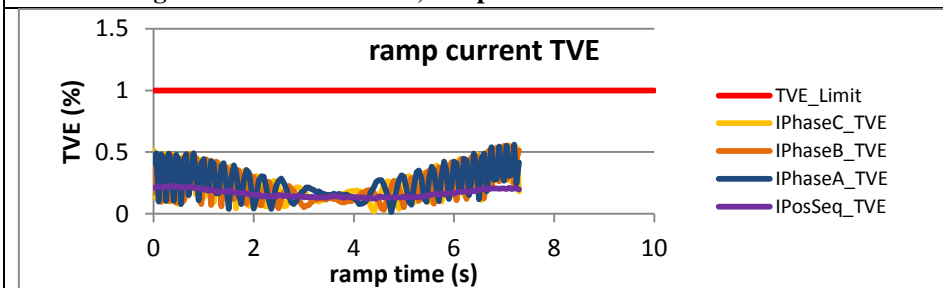


Figure 2313:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

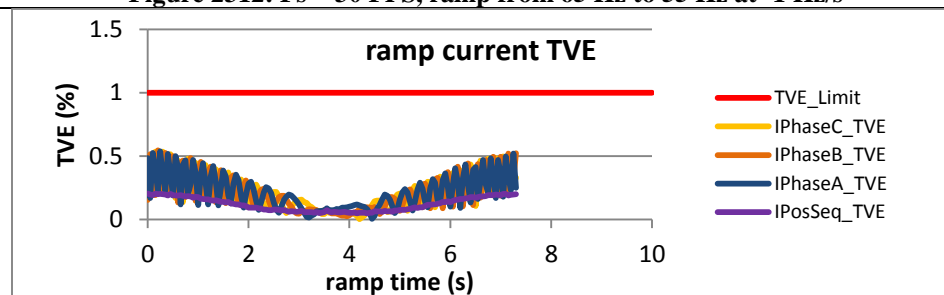


Figure 2314:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

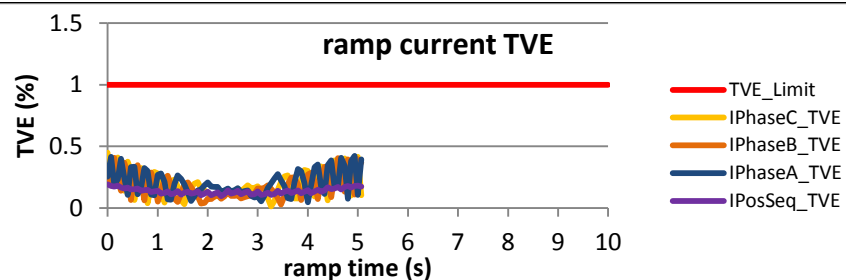


Figure 2315:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

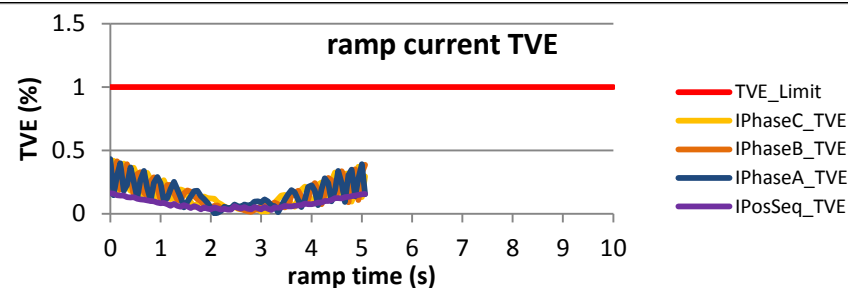


Figure 2316:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

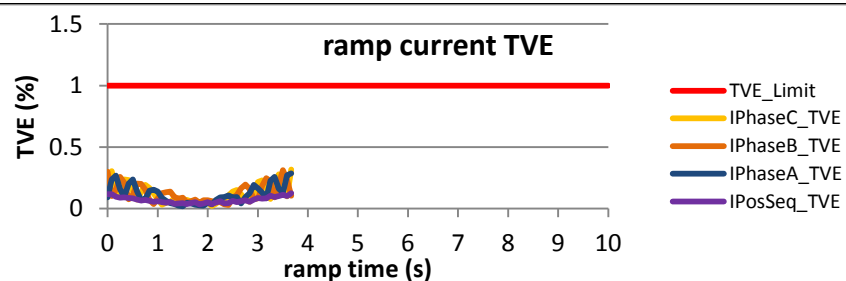


Figure 2317:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

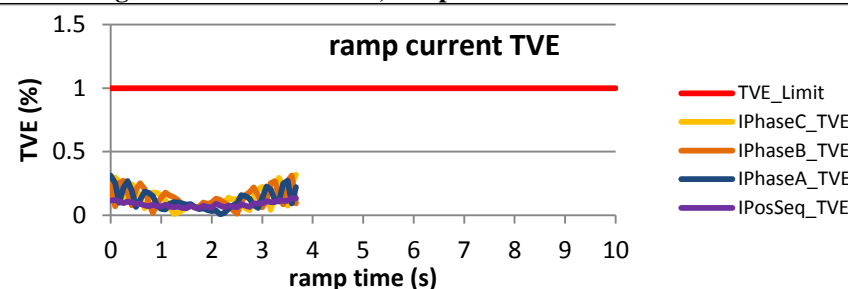


Figure 2318:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

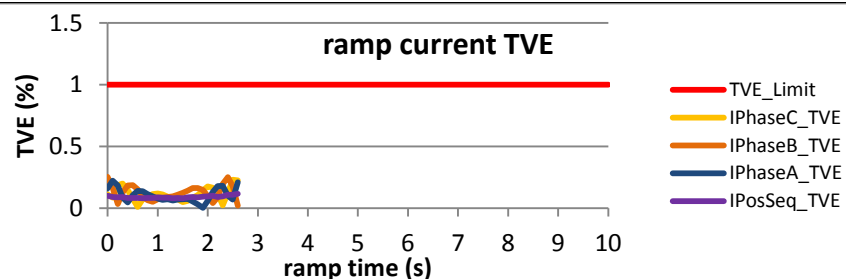


Figure 2319:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

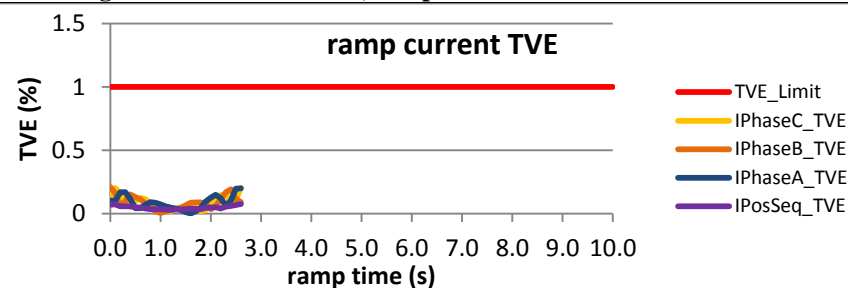
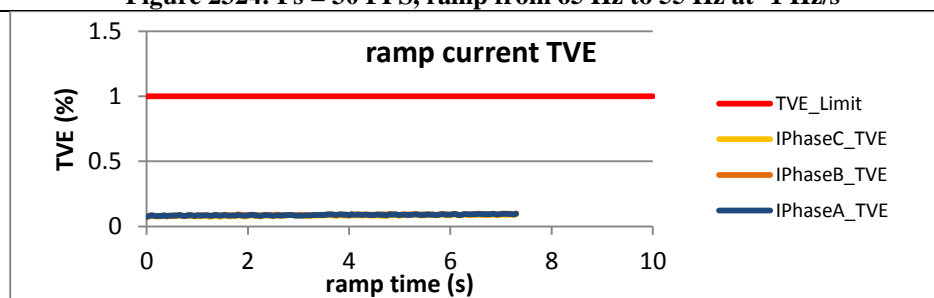
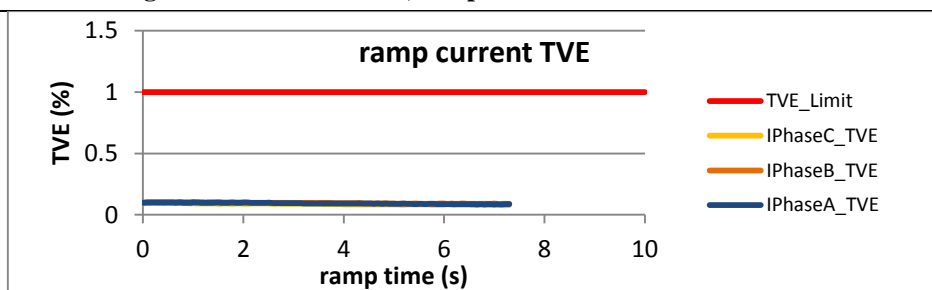
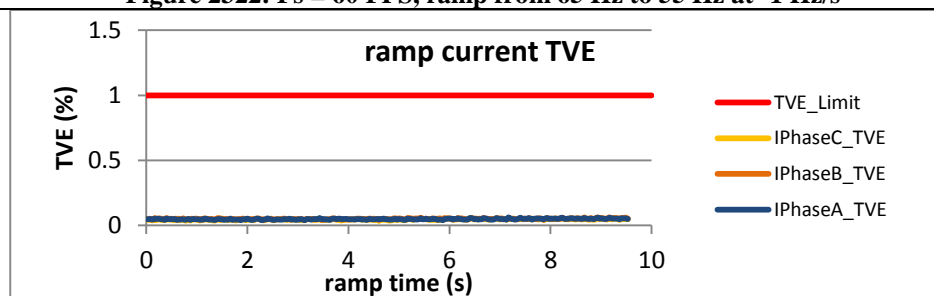
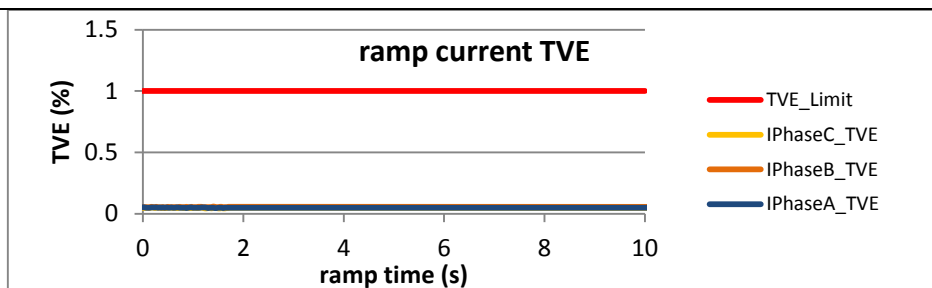
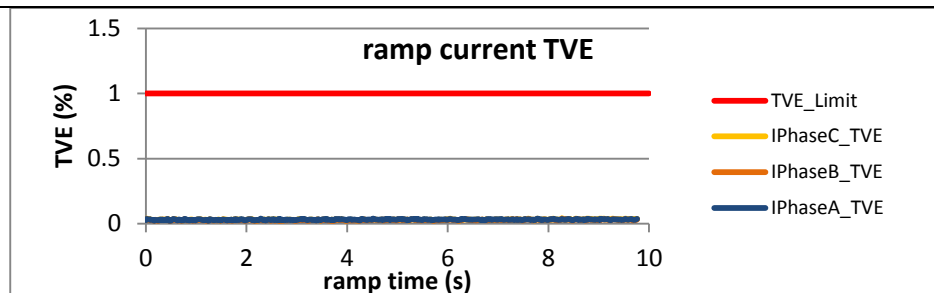
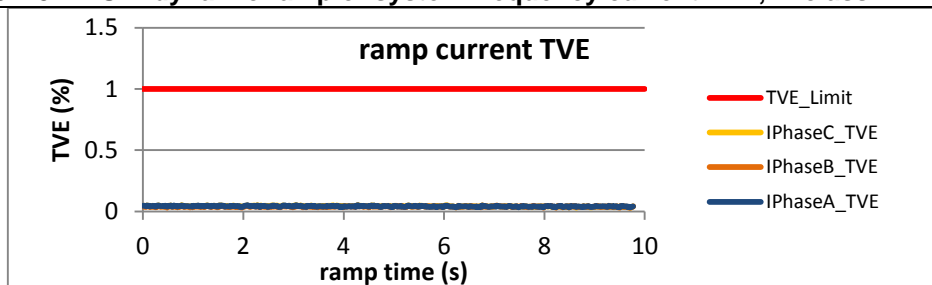


Figure 2320:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.2.5 PMU D dynamic ramp of system frequency current TVE, M class



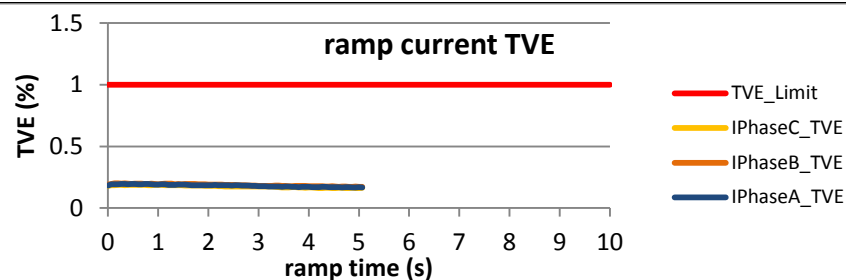


Figure 2327:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

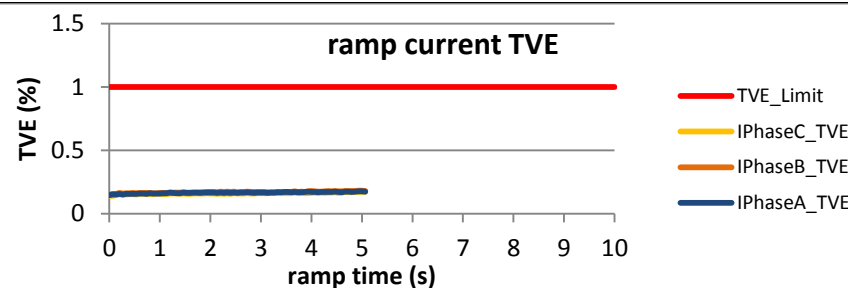


Figure 2328:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

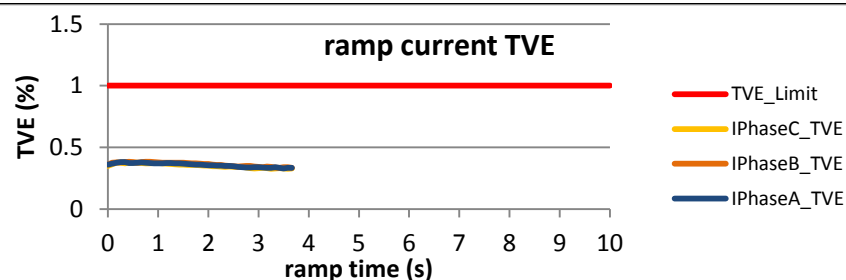


Figure 2329:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

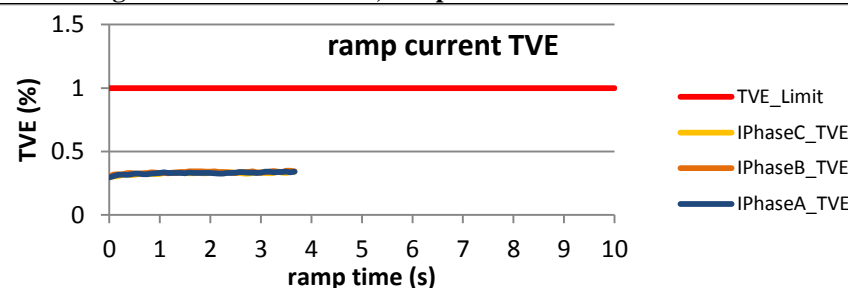


Figure 2330:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

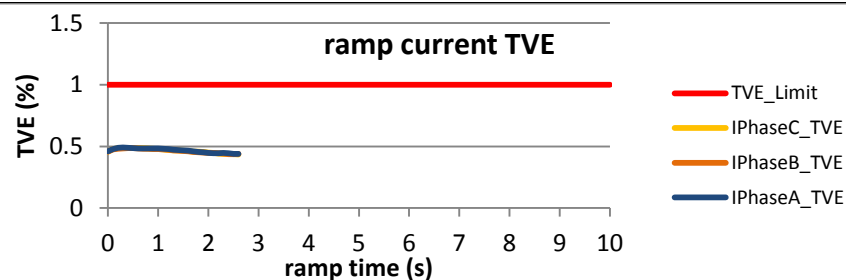


Figure 2331:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

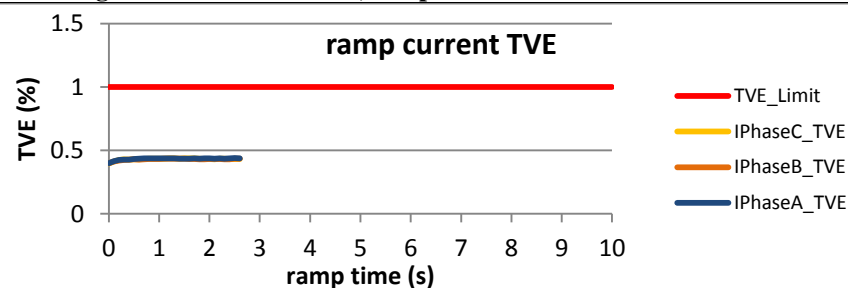


Figure 2332:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.2.6 PMU E dynamic ramp of system frequency current TVE, M class

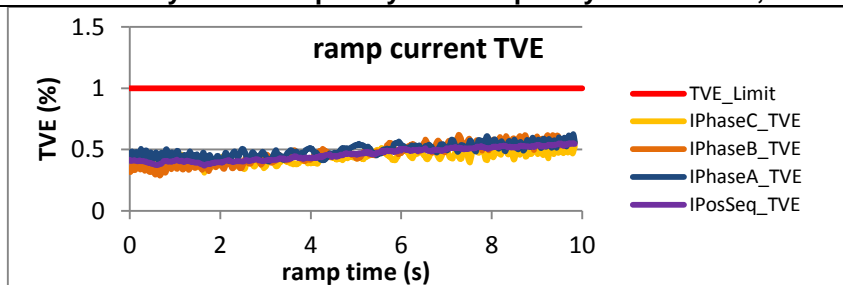


Figure 2333: Fs = 60 FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

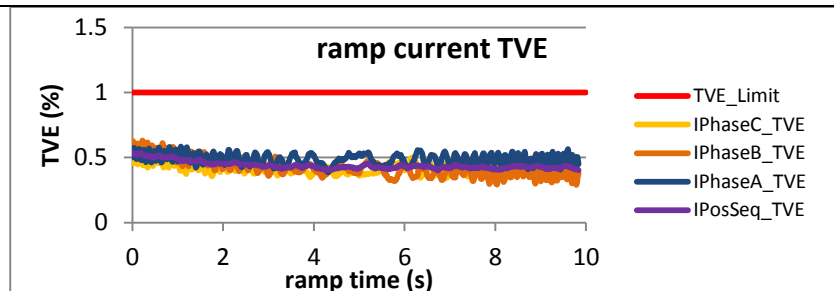


Figure 2334: Fs = 60 FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

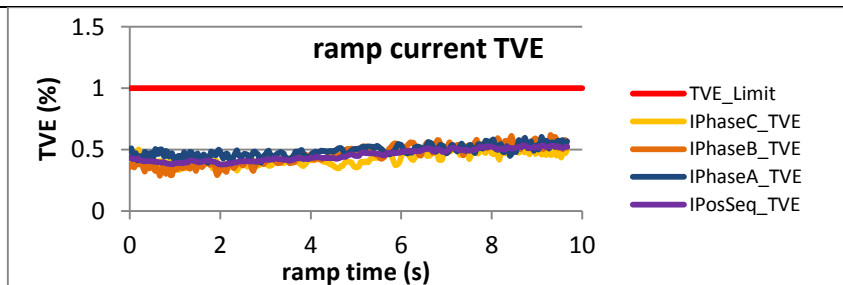


Figure 2335: Fs = 30 FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

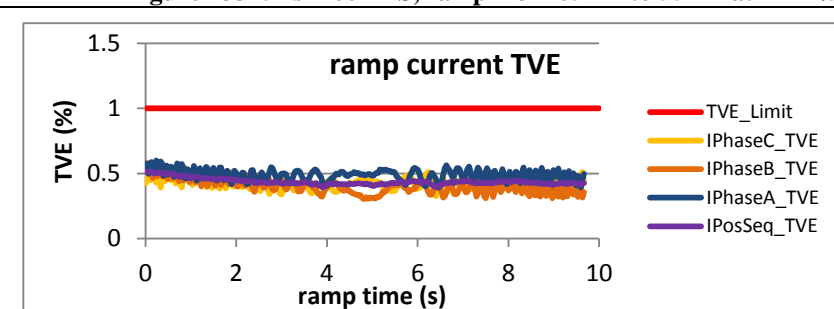


Figure 2336: Fs = 30 FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

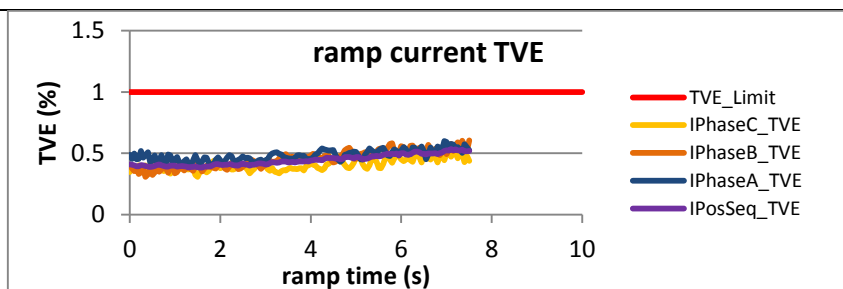


Figure 2337: Fs = 20 FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

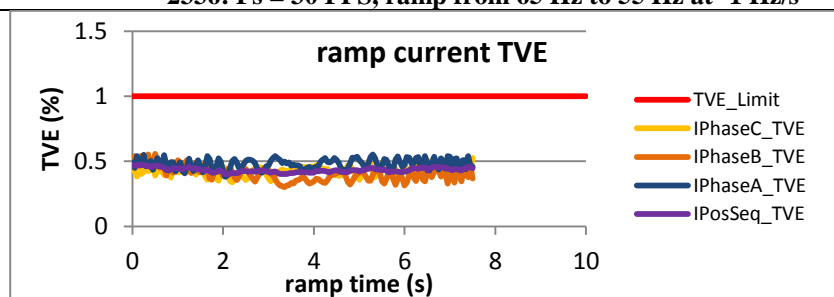


Figure 2338: Fs = 20 FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

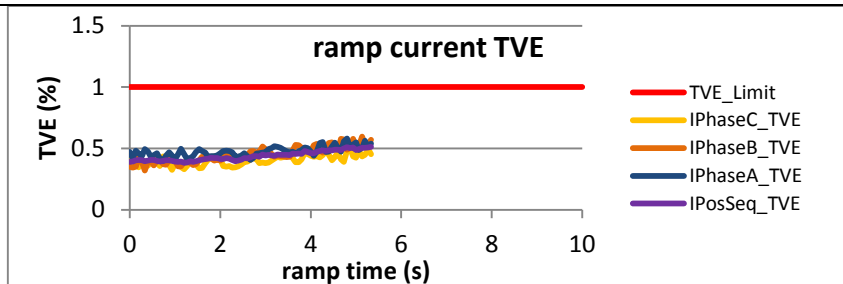


Figure 2339:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

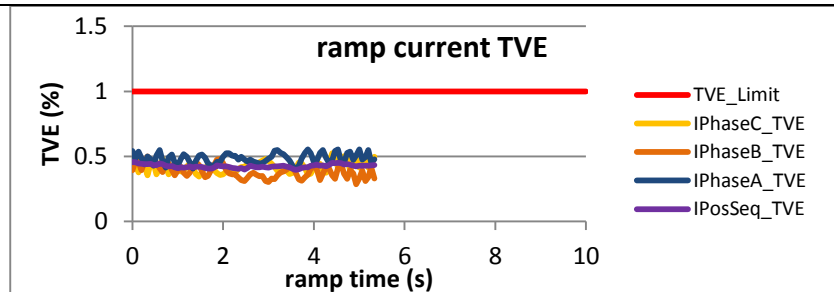


Figure 2340:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

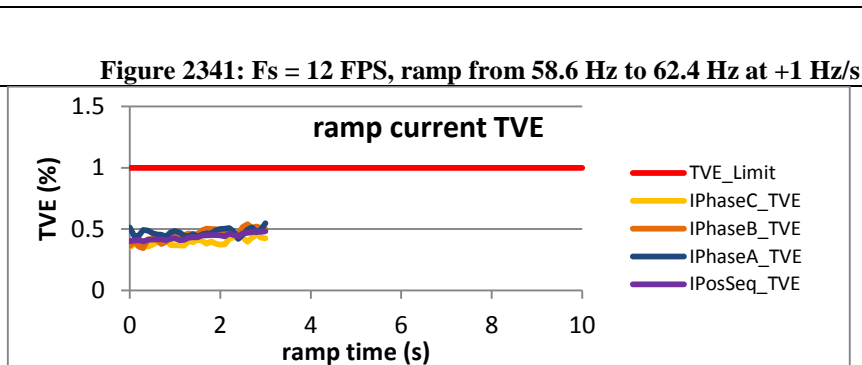


Figure 2341:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

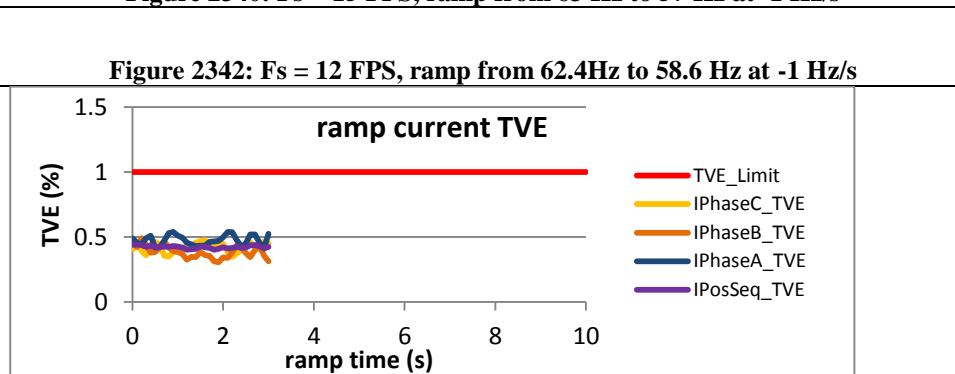


Figure 2342:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s



Figure 2343:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

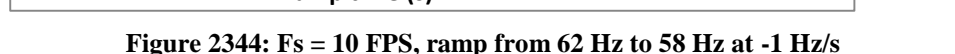


Figure 2344:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.2.7 PMU F dynamic ramp of system frequency current TVE, M class

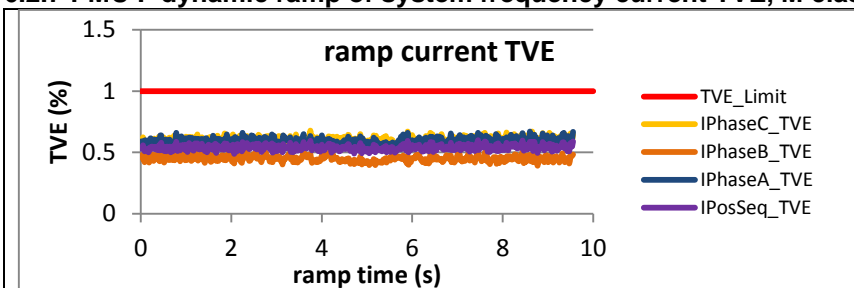


Figure 2345:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

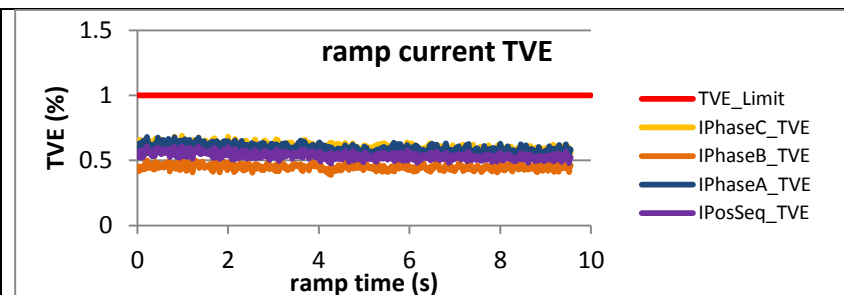


Figure 2346:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

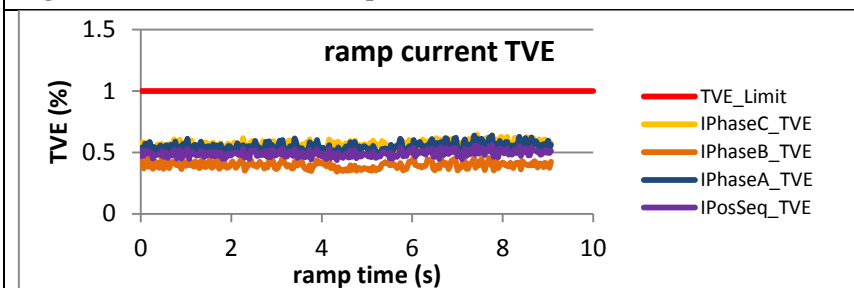


Figure 2347:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

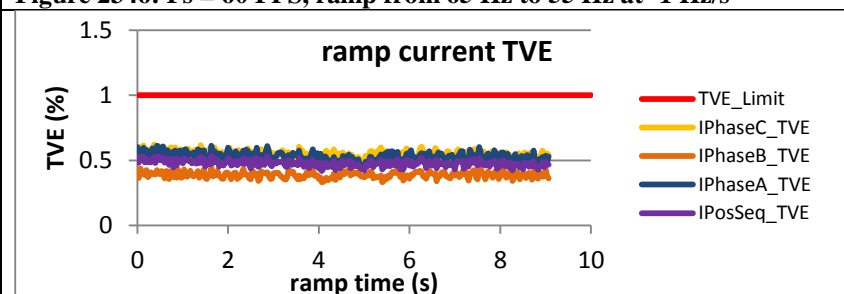


Figure 2348:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

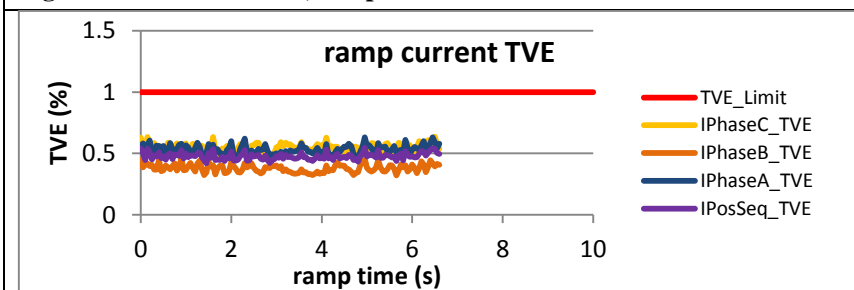


Figure 2349:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

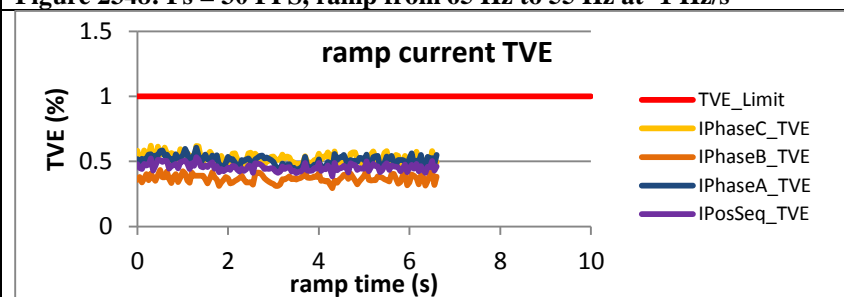


Figure 2350:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s



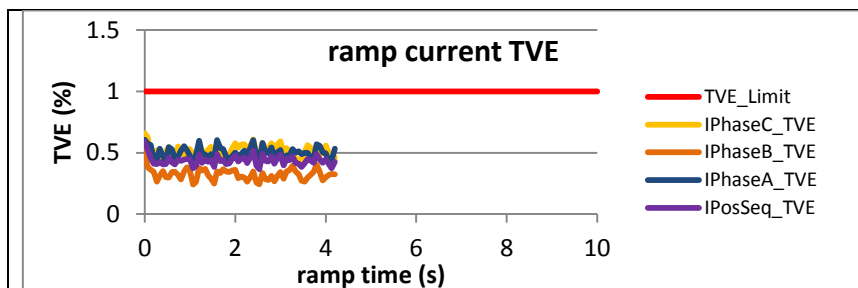


Figure 2351:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

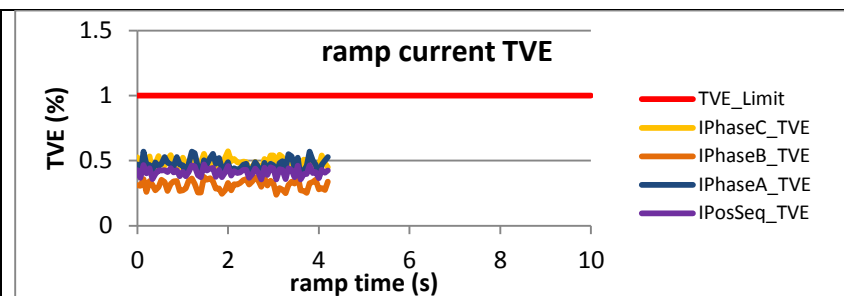


Figure 2352:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

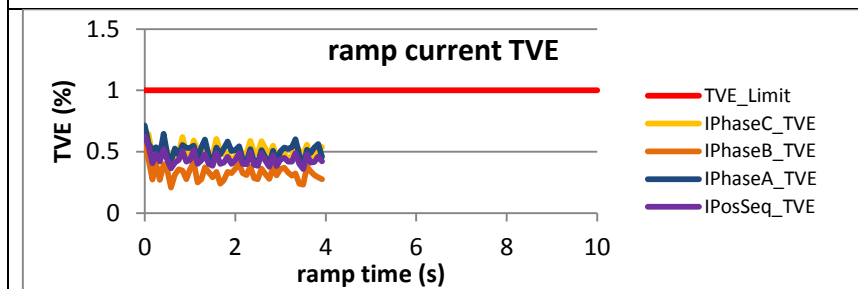


Figure 2353:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

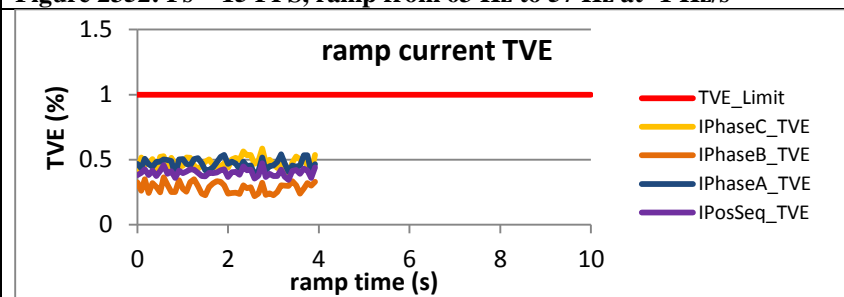


Figure 2354:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

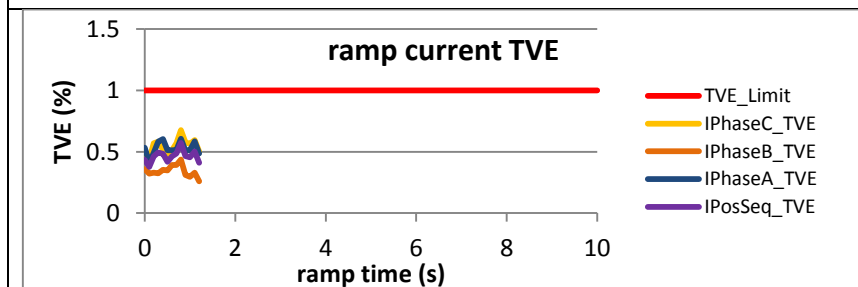


Figure 2355:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

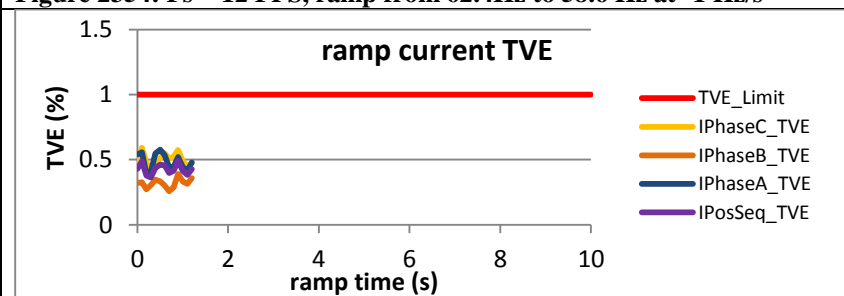


Figure 2356:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.2.8 PMU G dynamic ramp of system frequency current TVE, M class

Figure 2357:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

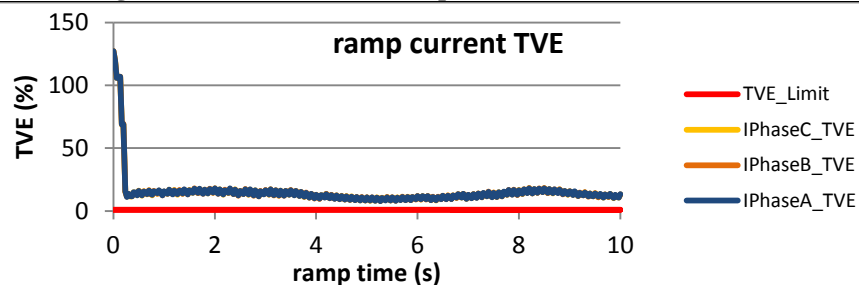


Figure 2358:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

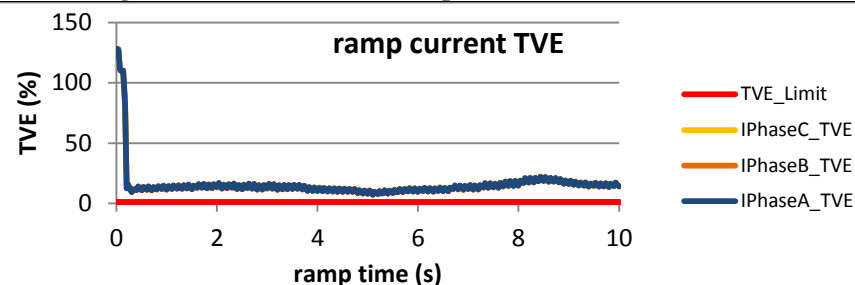


Figure 2359:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

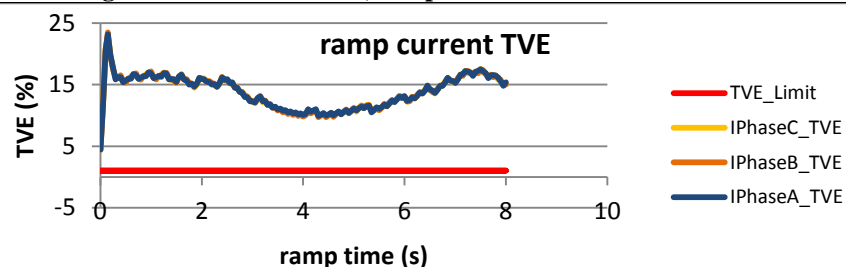


Figure 2360:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

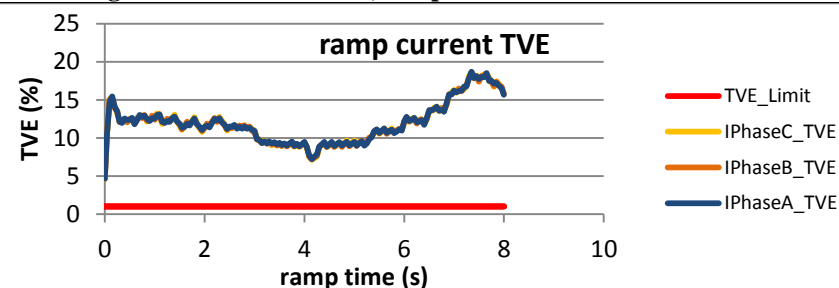


Figure 2361:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

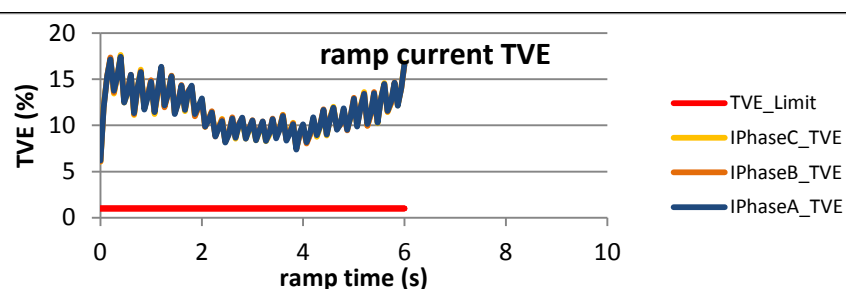


Figure 2362:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

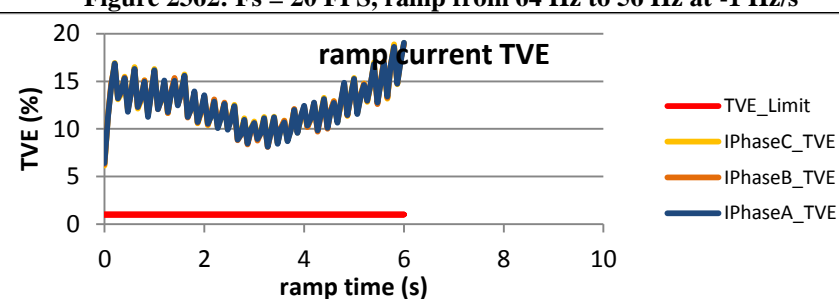
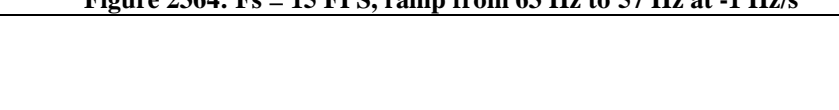


Figure 2363:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s



Figure 2364:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s



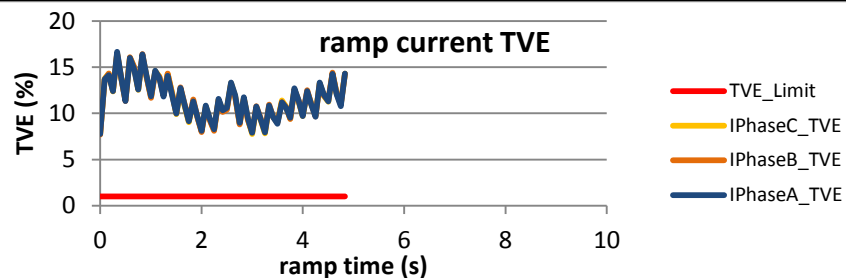


Figure 2365:  $F_s = 12$  FPS, ramp from 57.6 Hz to 62.4 Hz at +1 Hz/s

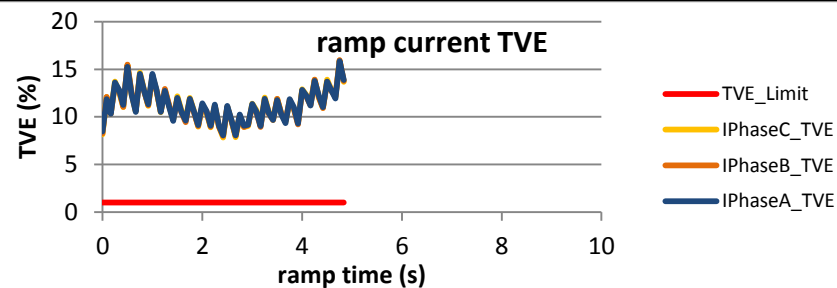


Figure 2366:  $F_s = 12$  FPS, ramp from 62.4 Hz to 57.6 Hz at -1 Hz/s

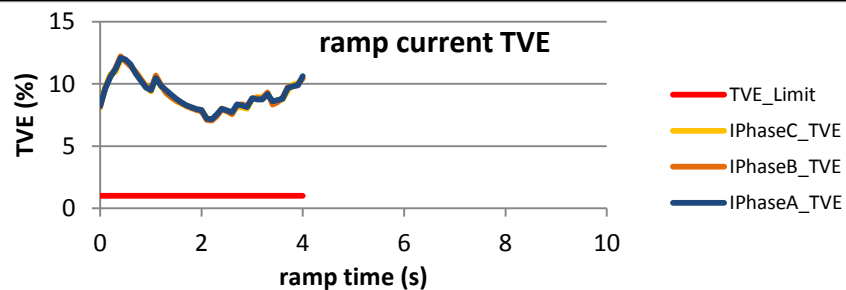


Figure 2367:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

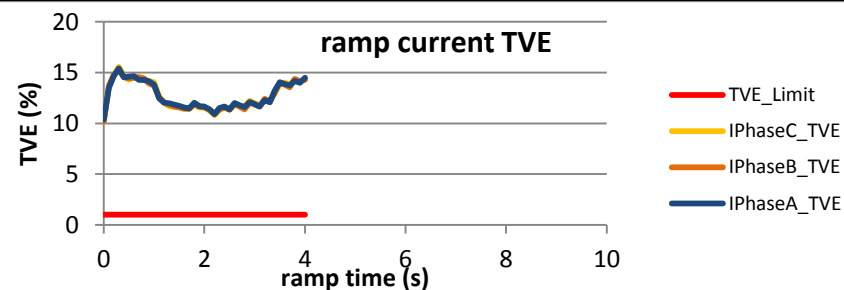


Figure 2368:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.2.9 PMU H dynamic ramp of system frequency current TVE, M class

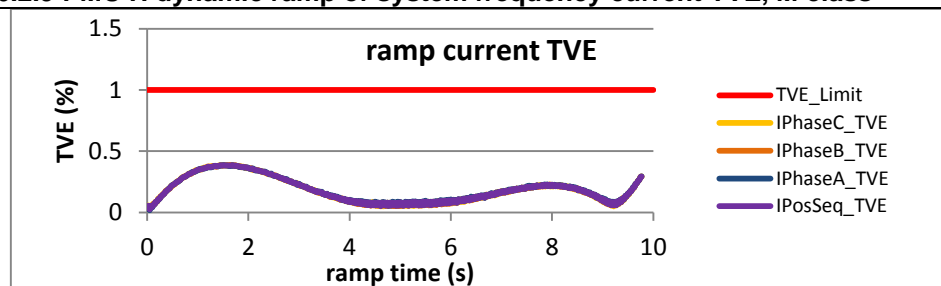


Figure 2369:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

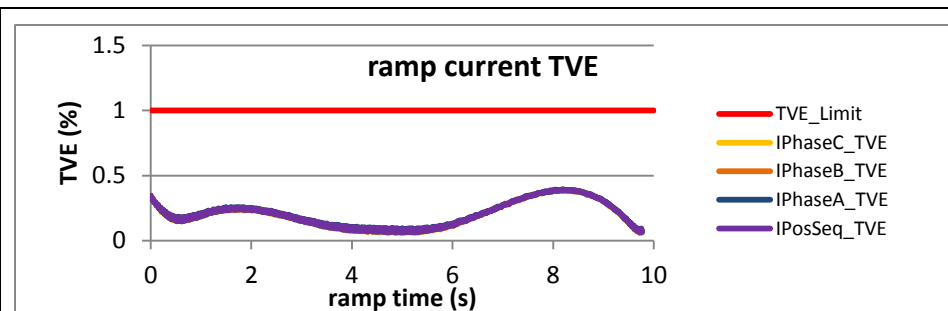


Figure 2370:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

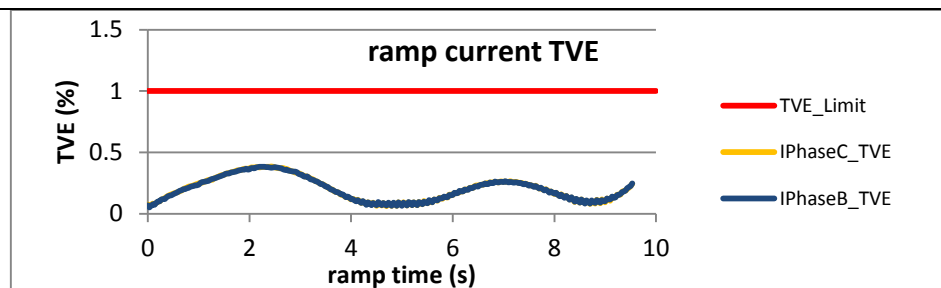


Figure 2371:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

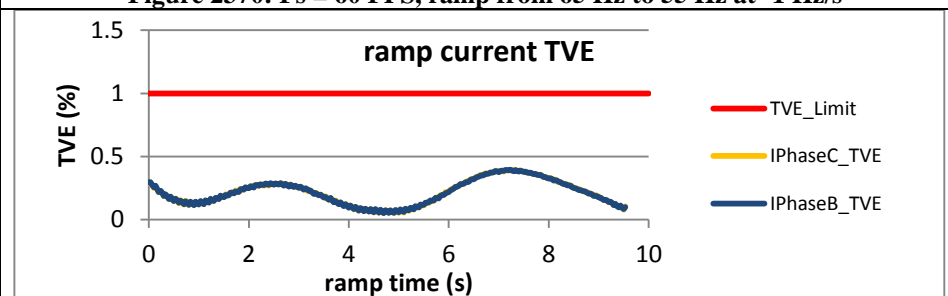


Figure 2372:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

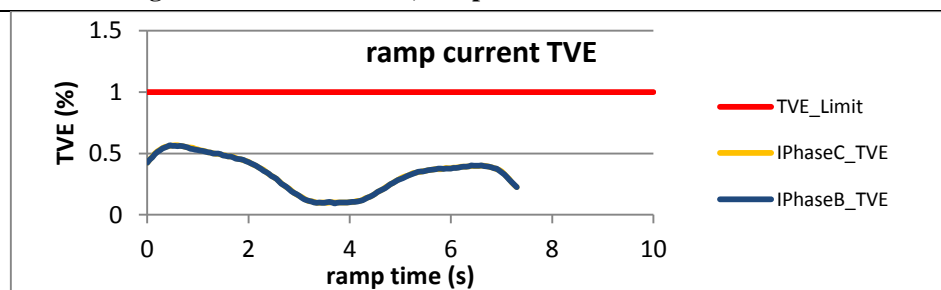


Figure 2373:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

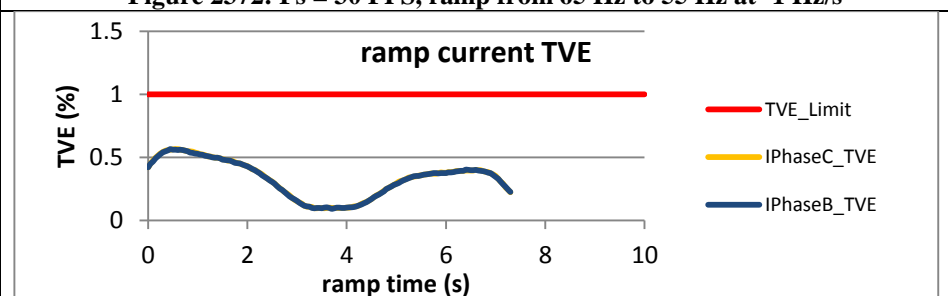
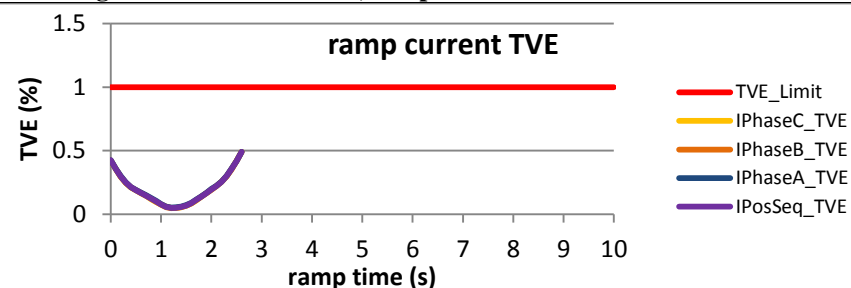
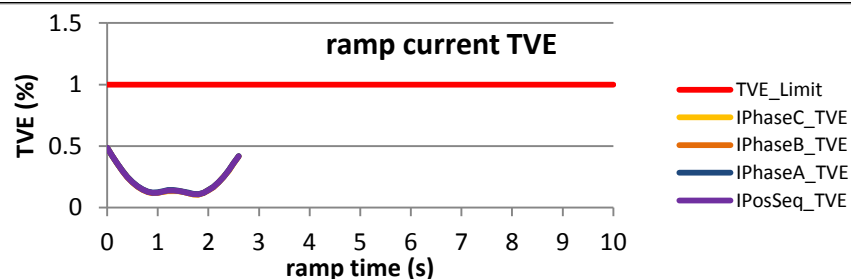
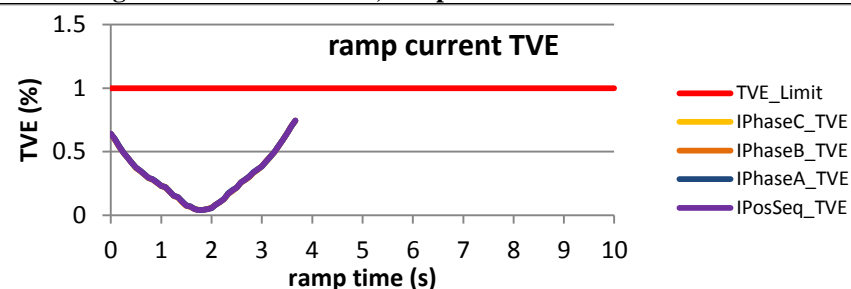
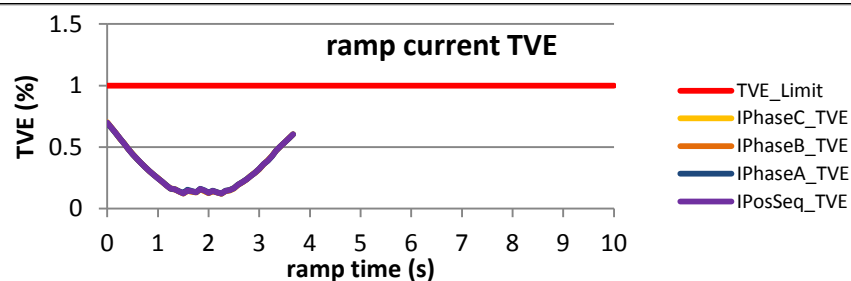
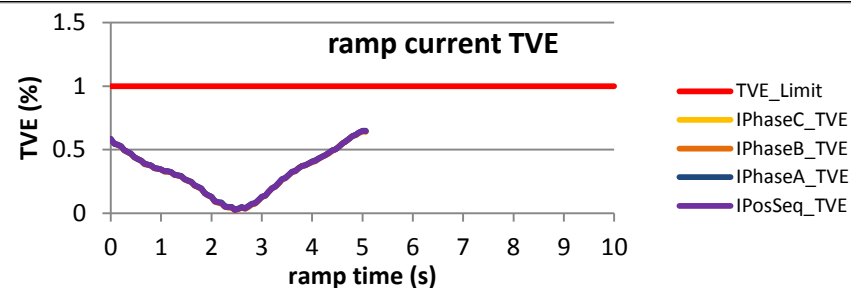
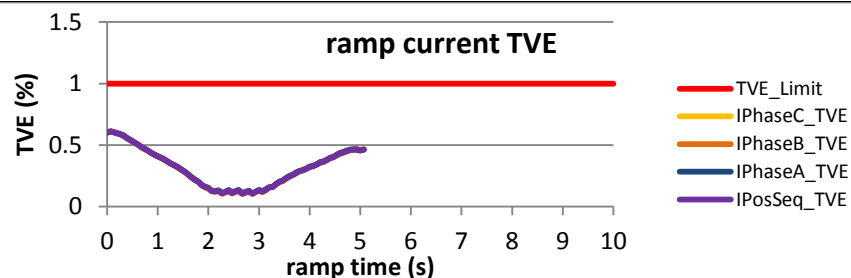


Figure 2374:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s



## 6.2.10 PMU I dynamic ramp of system frequency current TVE, M class

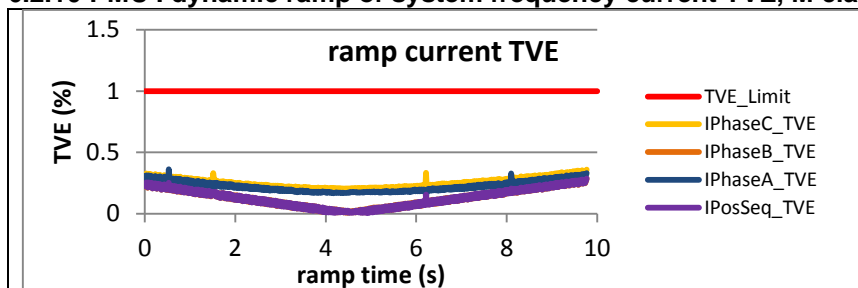


Figure 2381:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

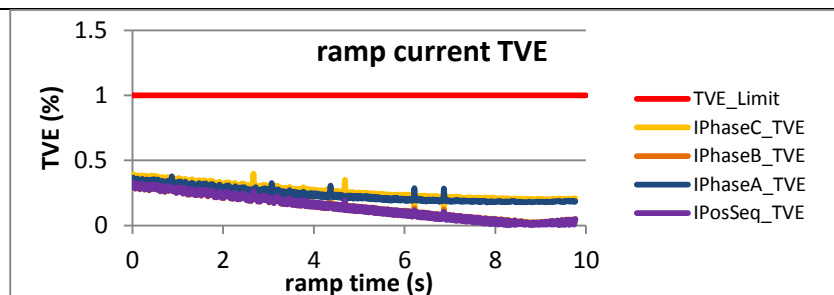


Figure 2382:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

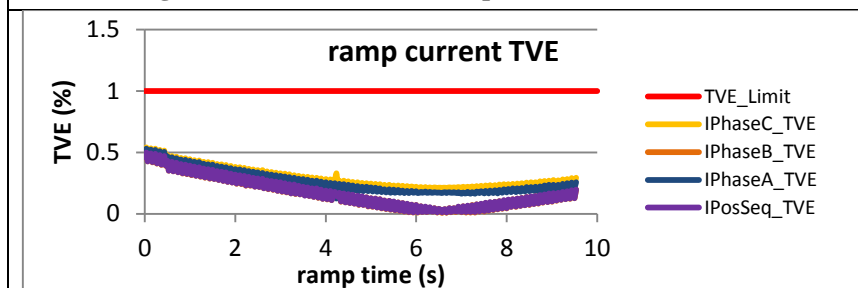


Figure 2383:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

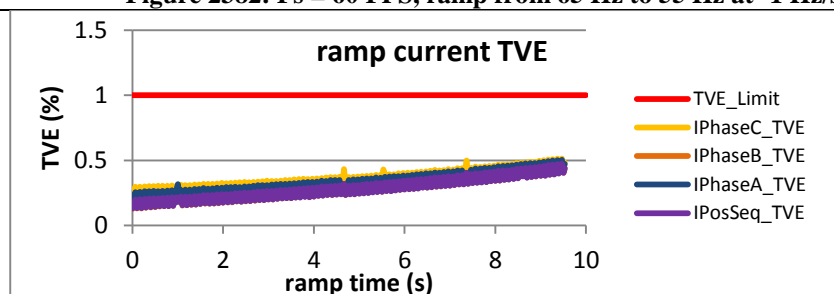


Figure 2384:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

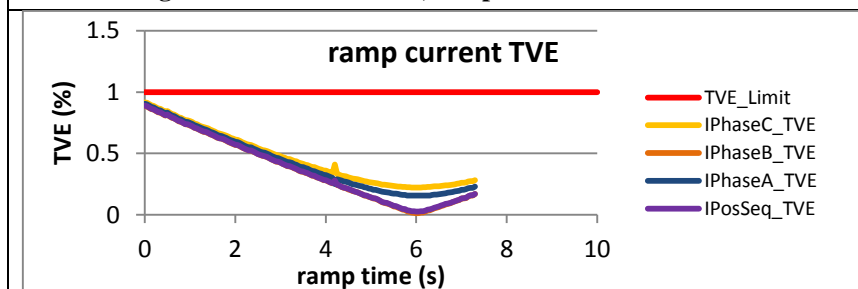


Figure 2385:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

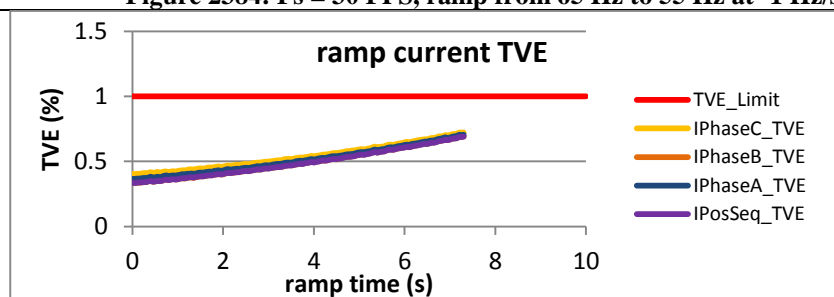


Figure 2386:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

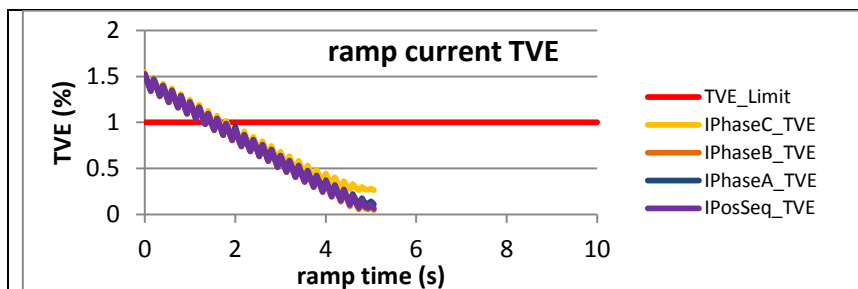


Figure 2387:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

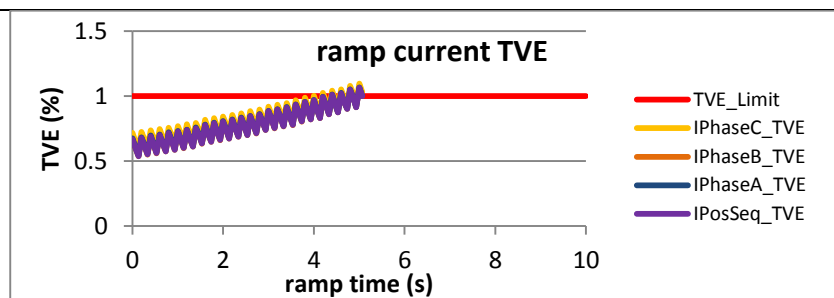


Figure 2388:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

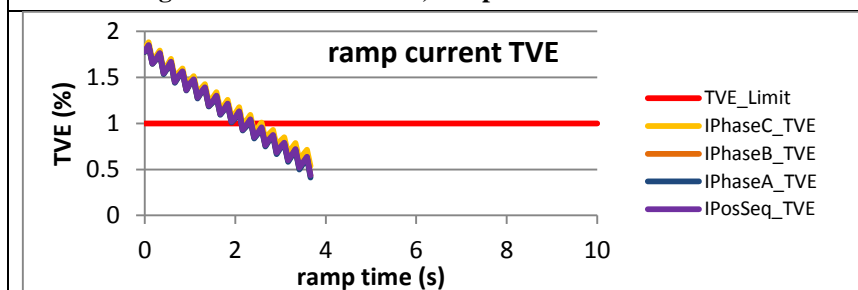


Figure 2389:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

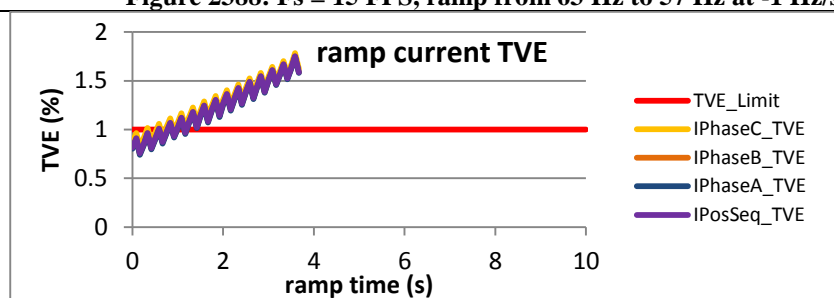


Figure 2390:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

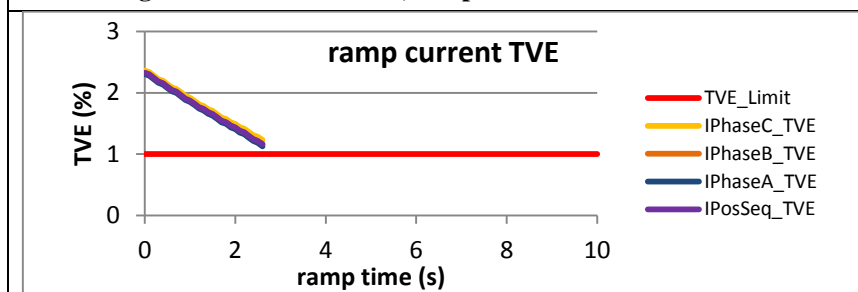


Figure 2391:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

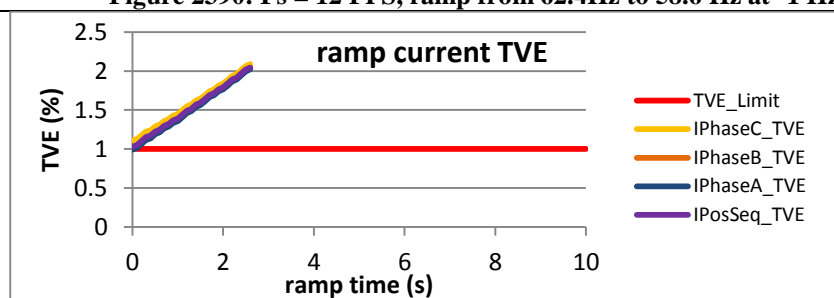


Figure 2392:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.2.11 PMU J dynamic ramp of system frequency current TVE, M class

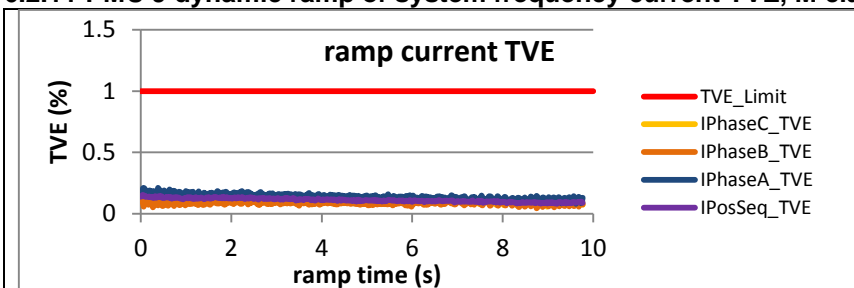


Figure 2393:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

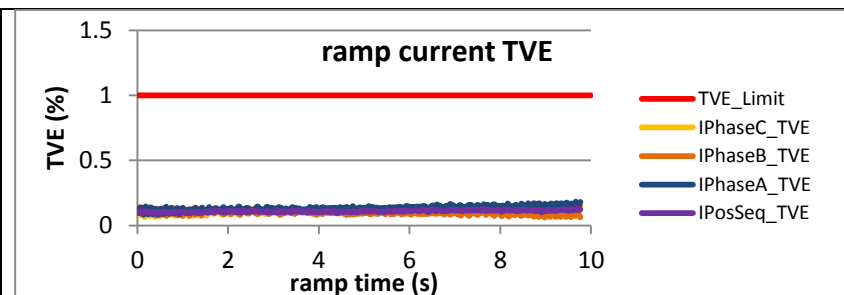


Figure 2394:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

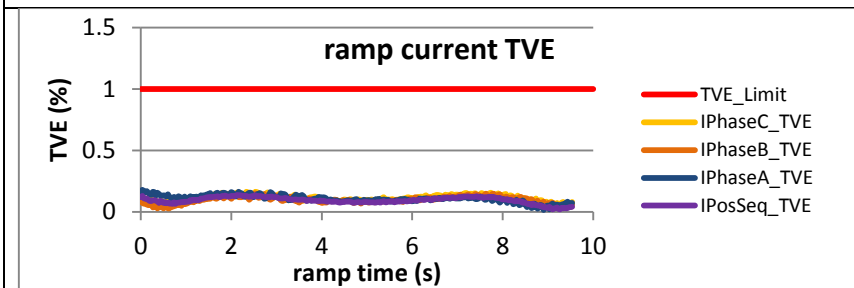


Figure 2395:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

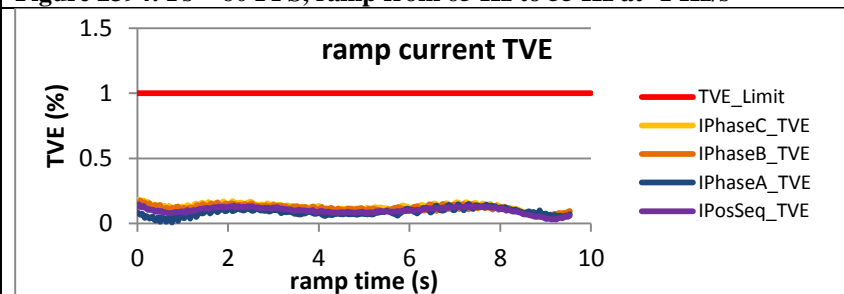


Figure 2396:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

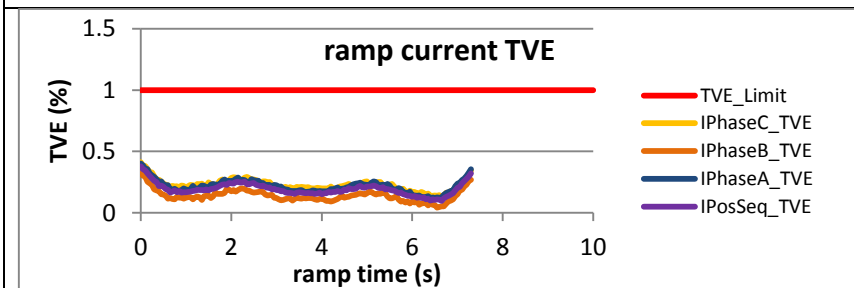


Figure 2397:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

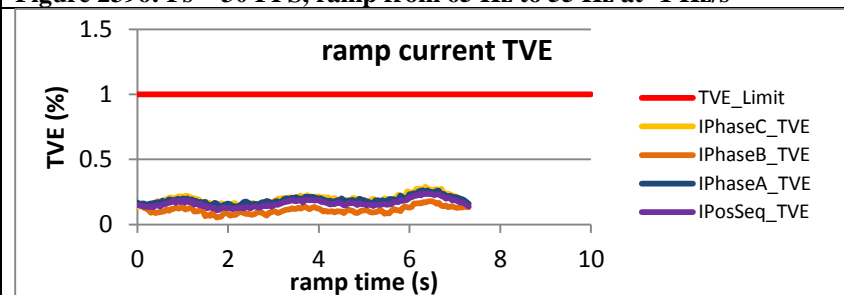


Figure 2398:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s



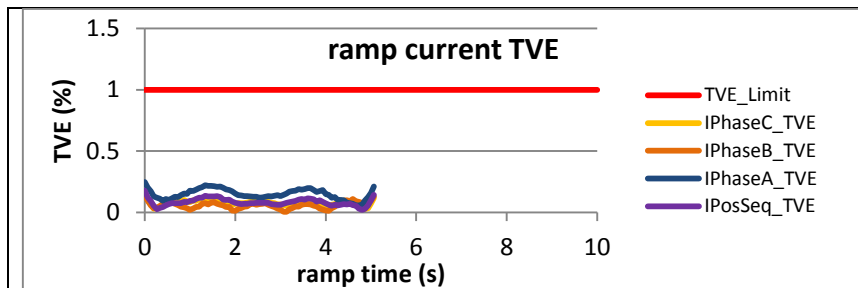


Figure 2399:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

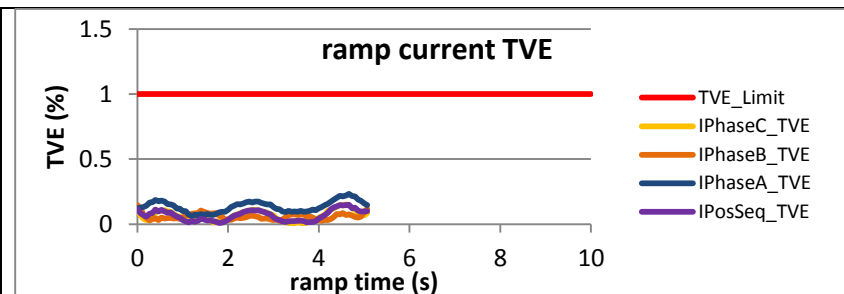


Figure 2400:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

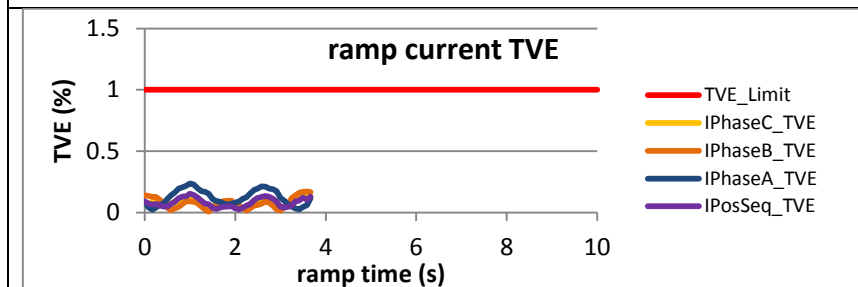


Figure 2401:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

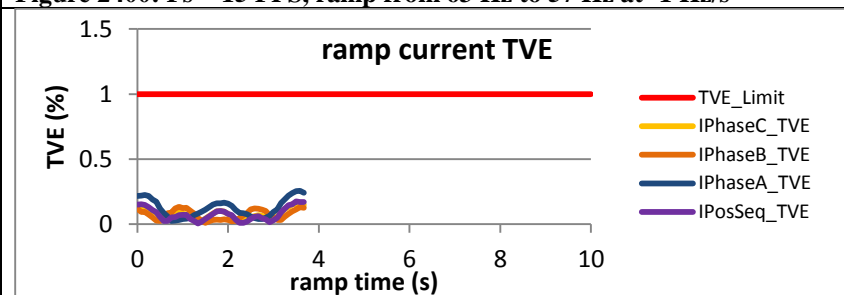


Figure 2402:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

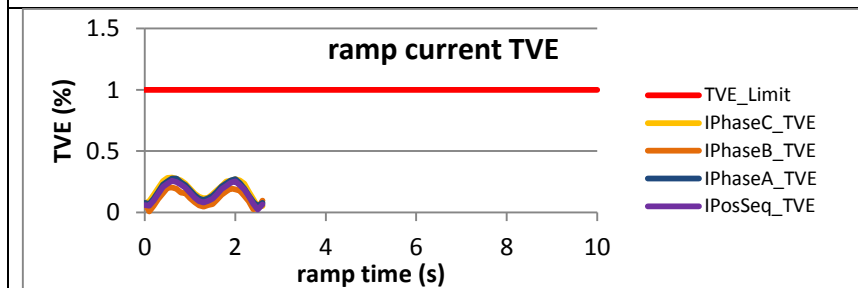


Figure 2403:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

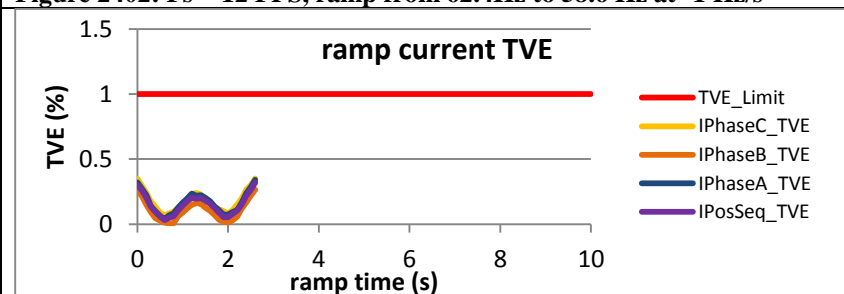
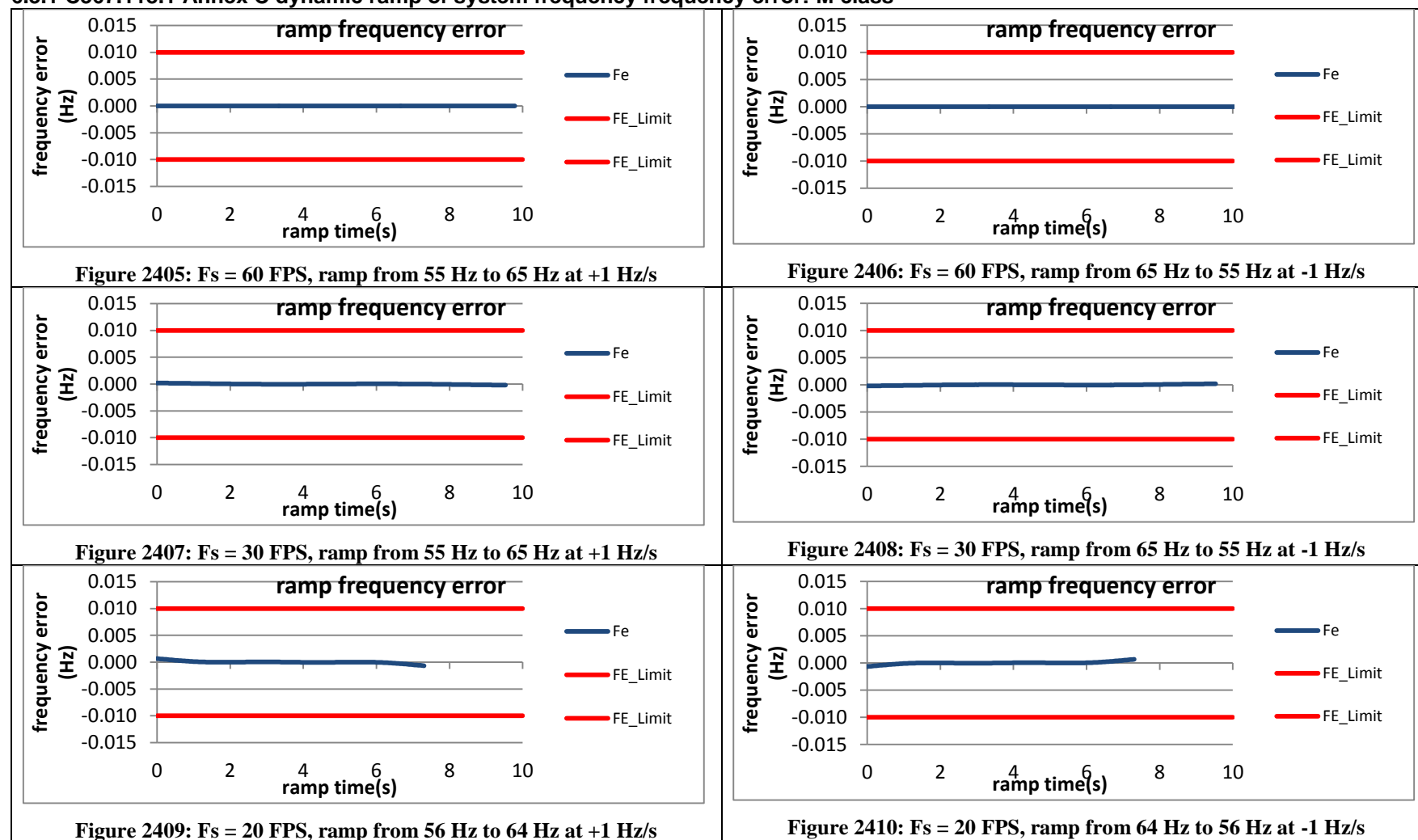


Figure 2404:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.3 Dynamic ramp of system frequency frequency error, M class

#### 6.3.1 C367.118.1 Annex C dynamic ramp of system frequency frequency error: M class



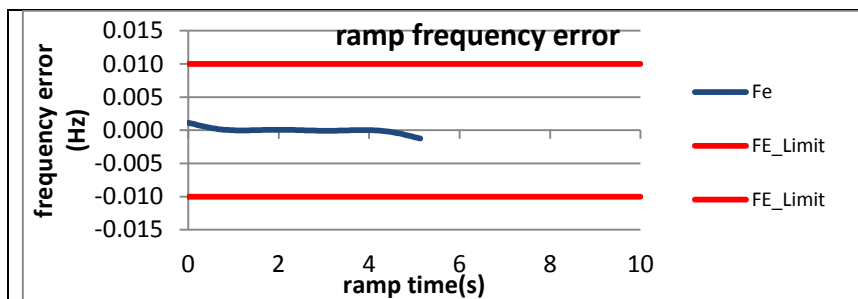


Figure 2411:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

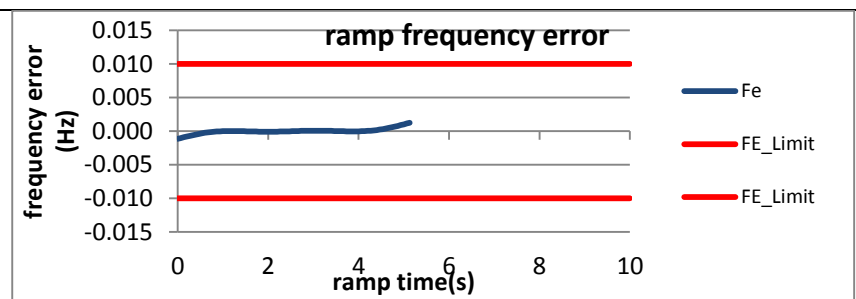


Figure 2412:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

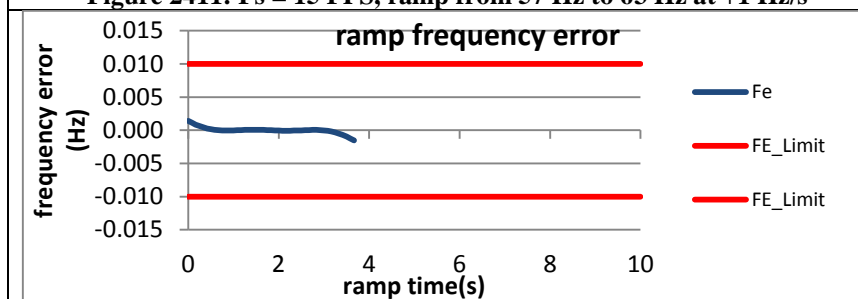


Figure 2413:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

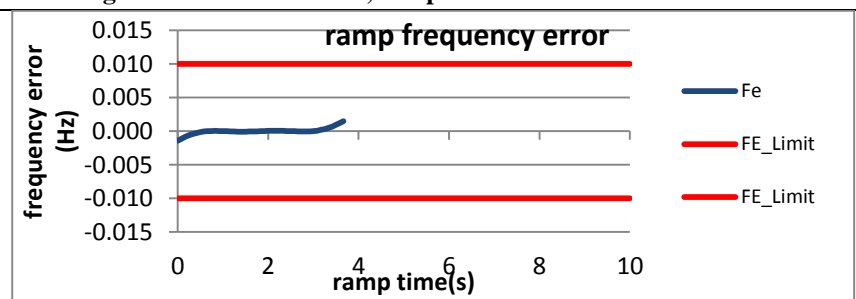


Figure 2414:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

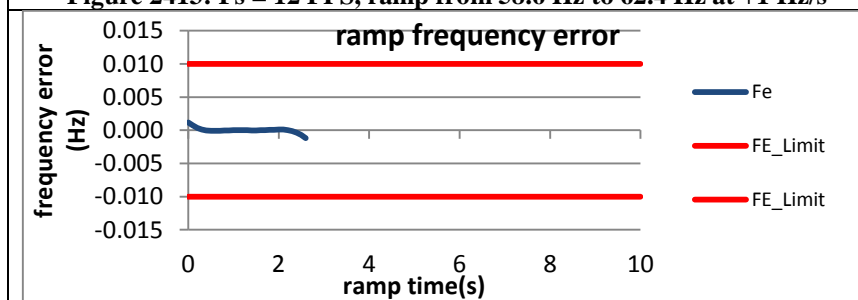


Figure 2415:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

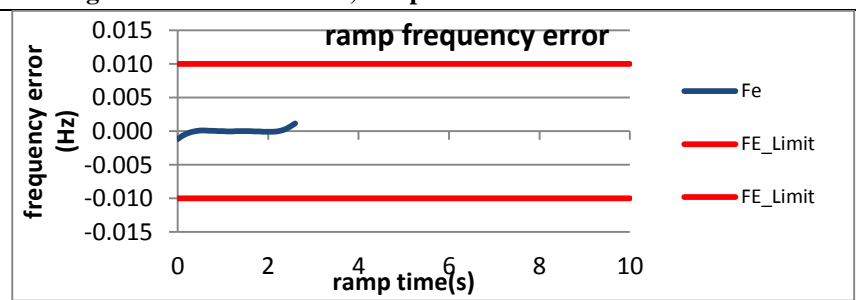
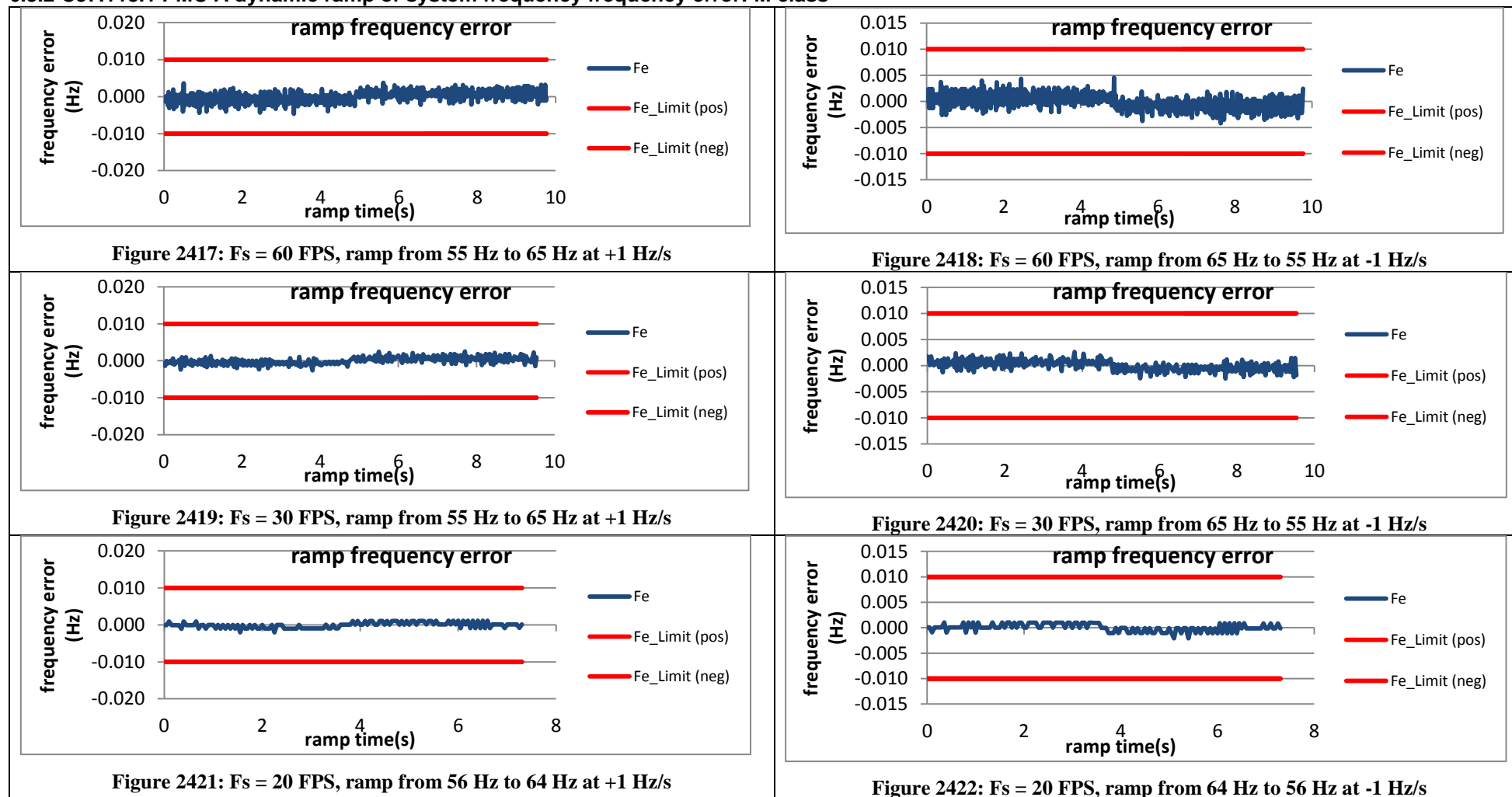


Figure 2416:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.3.2 C37.118.1 PMU A dynamic ramp of system frequency frequency error: M class



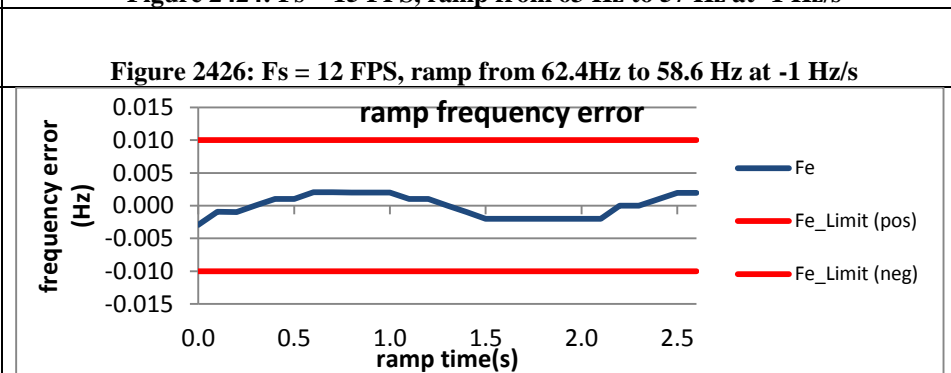
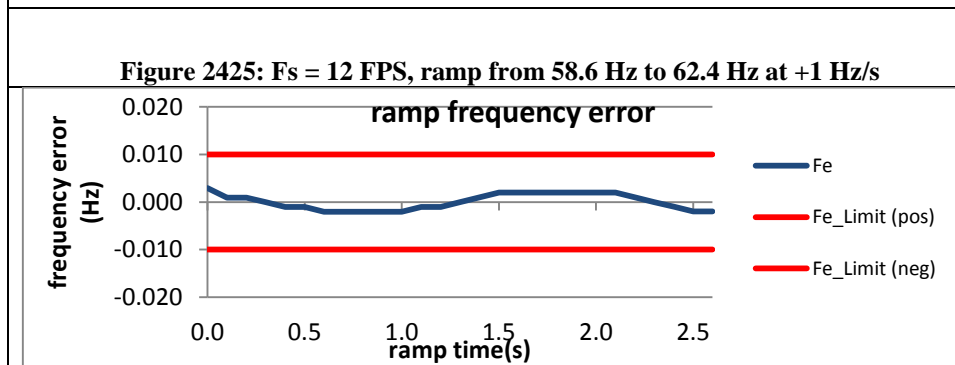
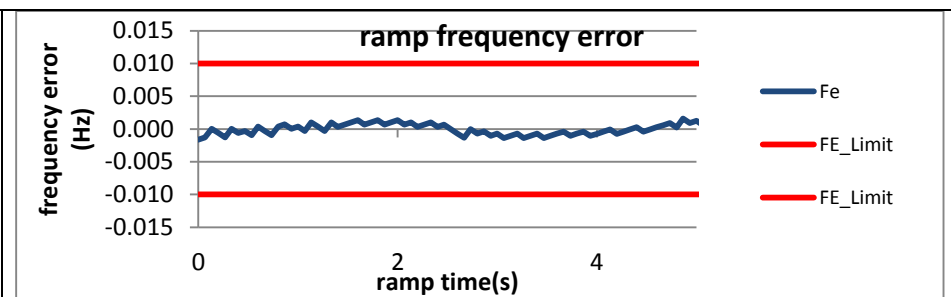
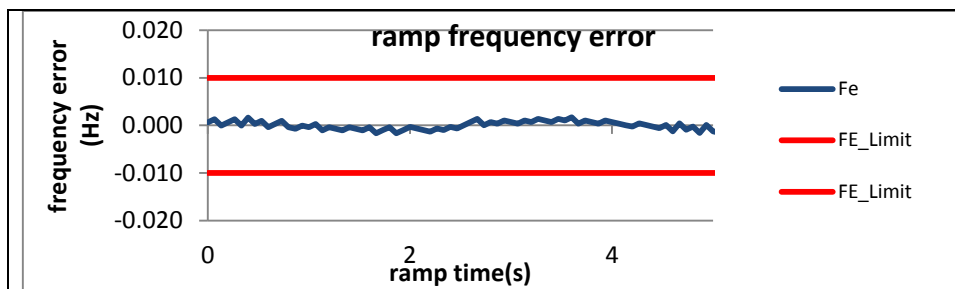


Figure 2427:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

Figure 2428:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.3.3 PMU B dynamic ramp of system frequency frequency error: M class

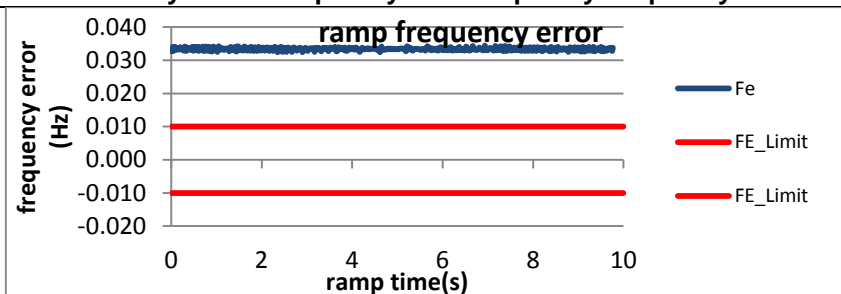


Figure 2429:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

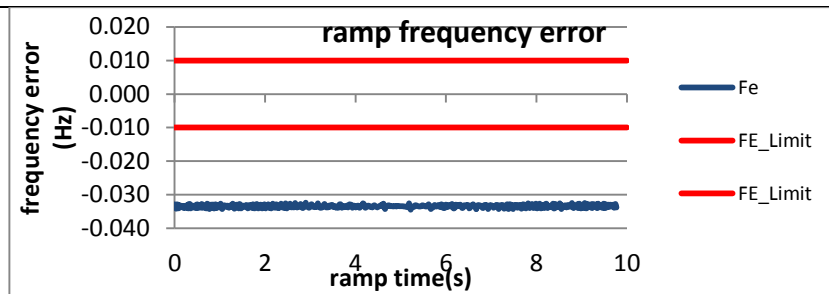


Figure 2430:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

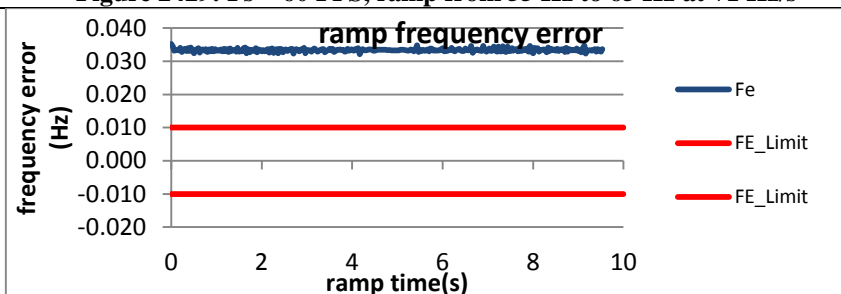


Figure 2431:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

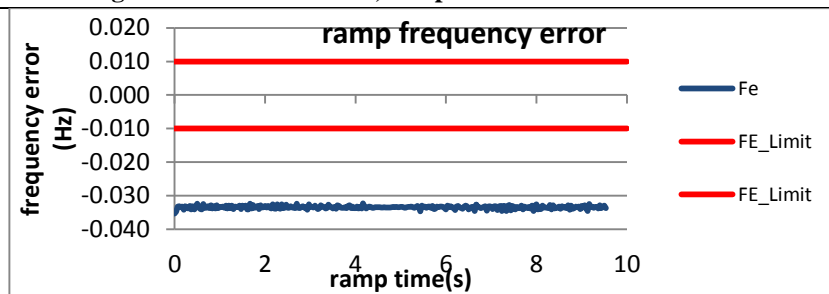


Figure 2432:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

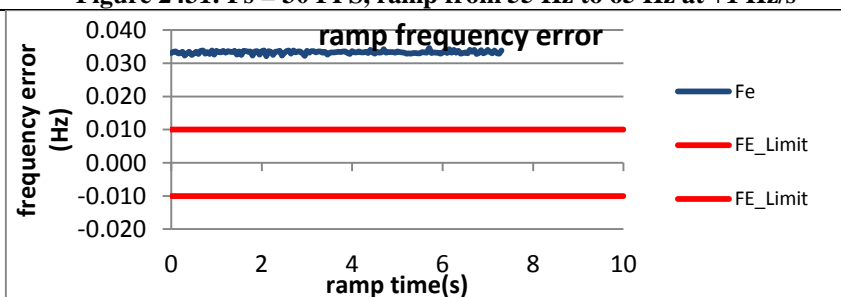


Figure 2433:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

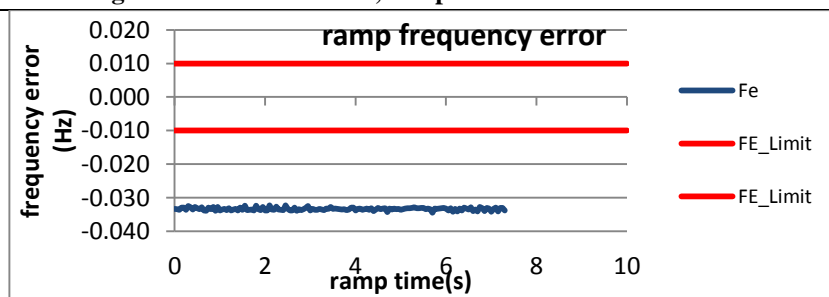


Figure 2434:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

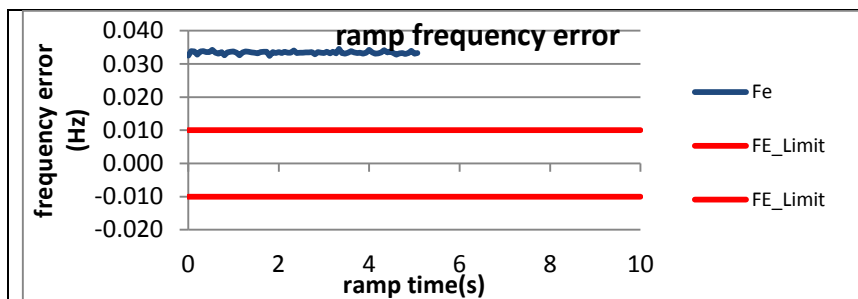


Figure 2435:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

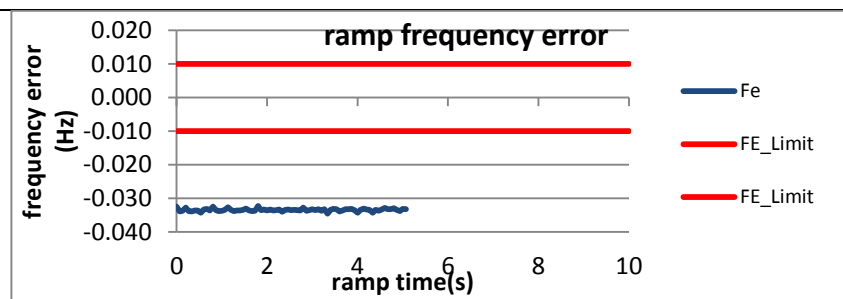


Figure 2436:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

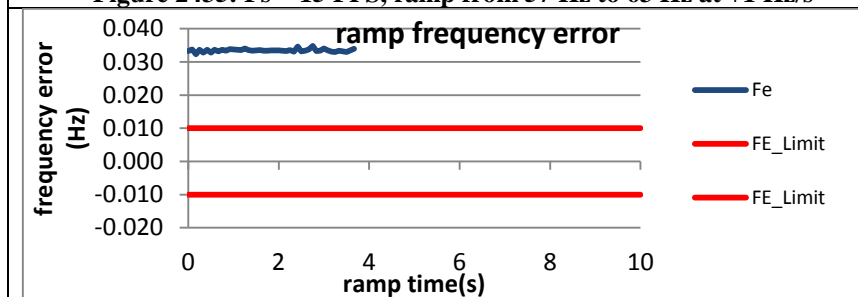


Figure 2437:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

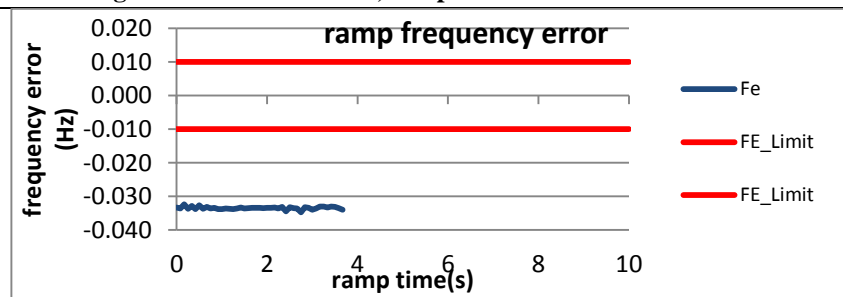


Figure 2438:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

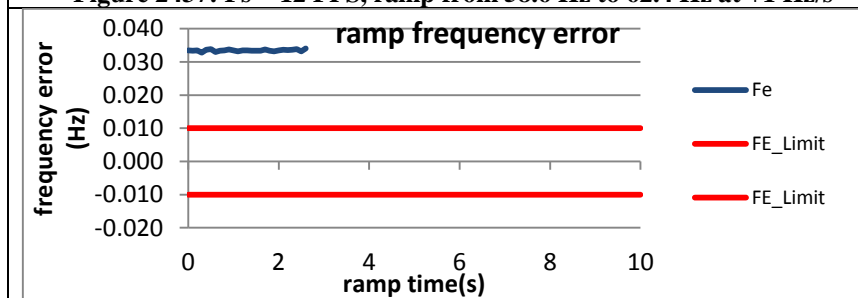


Figure 2439:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

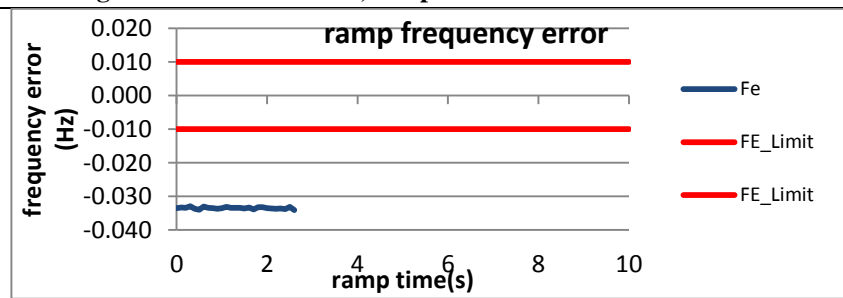


Figure 2440:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.3.4 PMU C dynamic ramp of system frequency frequency error: M class

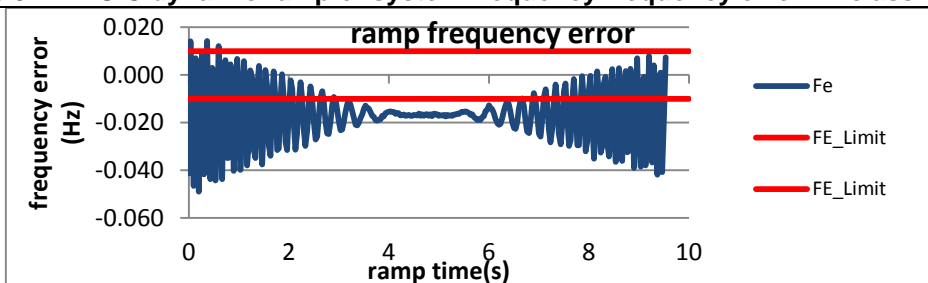


Figure 2441:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

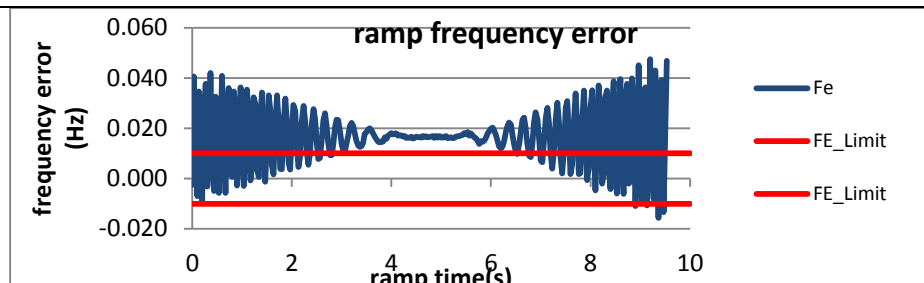


Figure 2442:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

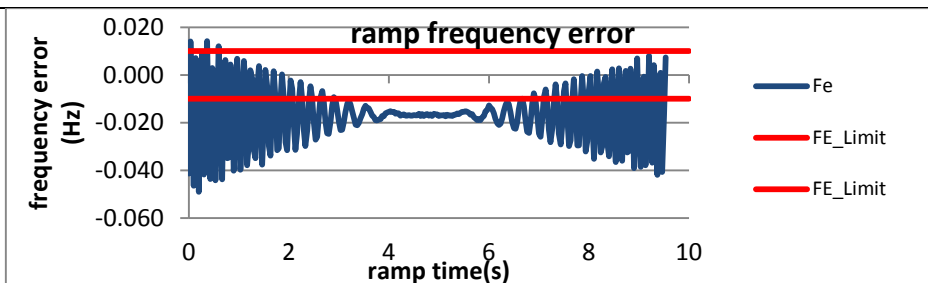


Figure 2443:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

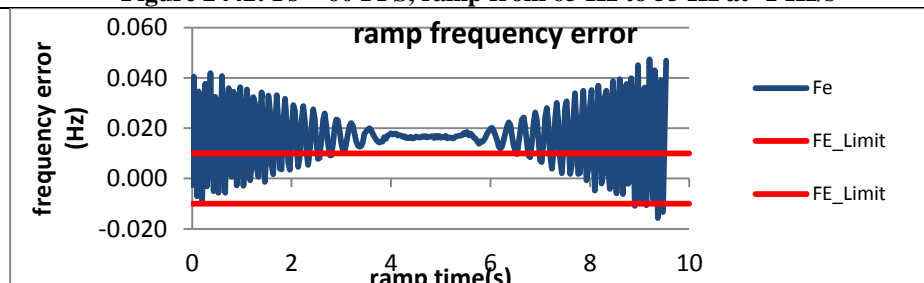


Figure 2444:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

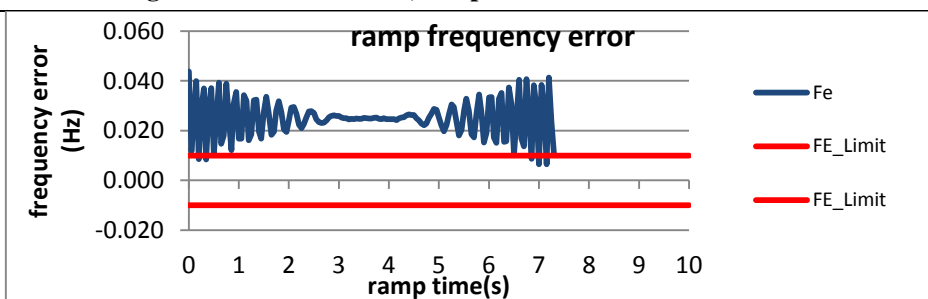


Figure 2445:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

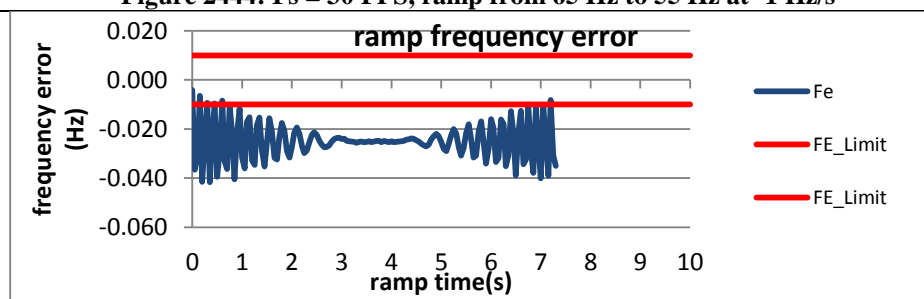
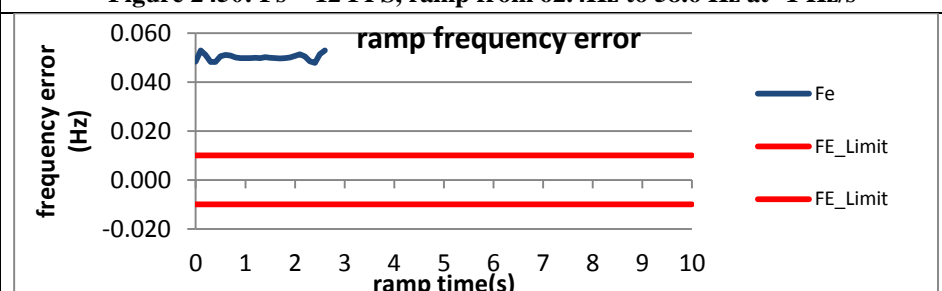
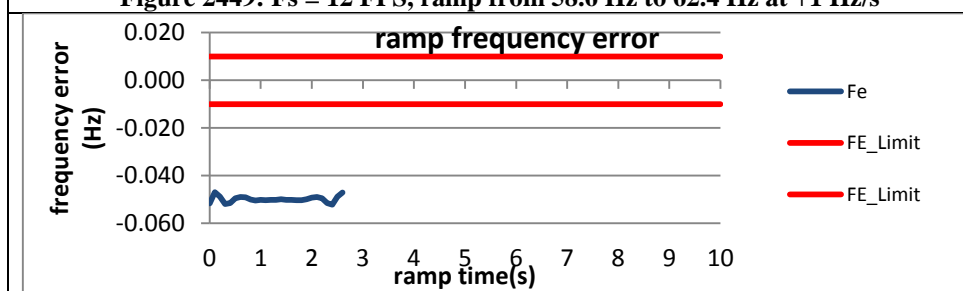
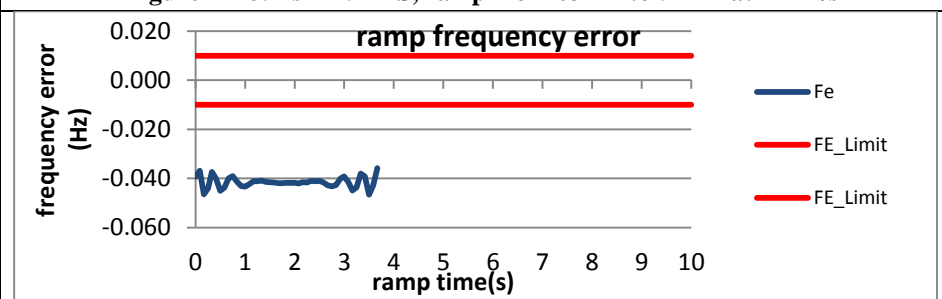
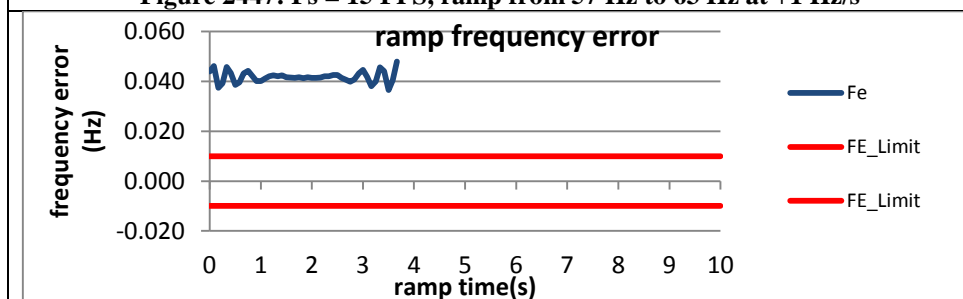
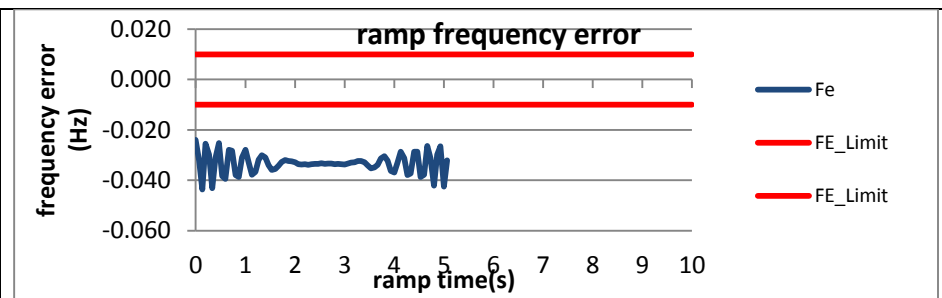
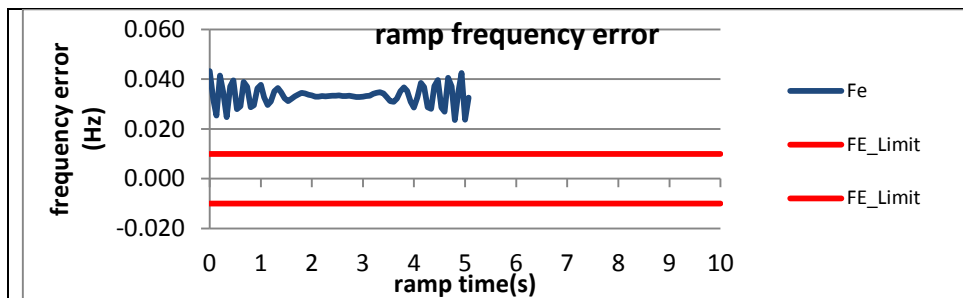
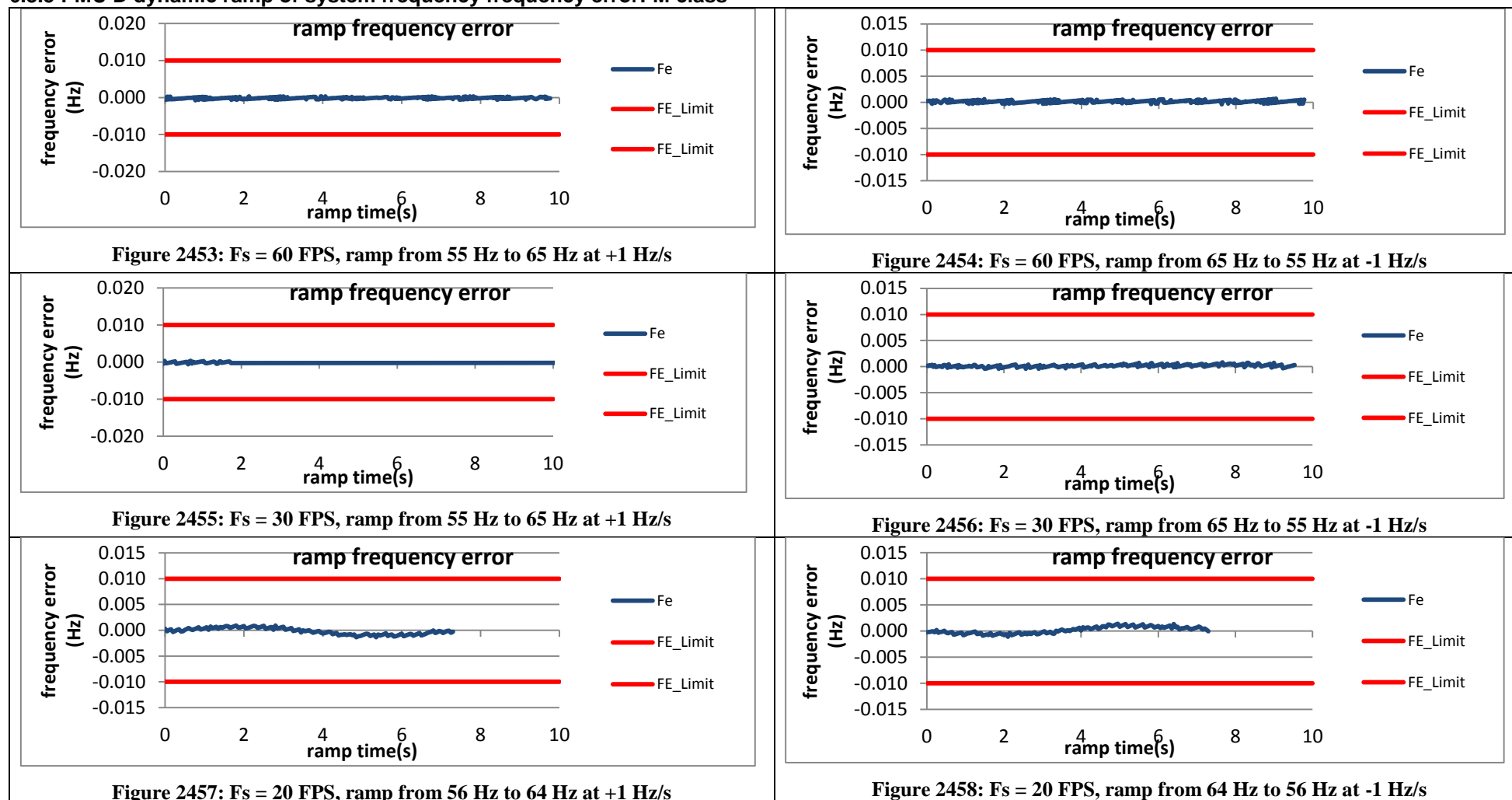


Figure 2446:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s





### 6.3.5 PMU D dynamic ramp of system frequency frequency error: M class



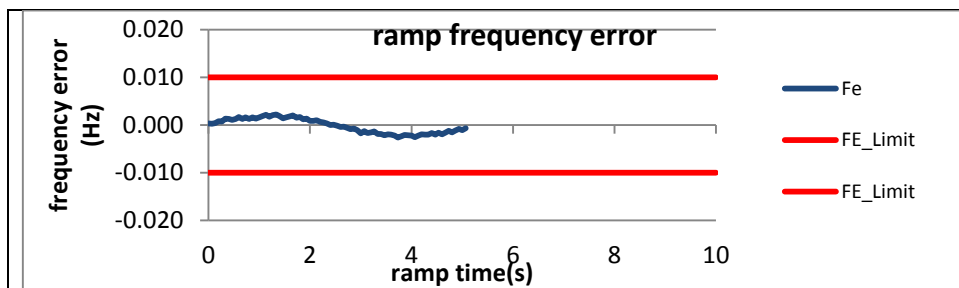


Figure 2459:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

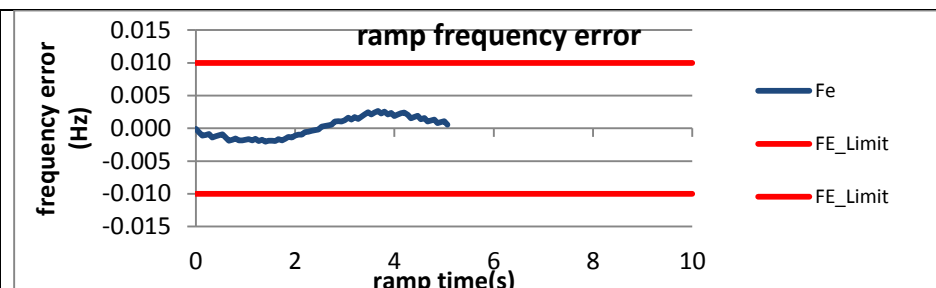


Figure 2460:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

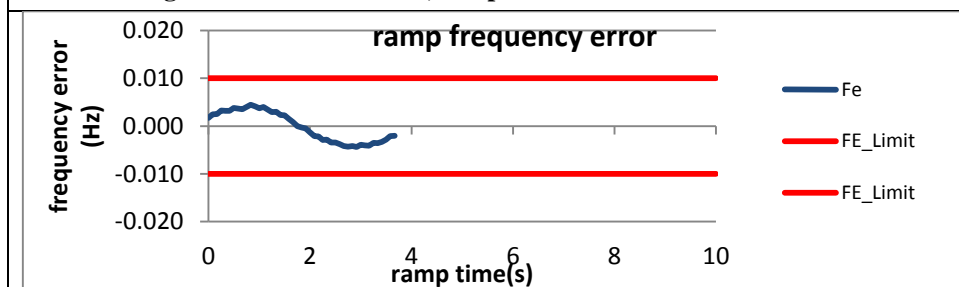


Figure 2461:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

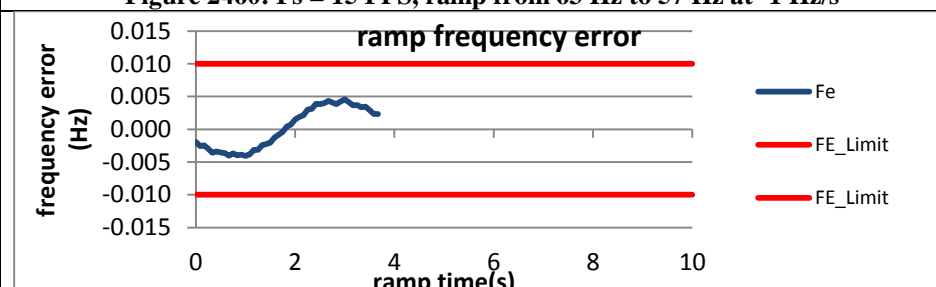


Figure 2462:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

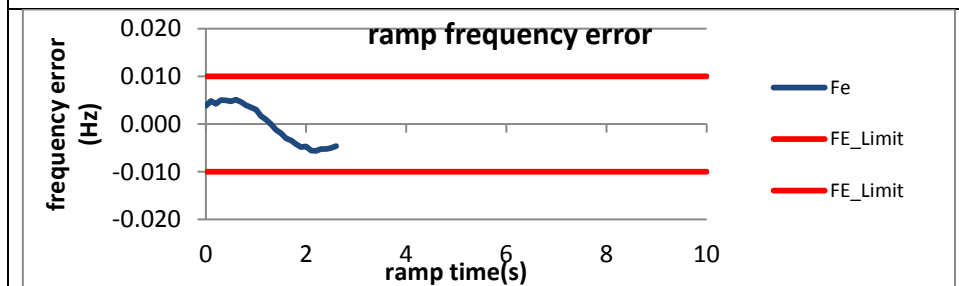


Figure 2463:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

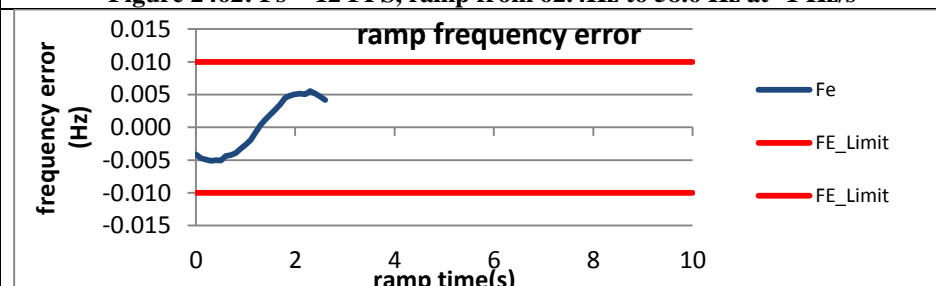


Figure 2464:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.3.6 PMU E dynamic ramp of system frequency frequency error: M class

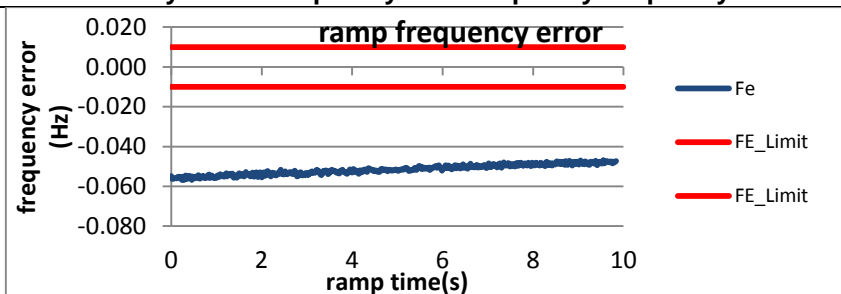


Figure 2465:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

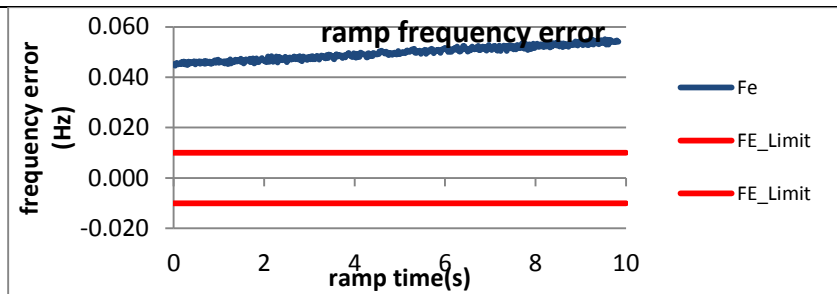


Figure 2466:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

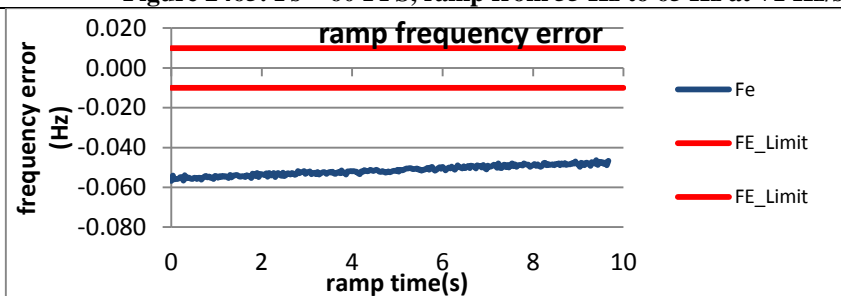


Figure 2467:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

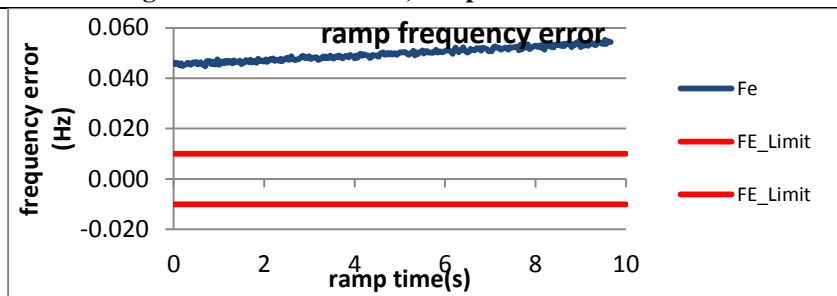


Figure 2468:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

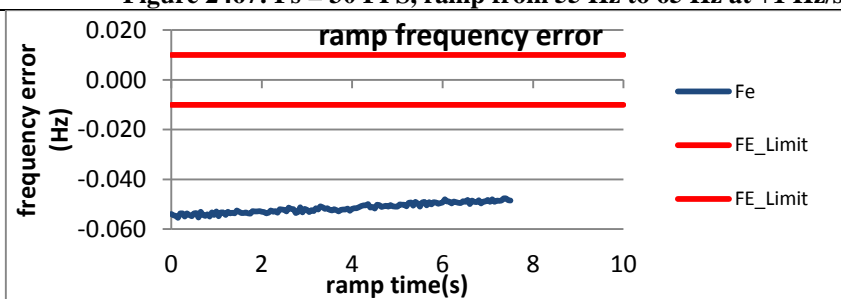


Figure 2469:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

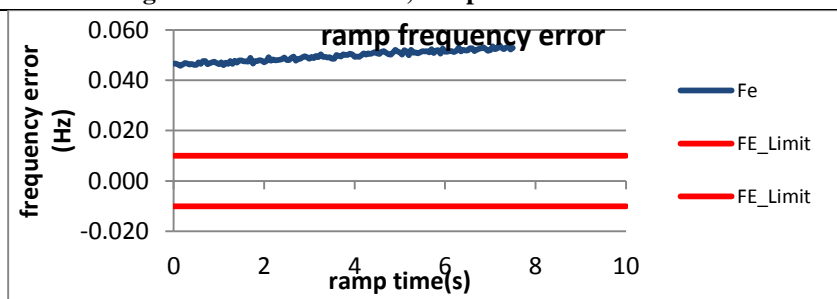


Figure 2470:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

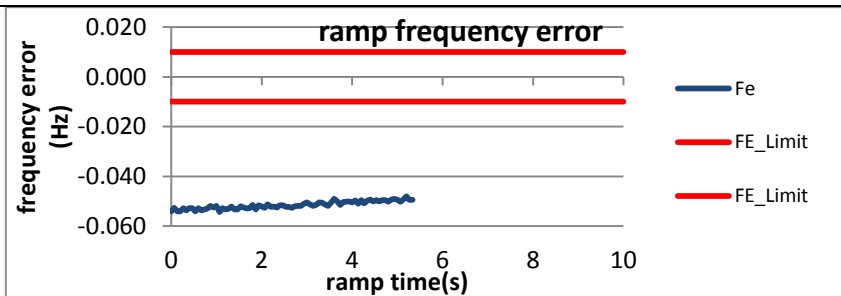


Figure 2471:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

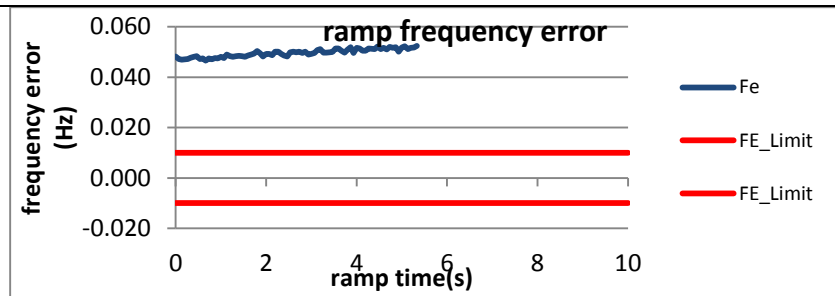


Figure 2472:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

Figure 2473:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

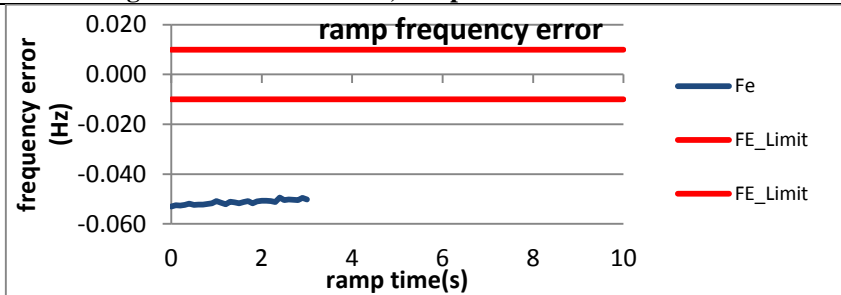


Figure 2475:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

Figure 2474:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

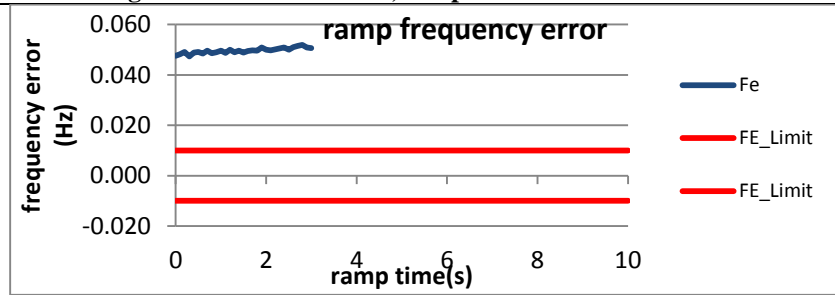


Figure 2476:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.3.7 PMU F dynamic ramp of system frequency frequency error: M class

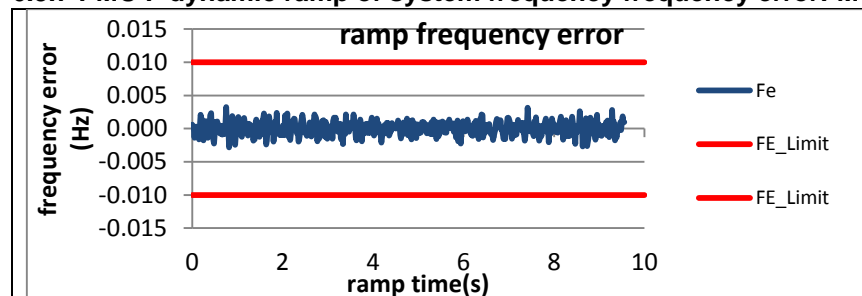


Figure 2477:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

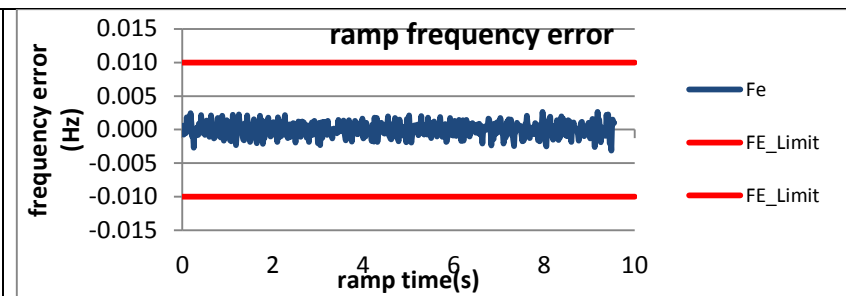


Figure 2478:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

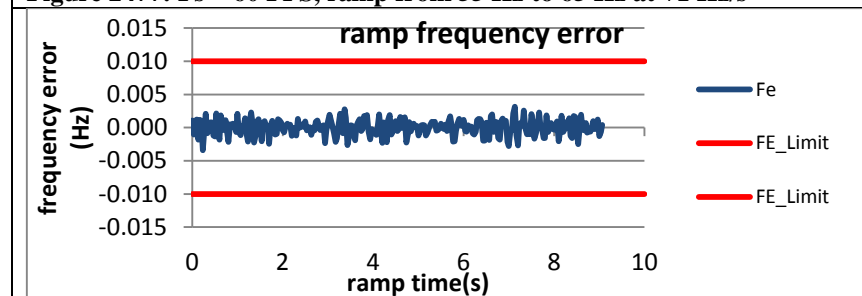


Figure 2479:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

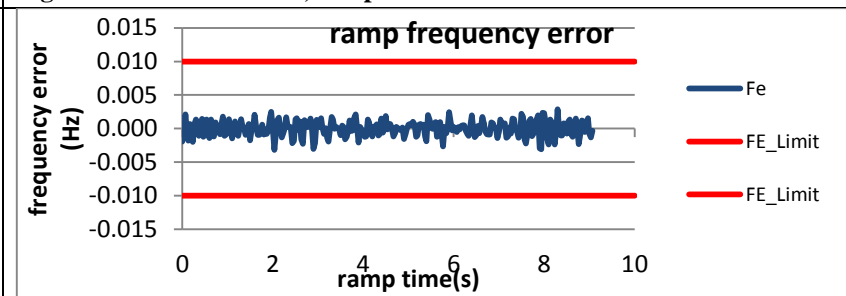


Figure 2480:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

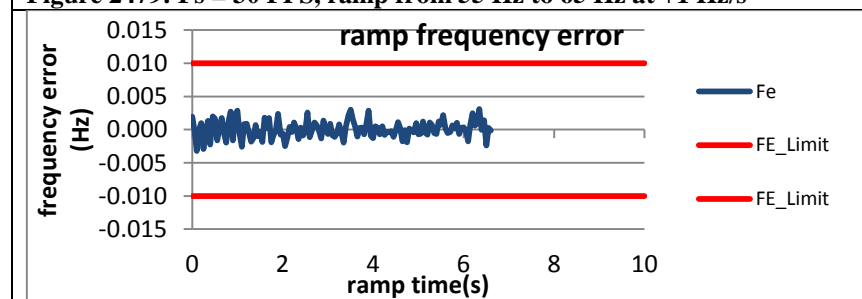


Figure 2481:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

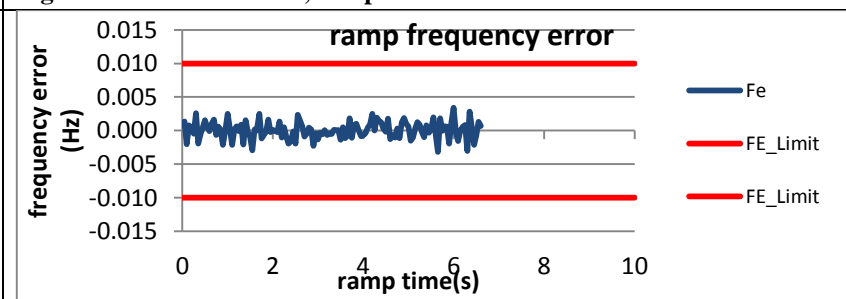


Figure 2482:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

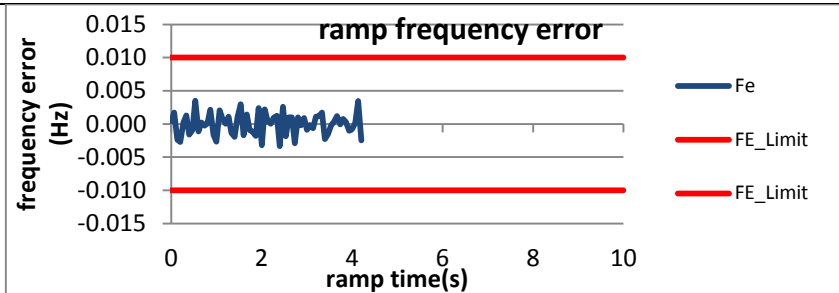


Figure 2483:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

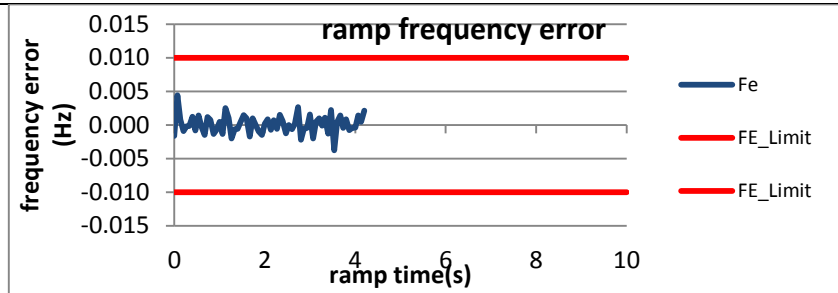


Figure 2484:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

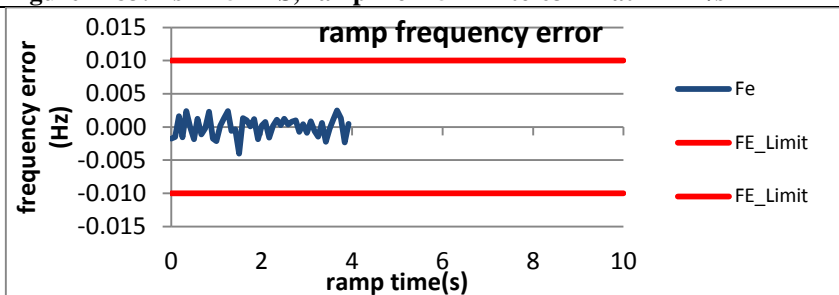


Figure 2485:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

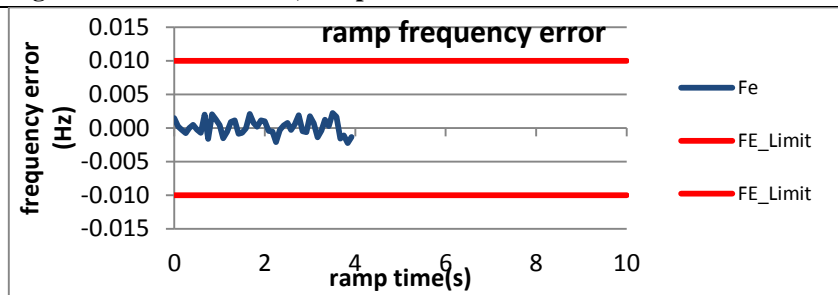


Figure 2486:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

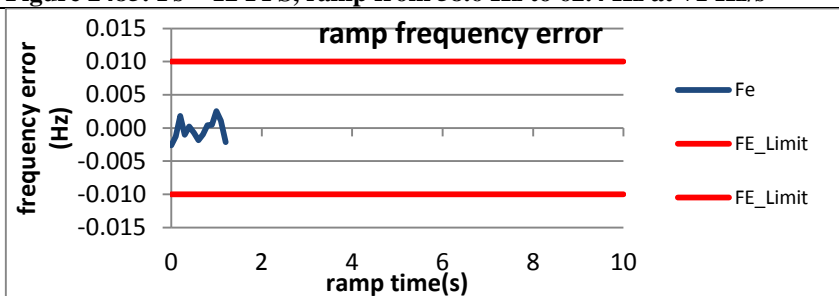


Figure 2487:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

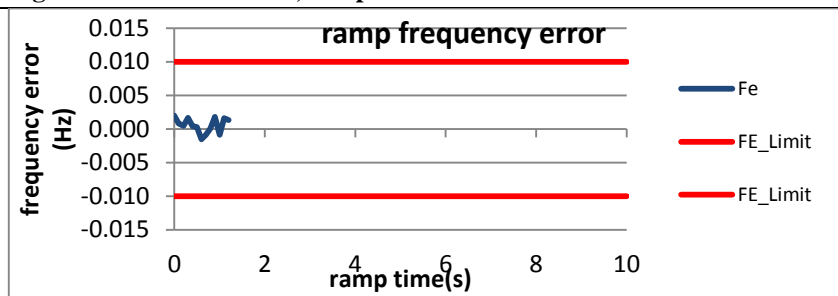


Figure 2488:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.3.8 PMU G dynamic ramp of system frequency frequency error: M class

Figure 2489:  $F_s = 60$  FPS is not supported by this PMU

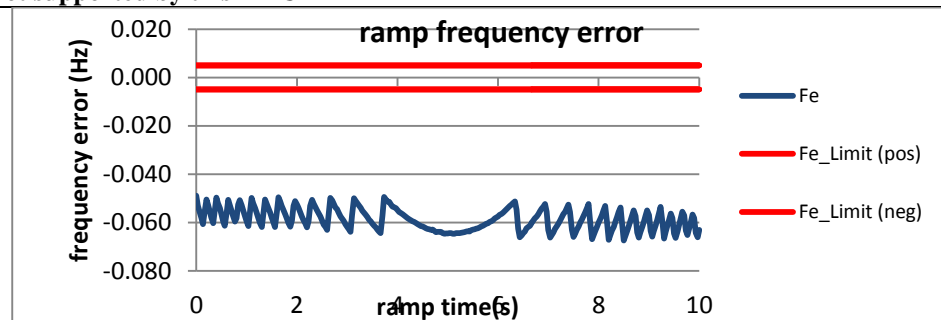
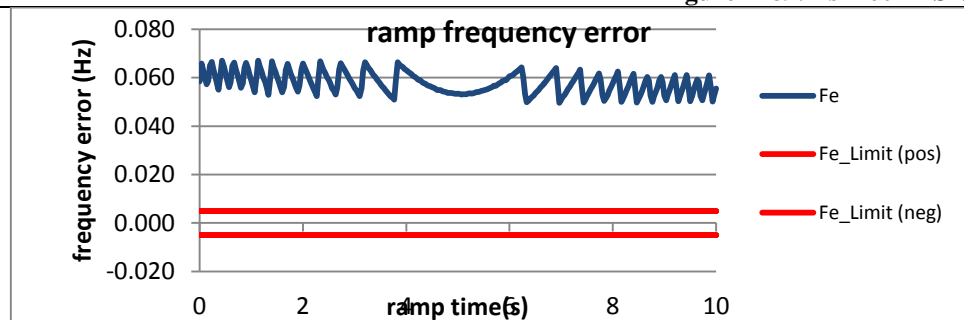


Figure 2490:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

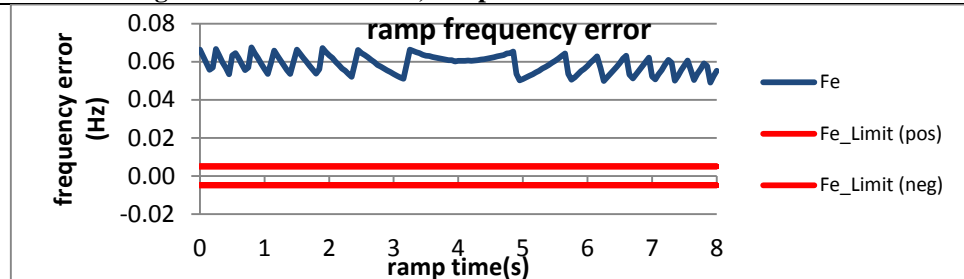


Figure 2491:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

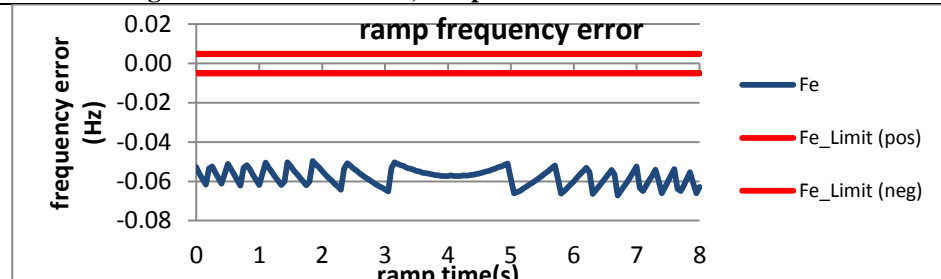


Figure 2492:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

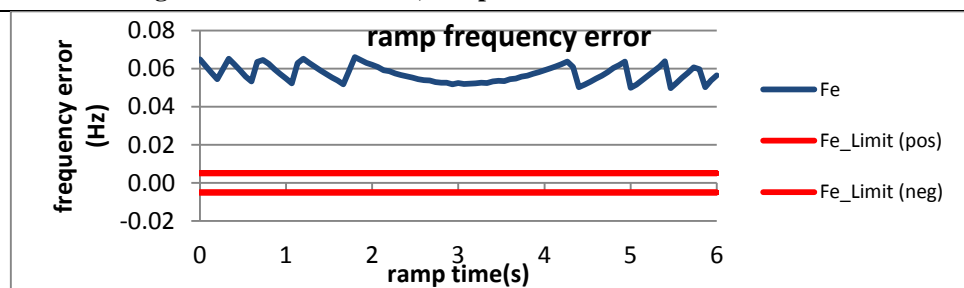


Figure 2493:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

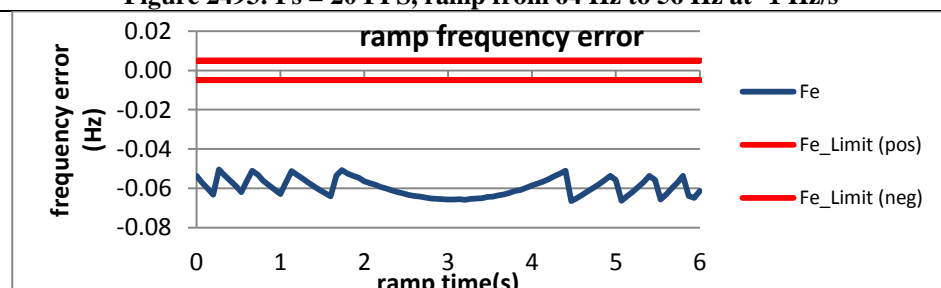


Figure 2494:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

Figure 2495:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s





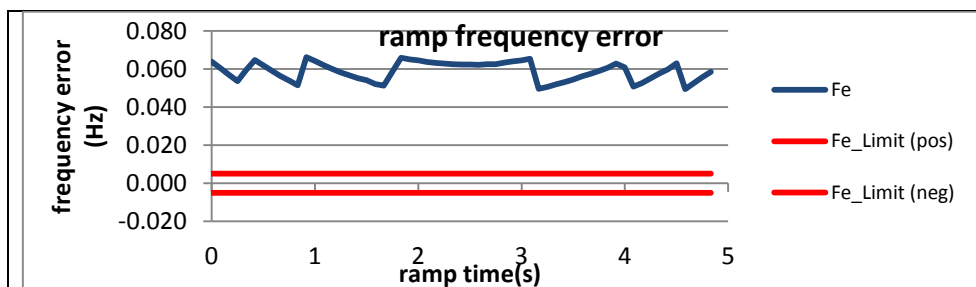


Figure 2496:  $F_s = 12$  FPS, ramp from 57.6 Hz to 62.4 Hz at +1 Hz/s

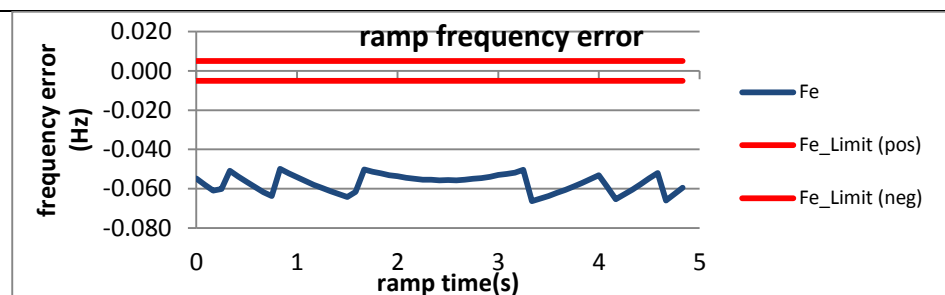


Figure 2497:  $F_s = 12$  FPS, ramp from 62.4 Hz to 57.6 Hz at -1 Hz/s

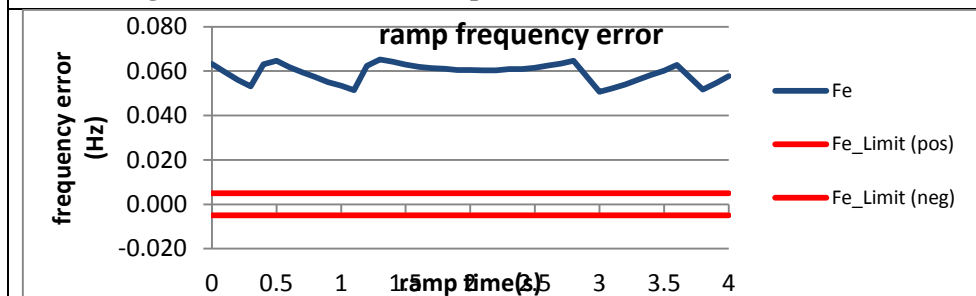


Figure 2498:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

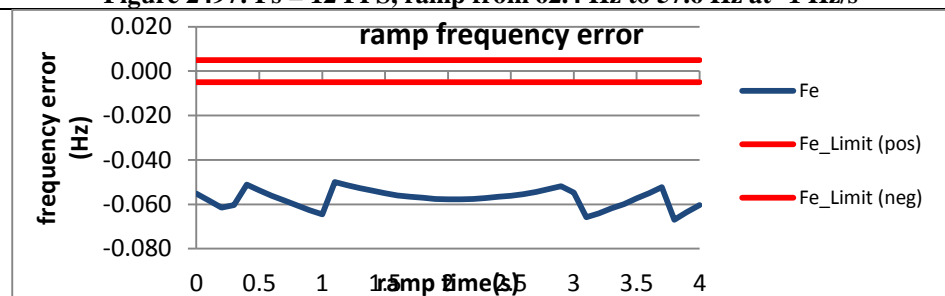


Figure 2499:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.3.9 PMU H dynamic ramp of system frequency frequency error: M class

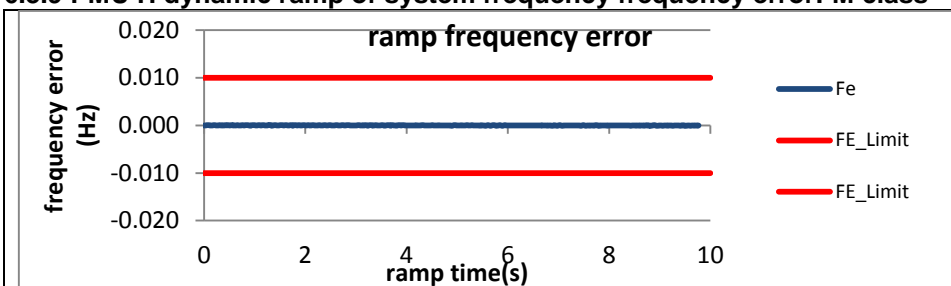


Figure 2500:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

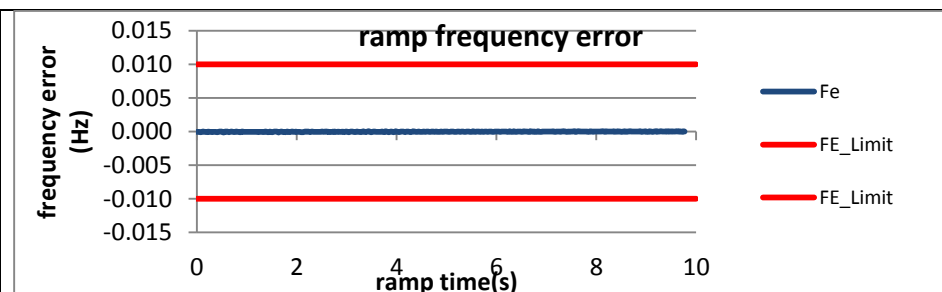


Figure 2501:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

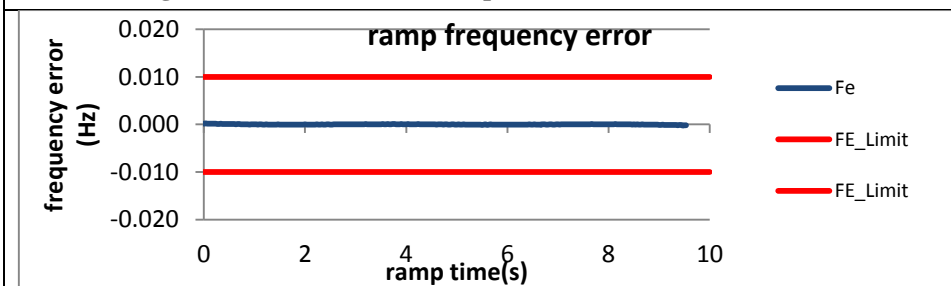


Figure 2502:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

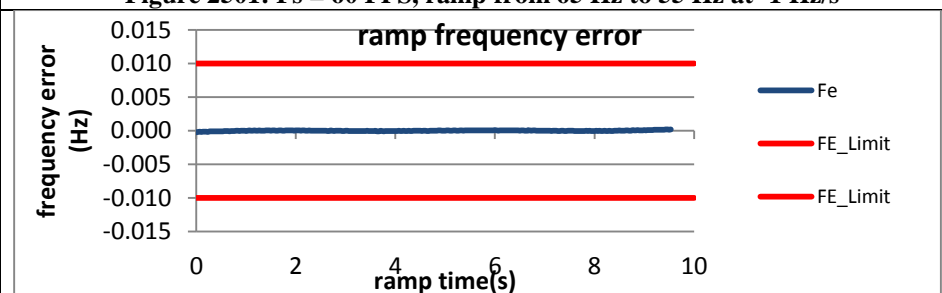


Figure 2503:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

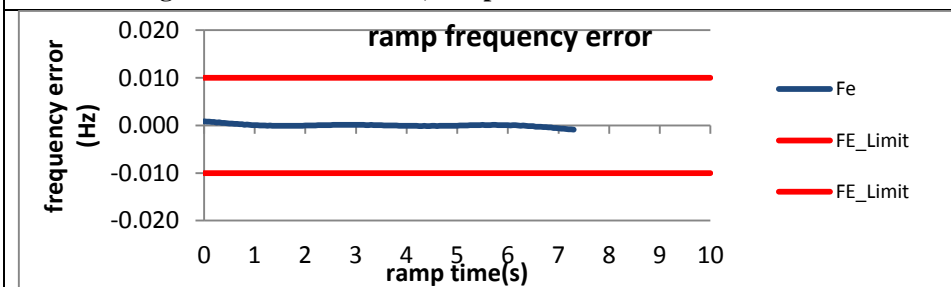


Figure 2504:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

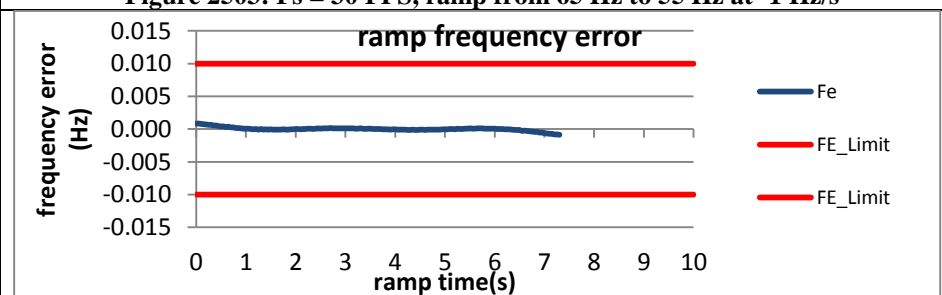


Figure 2505:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

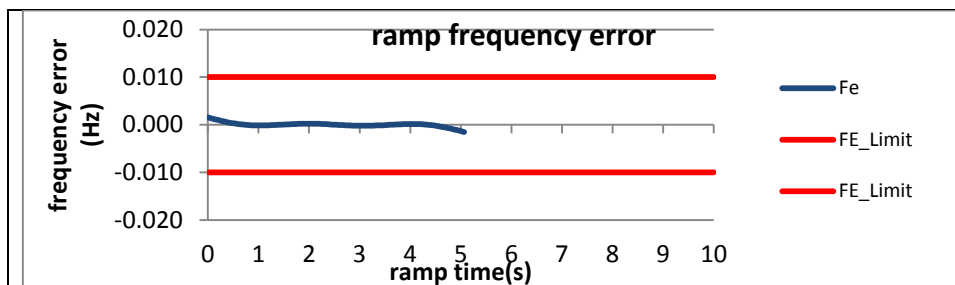


Figure 2506:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

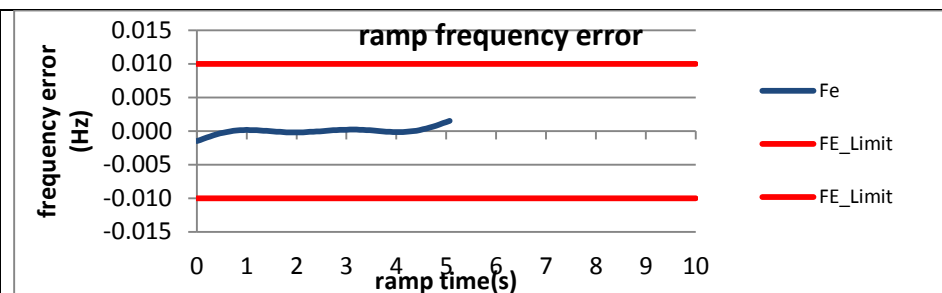


Figure 2507:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

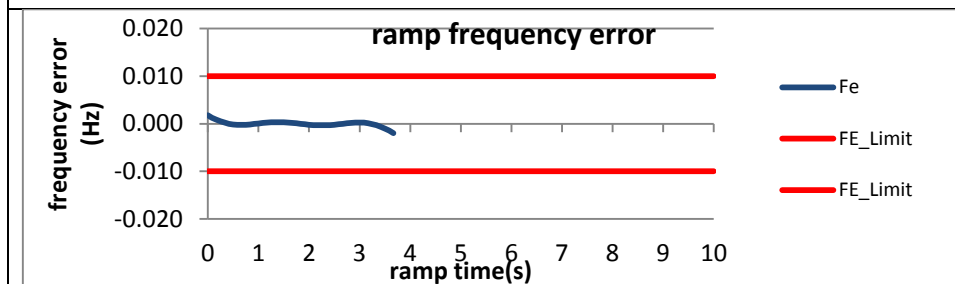


Figure 2508:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

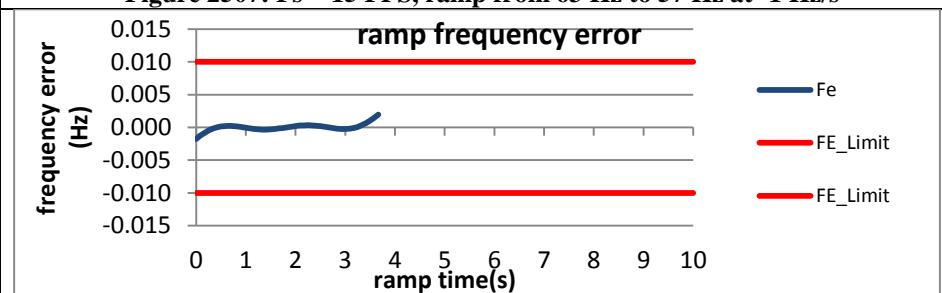


Figure 2509:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

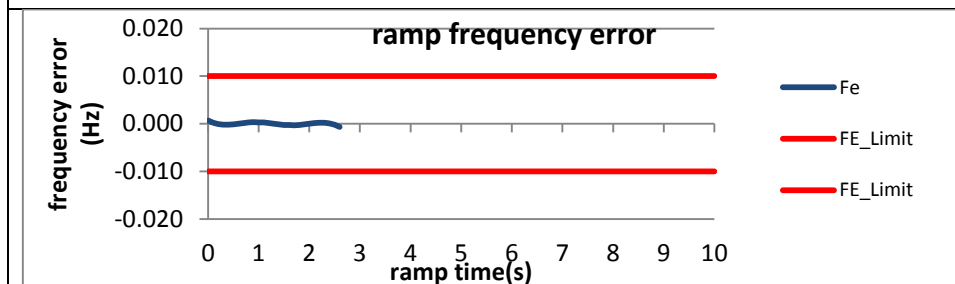


Figure 2510:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

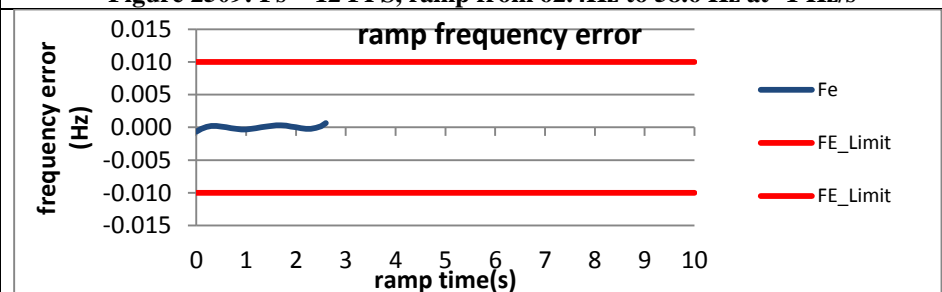


Figure 2511:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.3.10 PMU I dynamic ramp of system frequency frequency error: M class

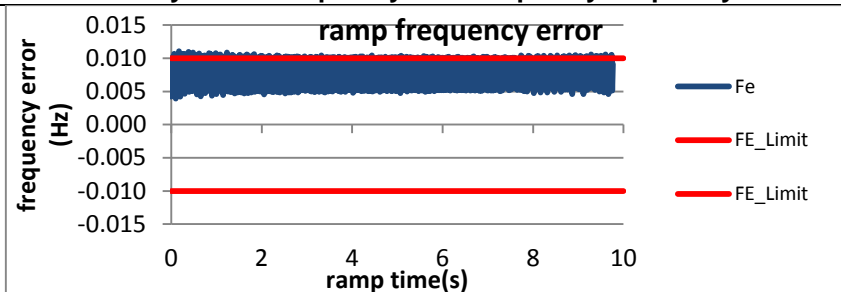


Figure 2512:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

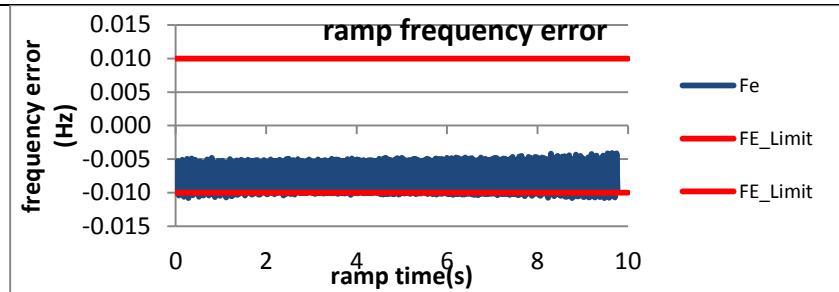


Figure 2513:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

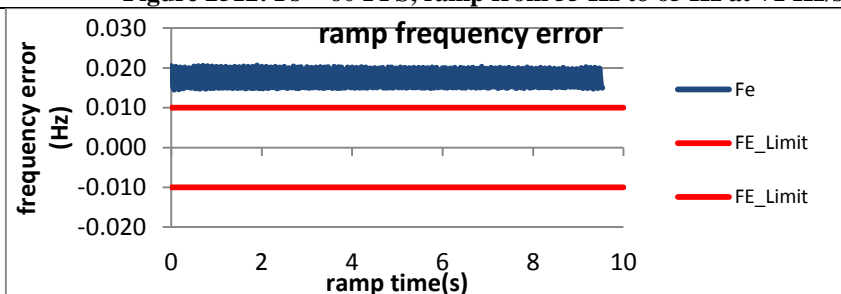


Figure 2514:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

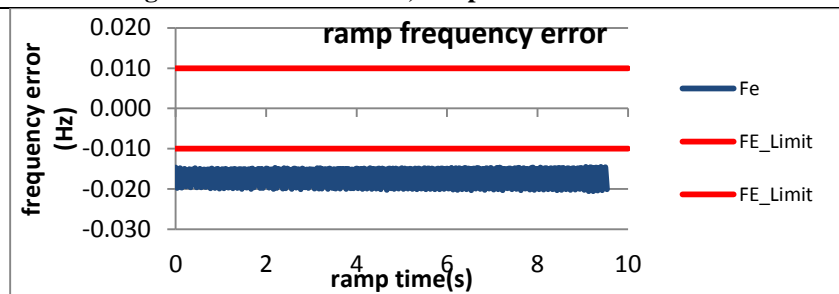


Figure 2515:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

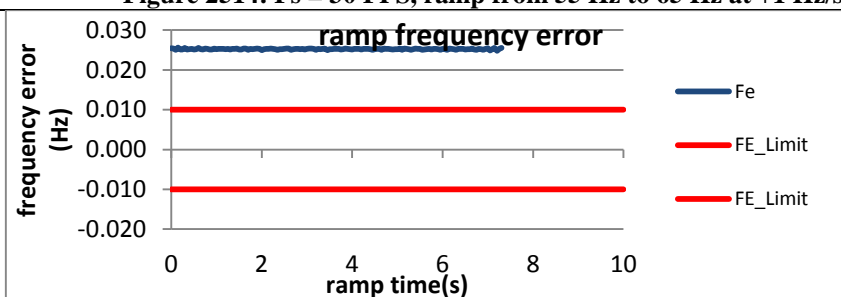


Figure 2516:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

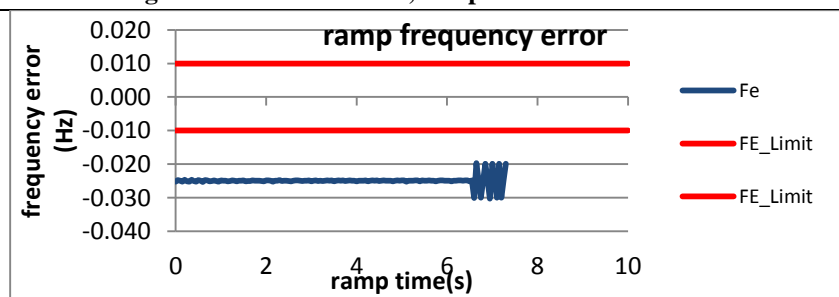


Figure 2517:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

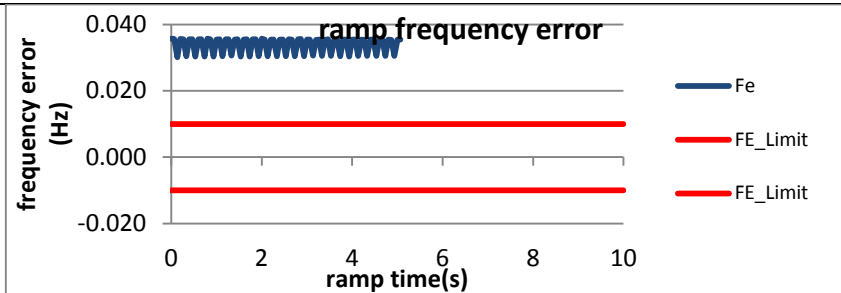


Figure 2518:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

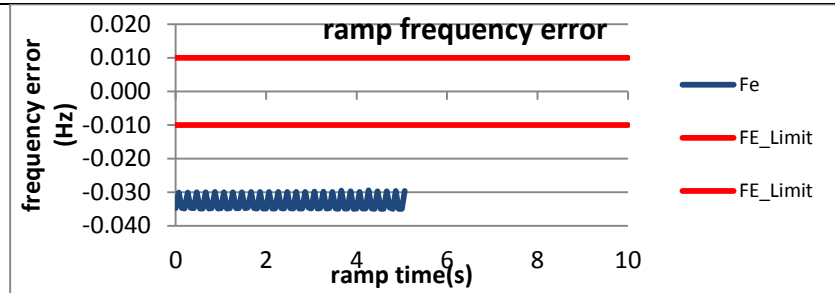


Figure 2519:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

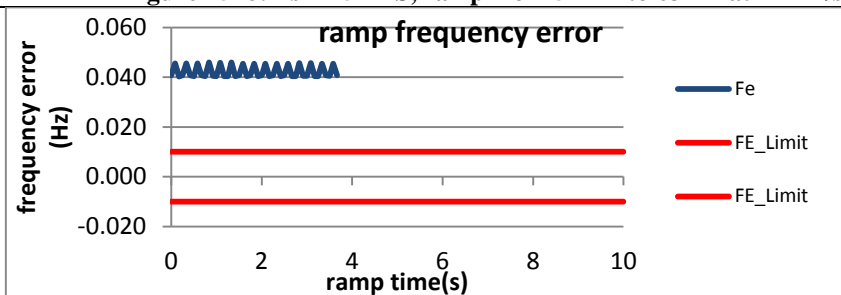


Figure 2520:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

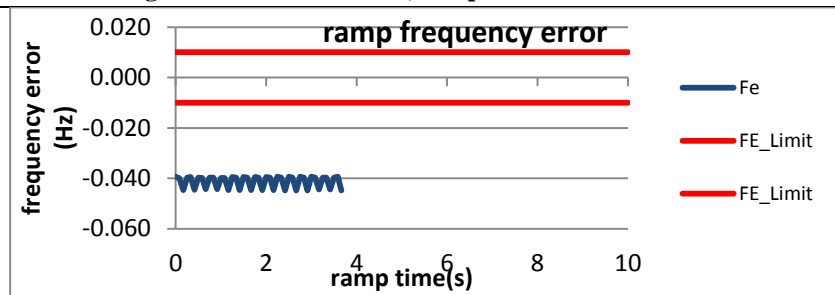


Figure 2521:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

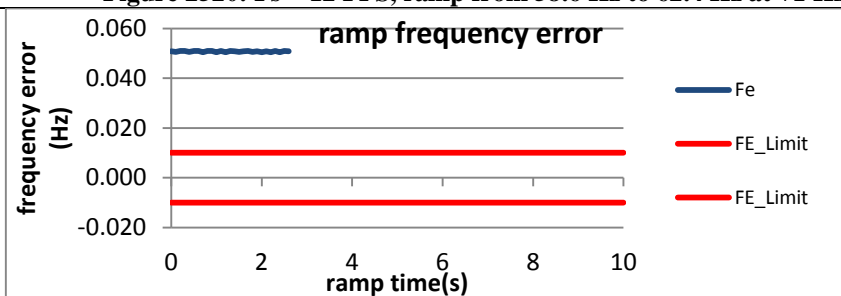


Figure 2522:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

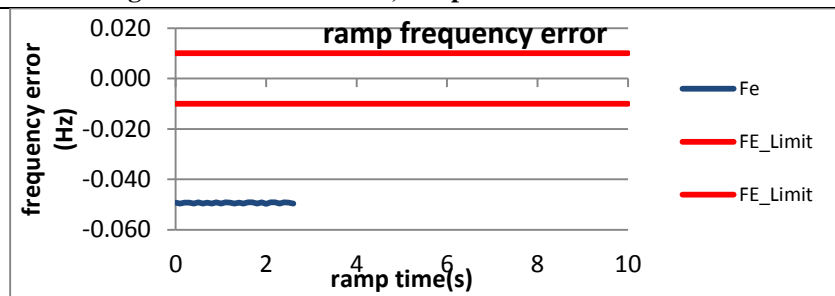


Figure 2523:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.3.11 PMU J dynamic ramp of system frequency frequency error: M class

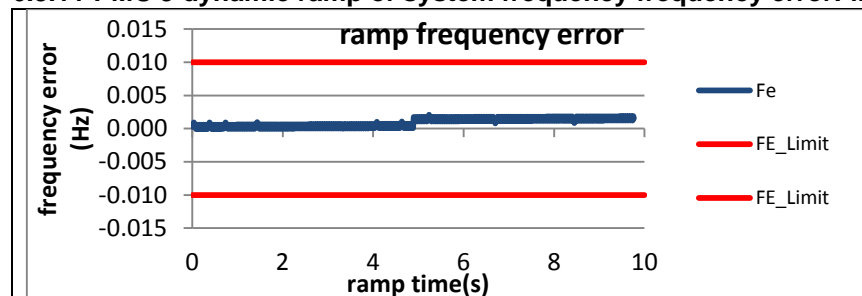


Figure 2524:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

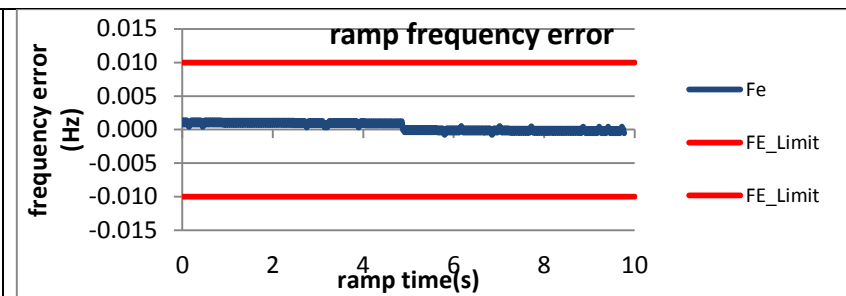


Figure 2525:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

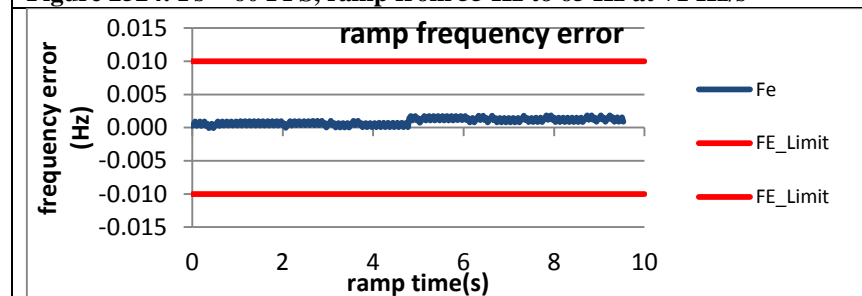


Figure 2526:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

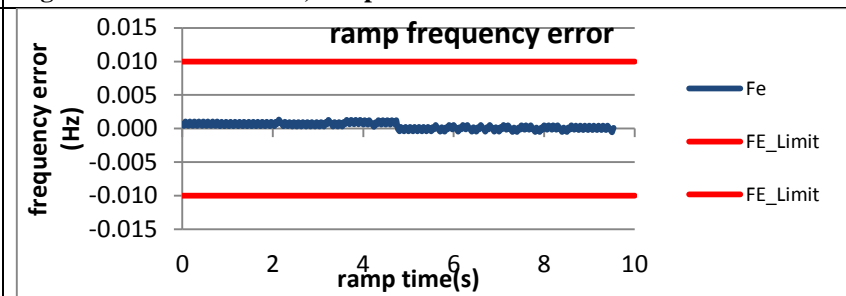


Figure 2527:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

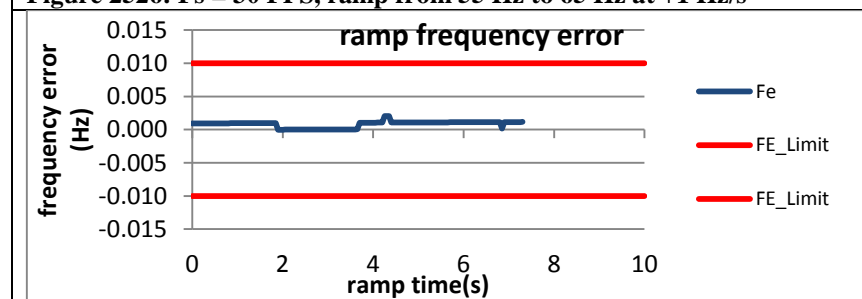


Figure 2528:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

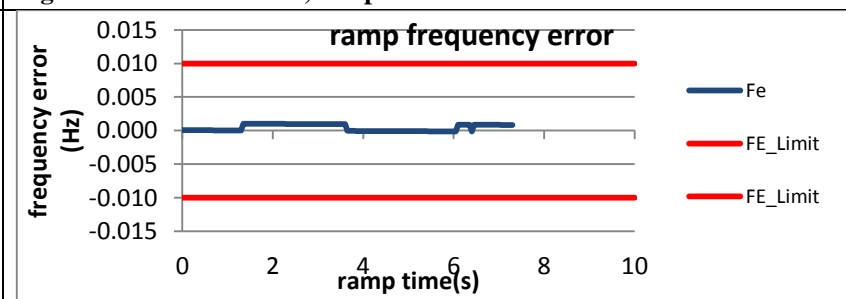


Figure 2529:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

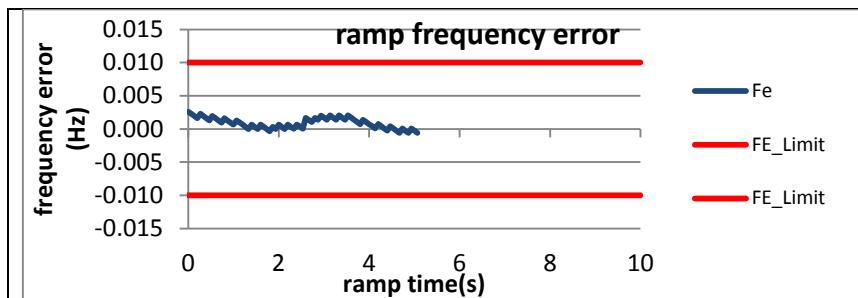


Figure 2530:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

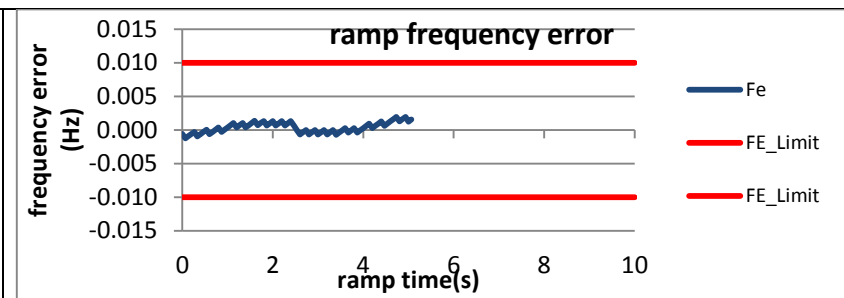


Figure 2531:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

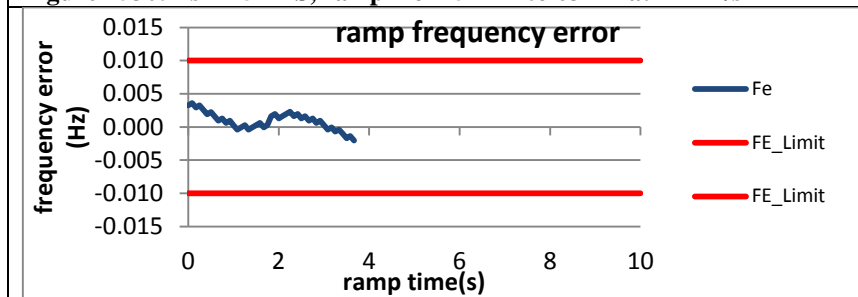


Figure 2532:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

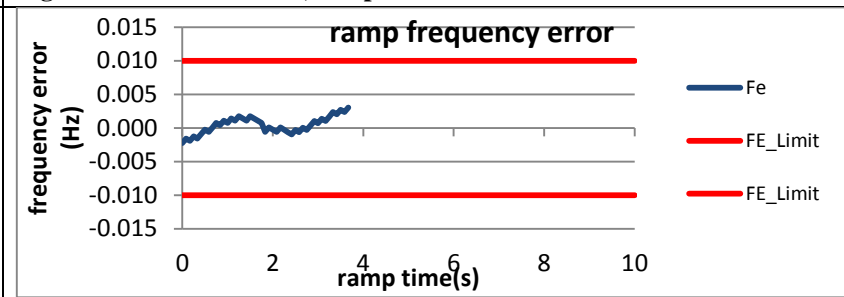


Figure 2533:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

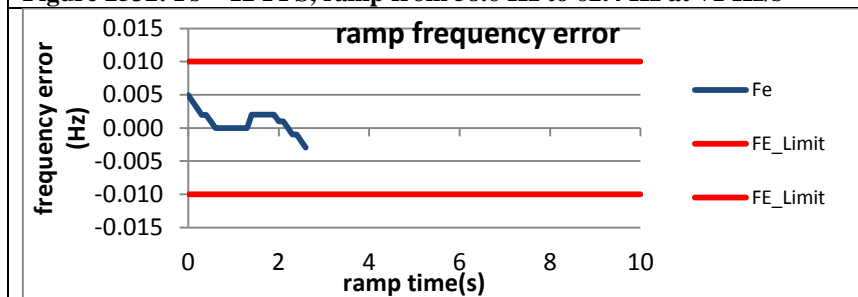


Figure 2534:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

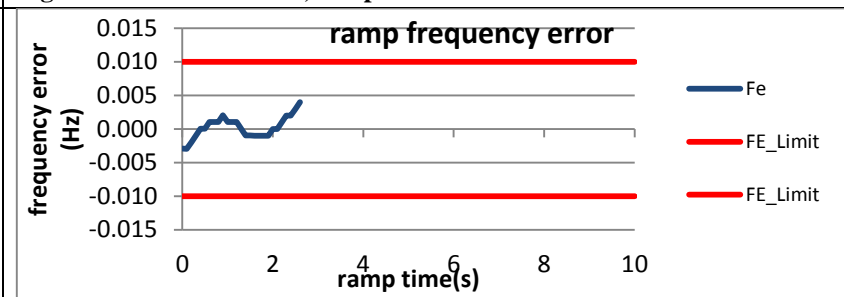


Figure 2535:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.4 Dynamic ramp of system frequency ROCOF error

### 6.4.1 C37.118.1 Annex C dynamic ramp of system frequency ROCOF error: M class

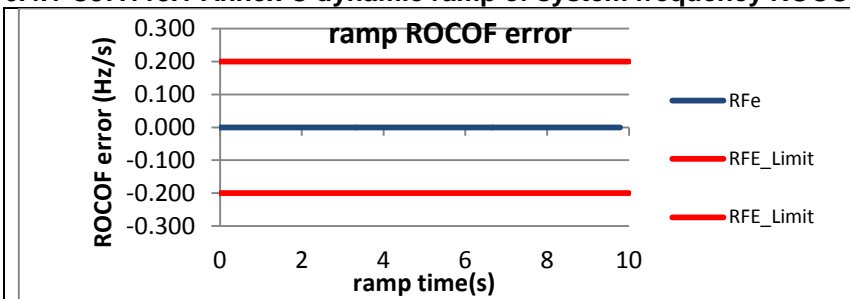


Figure 2536:  $F_s = 60$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

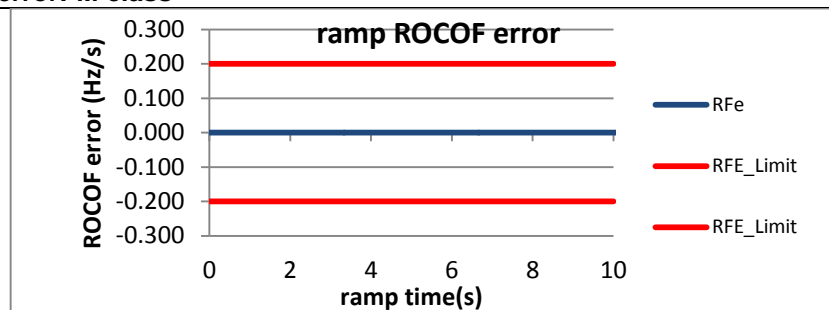


Figure 2537:  $F_s = 60$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

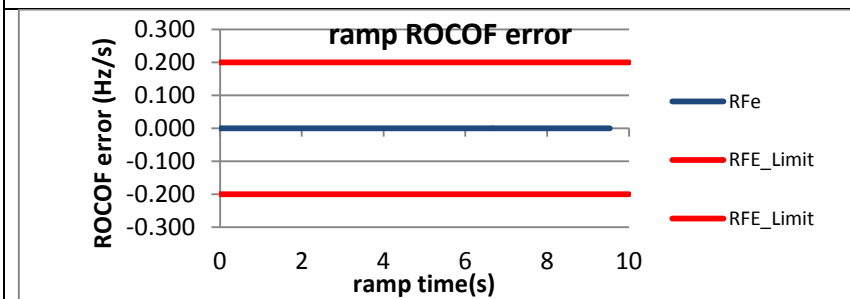


Figure 2538:  $F_s = 30$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

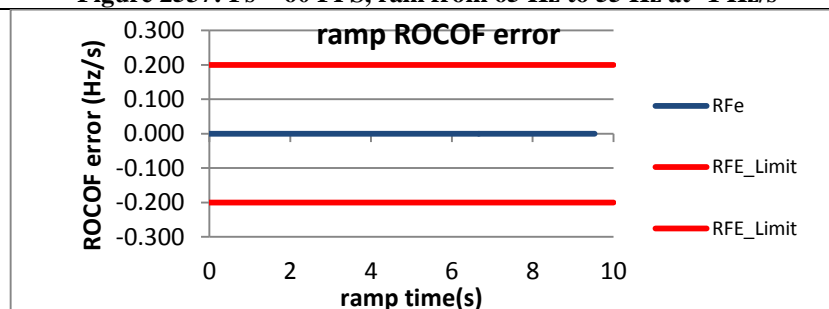


Figure 2539:  $F_s = 30$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

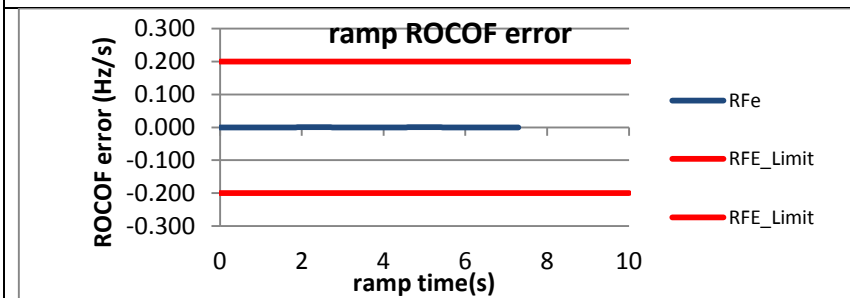


Figure 2540:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

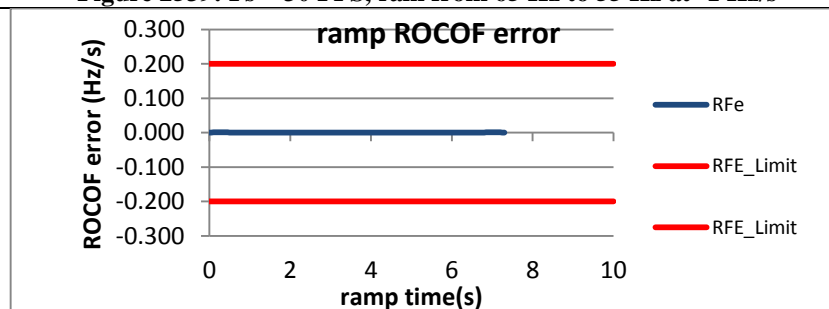


Figure 2541:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at =1 Hz/s



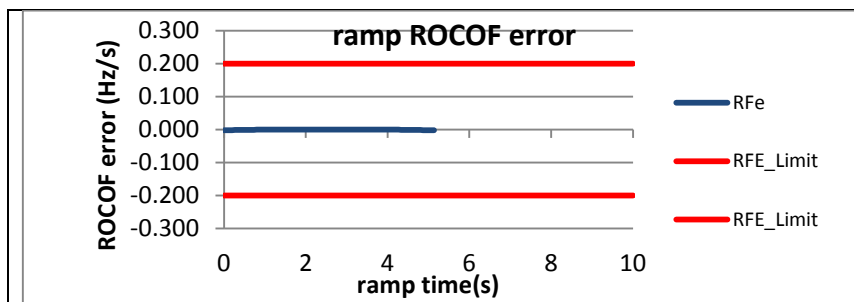


Figure 2542:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

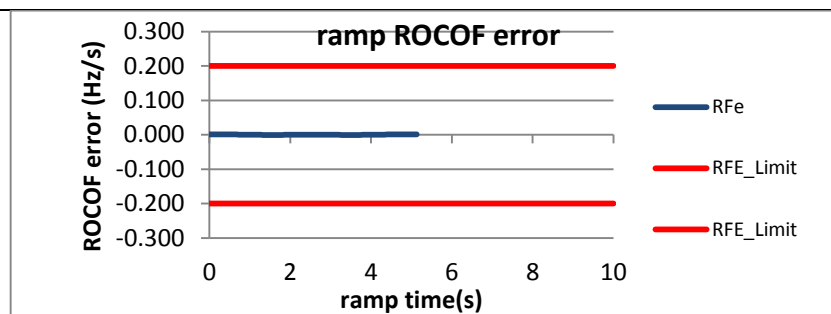


Figure 2543:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

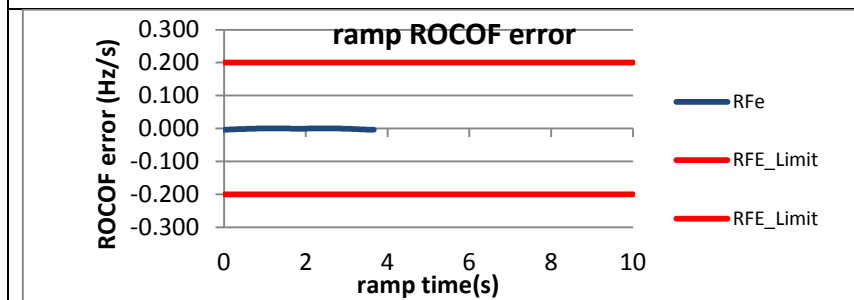


Figure 2544:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

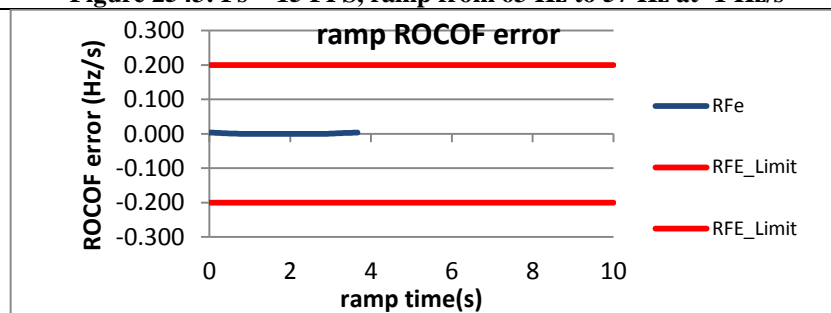


Figure 2545:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

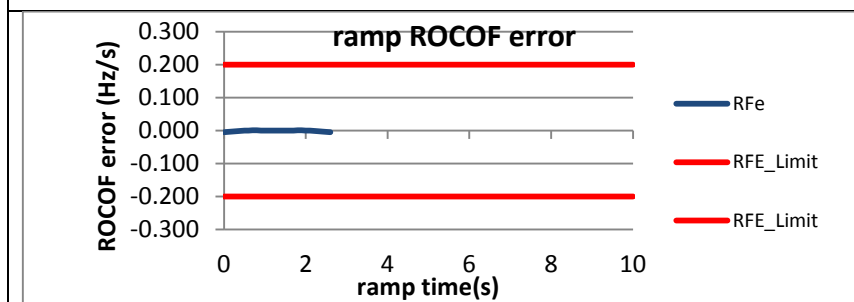


Figure 2546:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

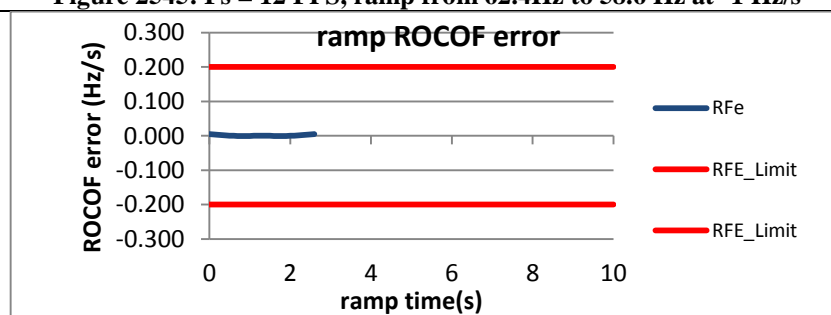


Figure 2547:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.4.2 PMU A dynamic ramp of system frequency ROCOF error: M class

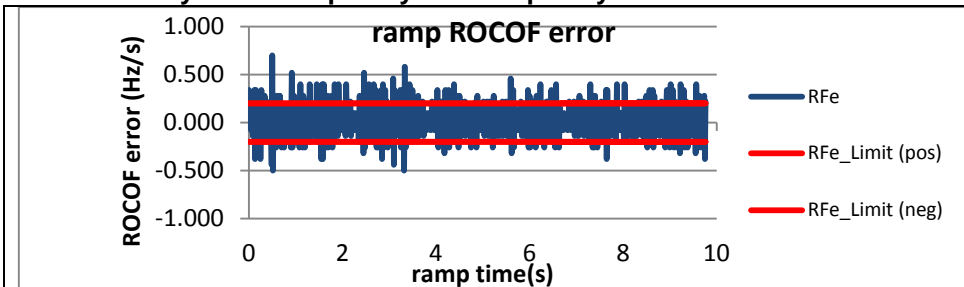


Figure 2548:  $F_s = 60$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

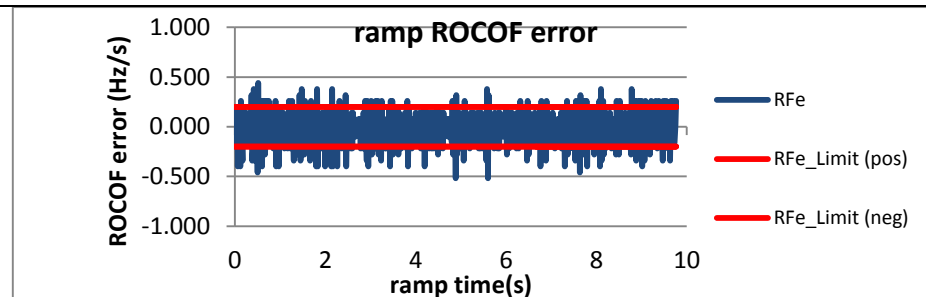


Figure 2549:  $F_s = 60$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

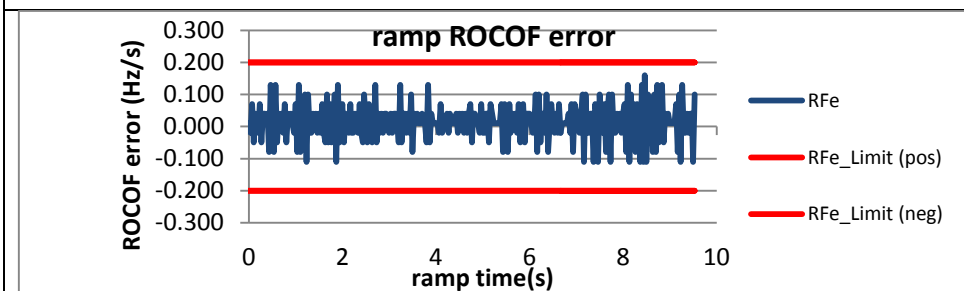


Figure 2550:  $F_s = 30$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

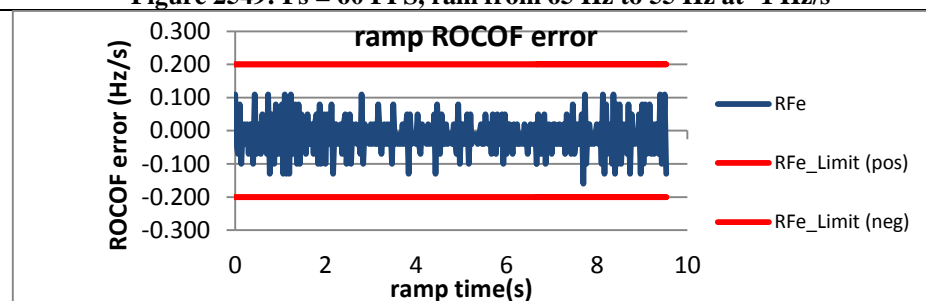


Figure 2551:  $F_s = 30$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

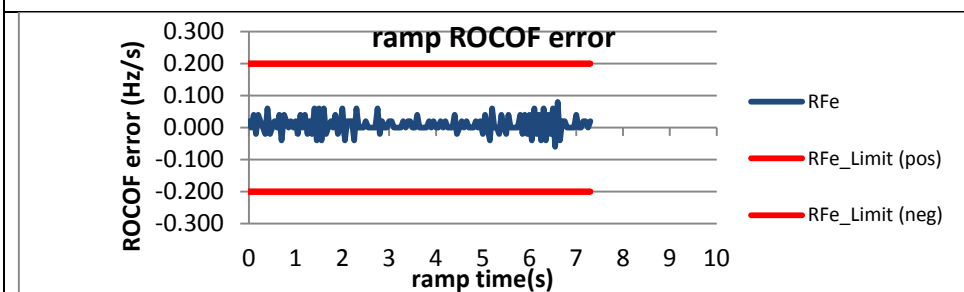


Figure 2552:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

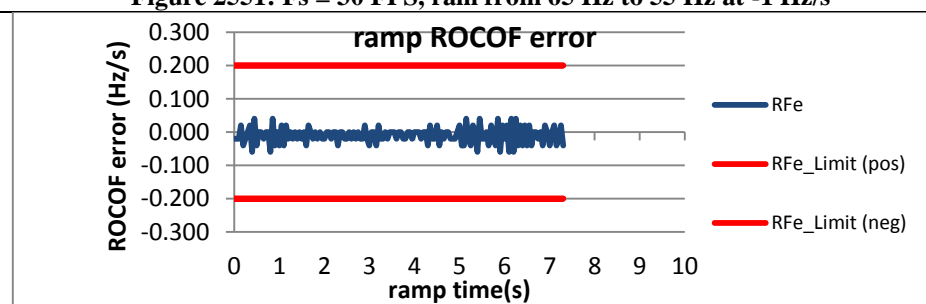


Figure 2553:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at =1 Hz/s

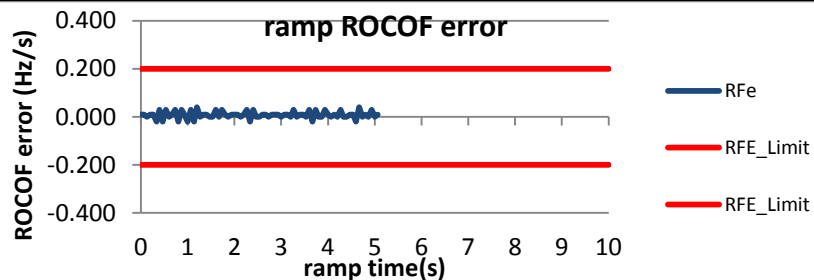


Figure 2554:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

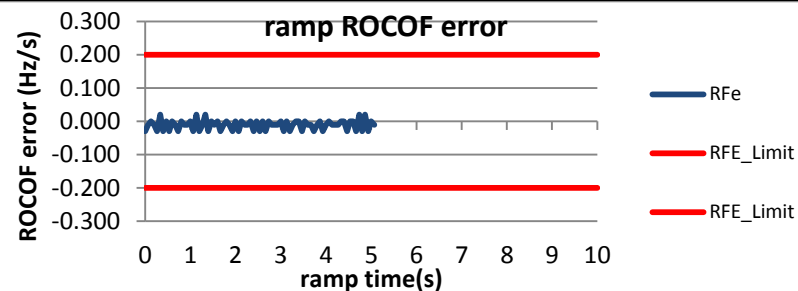


Figure 2555:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

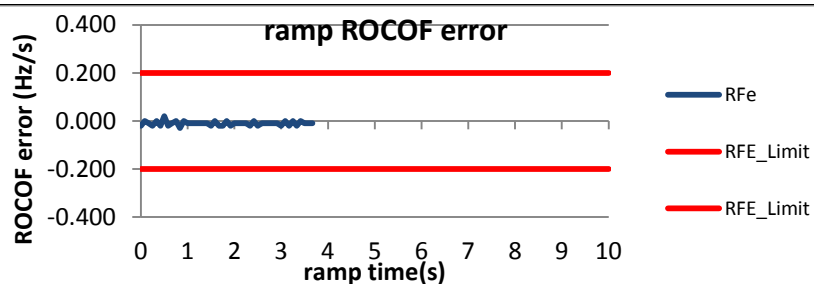


Figure 2556:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

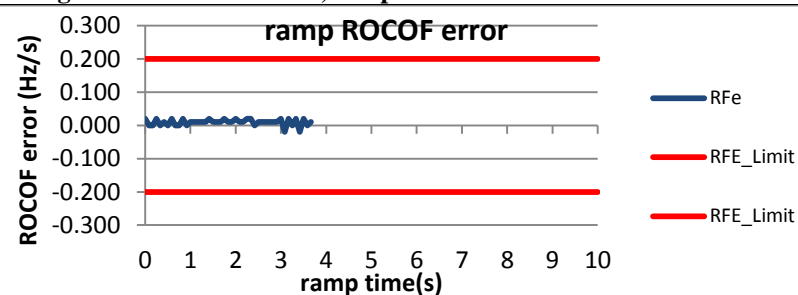


Figure 2557:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

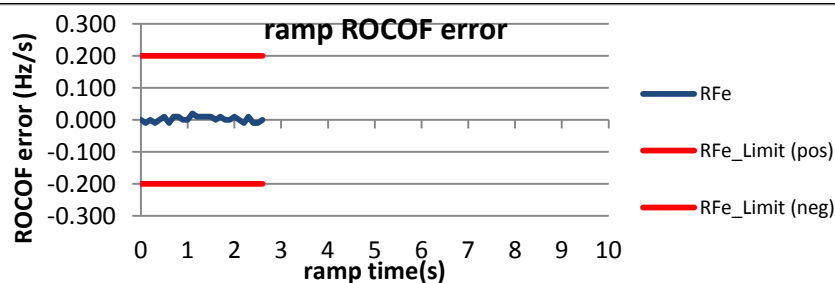


Figure 2558:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

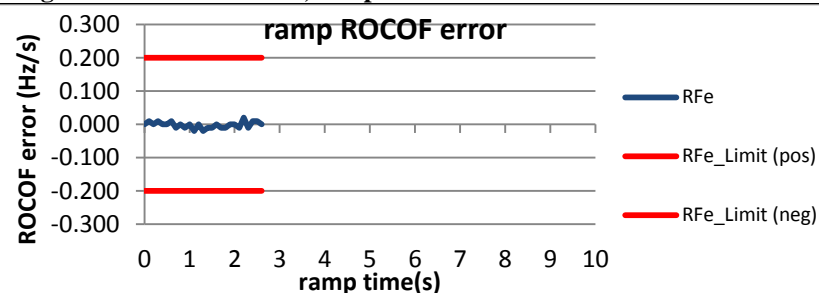


Figure 2559:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.4.3 PMU B dynamic ramp of system frequency ROCOF error: M class

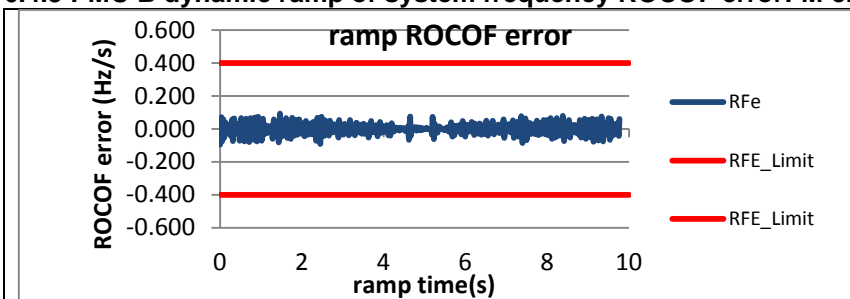


Figure 2560:  $F_s = 60$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

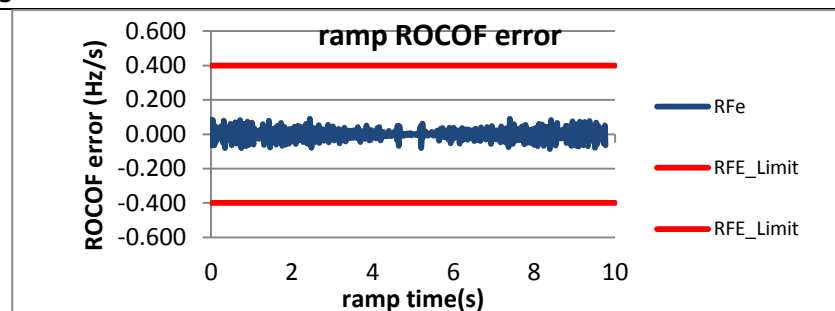


Figure 2561:  $F_s = 60$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

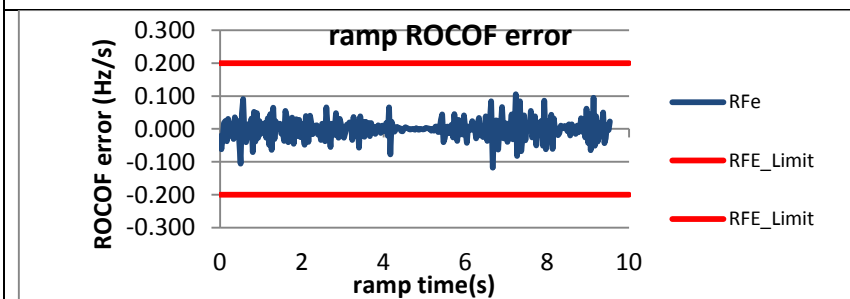


Figure 2562:  $F_s = 30$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

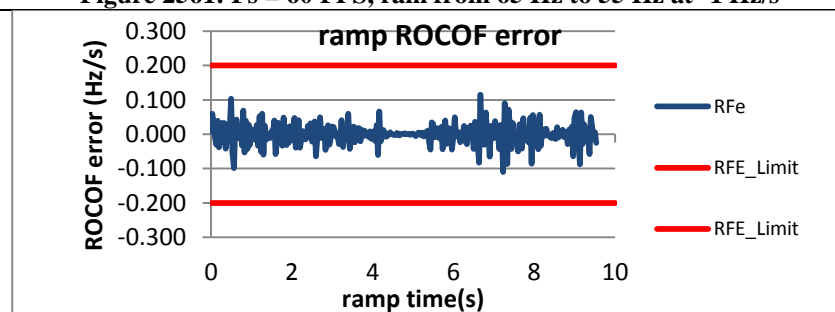


Figure 2563:  $F_s = 30$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

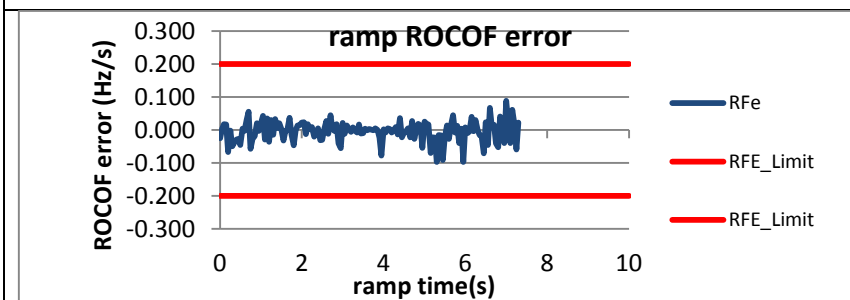


Figure 2564:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

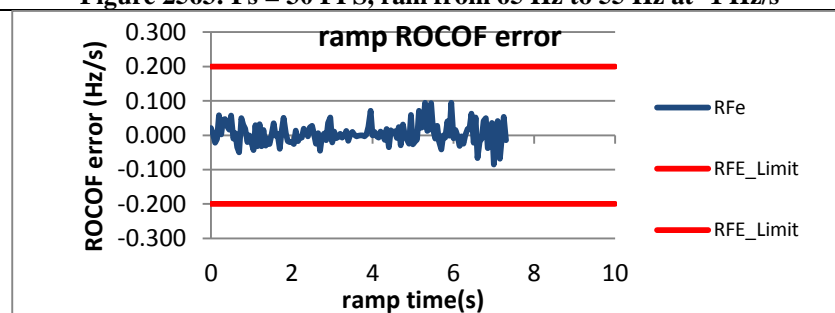


Figure 2565:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at =1 Hz/s

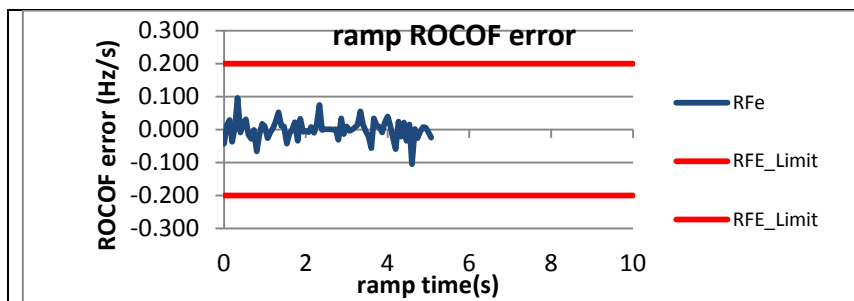


Figure 2566:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

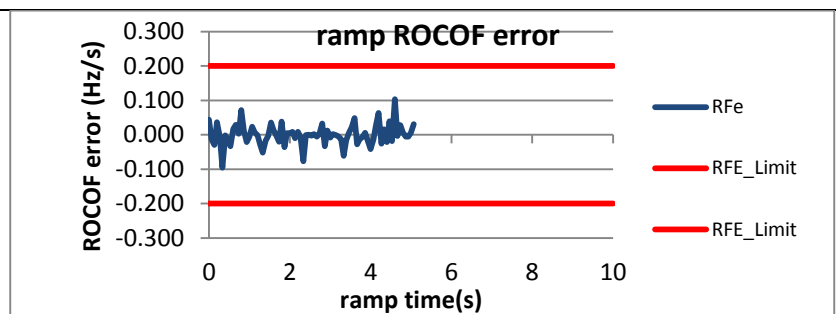


Figure 2567:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

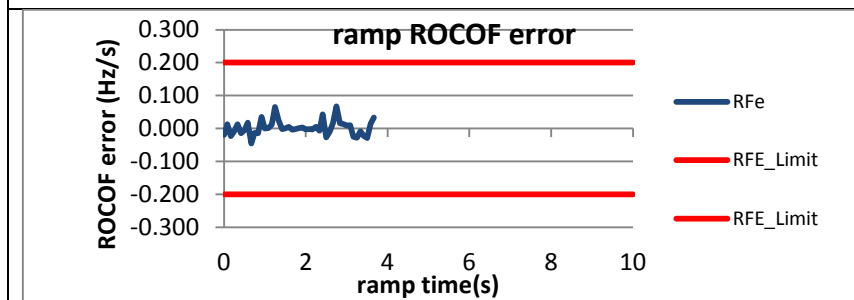


Figure 2568:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

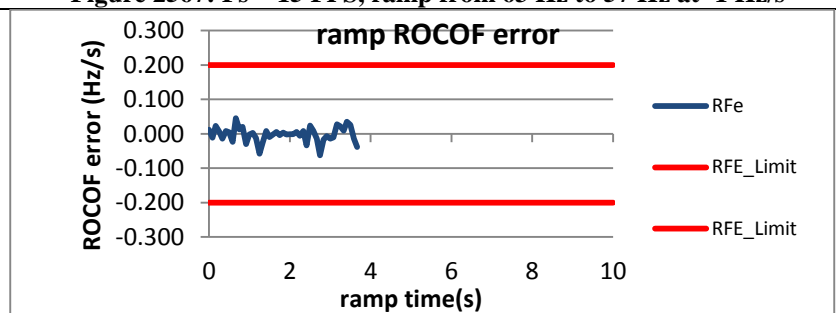


Figure 2569:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

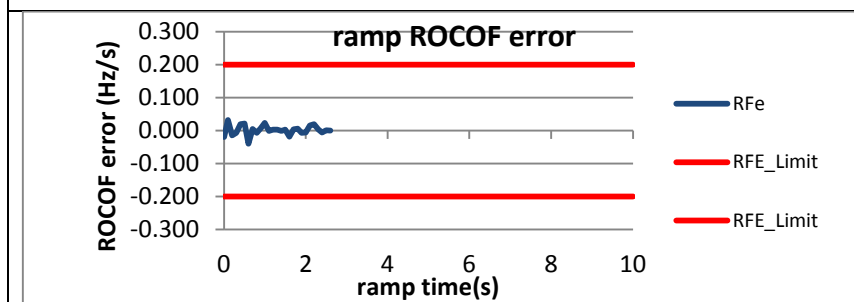


Figure 2570:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

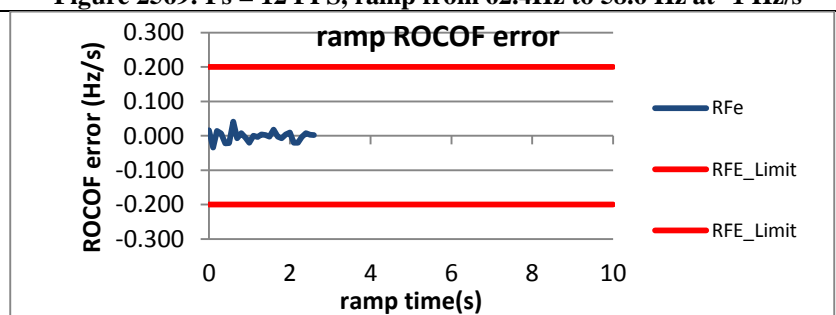


Figure 2571:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.4.4 PMU C dynamic ramp of system frequency ROCOF error: M class

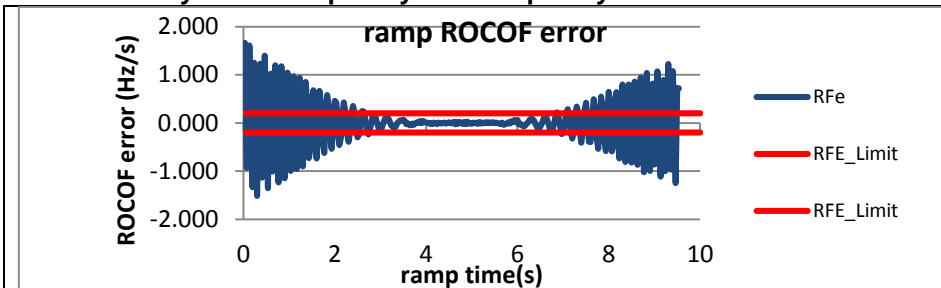


Figure 2572:  $F_s = 60$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

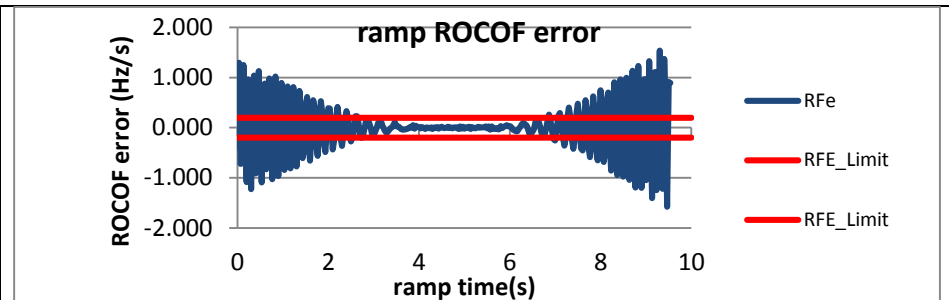


Figure 2573:  $F_s = 60$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

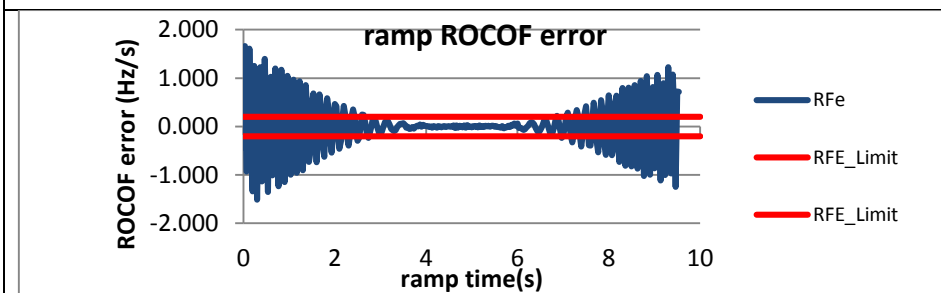


Figure 2574:  $F_s = 30$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

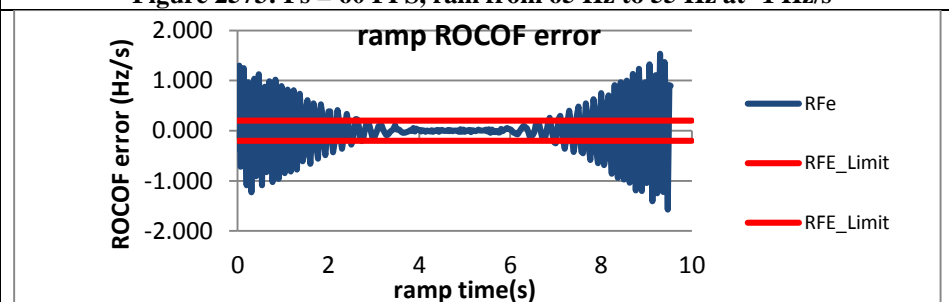


Figure 2575:  $F_s = 30$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

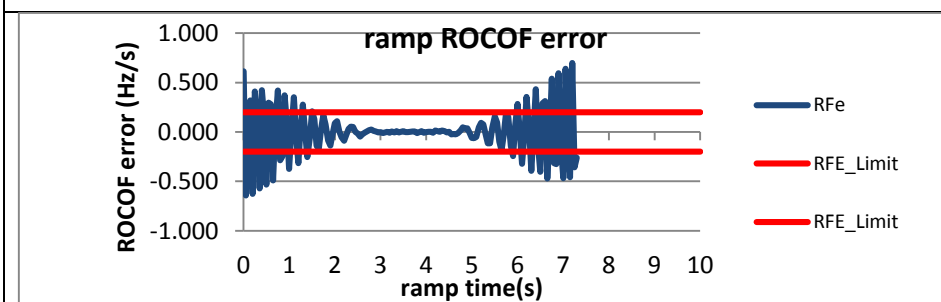


Figure 2576:  $F_s = 20$  FPS, ram from 56 Hz to 64 Hz at +1 Hz/s

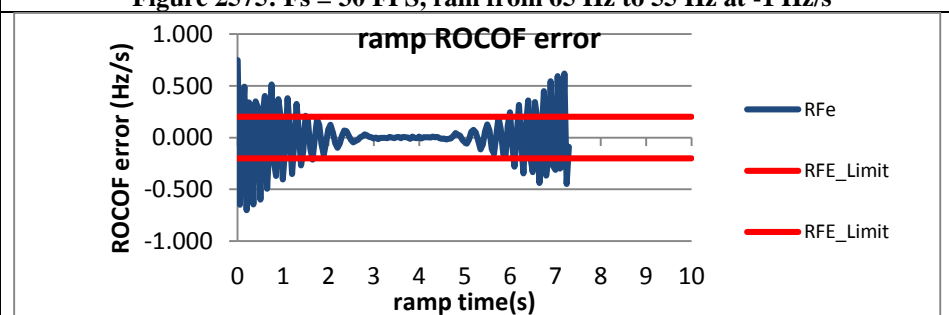


Figure 2577:  $F_s = 20$  FPS, ram from 64 Hz to 56 Hz at -1 Hz/s

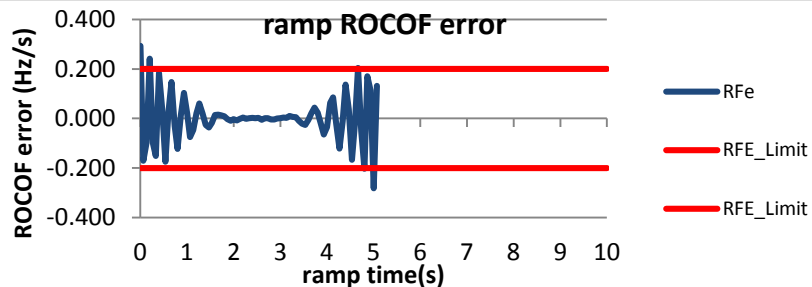


Figure 2578:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

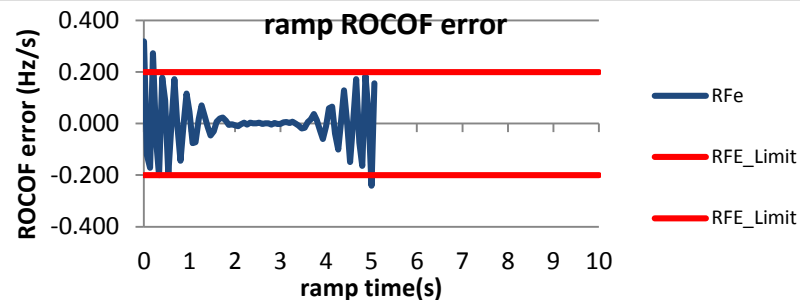


Figure 2579:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

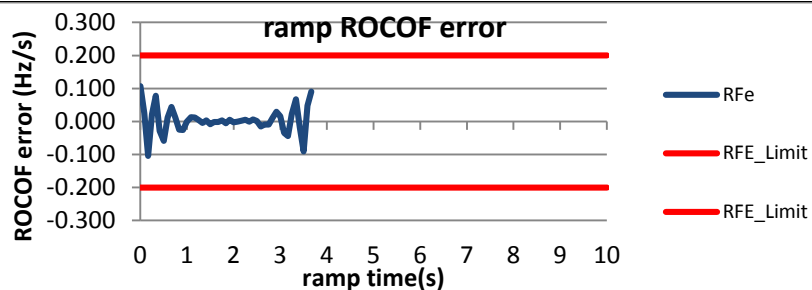


Figure 2580:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

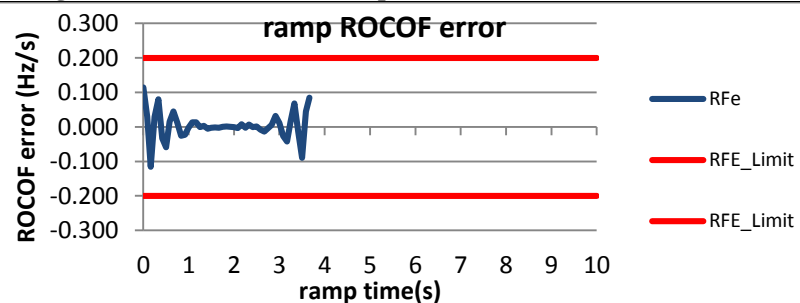


Figure 2581:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

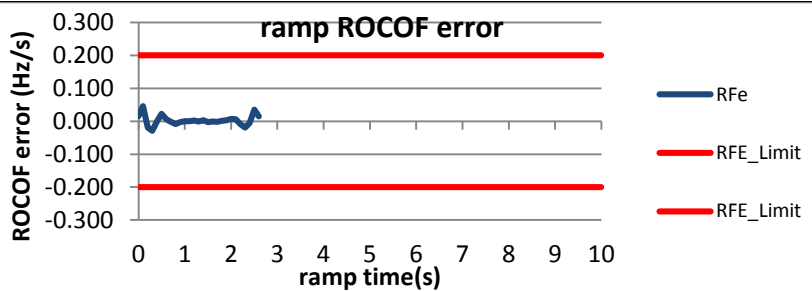


Figure 2582:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

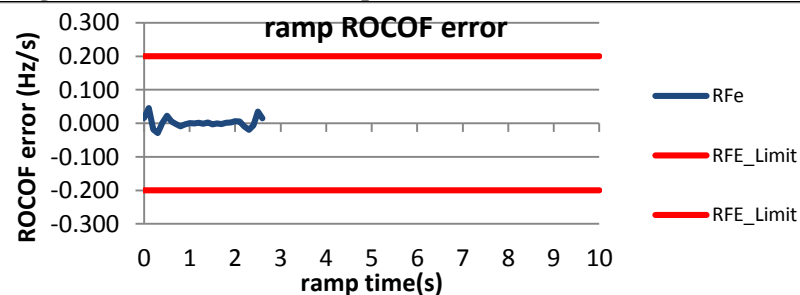


Figure 2583:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.4.5 PMU D dynamic ramp of system frequency ROCOF error: M class

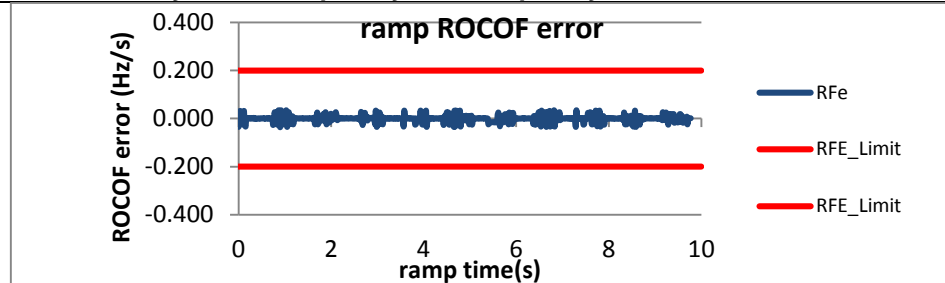


Figure 2584:  $F_s = 60$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

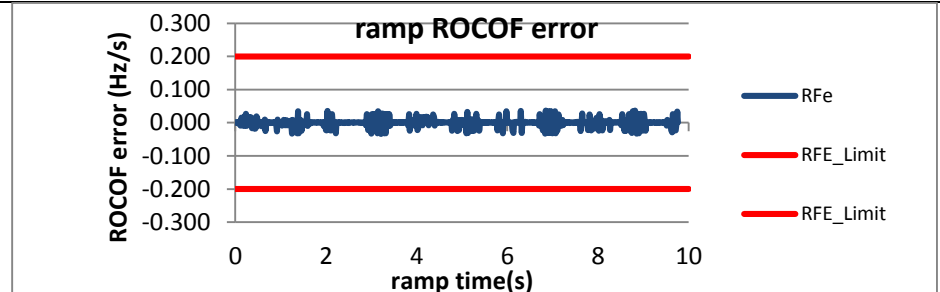


Figure 2585:  $F_s = 60$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

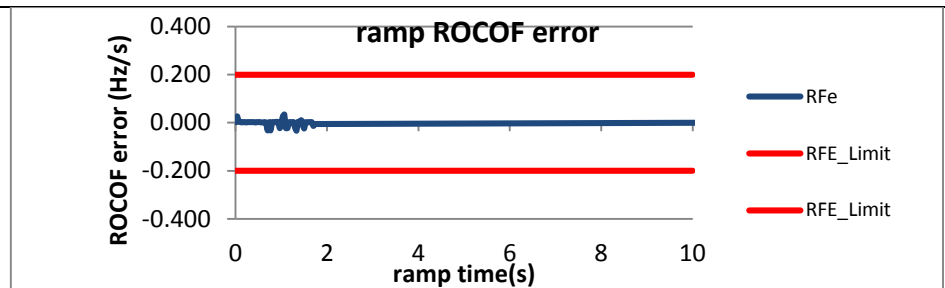


Figure 2586:  $F_s = 30$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

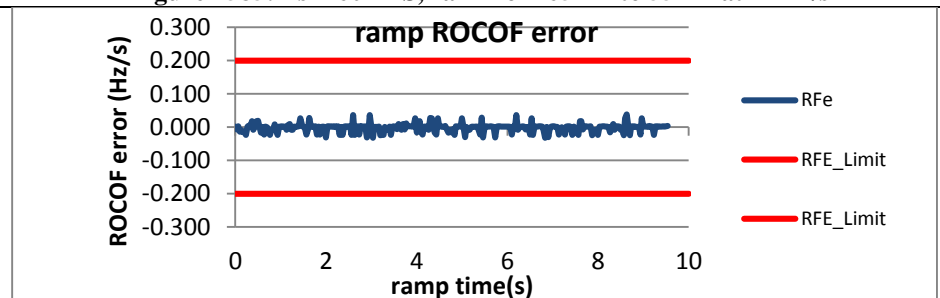


Figure 2587:  $F_s = 30$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

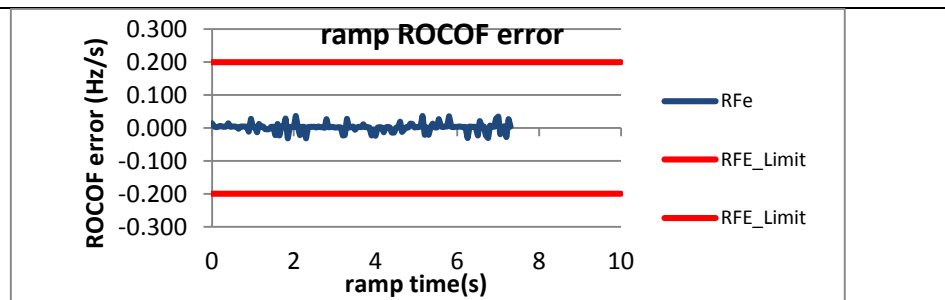


Figure 2588:  $F_s = 20$  FPS, ram from 56 Hz to 64 Hz at +1 Hz/s

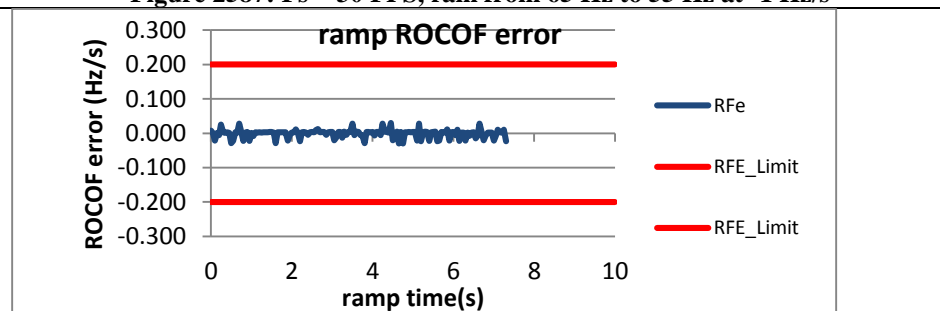


Figure 2589:  $F_s = 20$  FPS, ram from 64 Hz to 56 Hz at -1 Hz/s



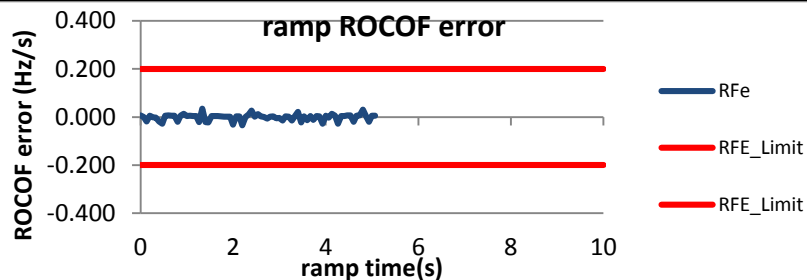


Figure 2590:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

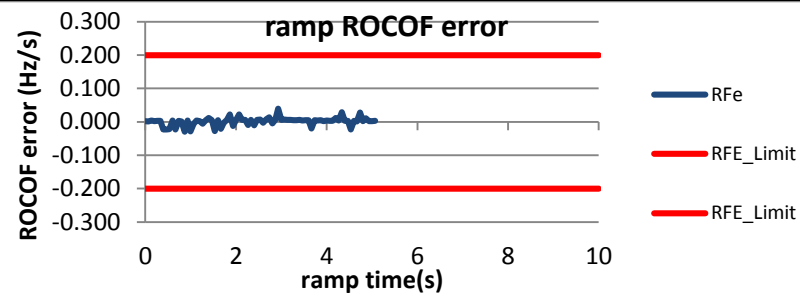


Figure 2591:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

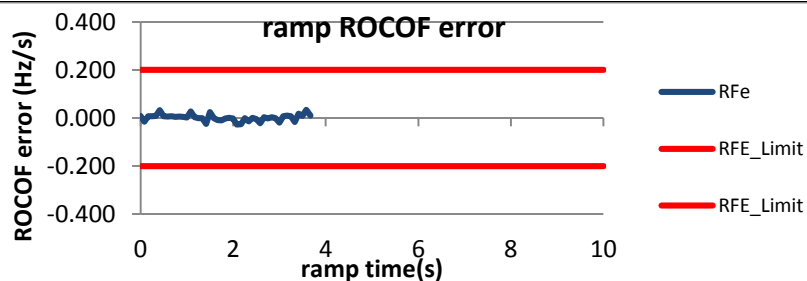


Figure 2592:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

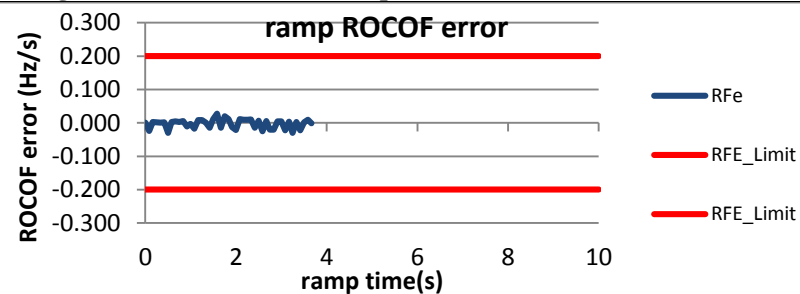


Figure 2593:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

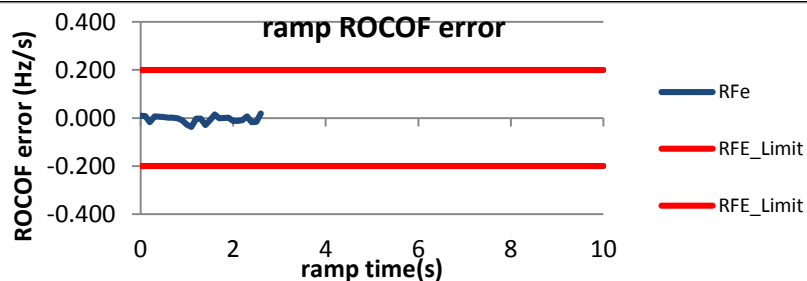


Figure 2594:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

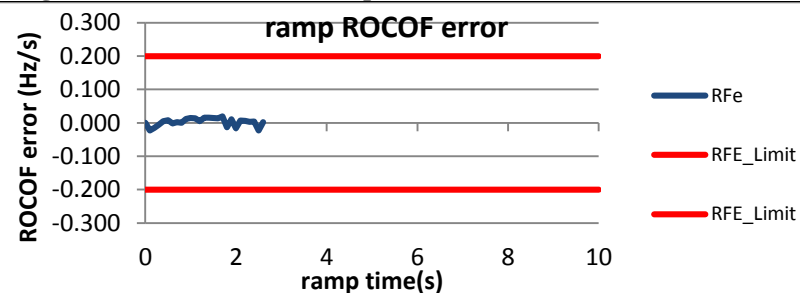


Figure 2595:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.4.6 PMU E dynamic ramp of system frequency ROCOF error: M class

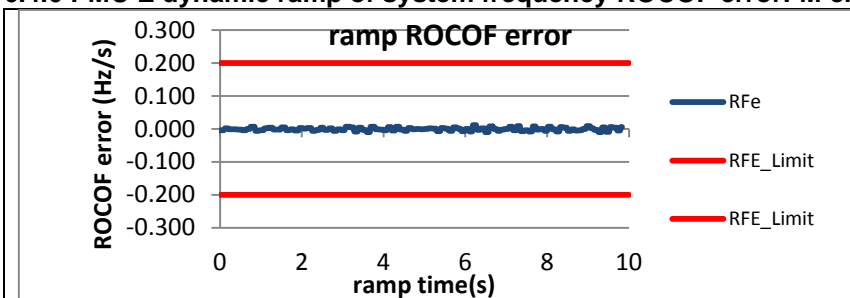


Figure 2596:  $F_s = 60$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

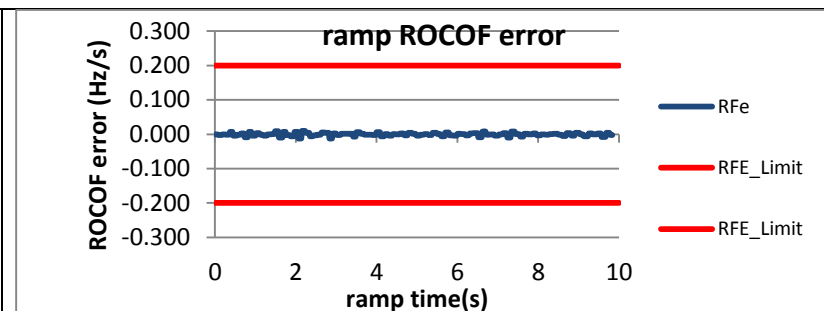


Figure 2597:  $F_s = 60$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

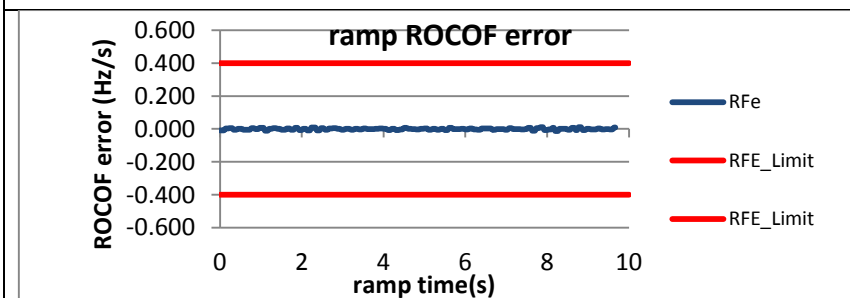


Figure 2598:  $F_s = 30$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

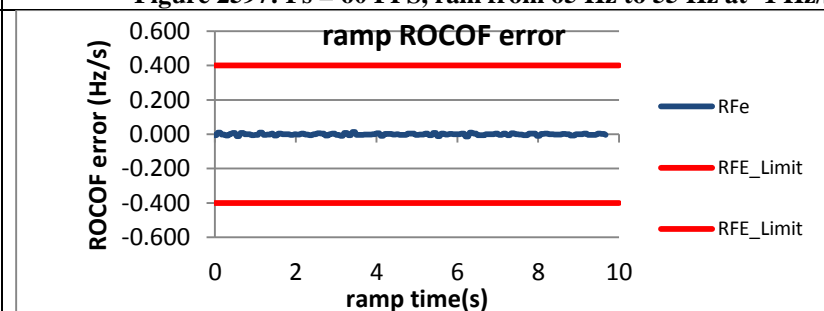


Figure 2599:  $F_s = 30$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

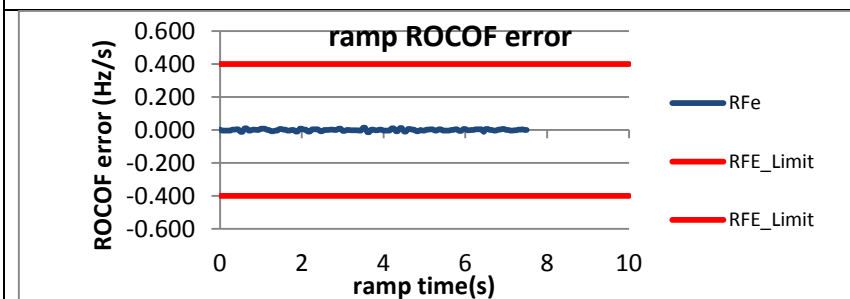


Figure 2600:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

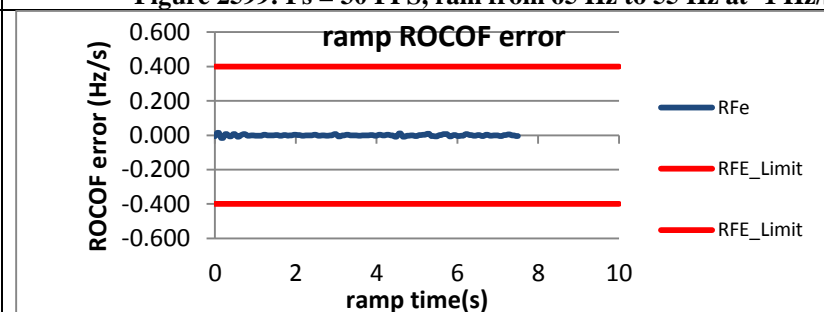


Figure 2601:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

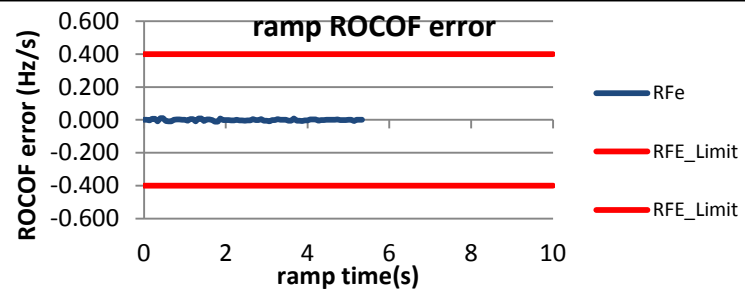


Figure 2602:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

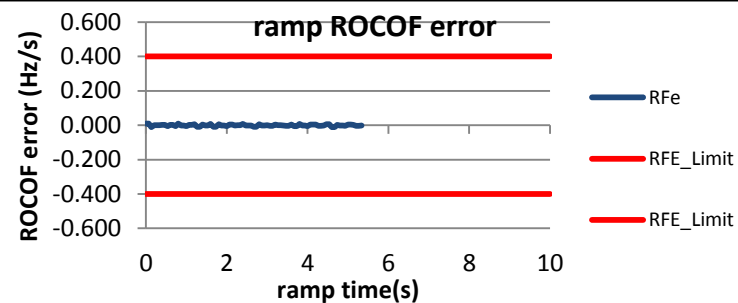


Figure 2603:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

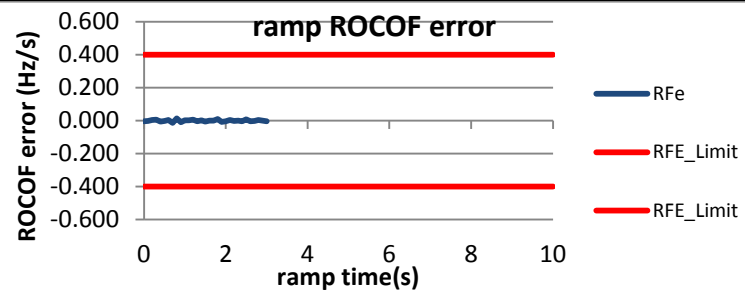


Figure 2604:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

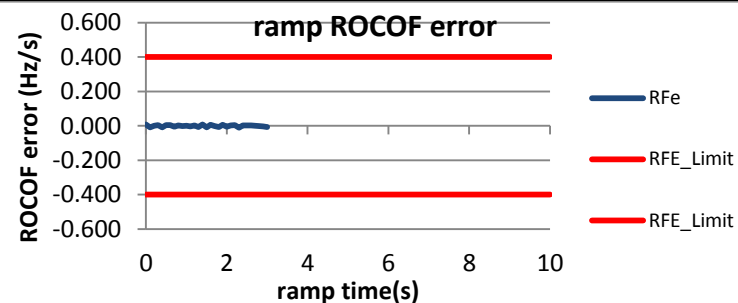


Figure 2605:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

Figure 2606:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

Figure 2607:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.4.7 PMU F dynamic ramp of system frequency ROCOF error: M class

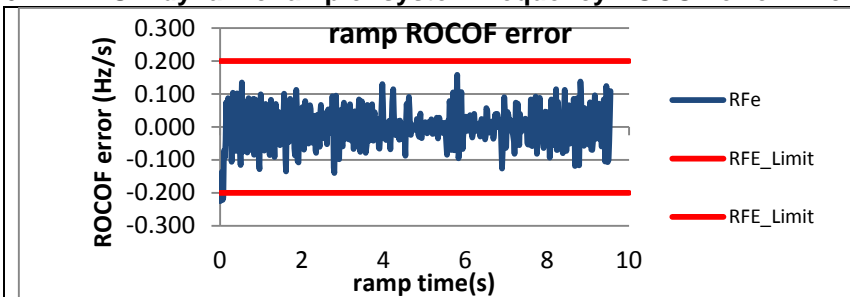


Figure 2608:  $F_s = 60$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

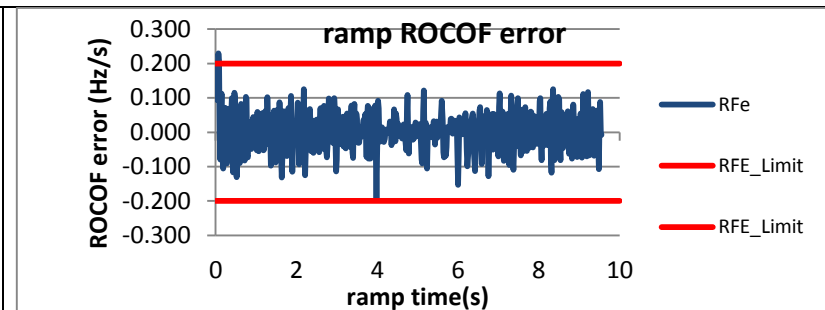


Figure 2609:  $F_s = 60$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

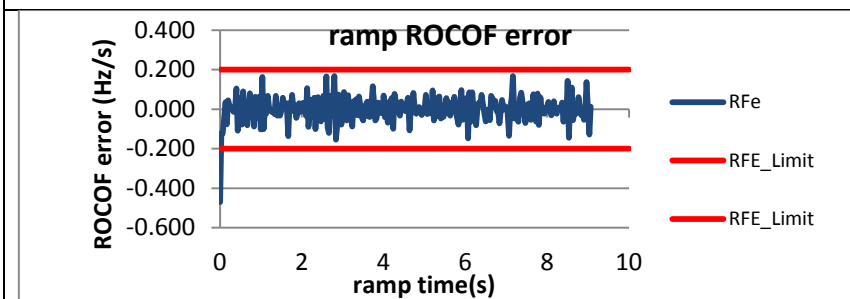


Figure 2610:  $F_s = 30$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

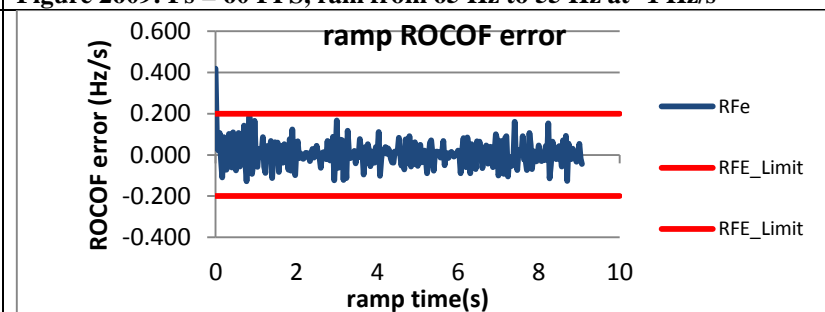


Figure 2611:  $F_s = 30$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

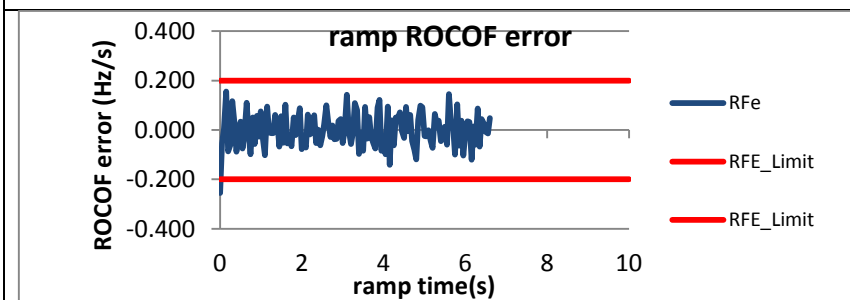


Figure 2612:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

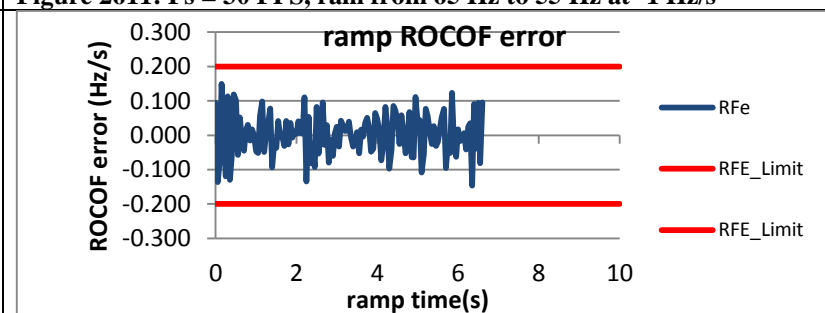


Figure 2613:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at =1 Hz/s

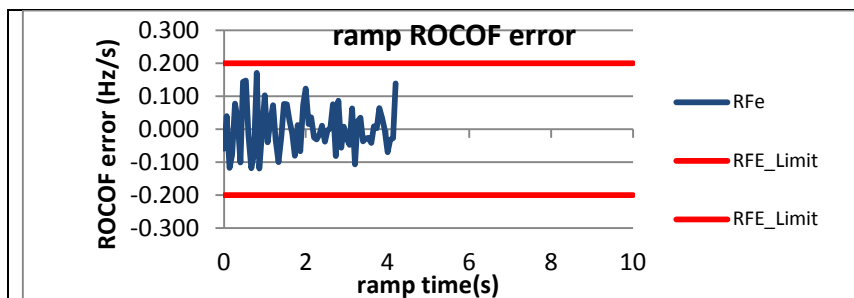


Figure 2614:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

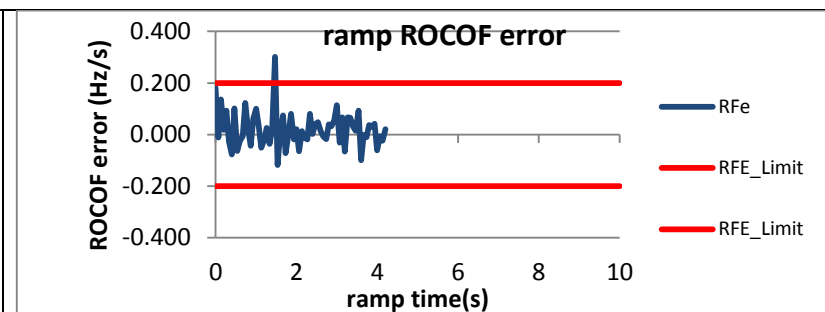


Figure 2615:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

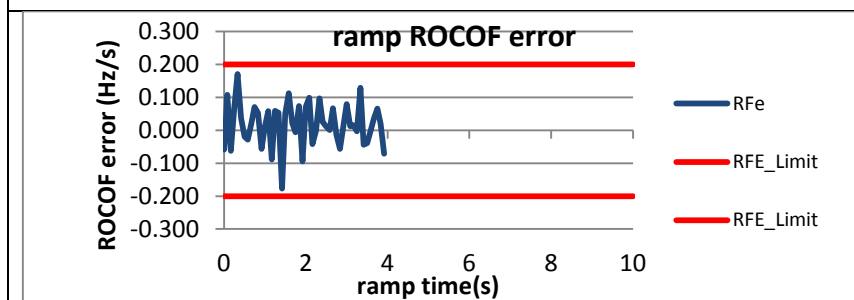


Figure 2616:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

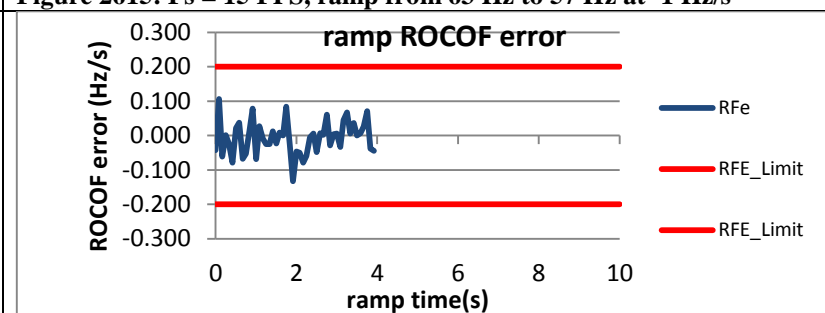


Figure 2617:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

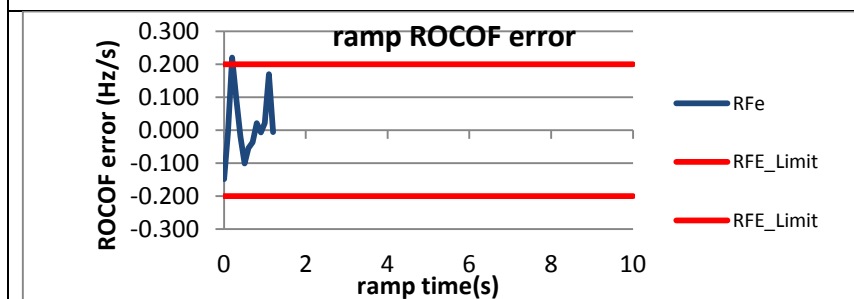


Figure 2618:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

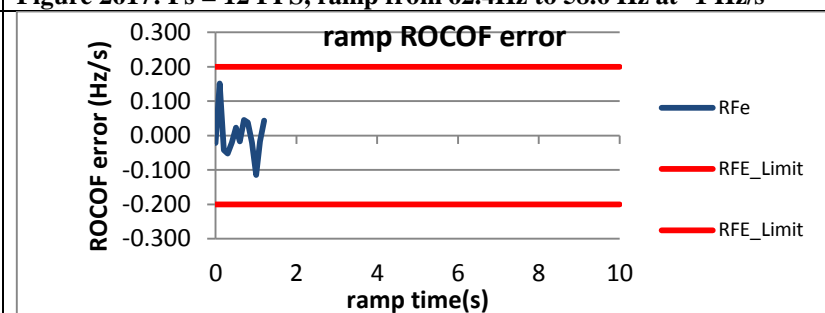


Figure 2619:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.4.8 PMU G\* dynamic ramp of system frequency ROCOF error: M class

Figure 2620:  $F_s = 60$  FPS is not supported by this PMU

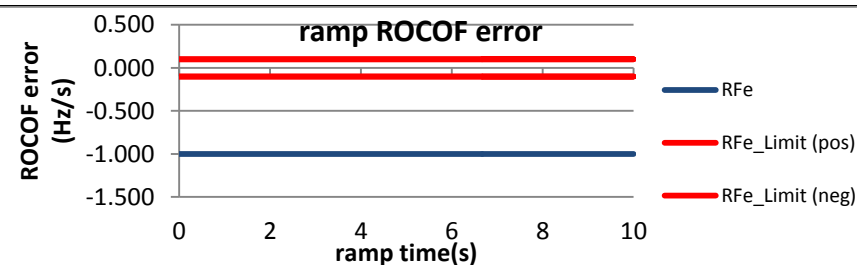
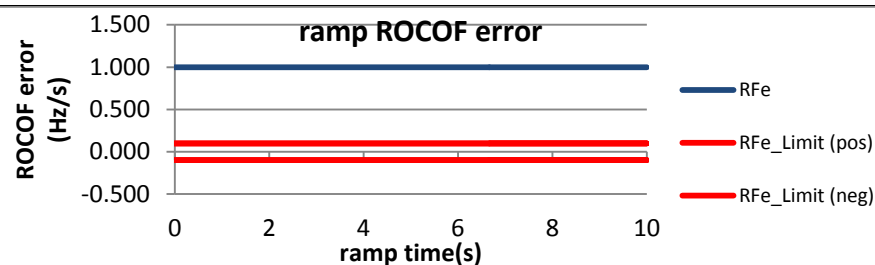


Figure 2621:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

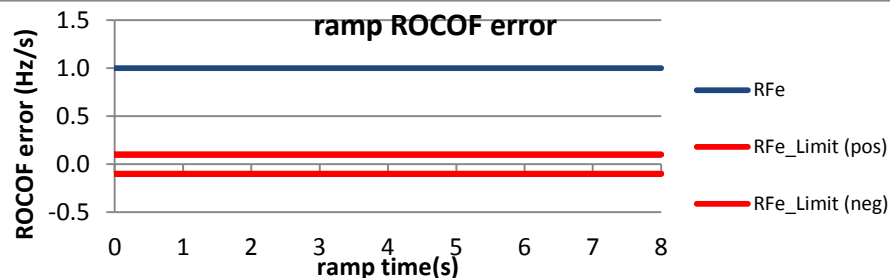


Figure 2622:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

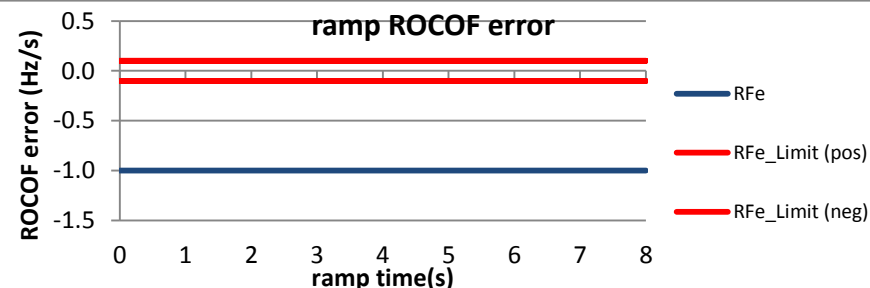


Figure 2623:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

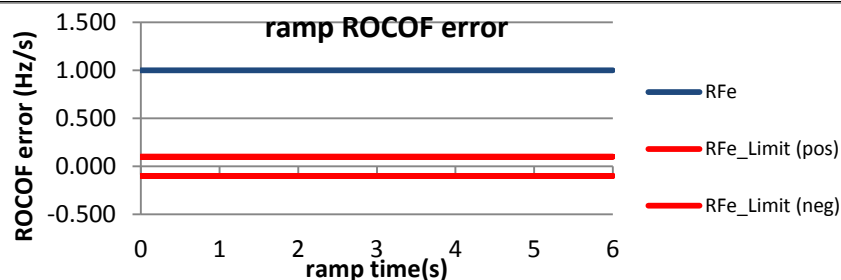


Figure 2624:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

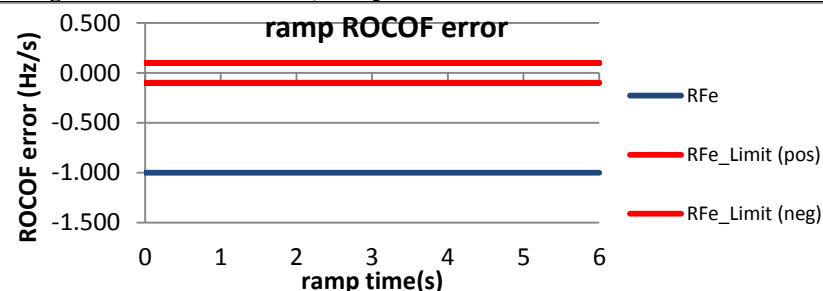


Figure 2625:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s



Figure 2626:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

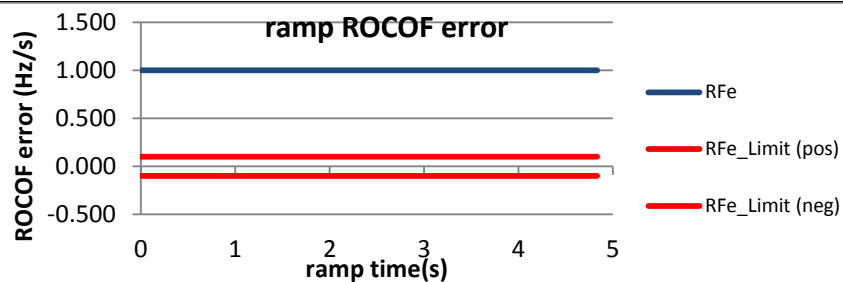


Figure 2627:  $F_s = 12$  FPS, ramp from 57.6 Hz to 62.4 Hz at +1 Hz/s

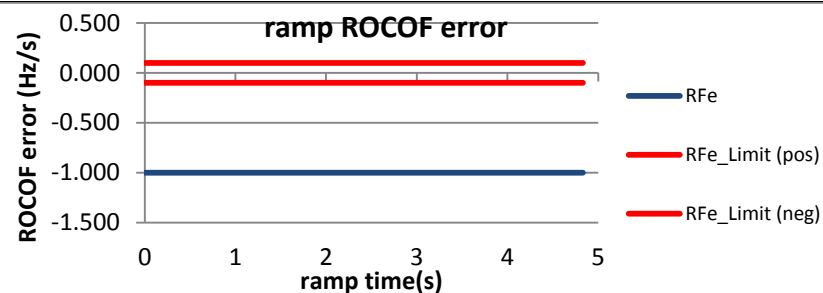


Figure 2628:  $F_s = 12$  FPS, ramp from 62.4 Hz to 57.6 Hz at -1 Hz/s

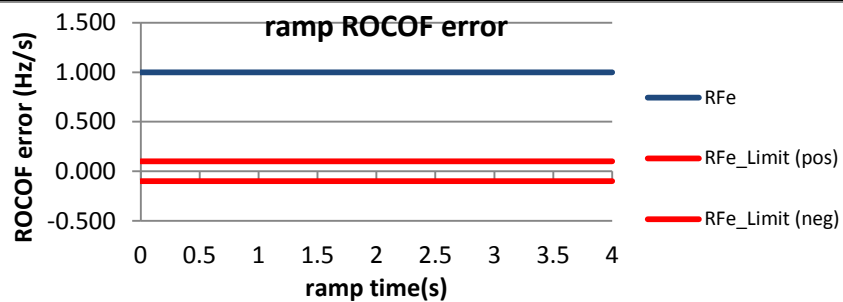


Figure 2629:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

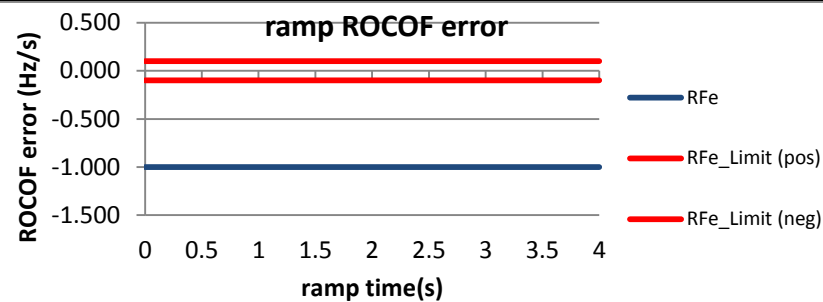


Figure 2630:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

\* PMU G always outputs ROCOF = 0.

#### 6.4.9 PMU H dynamic ramp of system frequency ROCOF error: M class

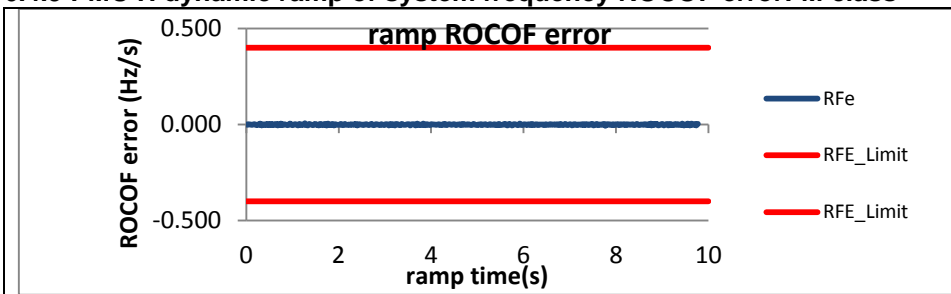


Figure 2631:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

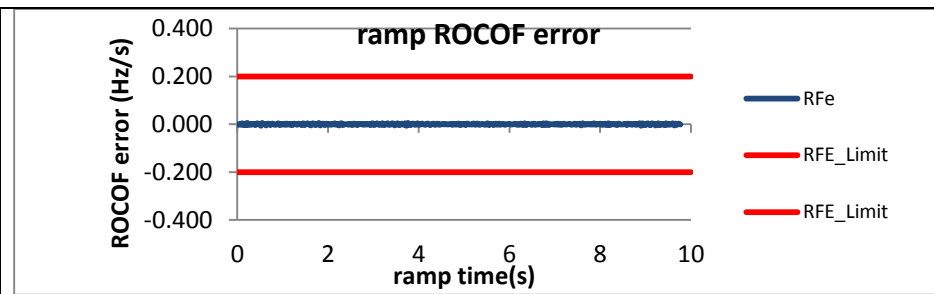


Figure 2632:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

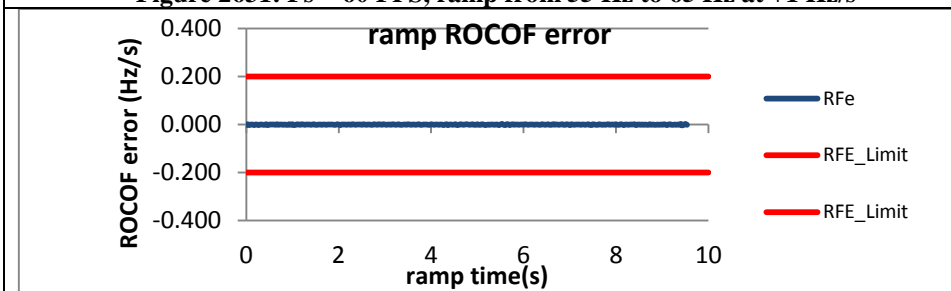


Figure 2633:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

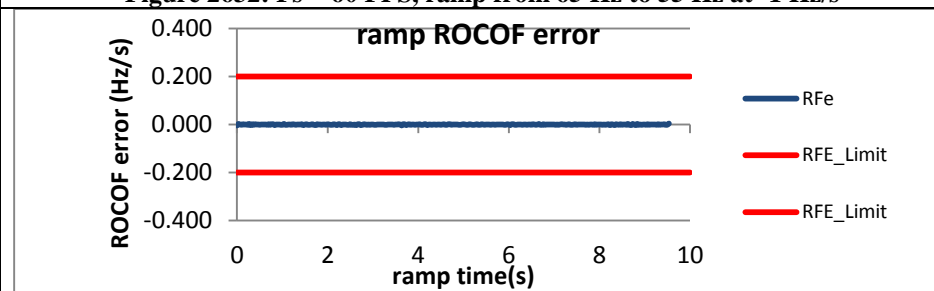


Figure 2634:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

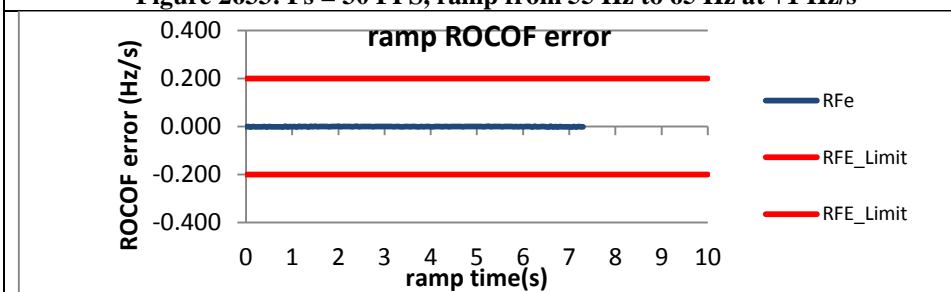


Figure 2635:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

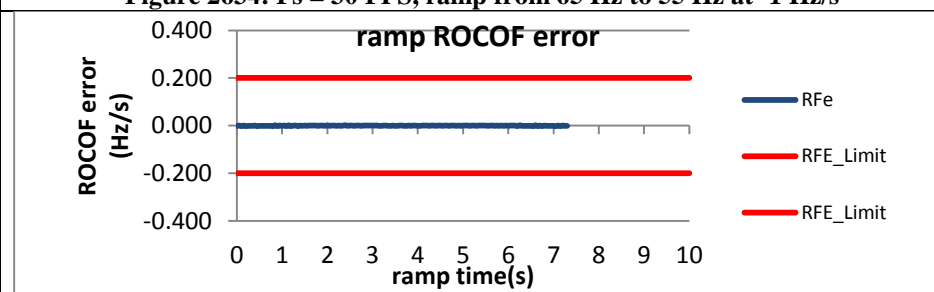


Figure 2636:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s



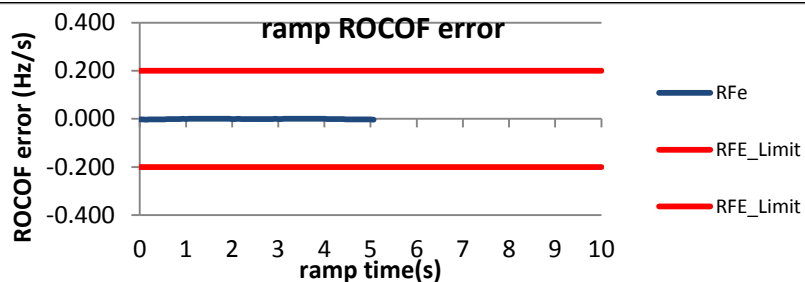


Figure 2637:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

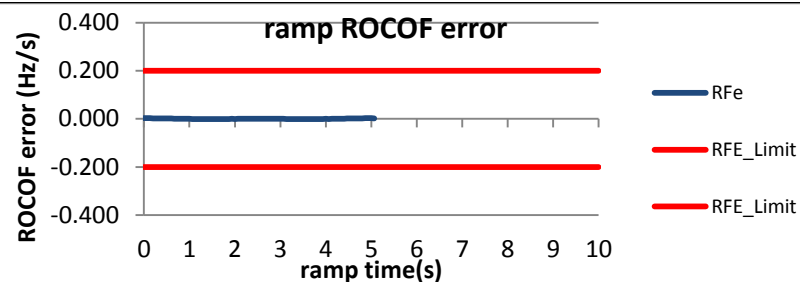


Figure 2638:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

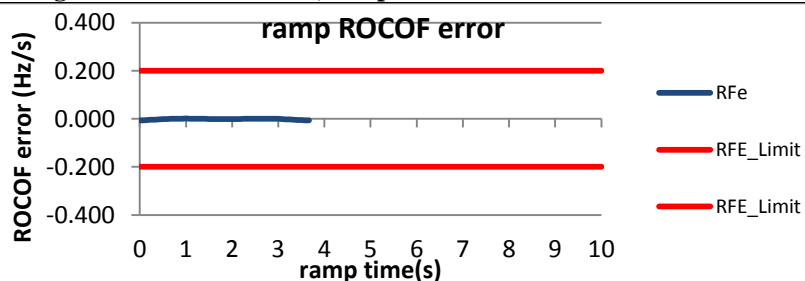


Figure 2639:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

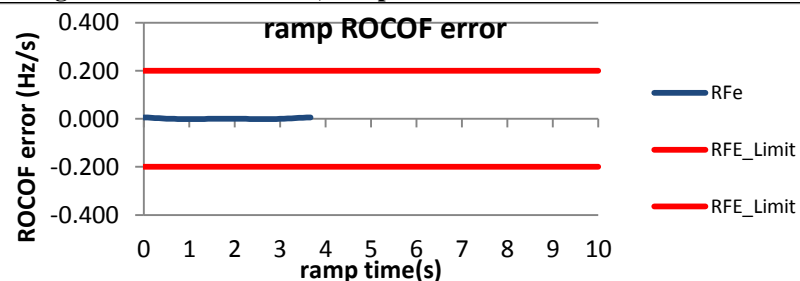


Figure 2640:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

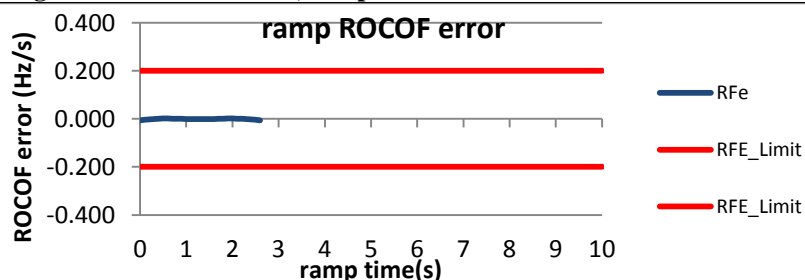


Figure 2641:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

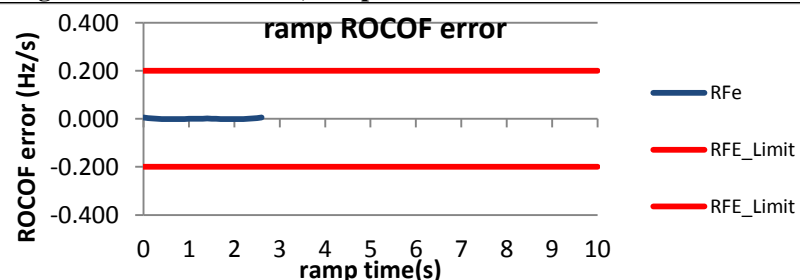


Figure 2642:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.4.10 PMU I dynamic ramp of system frequency ROCOF error: M class

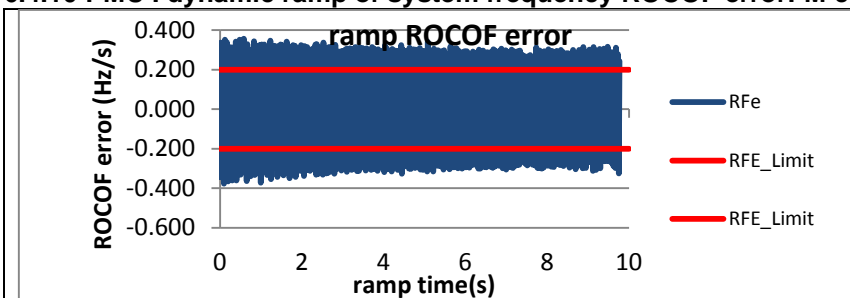


Figure 2643:  $F_s = 60$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

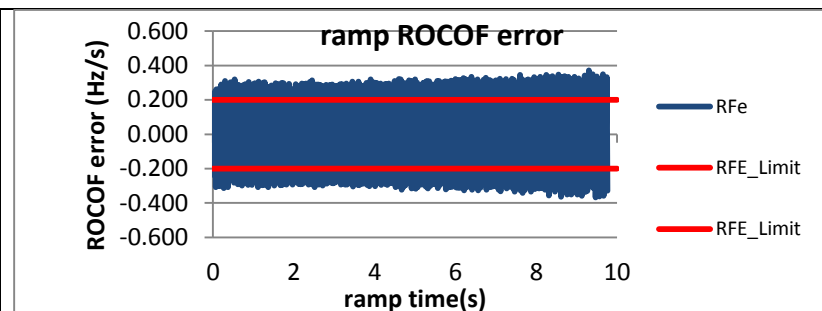


Figure 2644:  $F_s = 60$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

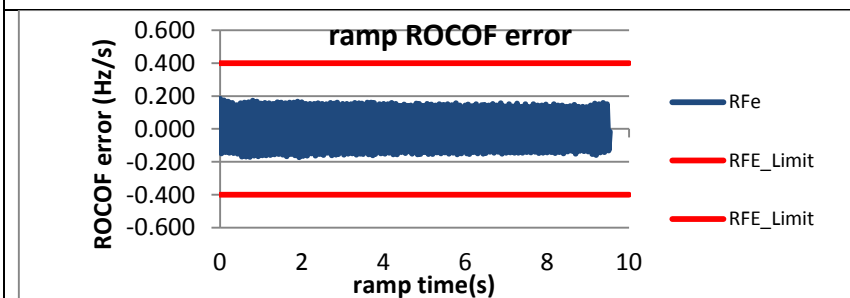


Figure 2645:  $F_s = 30$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

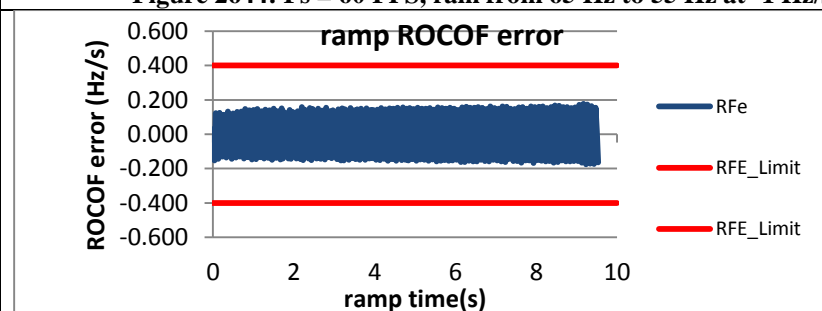


Figure 2646:  $F_s = 30$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

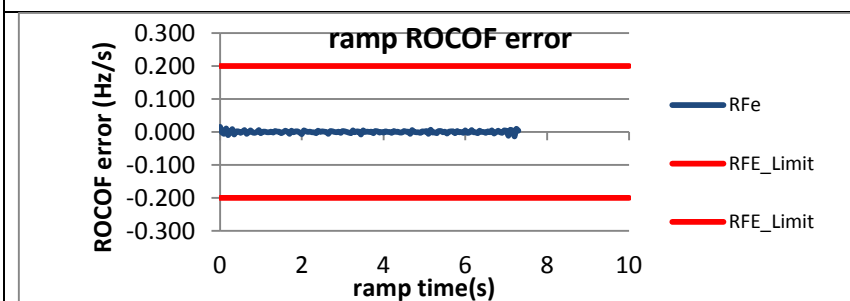


Figure 2647:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

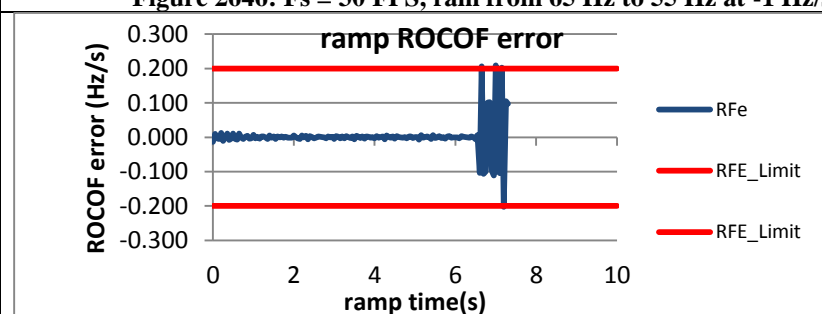


Figure 2648:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at =1 Hz/s

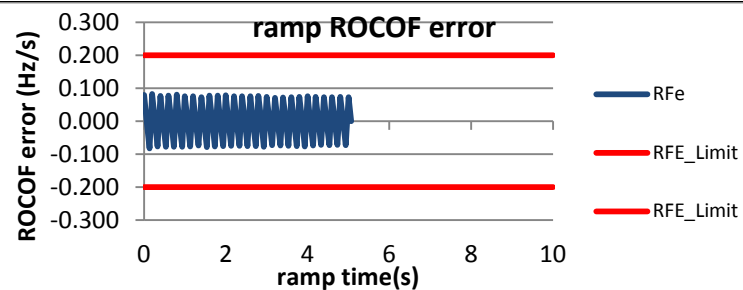


Figure 2649:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

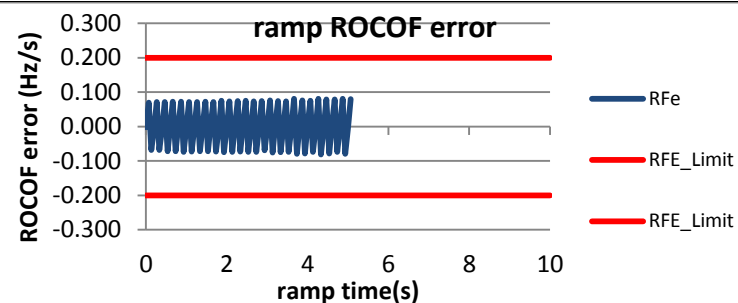


Figure 2650:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

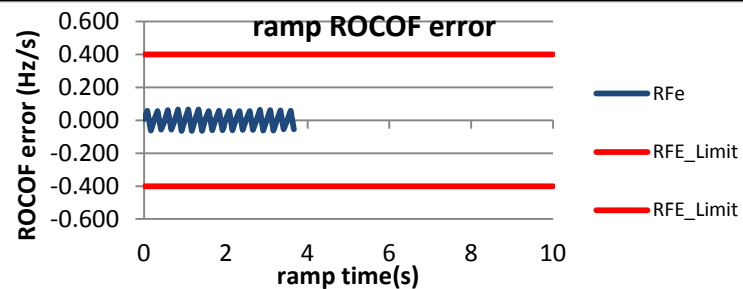


Figure 2651:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

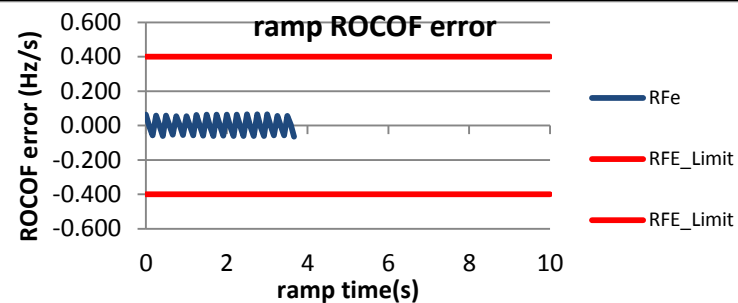


Figure 2652:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

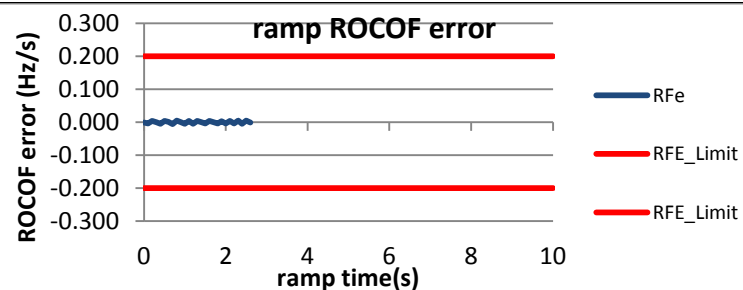


Figure 2653:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

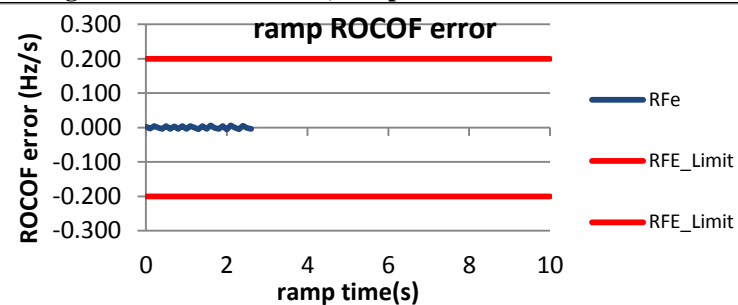


Figure 2654:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.4.11 PMU J dynamic ramp of system frequency ROCOF error: M class

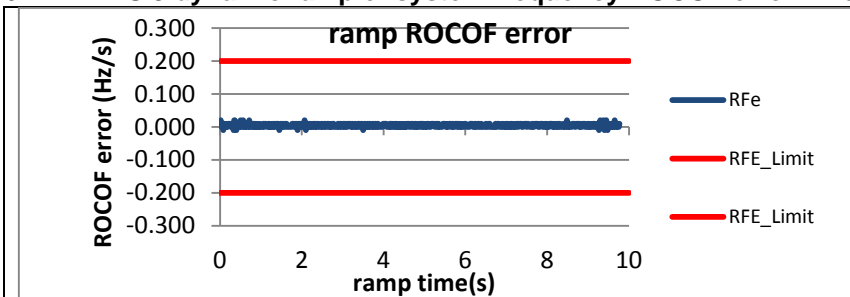


Figure 2655:  $F_s = 60$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

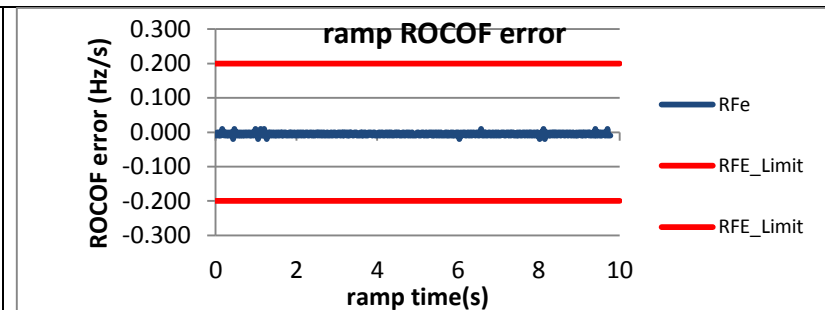


Figure 2656:  $F_s = 60$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

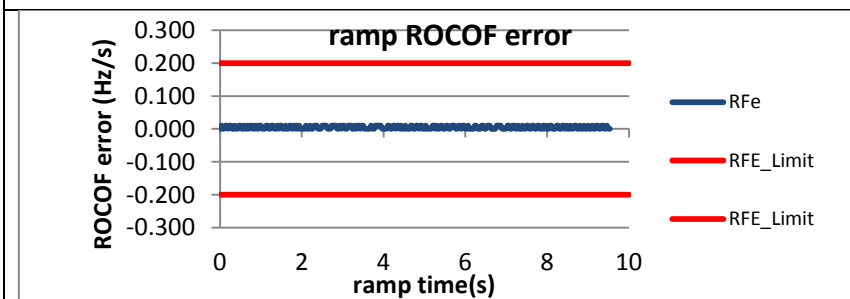


Figure 2657:  $F_s = 30$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

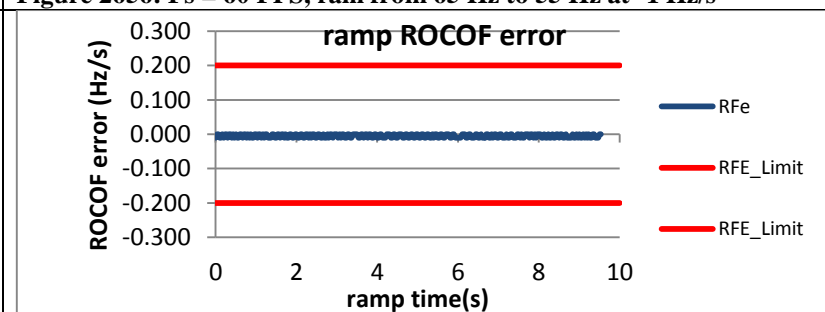


Figure 2658:  $F_s = 30$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

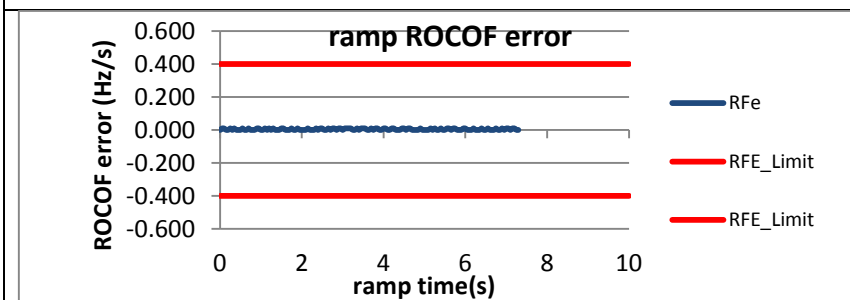


Figure 2659:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

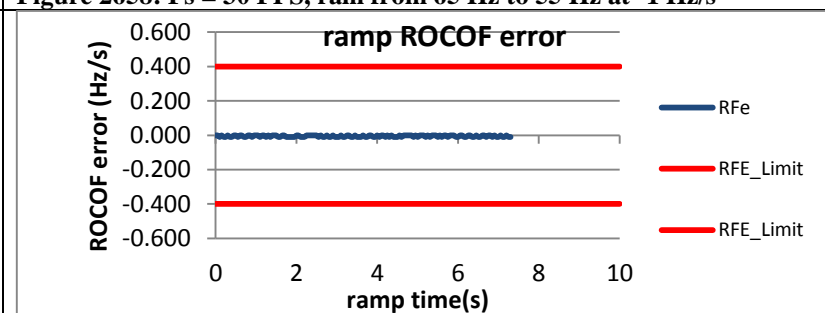


Figure 2660:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at =1 Hz/s

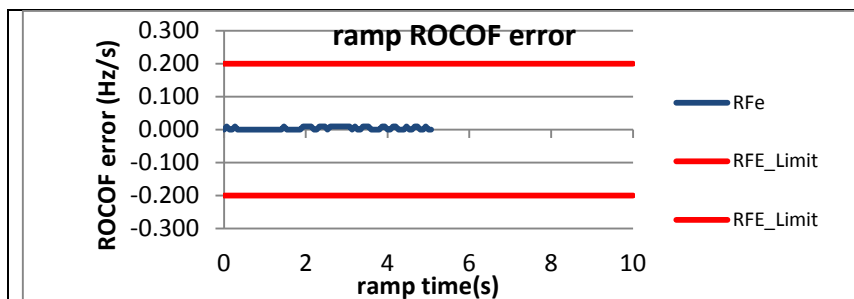


Figure 2661:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

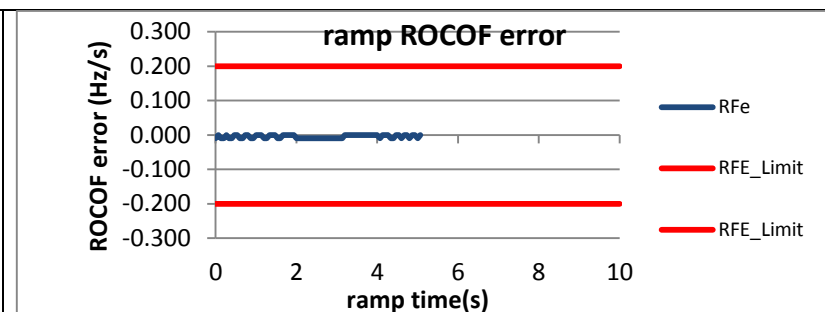


Figure 2662:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

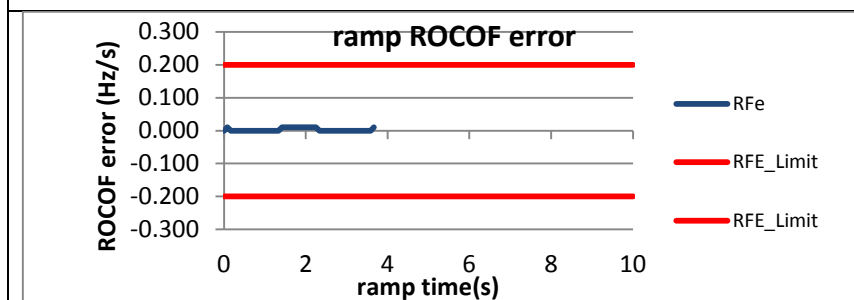


Figure 2663:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

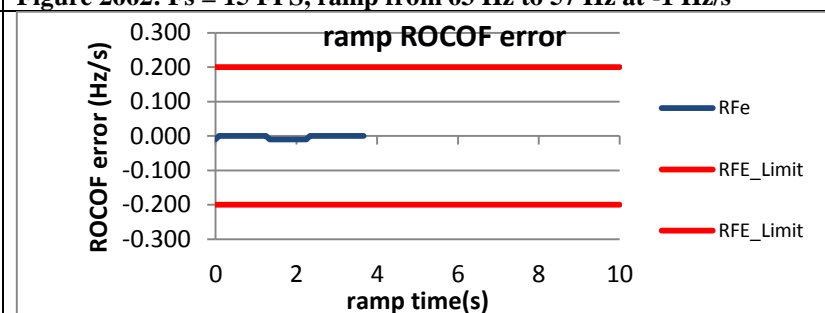


Figure 2664:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

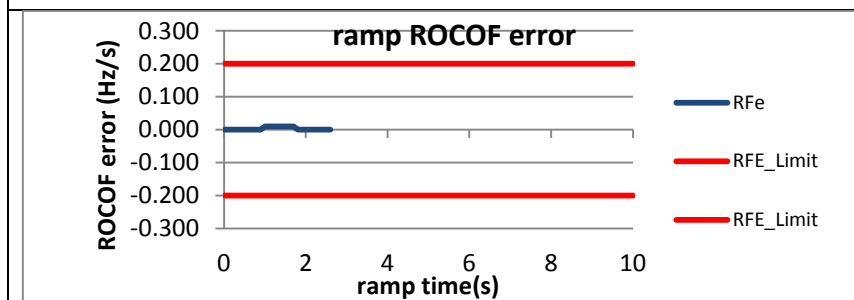


Figure 2665:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

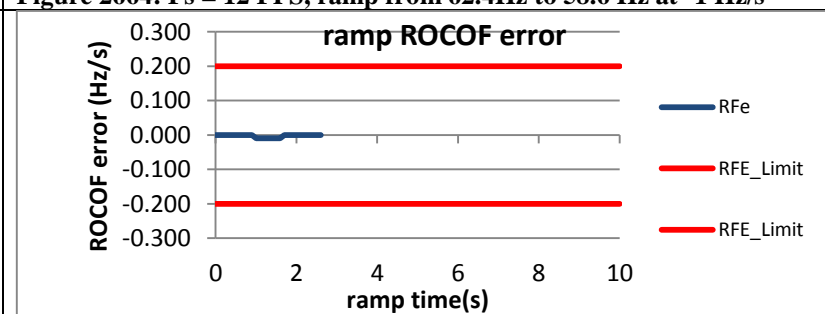
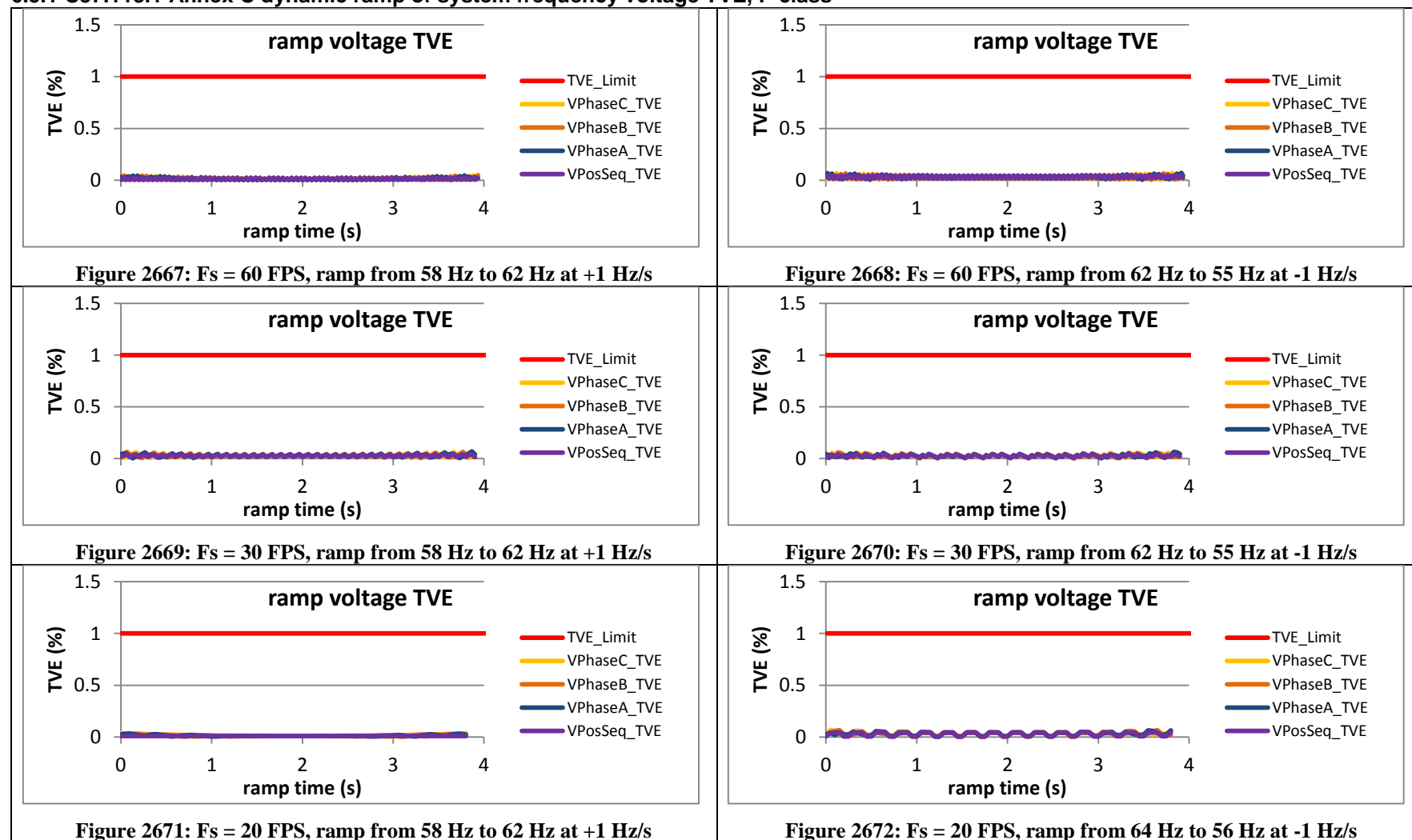


Figure 2666:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.5 Dynamic ramp of system frequency voltage TVE, P class

### 6.5.1 C37.118.1 Annex C dynamic ramp of system frequency voltage TVE, P class



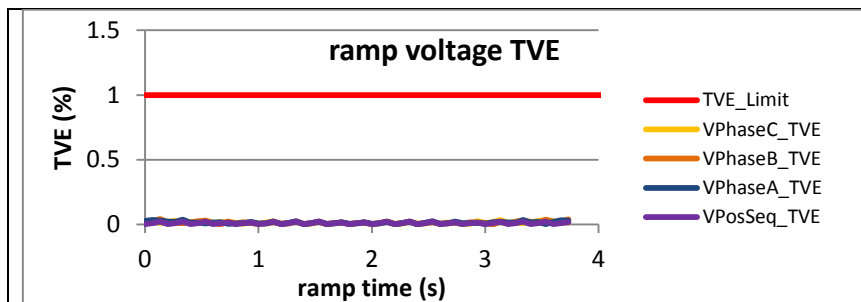


Figure 2673:  $F_s = 15$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

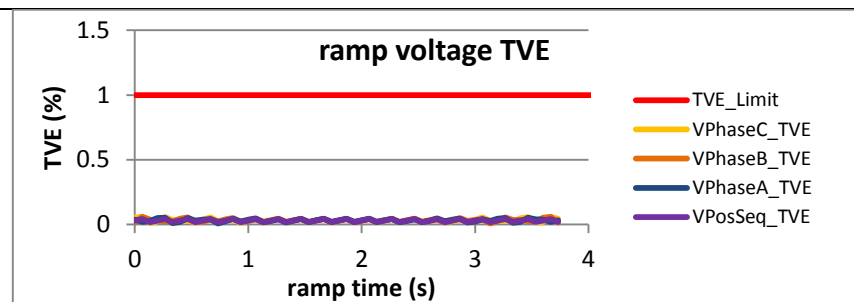


Figure 2674:  $F_s = 15$  FPS, ramp from 62 Hz to 57 Hz at -1 Hz/s

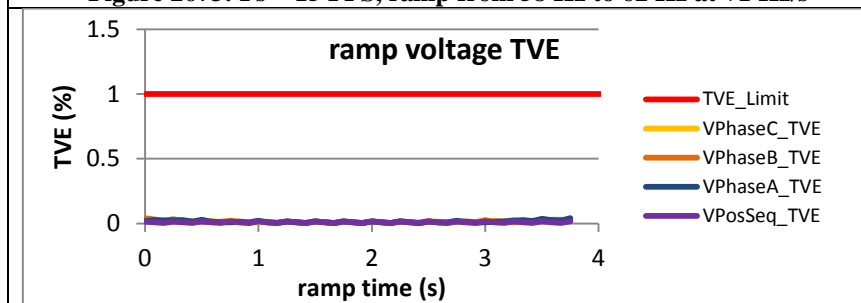


Figure 2675:  $F_s = 12$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

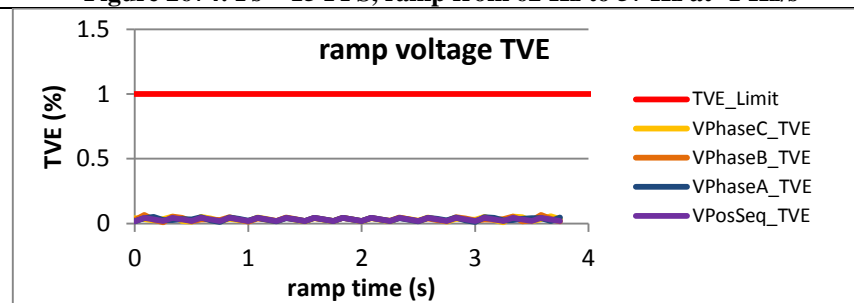


Figure 2676:  $F_s = 12$  FPS, ramp from 62 Hz to 58.6 Hz at -1 Hz/s

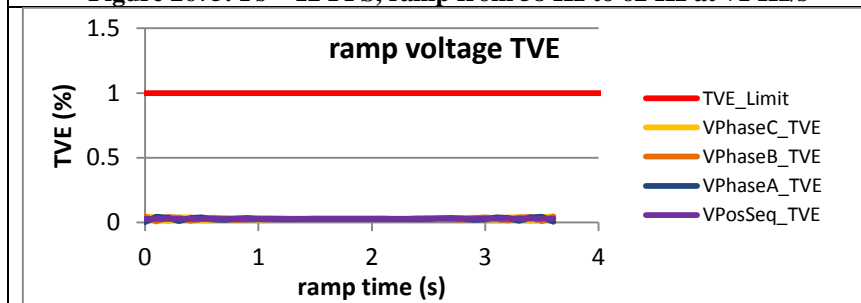


Figure 2677:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

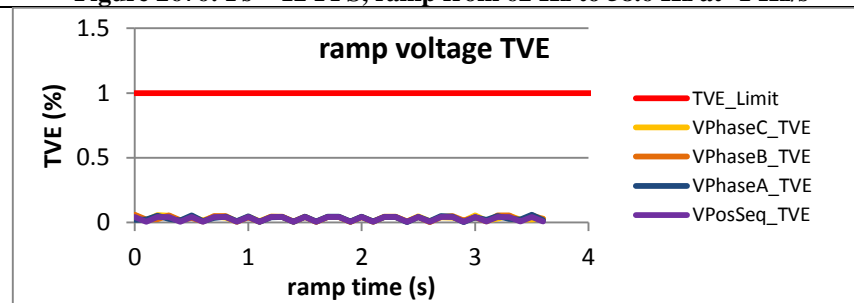
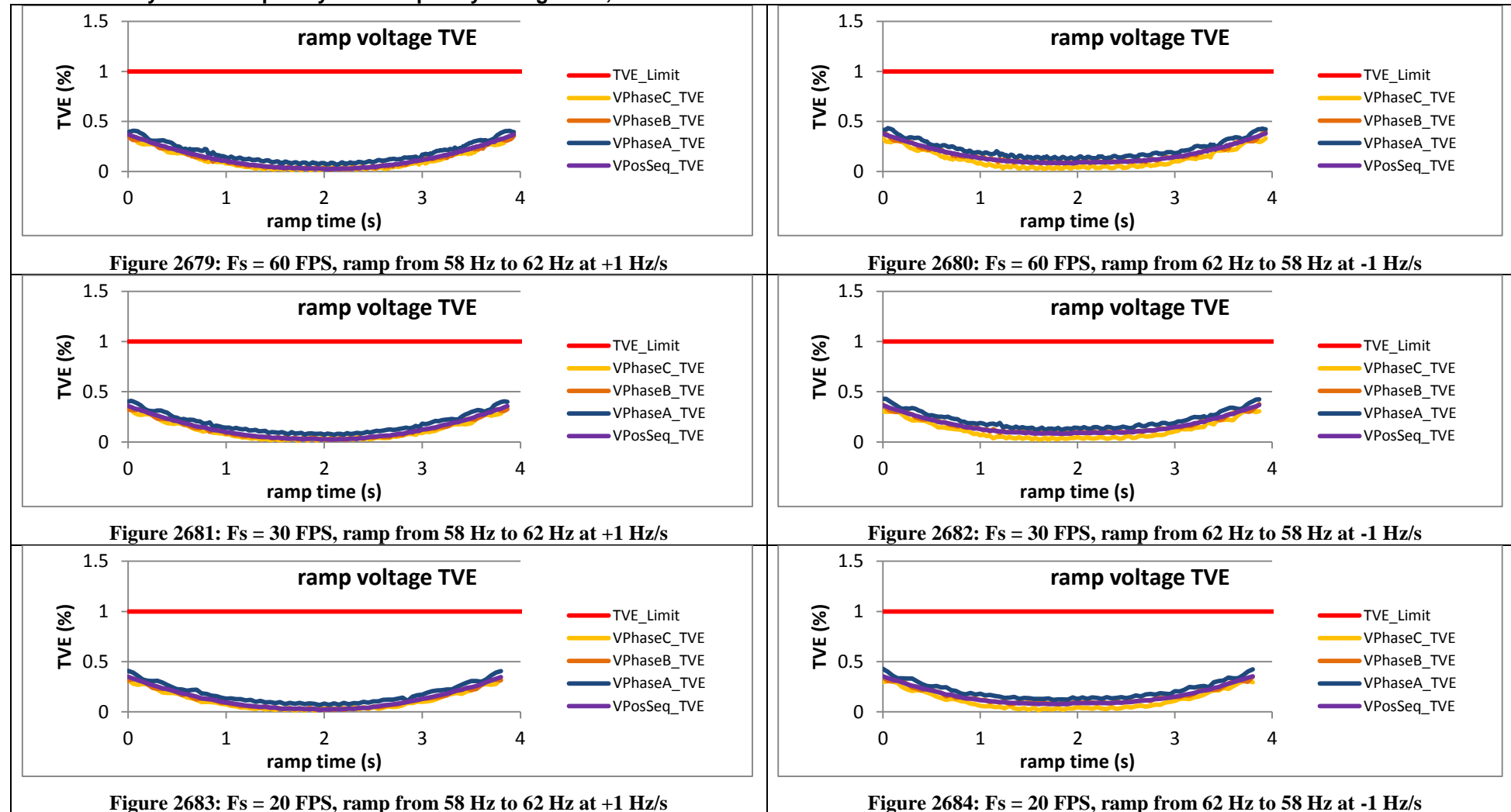


Figure 2678:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.5.2 PMU A dynamic ramp of system frequency voltage TVE, P class





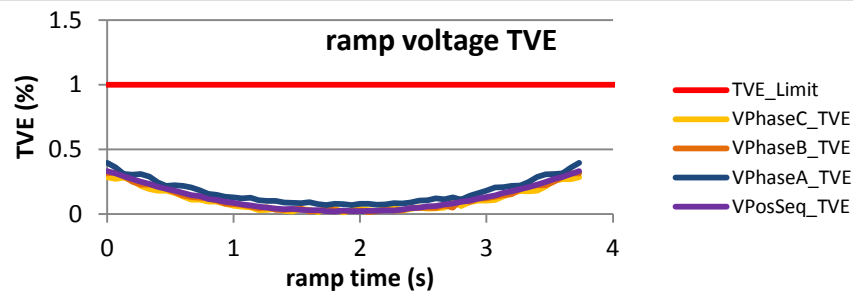


Figure 2685:  $F_s = 15$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

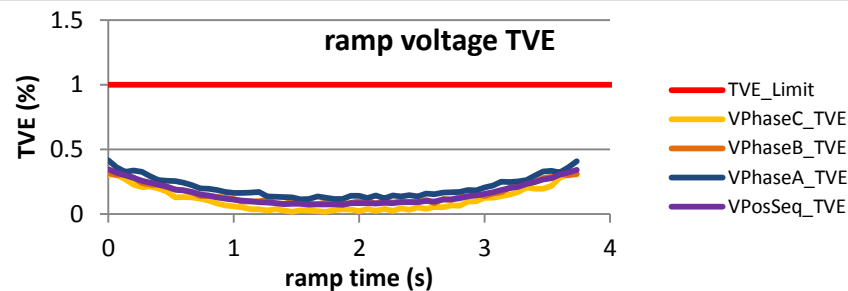


Figure 2686:  $F_s = 15$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

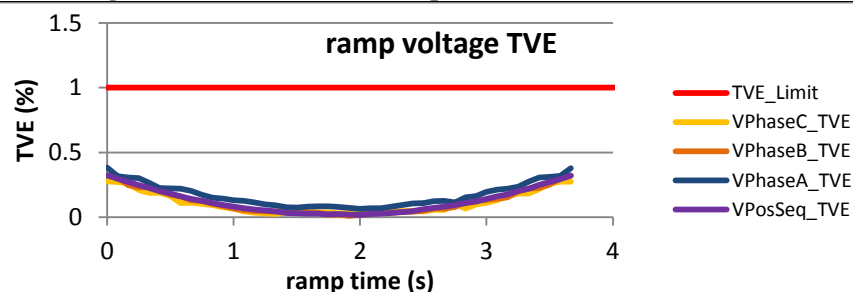


Figure 2687:  $F_s = 12$  FPS, ramp 58 Hz to 62 Hz at +1 Hz/s

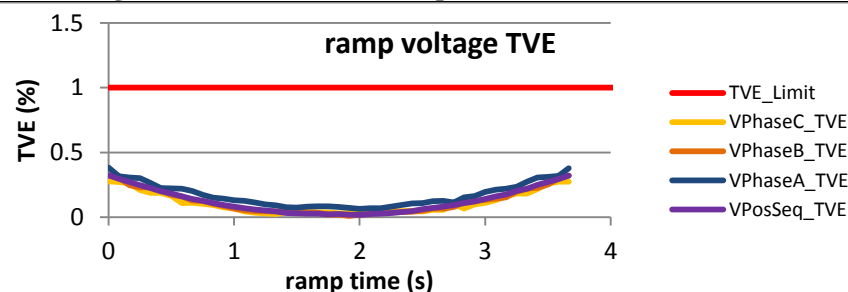


Figure 2688:  $F_s = 12$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

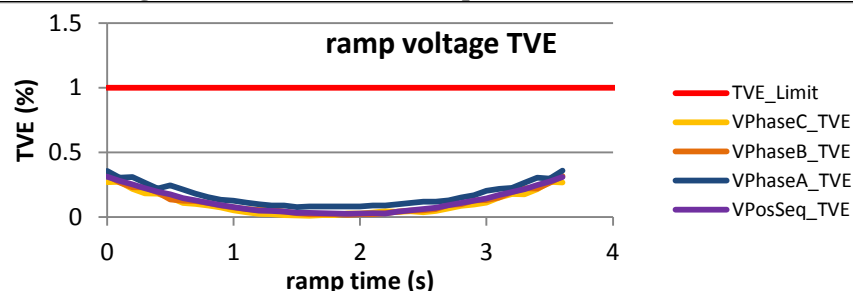


Figure 2689:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

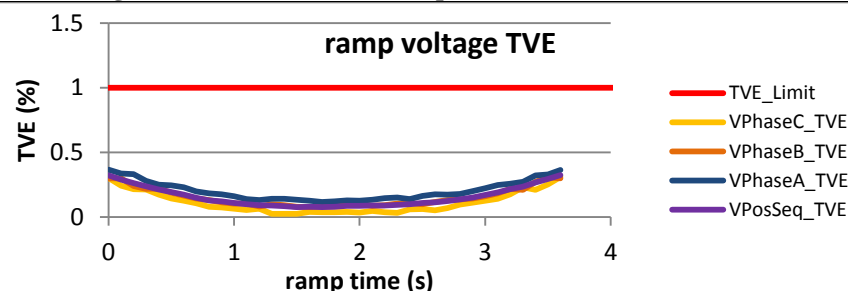
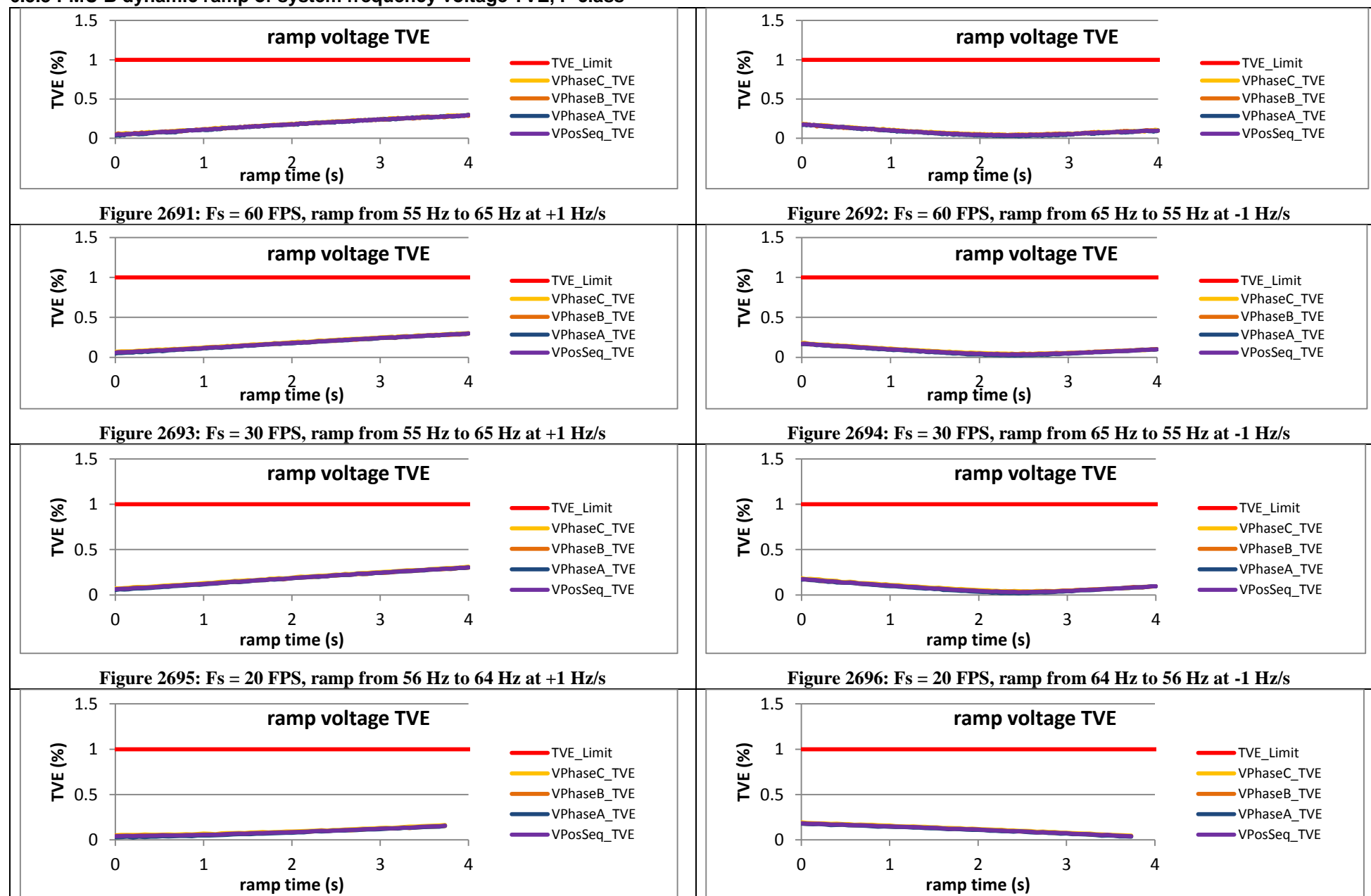
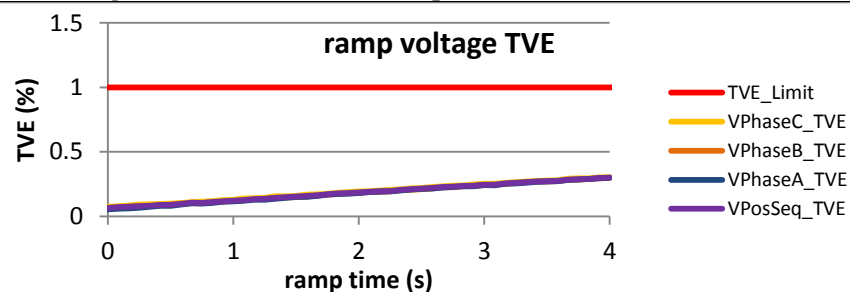


Figure 2690:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

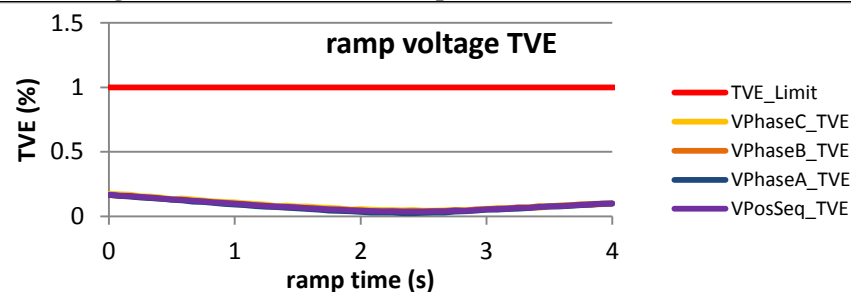
### 6.5.3 PMU B dynamic ramp of system frequency voltage TVE, P class



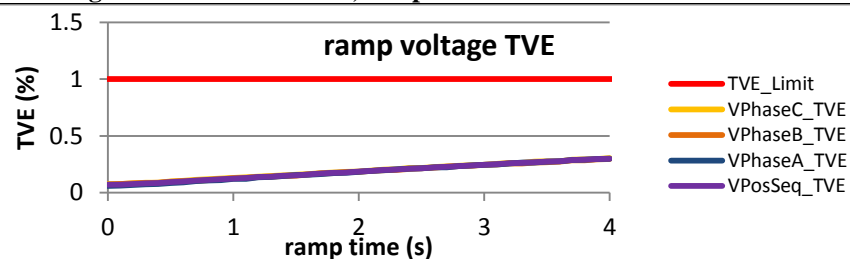
**Figure 2697:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s**



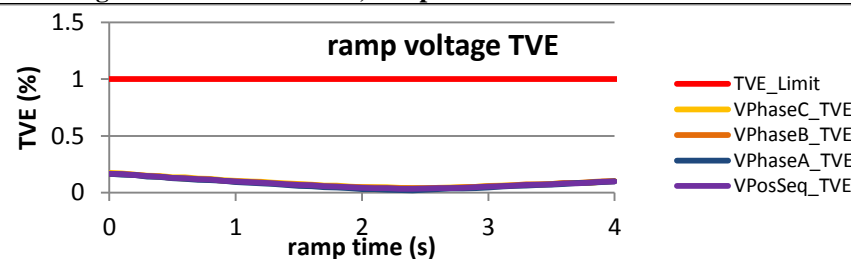
**Figure 2698:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s**



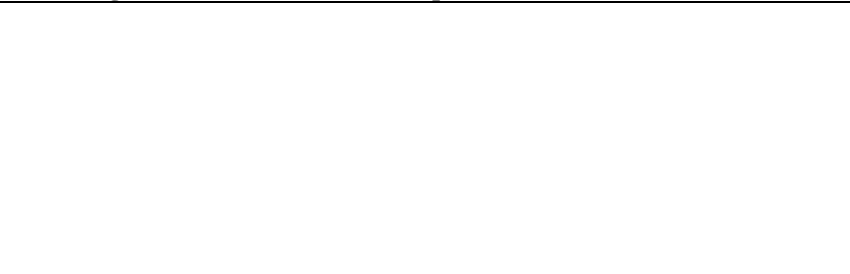
**Figure 2699:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s**



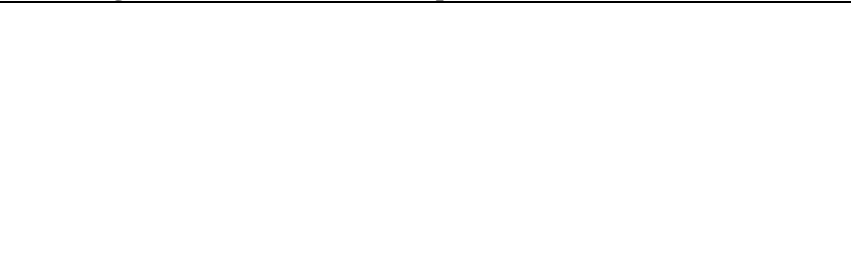
**Figure 2700:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s**



**Figure 2701:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s**



**Figure 2702:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s**



#### 6.5.4 PMU C dynamic ramp of system frequency voltage TVE, P class

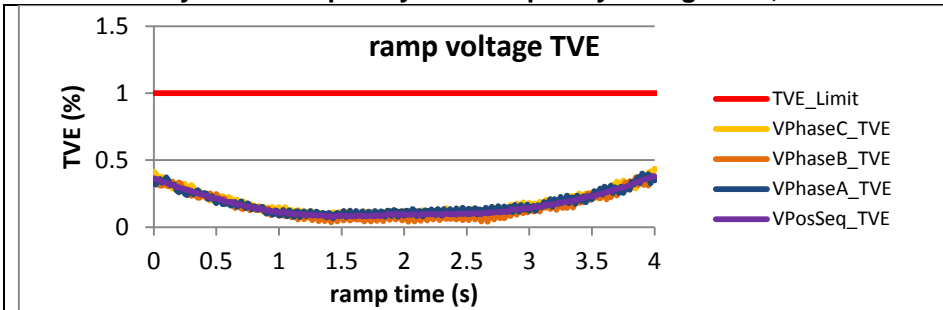


Figure 2703:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

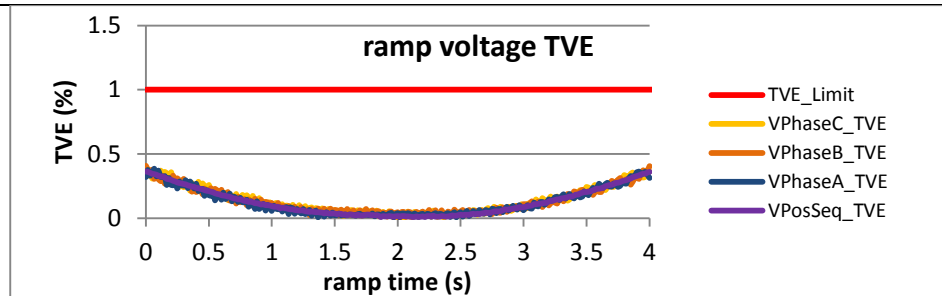


Figure 2704:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

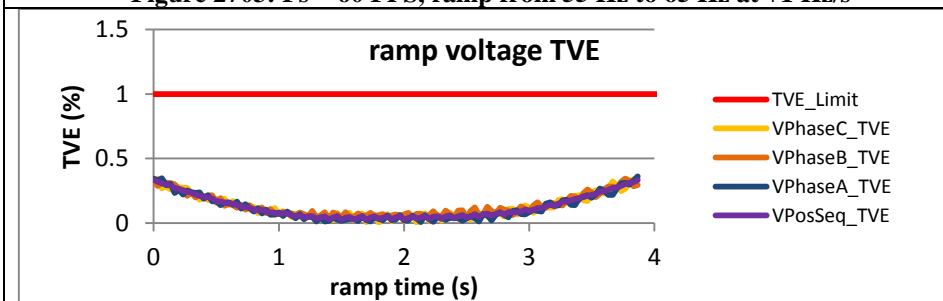


Figure 2705:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

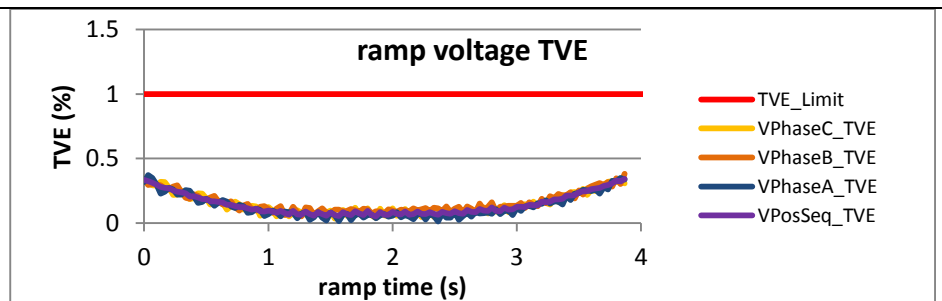


Figure 2706:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

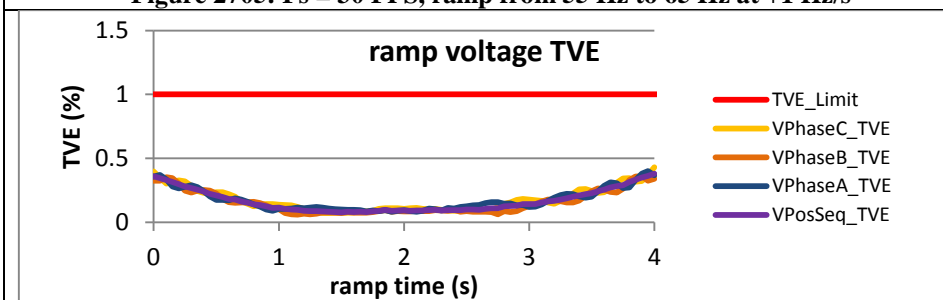


Figure 2707:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

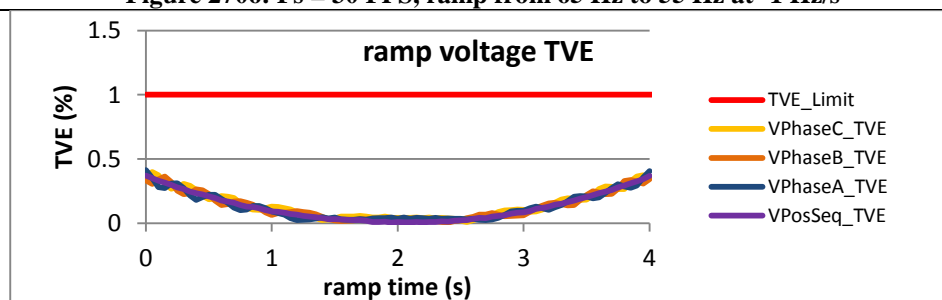


Figure 2708:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

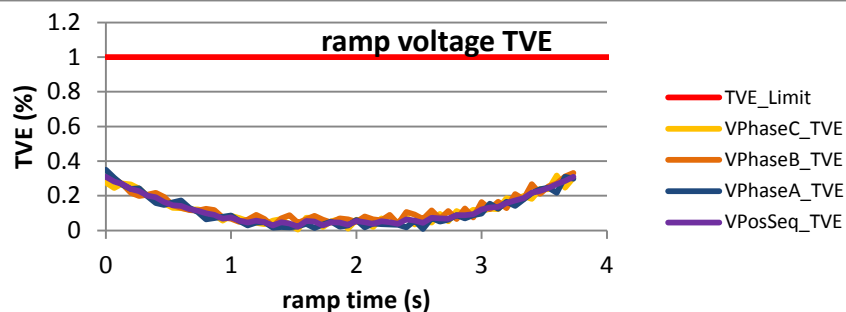


Figure 2709:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

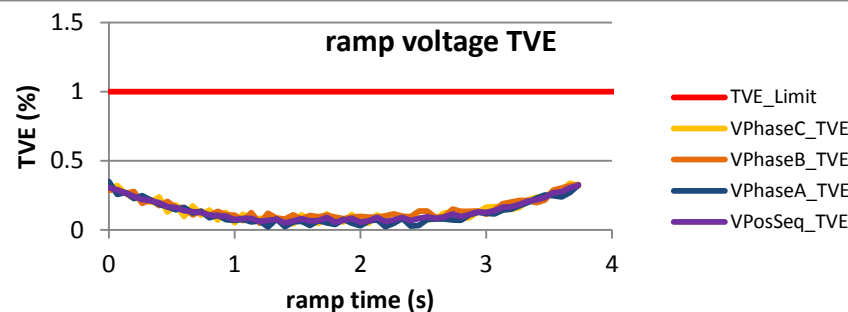


Figure 2710:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

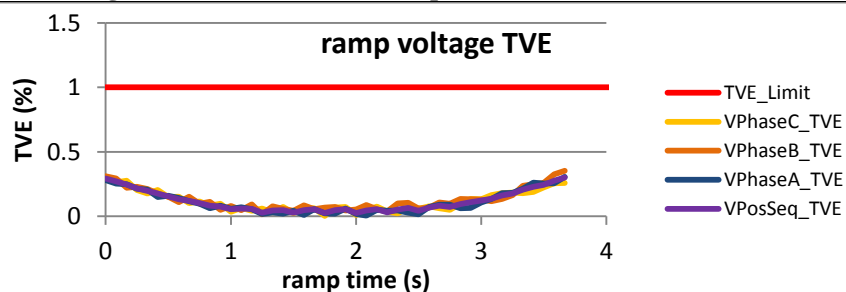


Figure 2711:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

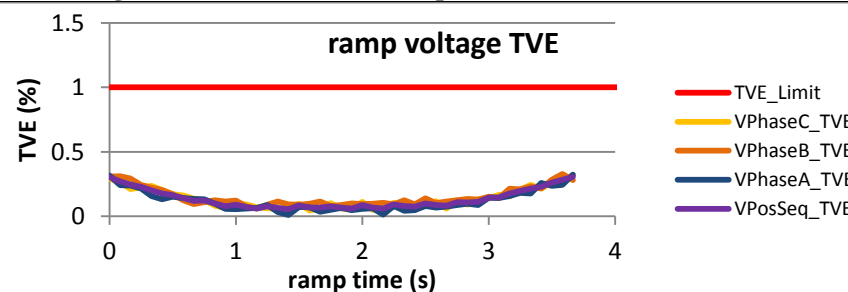


Figure 2712:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

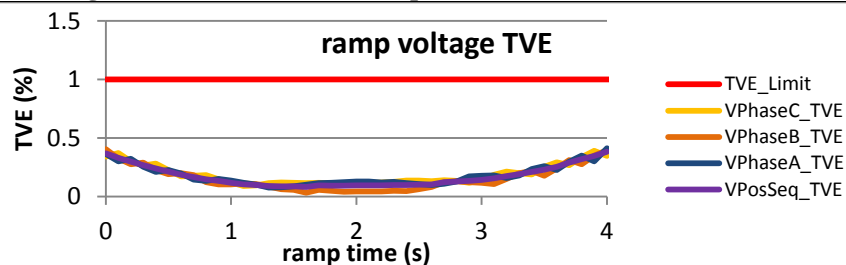


Figure 2713:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

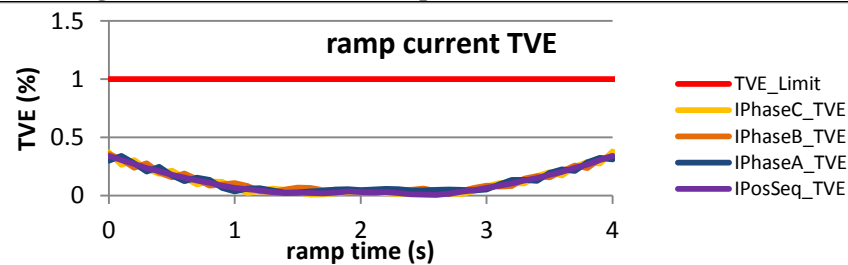


Figure 2714:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.5.5 PMU D dynamic ramp of system frequency voltage TVE, P class

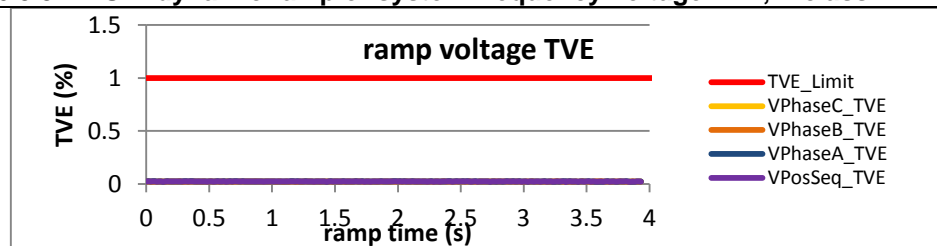


Figure 2715: Fs = 60 FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

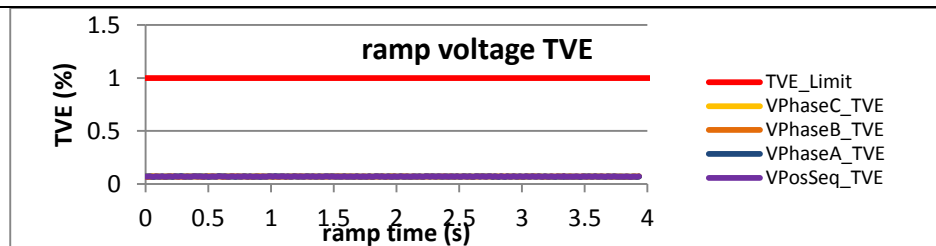


Figure 2716: Fs = 60 FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

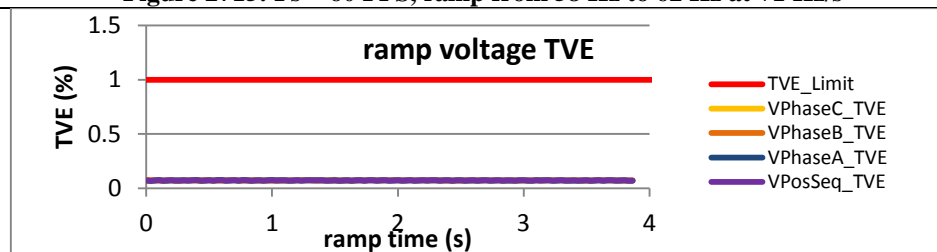


Figure 2717: Fs = 30 FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

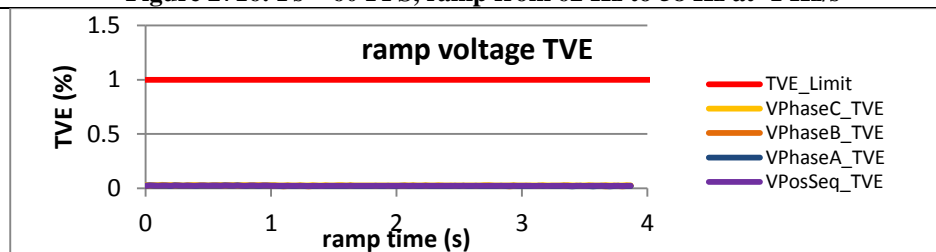


Figure 2718: Fs = 30 FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

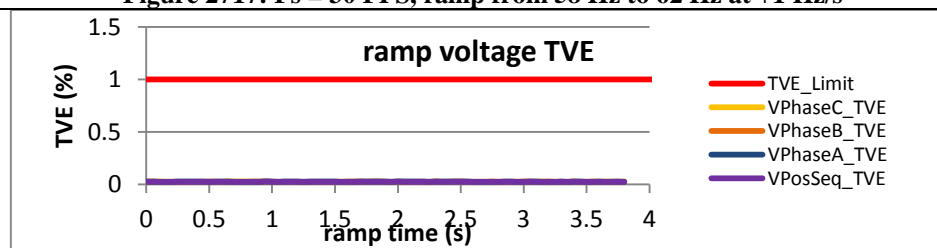


Figure 2719: Fs = 20 FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

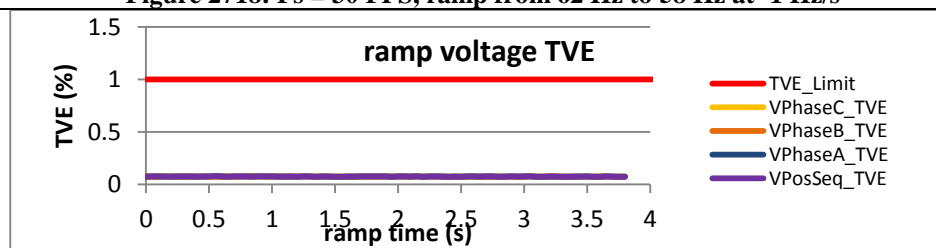


Figure 2720: Fs = 20 FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

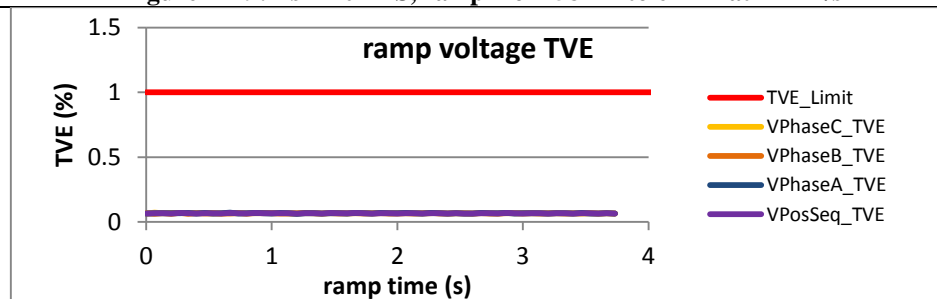


Figure 2721: Fs = 15 FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

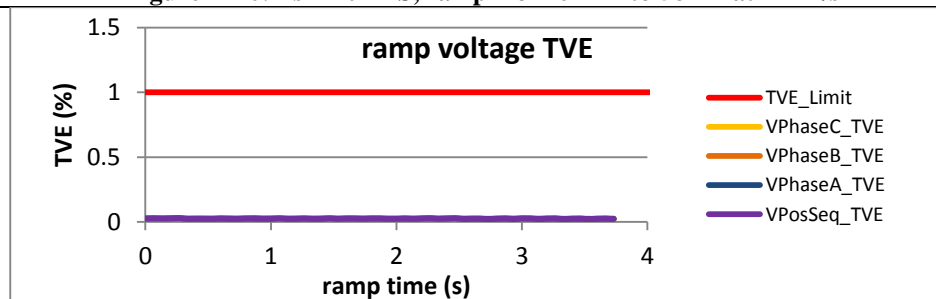


Figure 2722: Fs = 15 FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

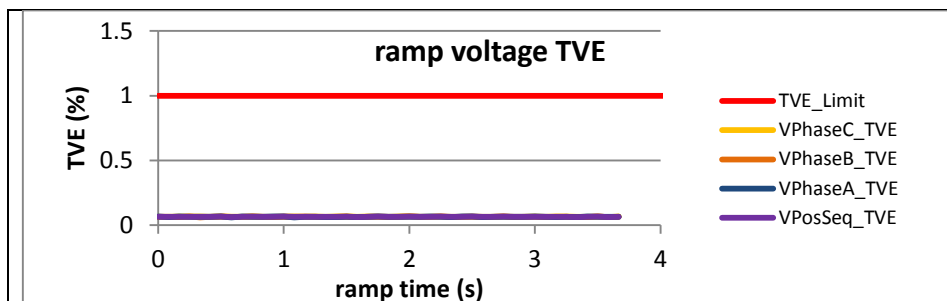


Figure 2723:  $F_s = 12$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

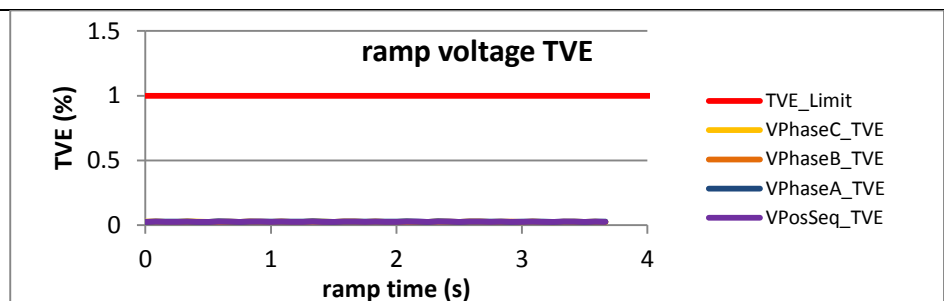


Figure 2724:  $F_s = 12$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

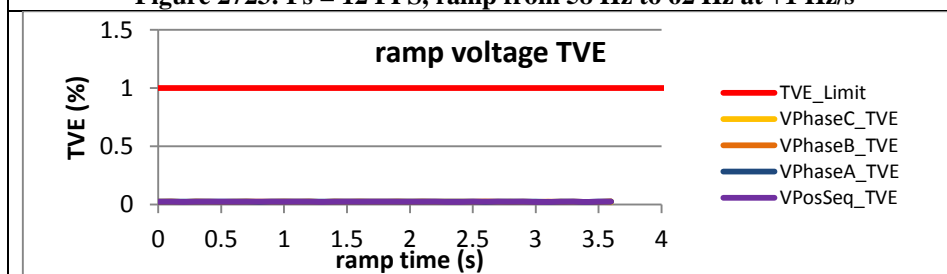


Figure 2725:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

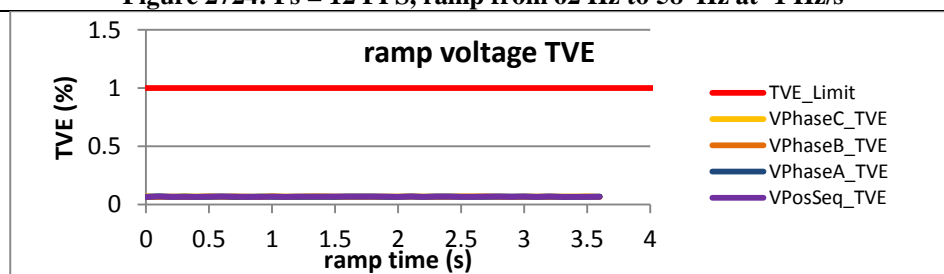
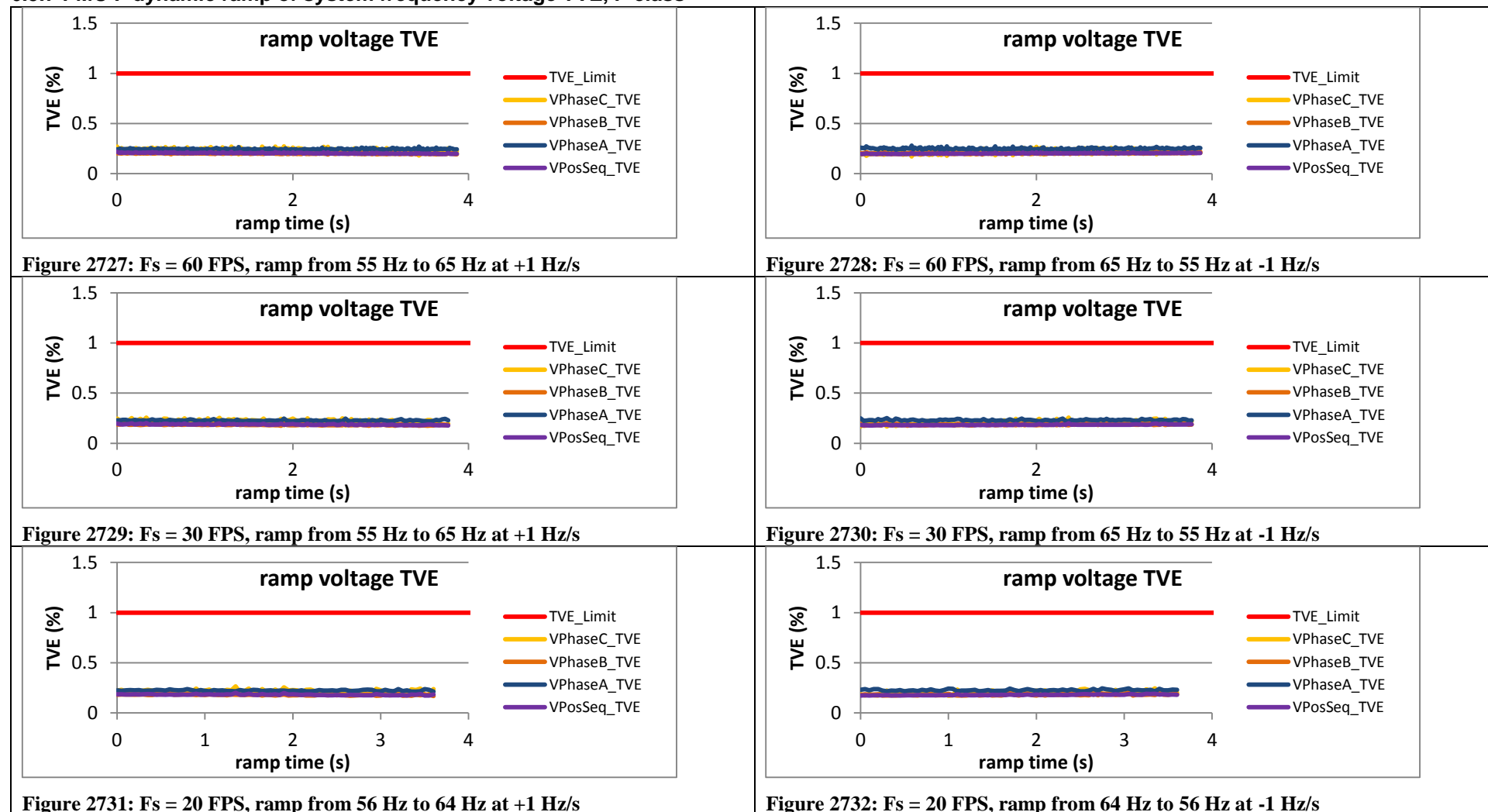


Figure 2726:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.5.6 PMU E dynamic ramp of system frequency voltage TVE, P class

PMU E does not support P class.

### 6.5.7 PMU F dynamic ramp of system frequency voltage TVE, P class





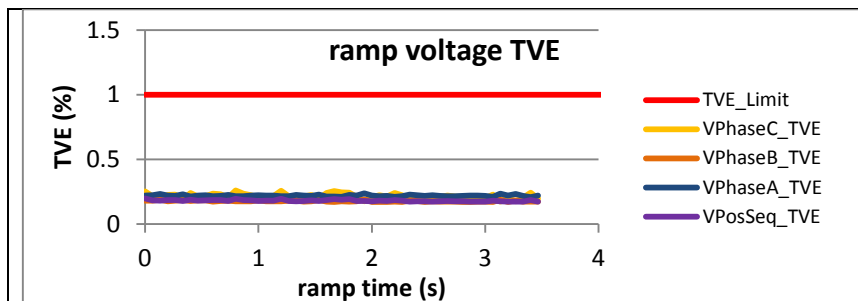


Figure 2733:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

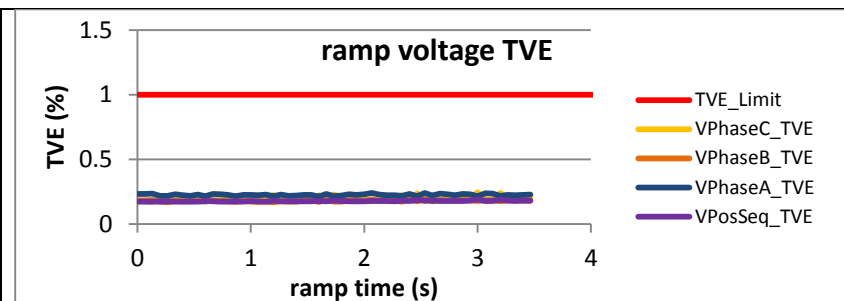


Figure 2734:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

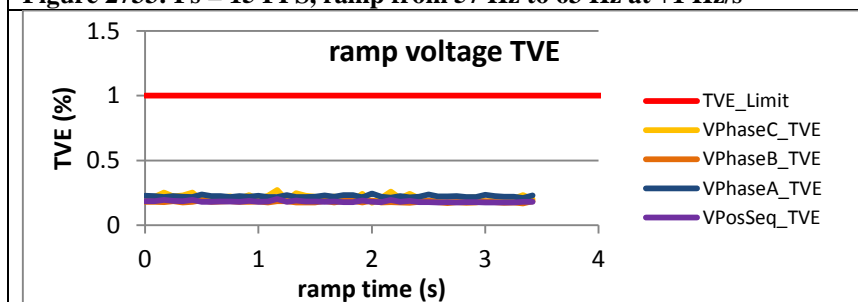


Figure 2735:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

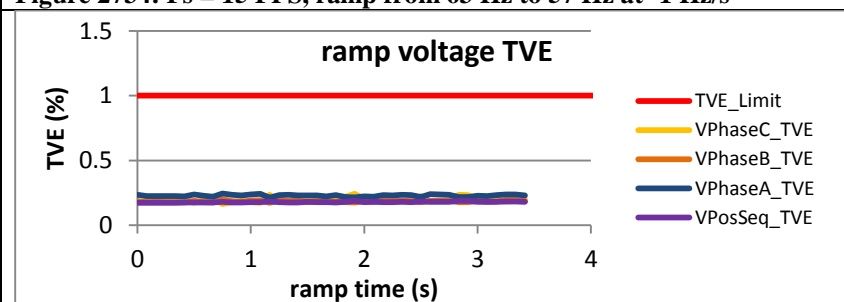


Figure 2736:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

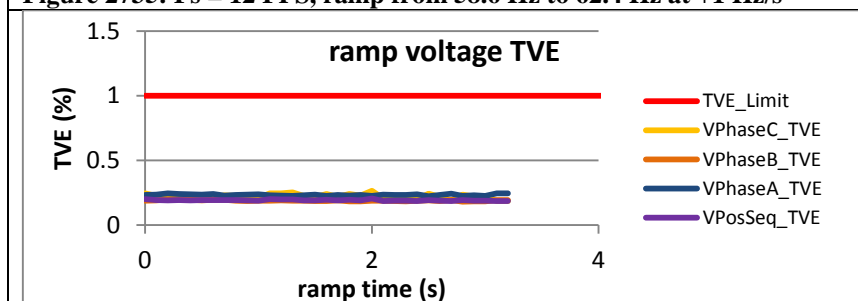


Figure 2737:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

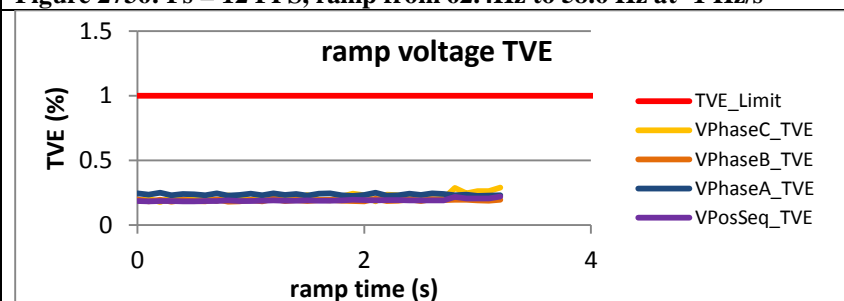


Figure 2738:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.5.8 PMU G dynamic ramp of system frequency voltage TVE, P class

PMU G does not support P class.

### 6.5.9 PMU H dynamic ramp of system frequency voltage TVE, P class

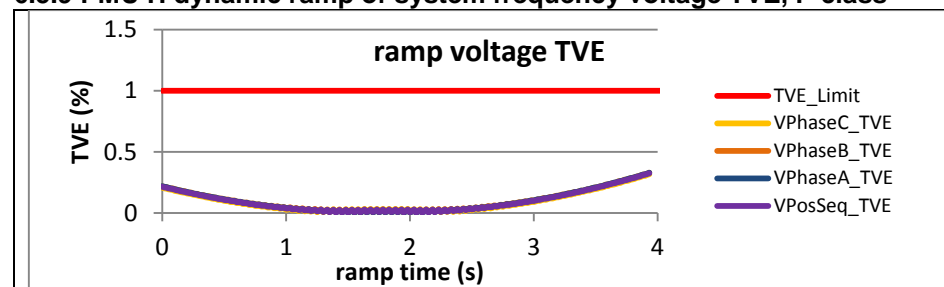


Figure 2739: Fs = 60 FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

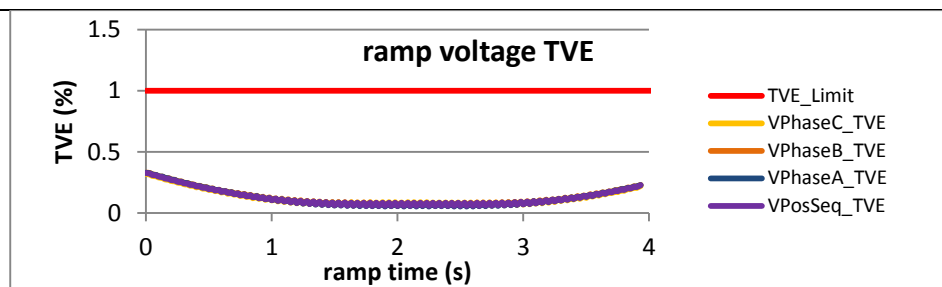


Figure 2740: Fs = 60 FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

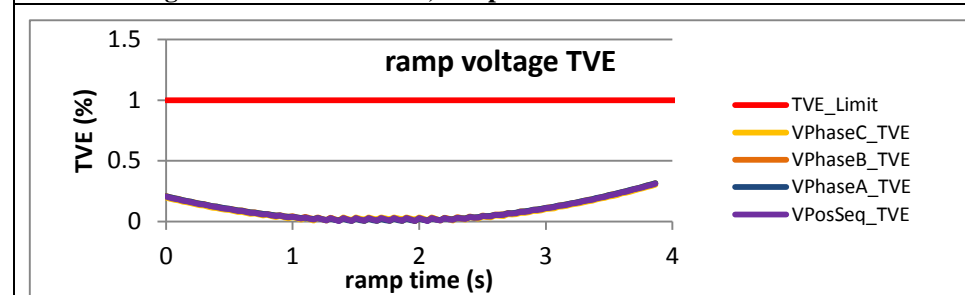


Figure 2741: Fs = 30 FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

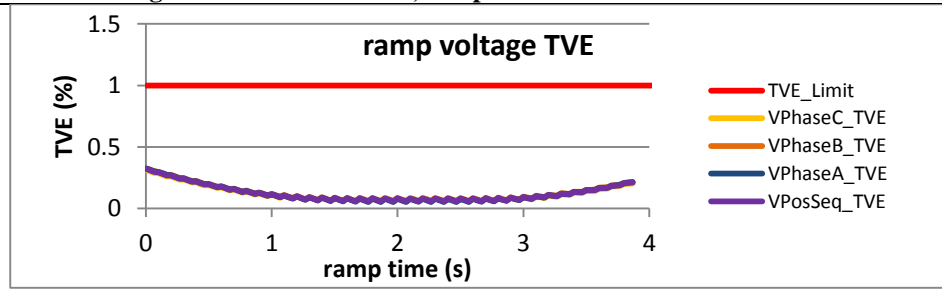


Figure 2742: Fs = 30 FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

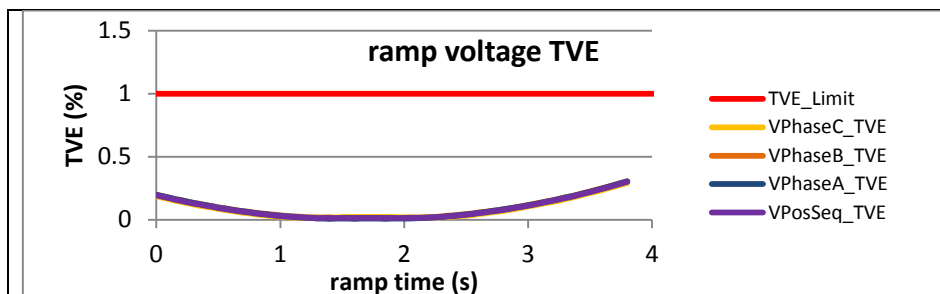


Figure 2743:  $F_s = 20$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

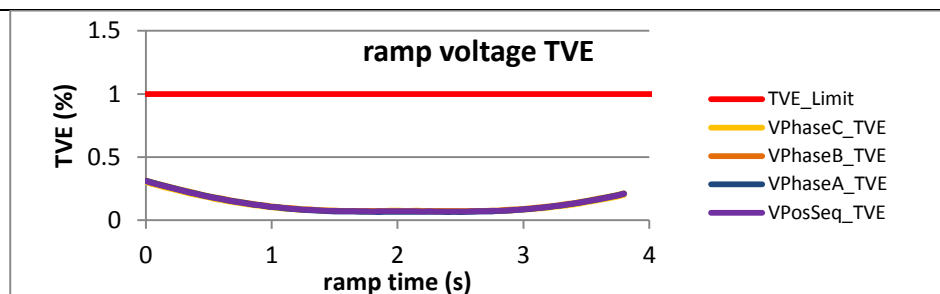


Figure 2744:  $F_s = 20$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

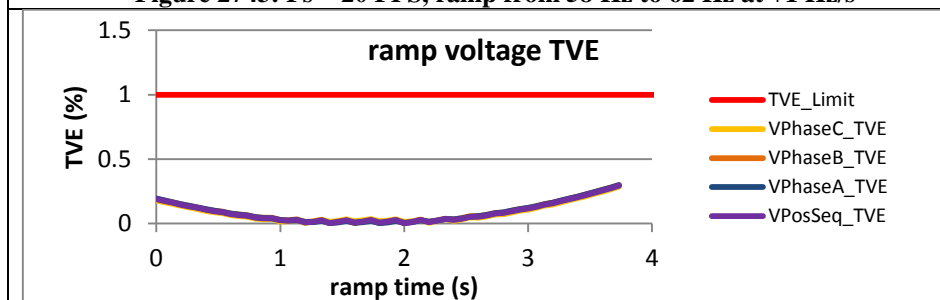


Figure 2745:  $F_s = 15$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

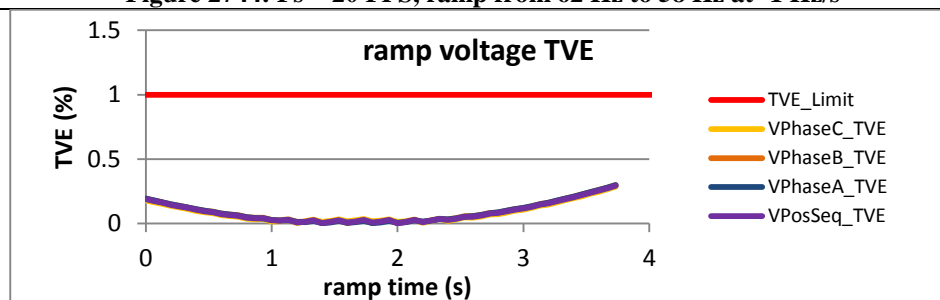


Figure 2746:  $F_s = 15$  FPS, ramp from 63 Hz to 58 Hz at -1 Hz/s

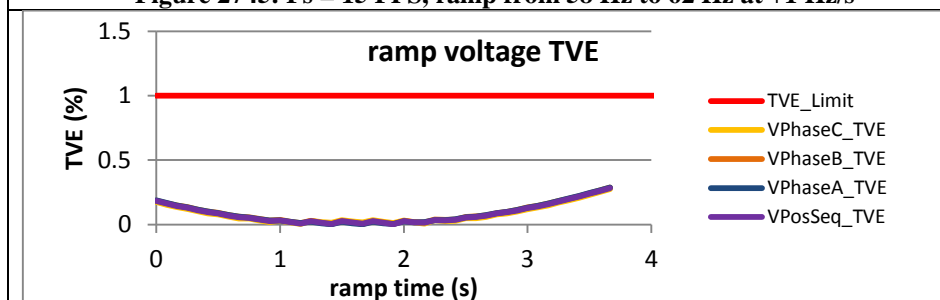


Figure 2747:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62 Hz at +1 Hz/s

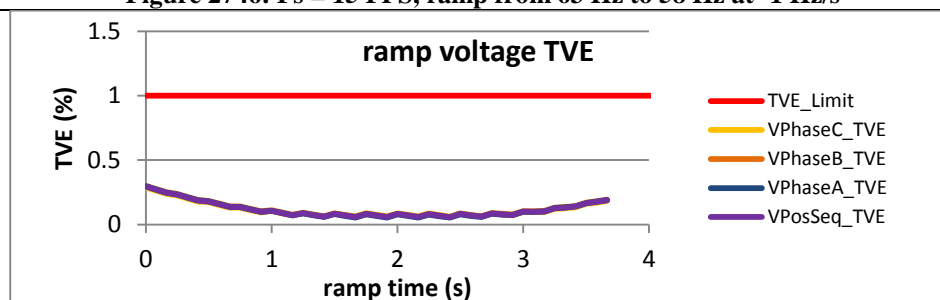


Figure 2748:  $F_s = 12$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

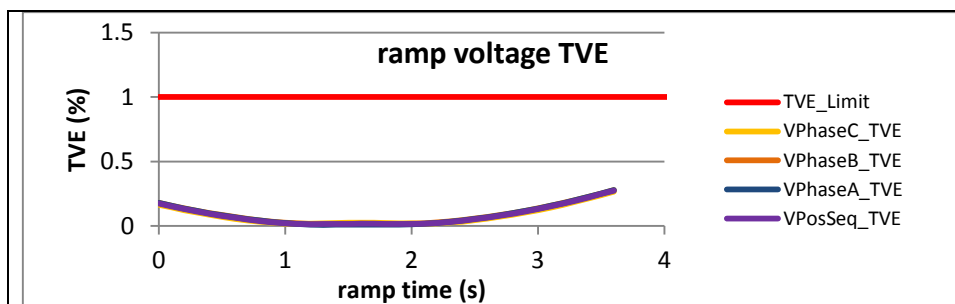


Figure 2749:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

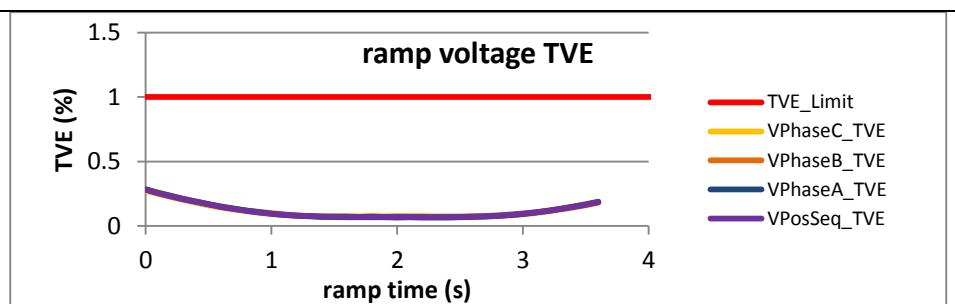
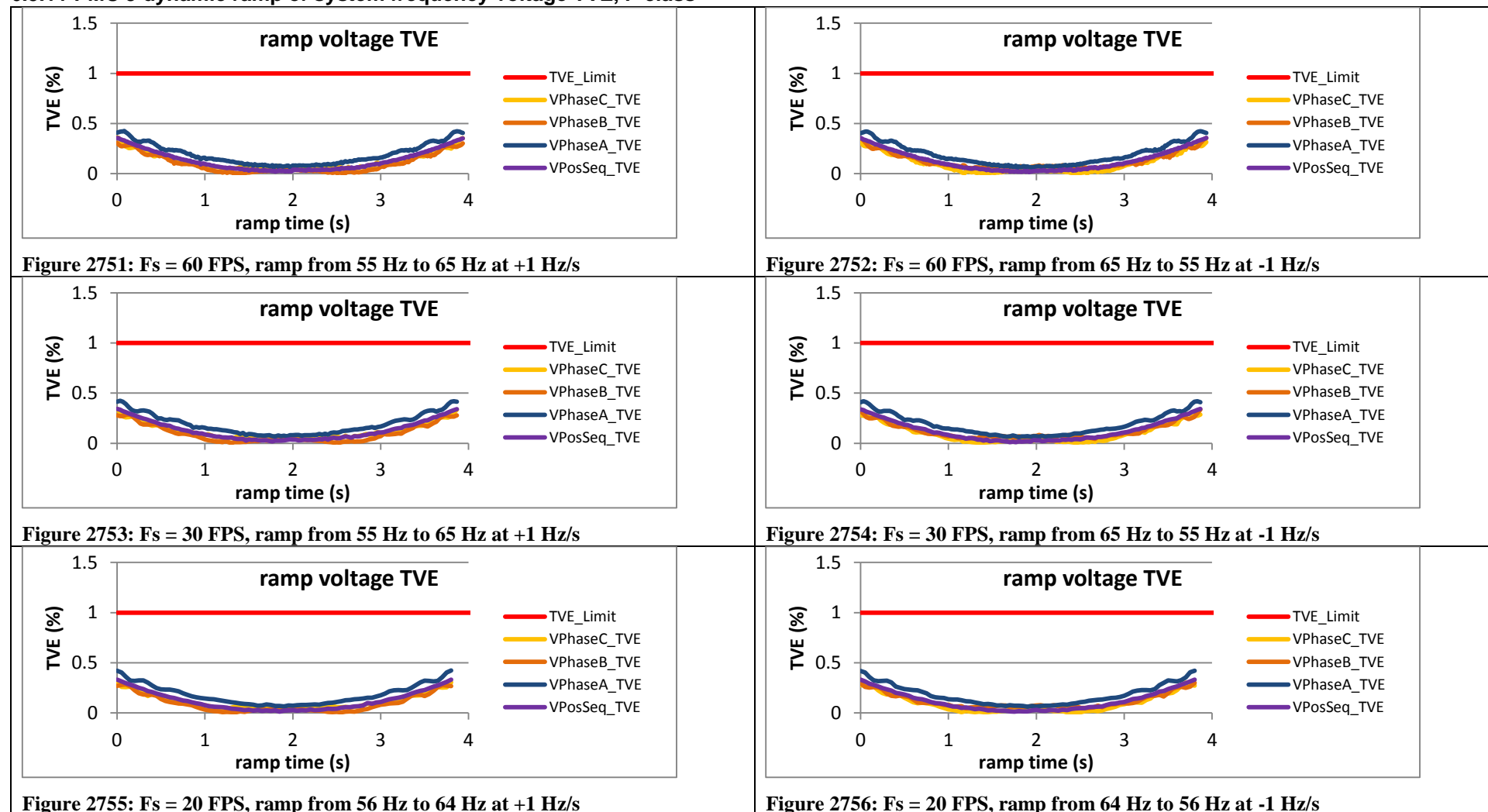


Figure 2750:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.5.10 PMU I dynamic ramp of system frequency voltage TVE, P class

PMU I does not support P class

#### 6.5.11 PMU J dynamic ramp of system frequency voltage TVE, P class



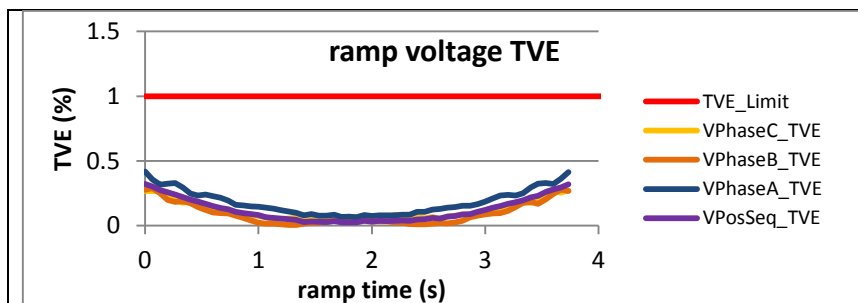


Figure 2757:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

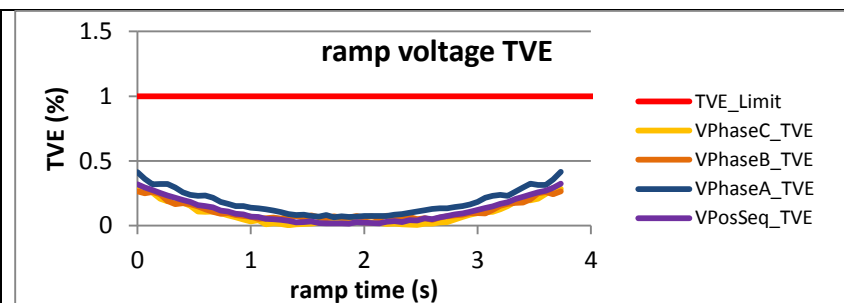


Figure 2758:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

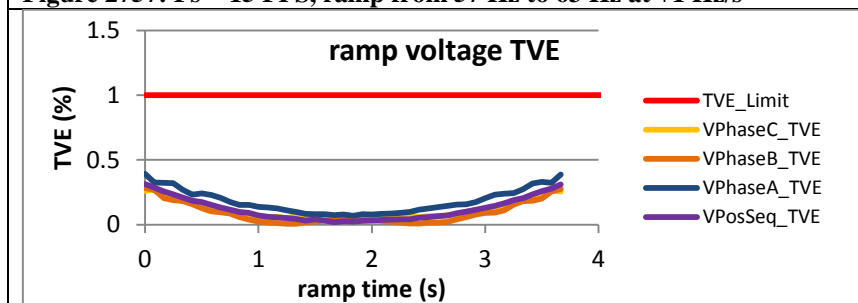


Figure 2759:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

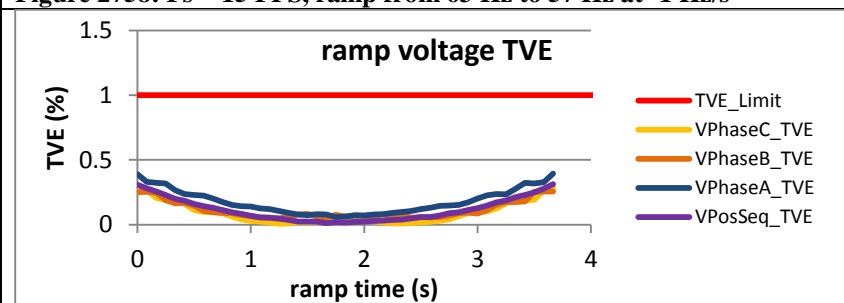


Figure 2760:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

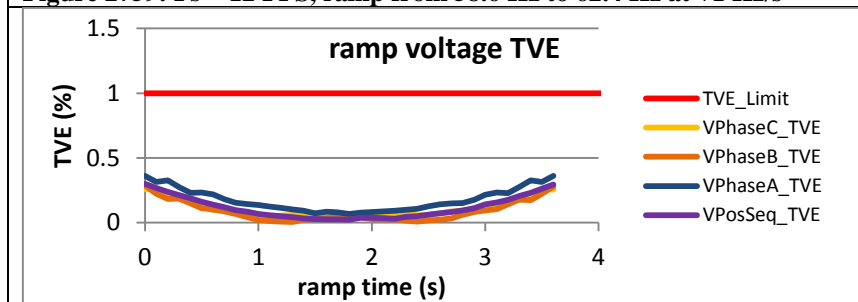


Figure 2761:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

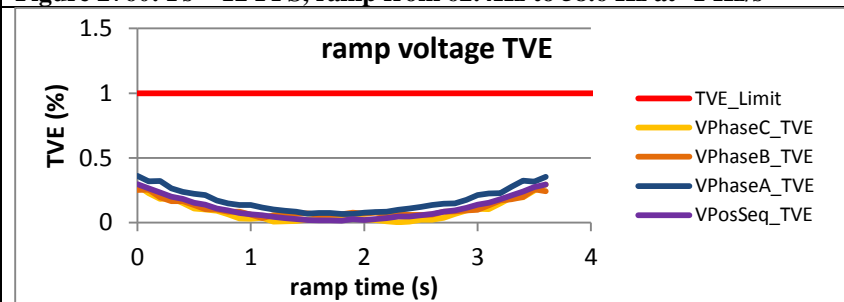
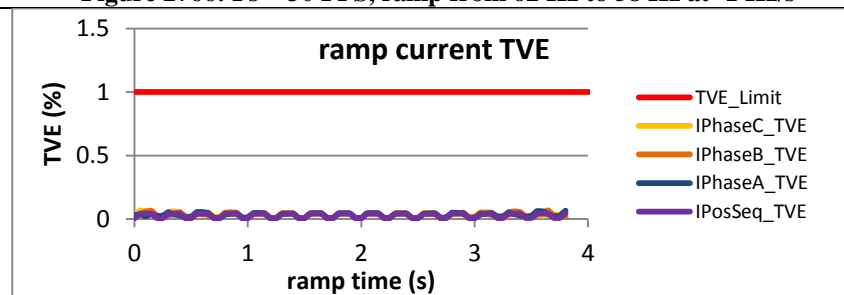
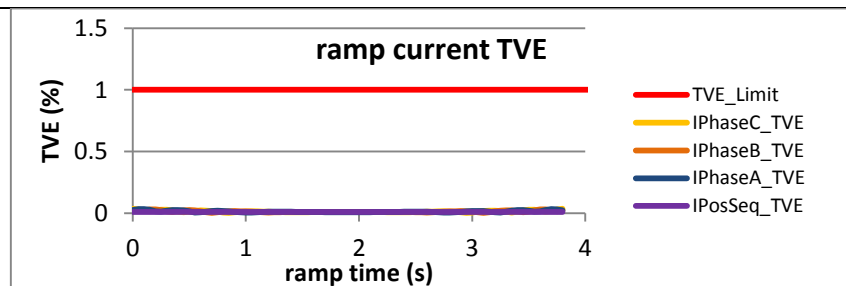
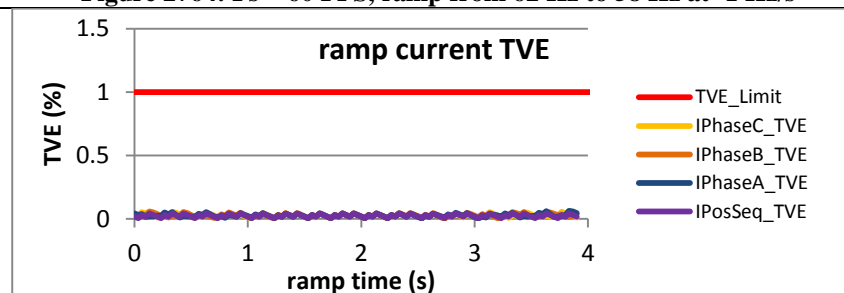
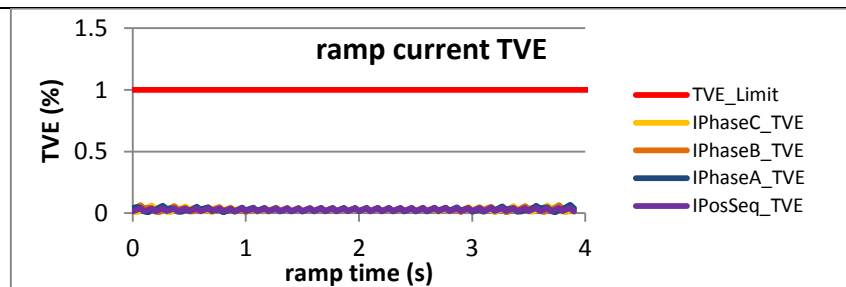
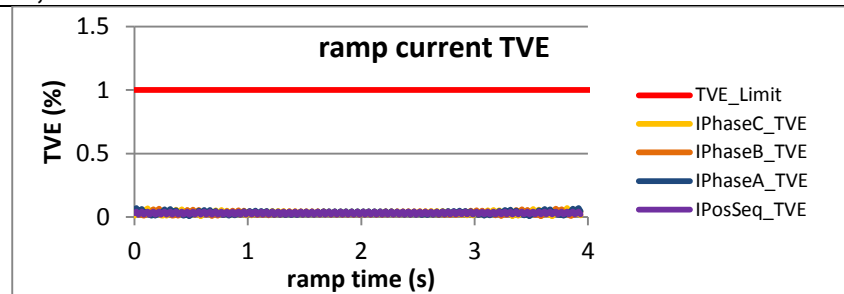
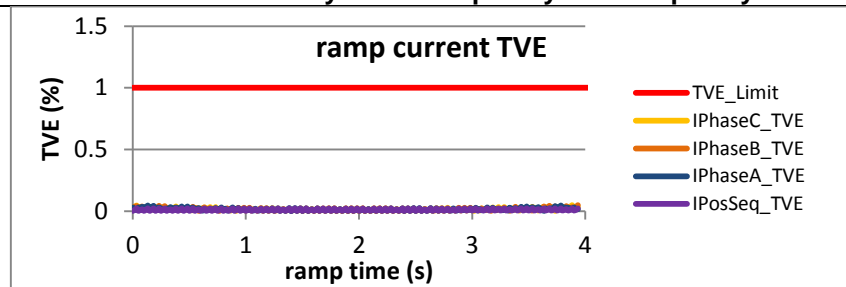


Figure 2762:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.6 Dynamic ramp of system frequency current TVE, P class

### 6.6.1 C37.118.1 Annex C dynamic ramp of system frequency current TVE, P class



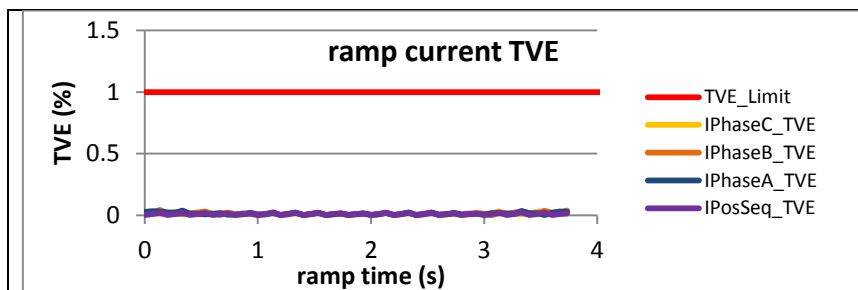


Figure 2769:  $F_s = 15$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

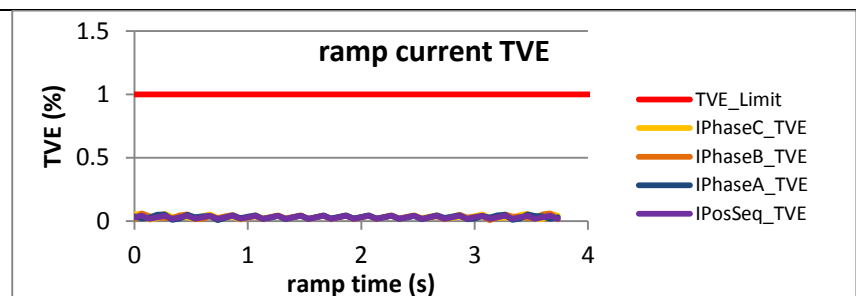


Figure 2770:  $F_s = 15$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

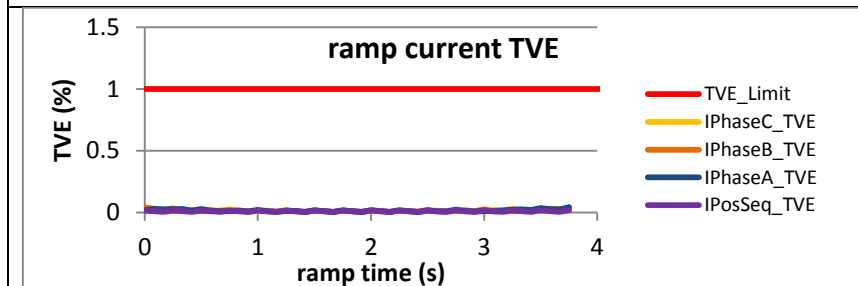


Figure 2771:  $F_s = 12$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

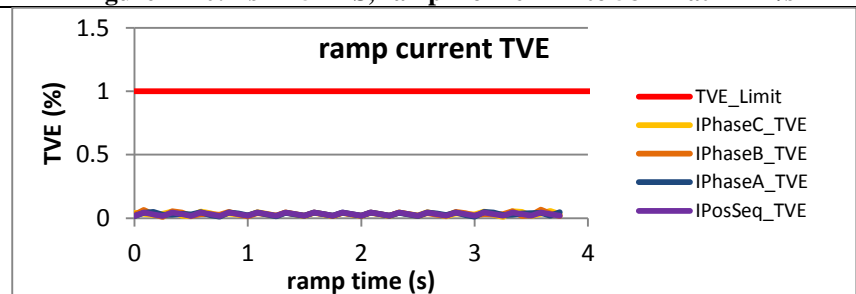


Figure 2772:  $F_s = 12$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

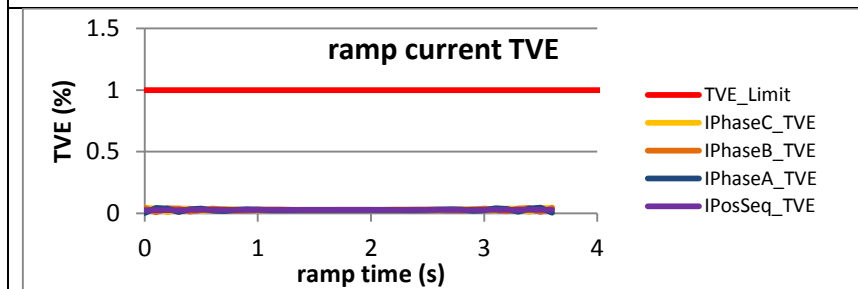


Figure 2773:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

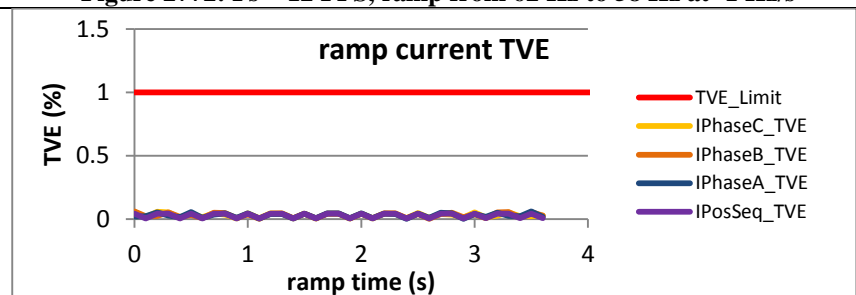
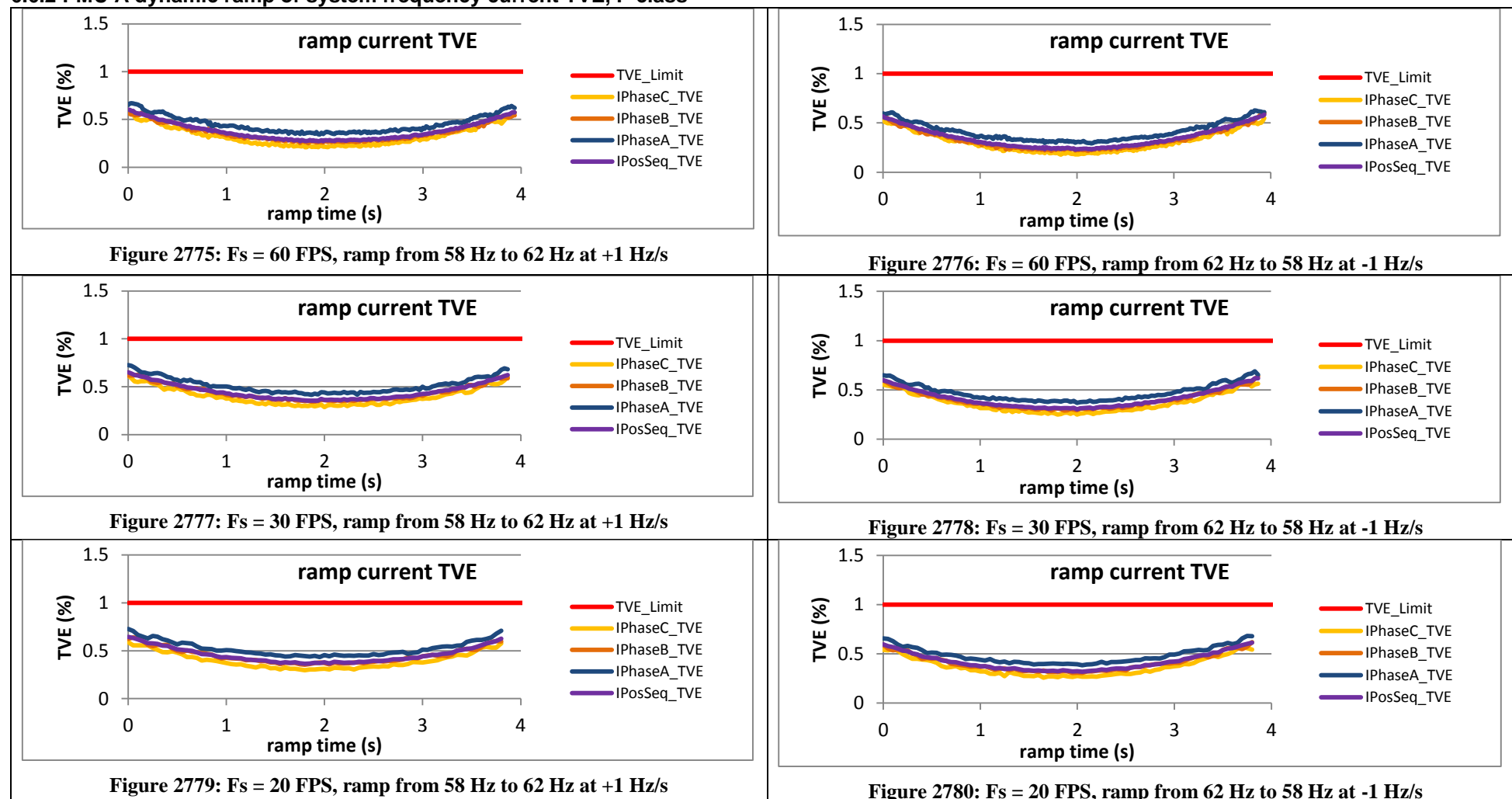


Figure 2774:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s



## 6.6.2 PMU A dynamic ramp of system frequency current TVE, P class



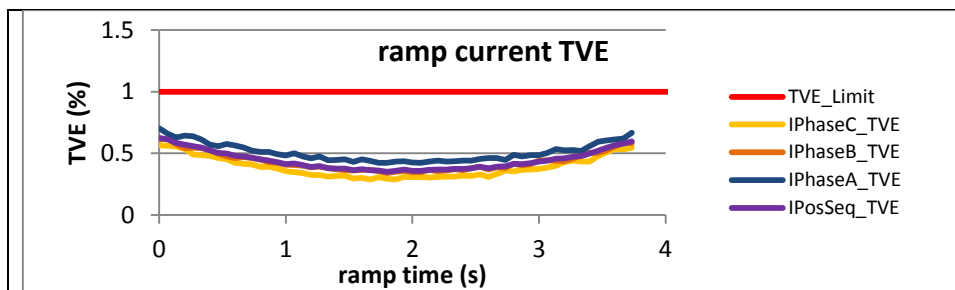


Figure 2781:  $F_s = 15$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

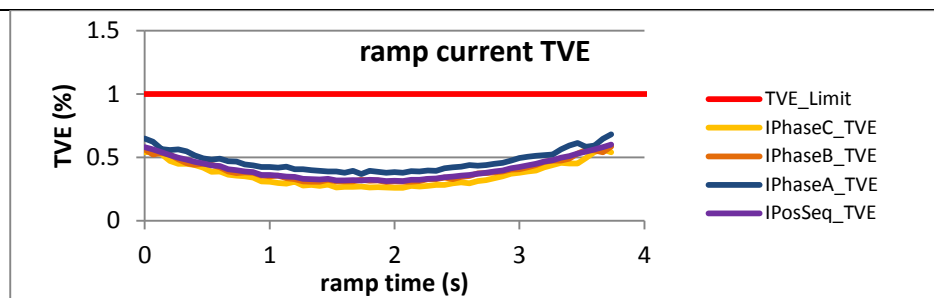


Figure 2782:  $F_s = 15$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

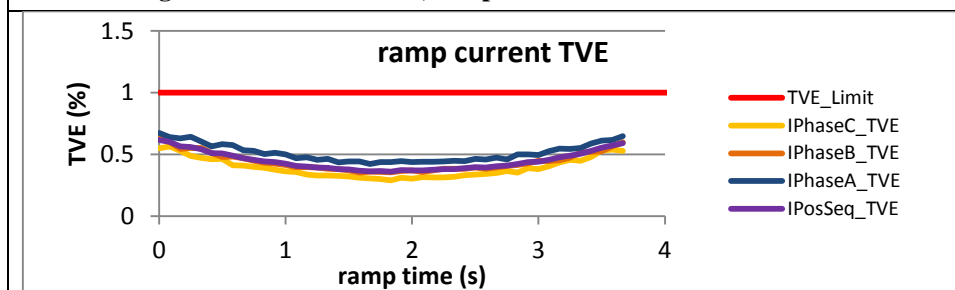


Figure 2783:  $F_s = 12$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

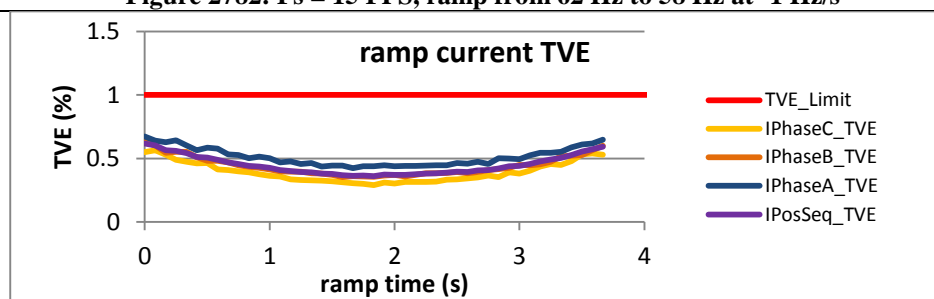


Figure 2784:  $F_s = 12$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

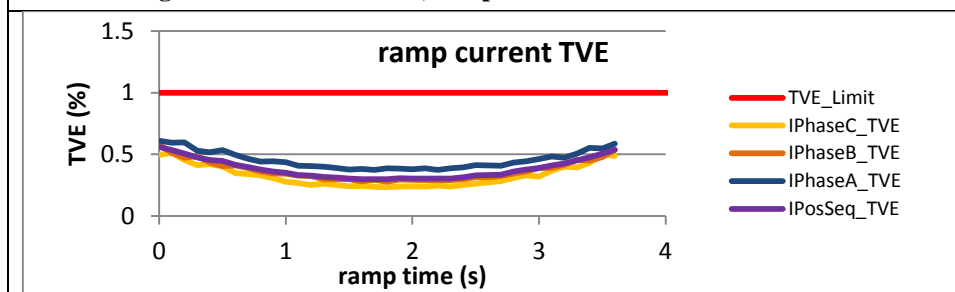


Figure 2785:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

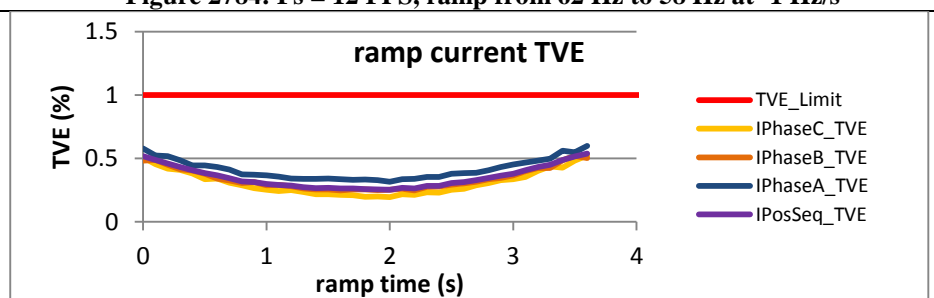


Figure 2786:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.6.3 PMU B dynamic ramp of system frequency current TVE, P class

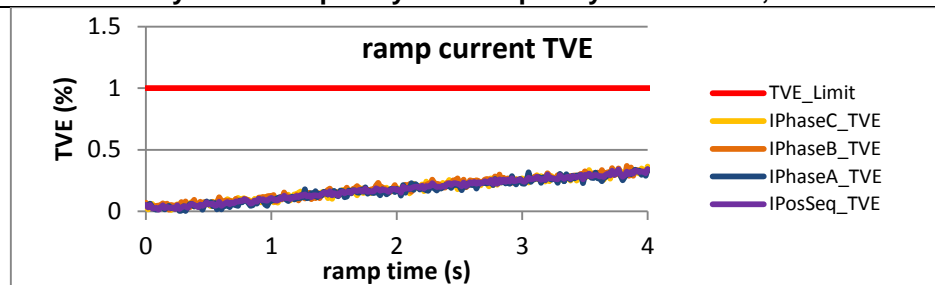


Figure 2787:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

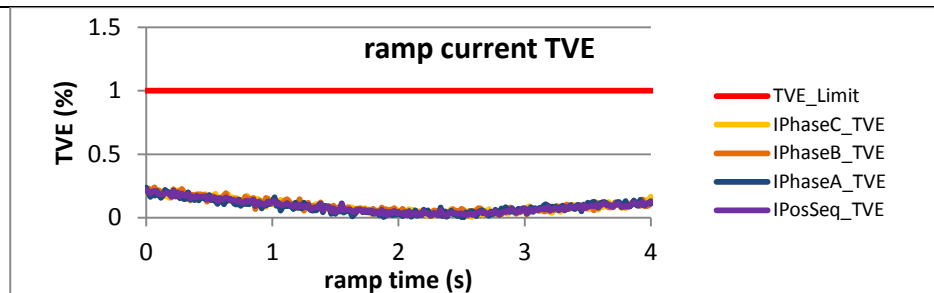


Figure 2788:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

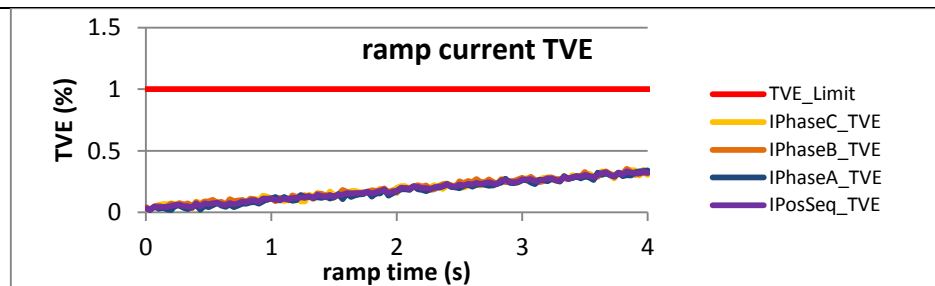


Figure 2789:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

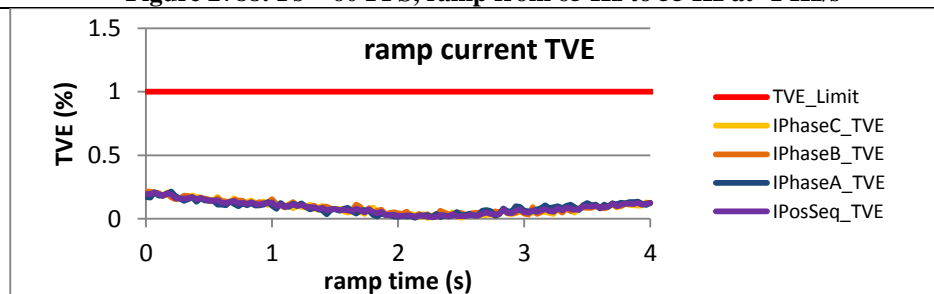


Figure 2790:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

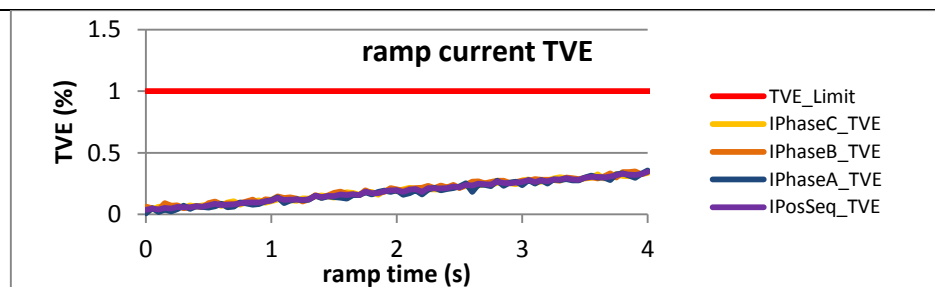


Figure 2791:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

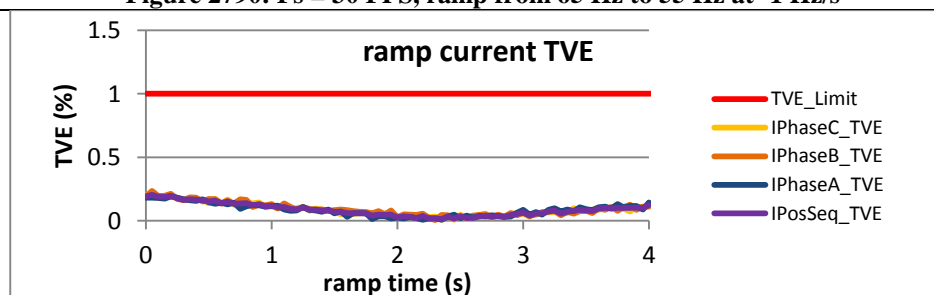


Figure 2792:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

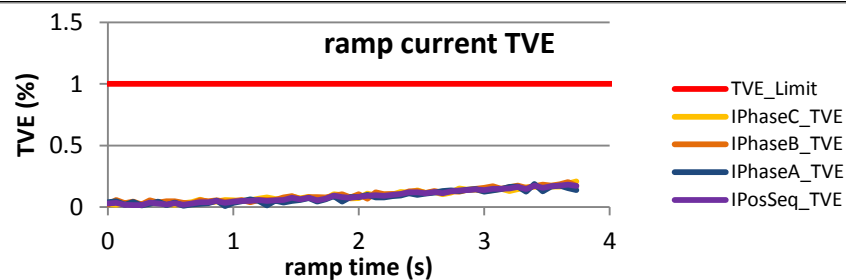


Figure 2793: Fs = 15 FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

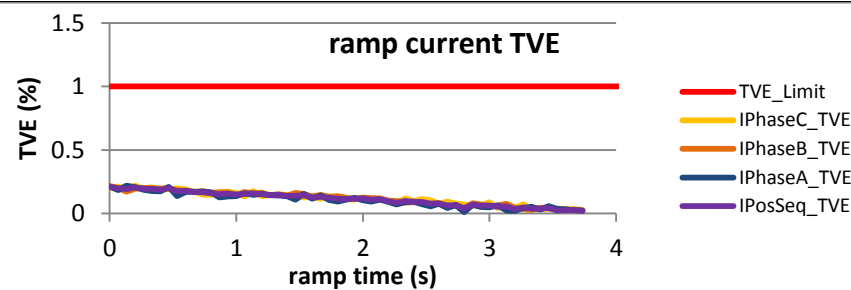


Figure 2794: Fs = 15 FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

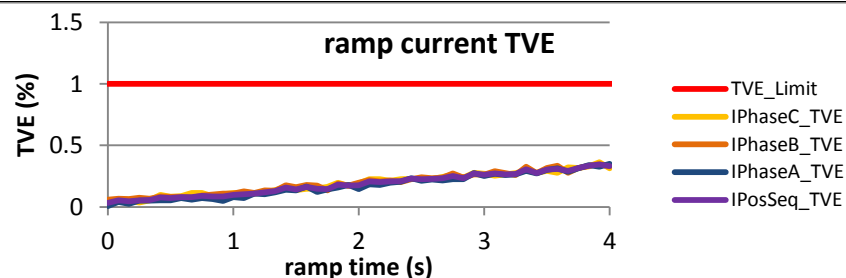


Figure 2795: Fs = 12 FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

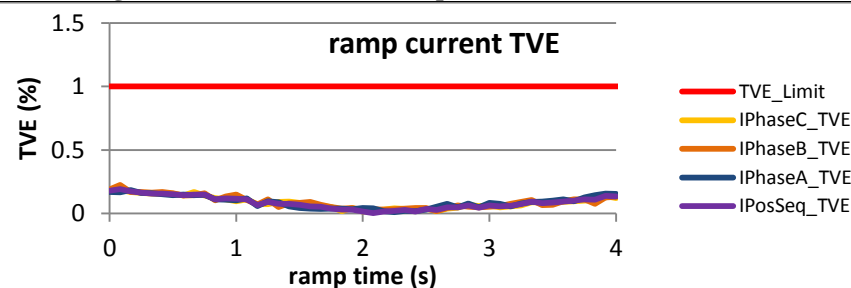
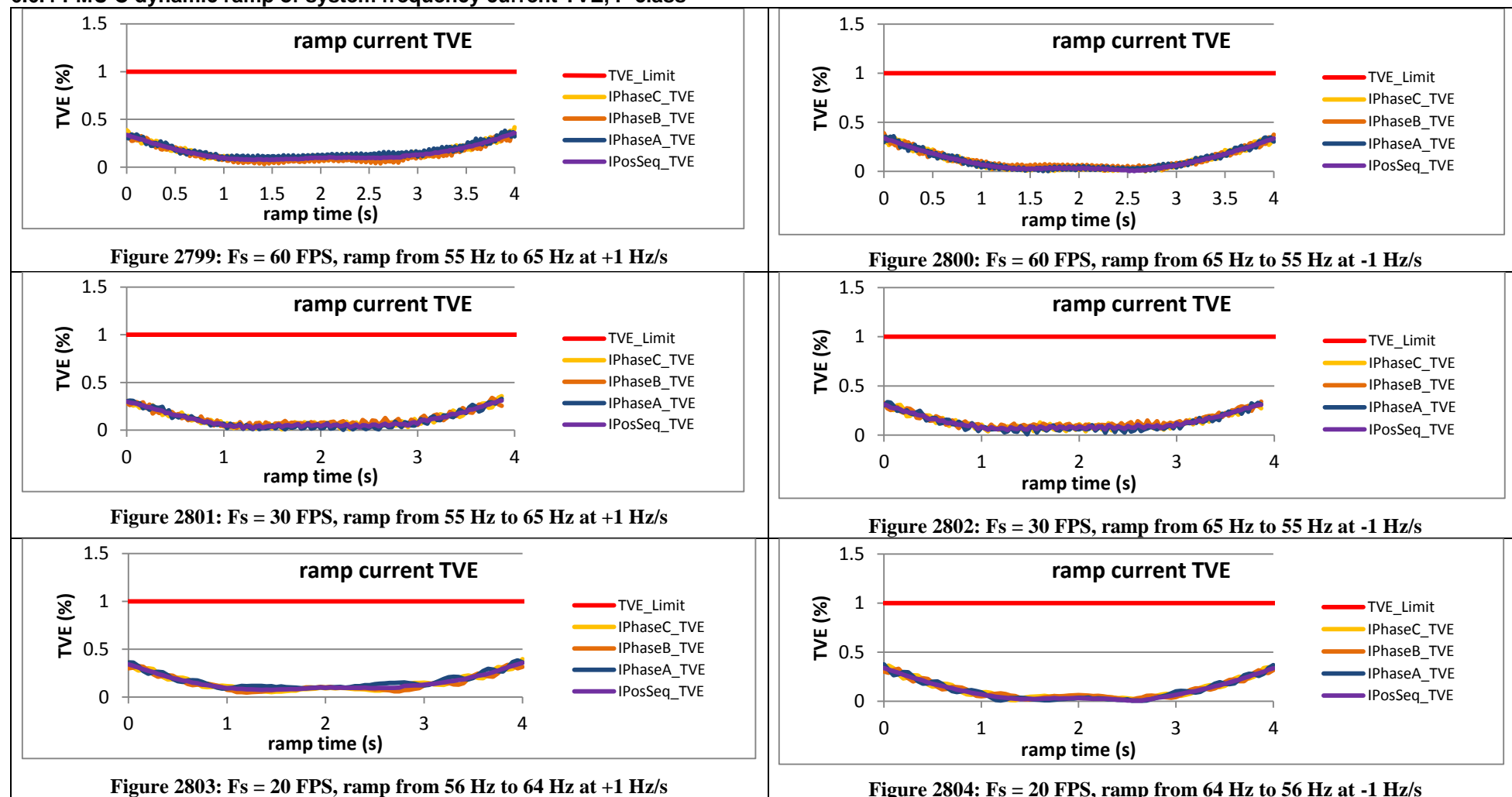


Figure 2796: Fs = 12 FPS, ramp from 62.4Hz to 58.6 Hz at -1 Hz/s

Figure 2797: Fs = 10 FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

Figure 2798: Fs = 10 FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.6.4 PMU C dynamic ramp of system frequency current TVE, P class



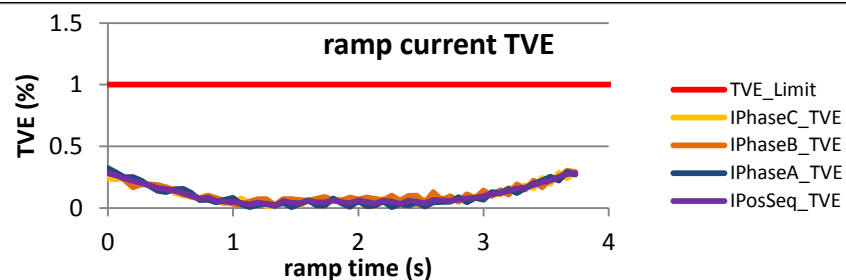


Figure 2805:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

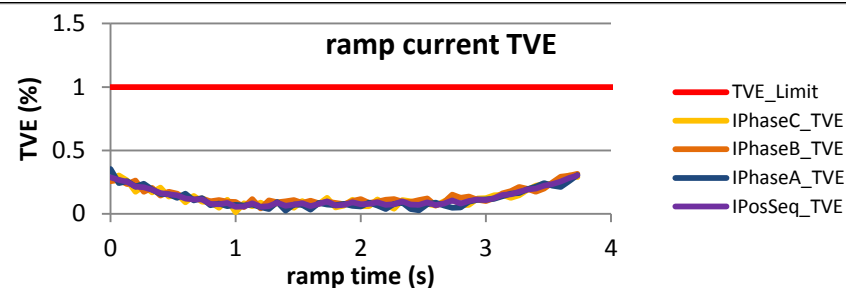


Figure 2806:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

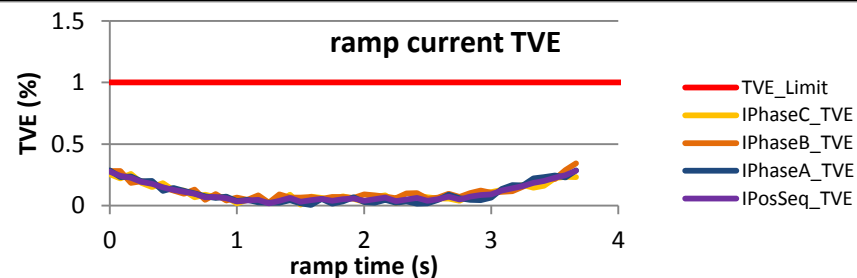


Figure 2807:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

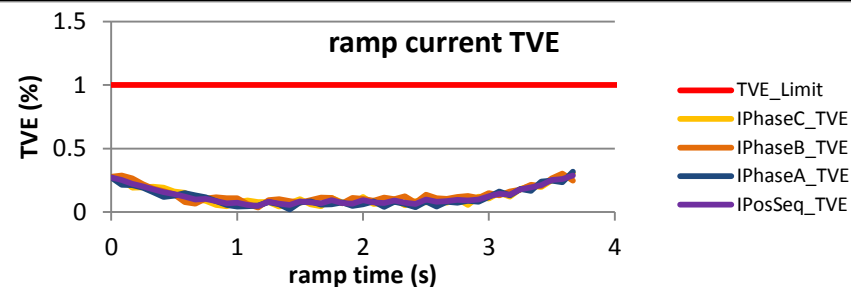


Figure 2808:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

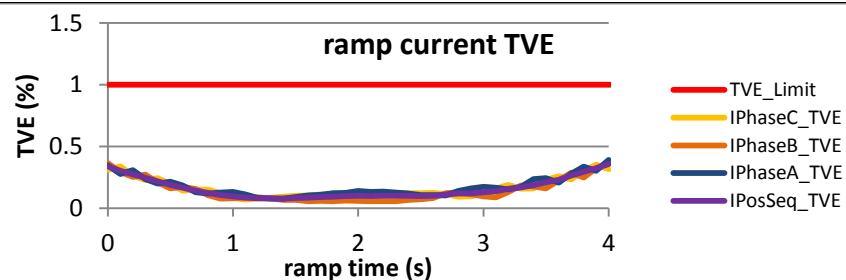


Figure 2809:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

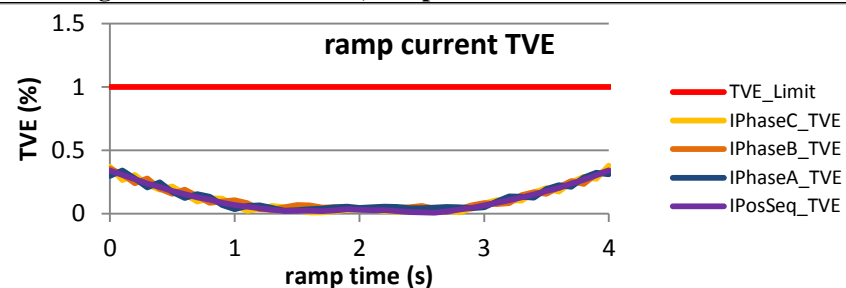
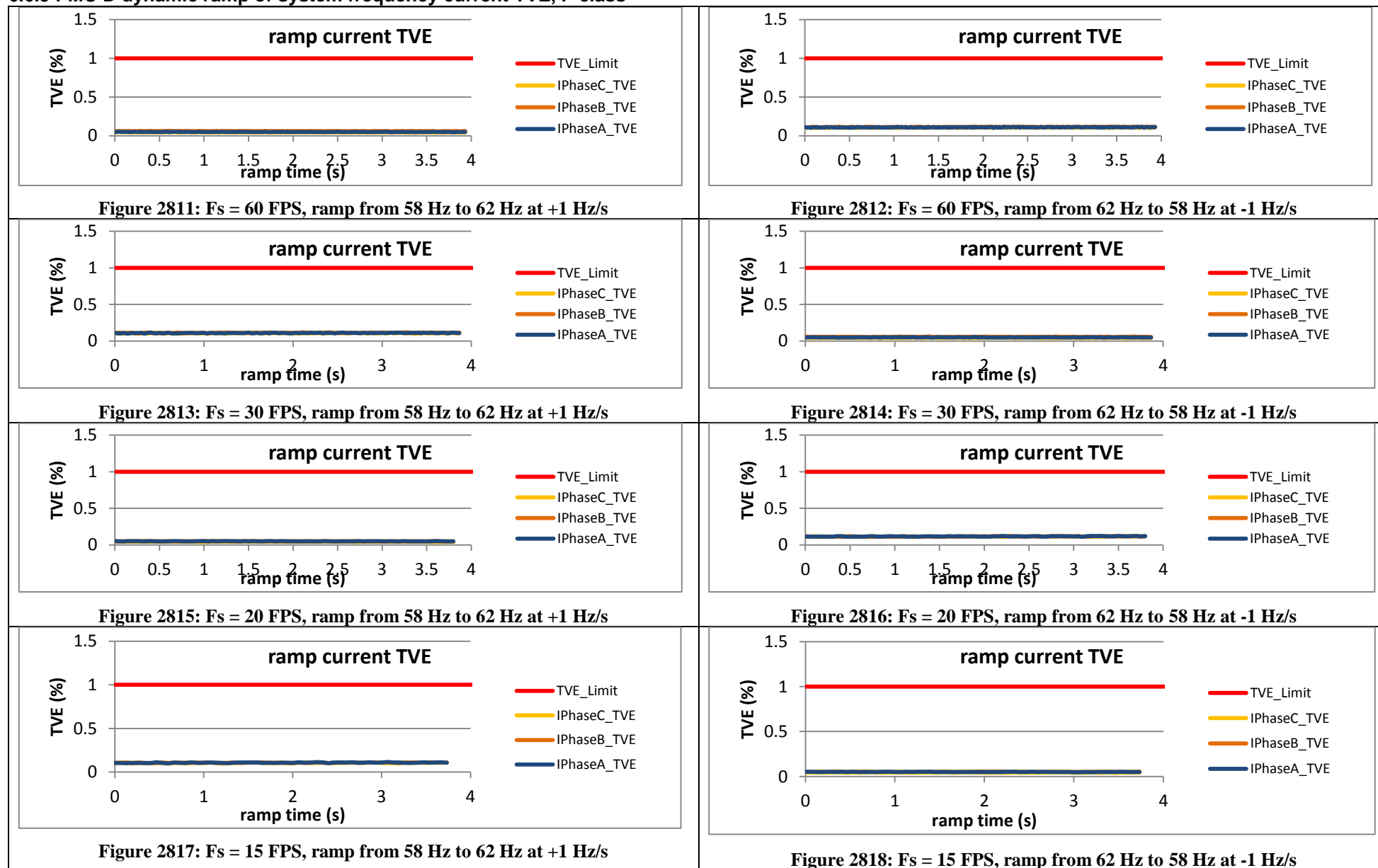


Figure 2810:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.6.5 PMU D dynamic ramp of system frequency current TVE, P class



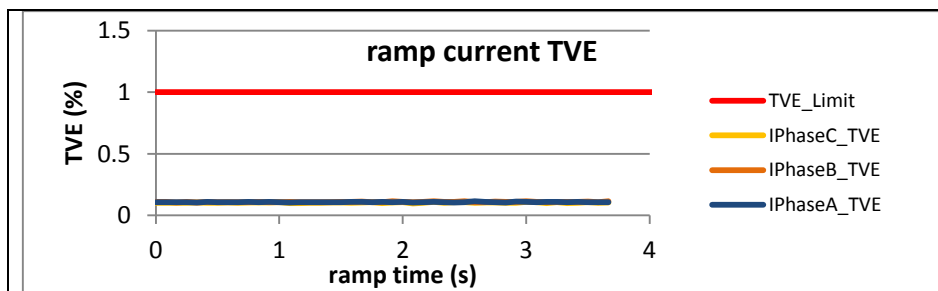


Figure 2819:  $F_s = 12$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

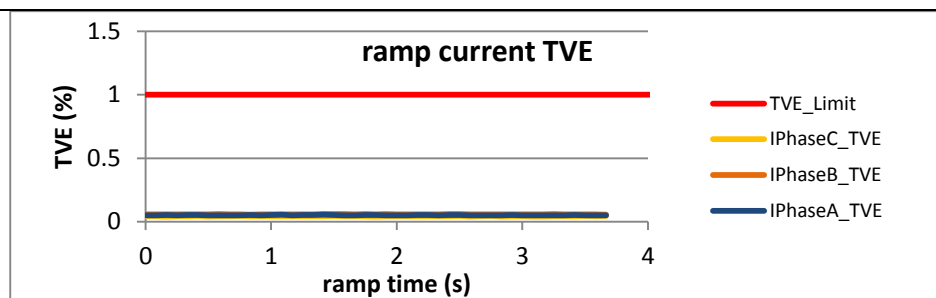


Figure 2820:  $F_s = 12$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

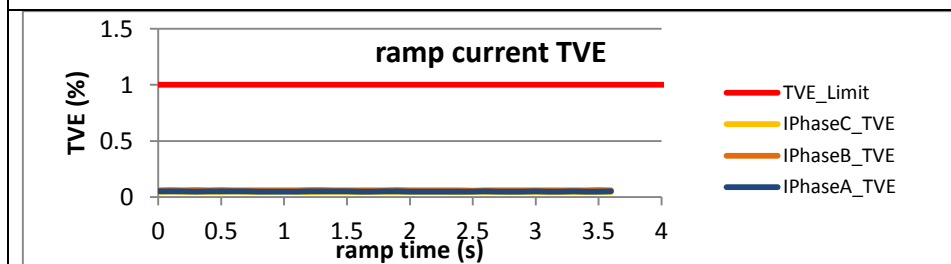


Figure 2821:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

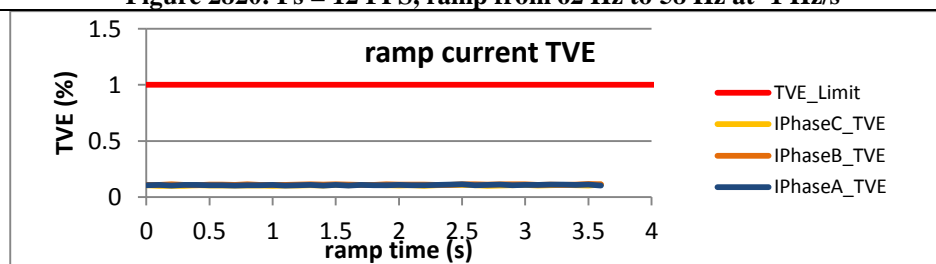


Figure 2822:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s



### 6.6.6 PMU E dynamic ramp of system frequency current TVE, P class

PMU E does not support P class

### 6.6.7 PMU F dynamic ramp of system frequency current TVE, P class

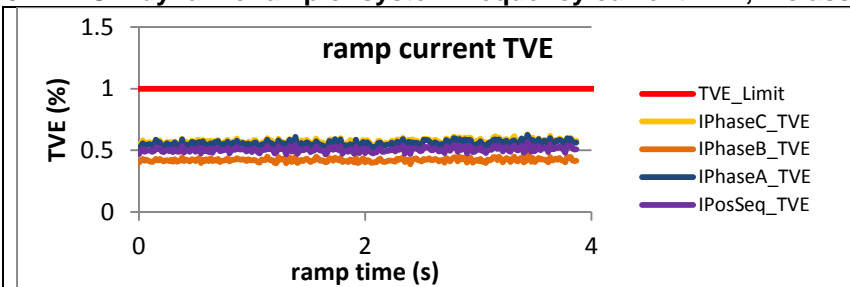


Figure 2823:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

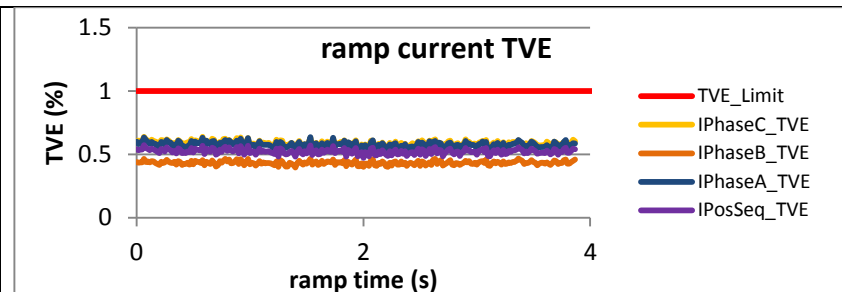


Figure 2824:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

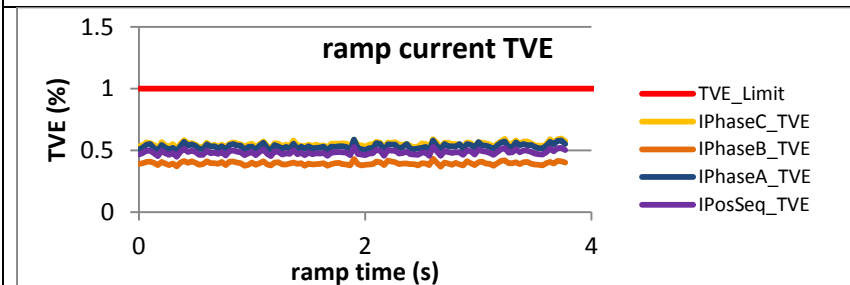


Figure 2825:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

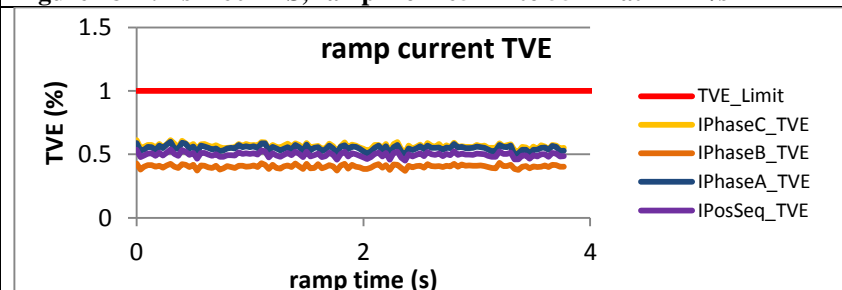


Figure 2826:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

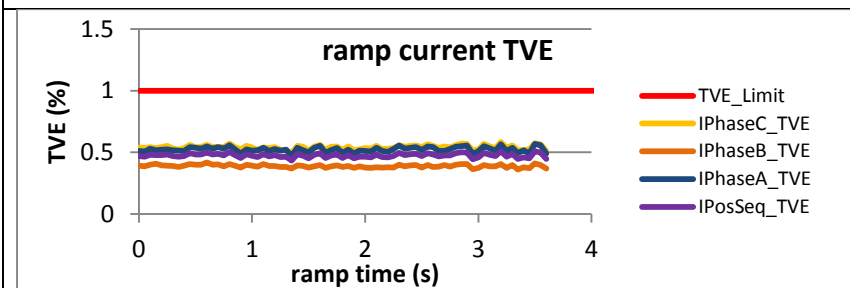


Figure 2827:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

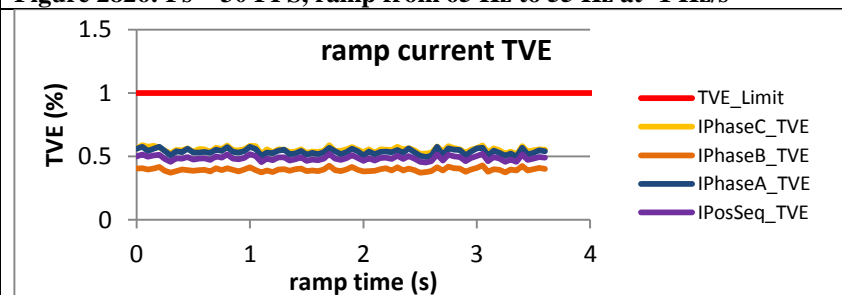


Figure 2828:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

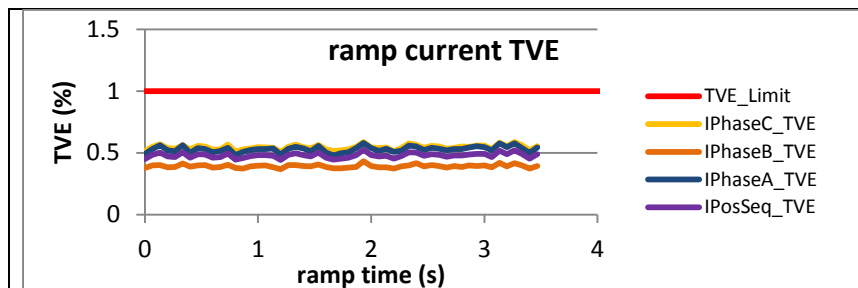


Figure 2829:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

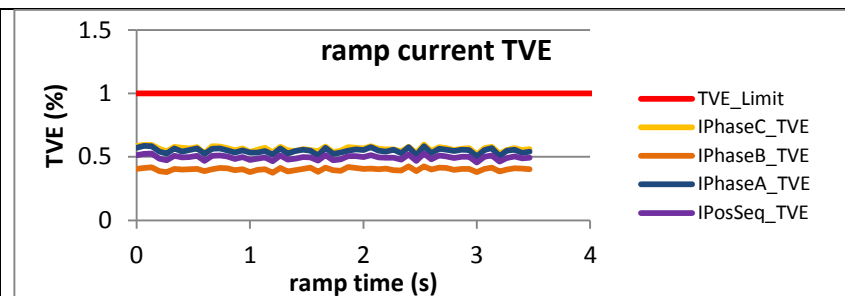


Figure 2830:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

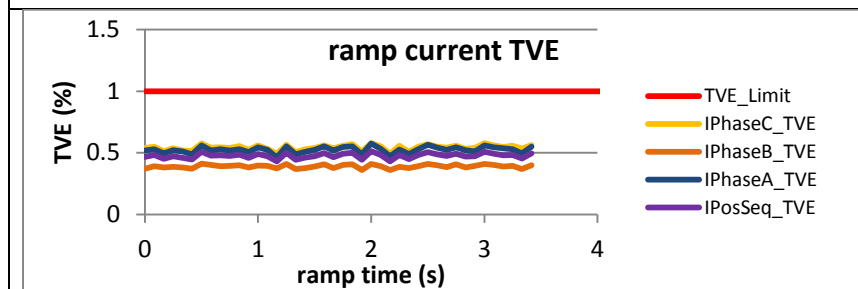


Figure 2831:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

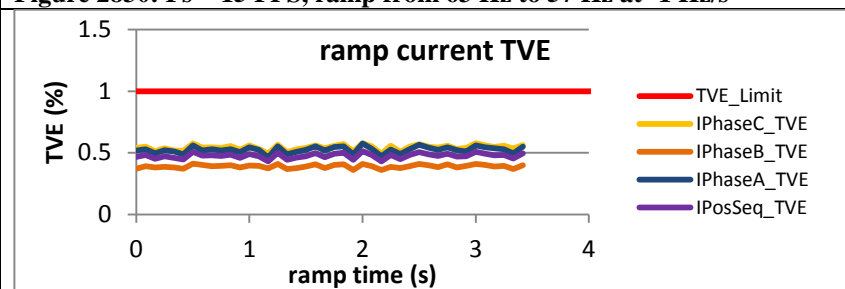


Figure 2832:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

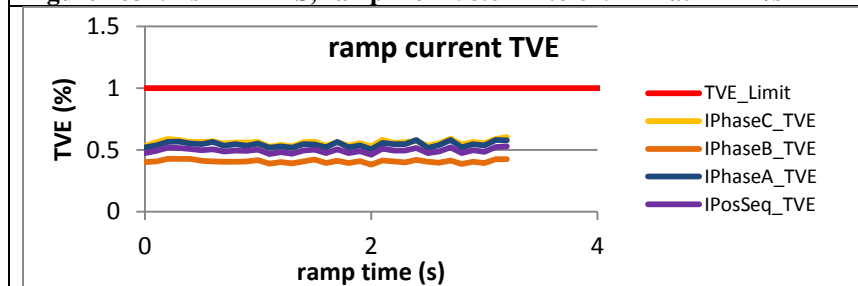


Figure 2833:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

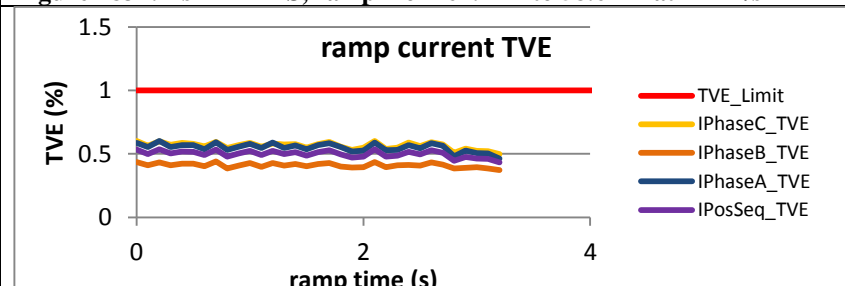
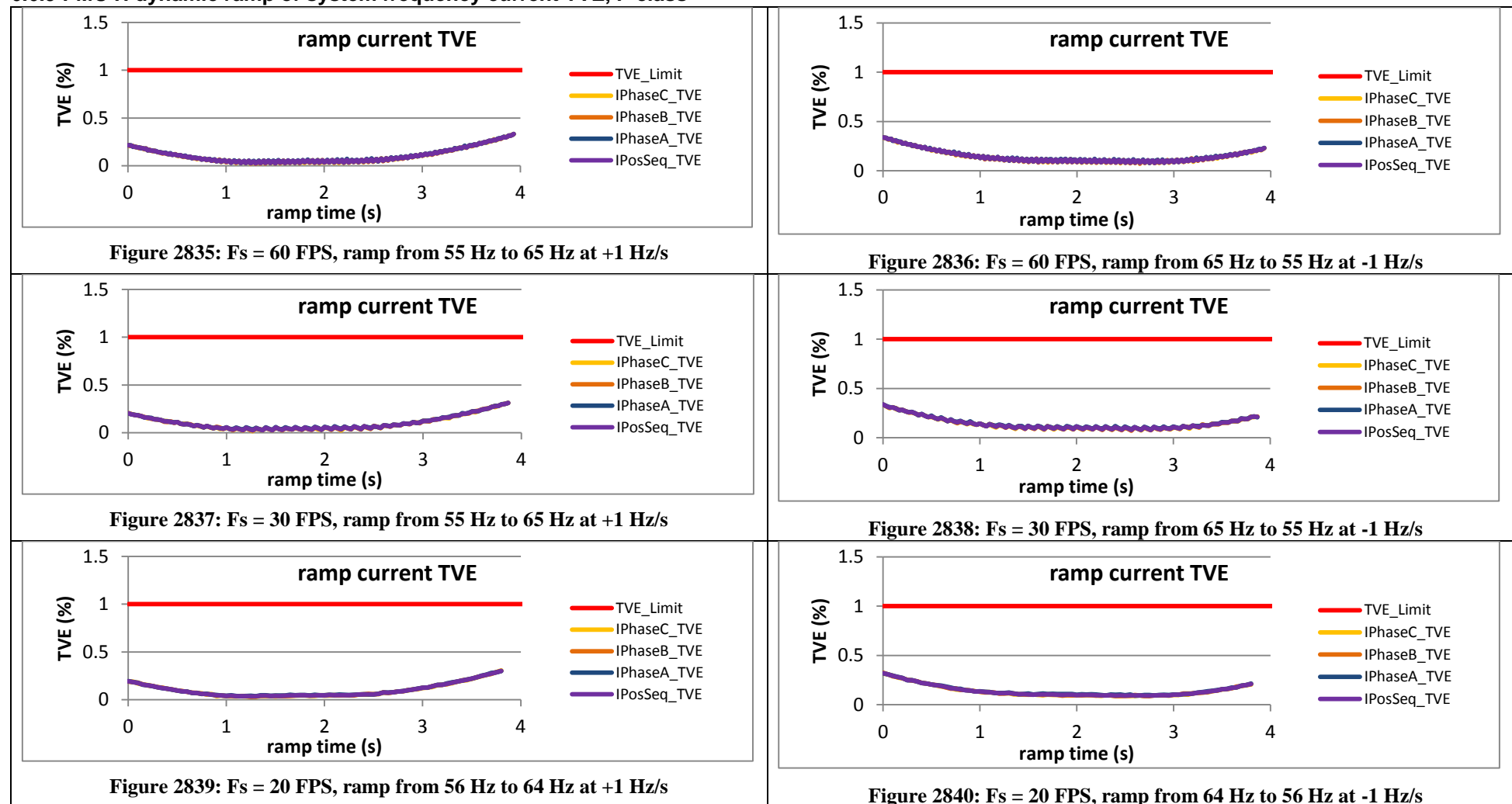


Figure 2834:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.6.8 PMU G dynamic ramp of system frequency current TVE, P class

PMU G does not support P class.

## 6.6.9 PMU H dynamic ramp of system frequency current TVE, P class



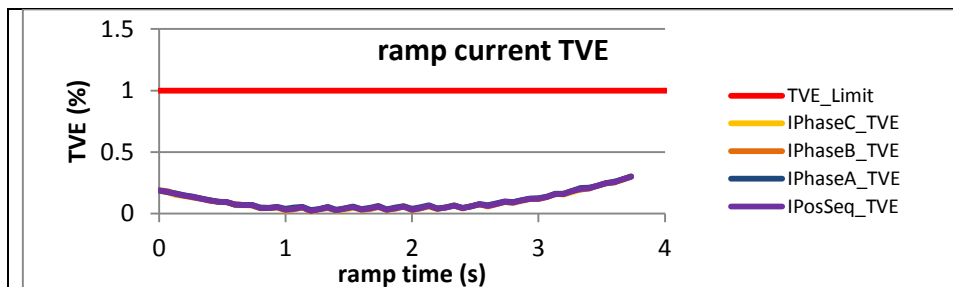


Figure 2841:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

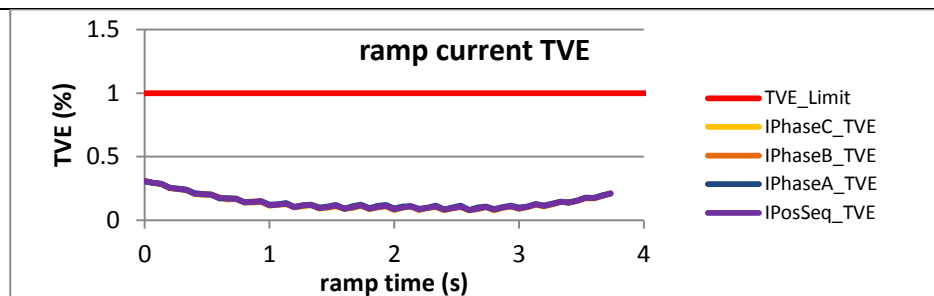


Figure 2842:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

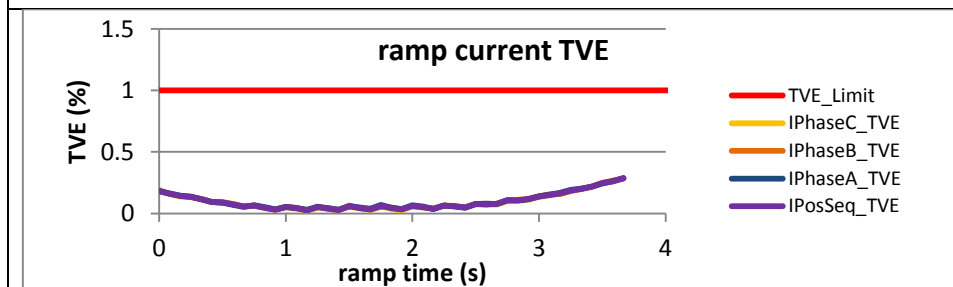


Figure 2843:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

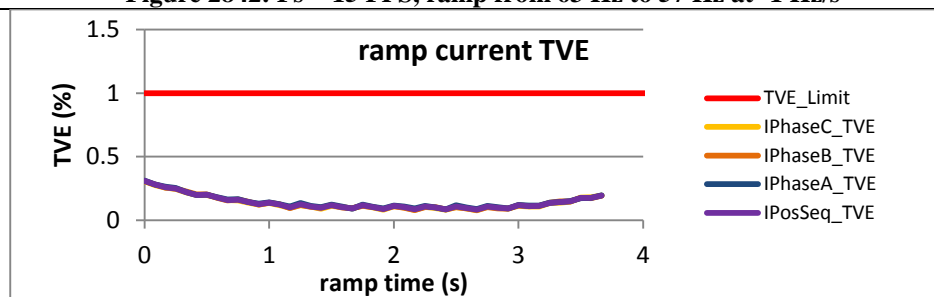


Figure 2844:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

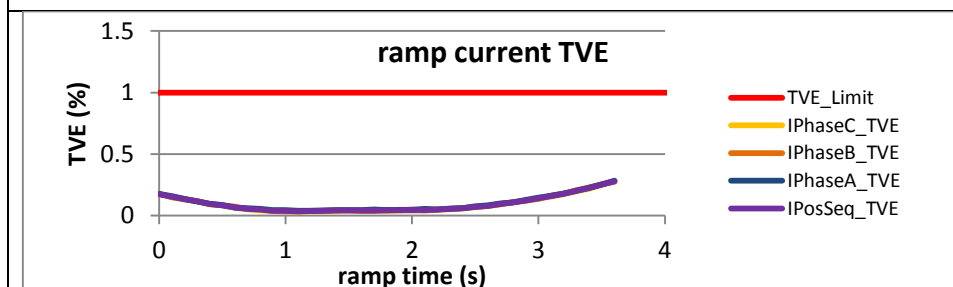


Figure 2845:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

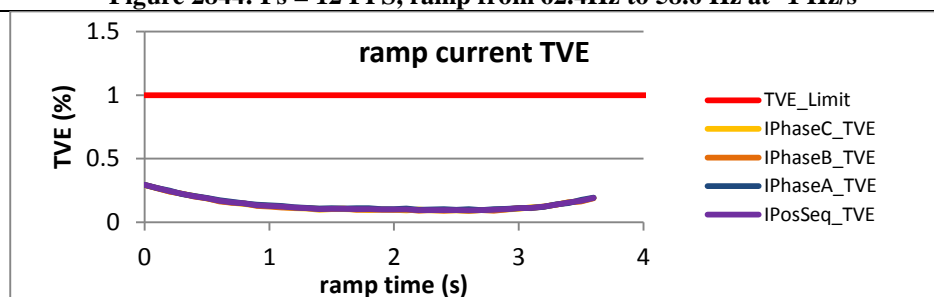


Figure 2846:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.6.10 PMU I dynamic ramp of system frequency current TVE, P class

PMU I does not support P class

#### 6.6.11 PMU J dynamic ramp of system frequency current TVE, P class

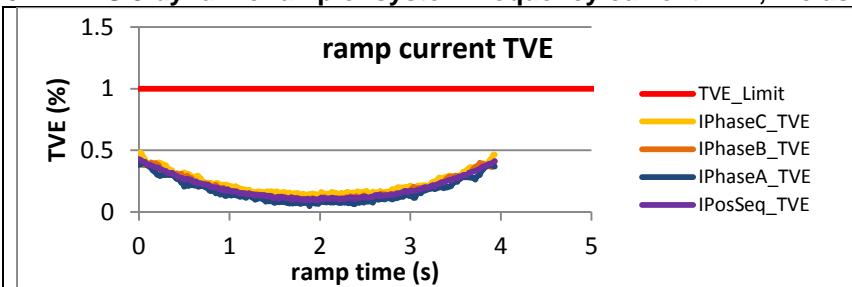


Figure 2847:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

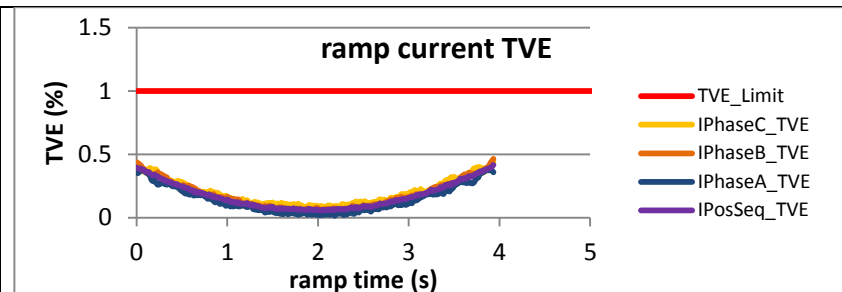


Figure 2848:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

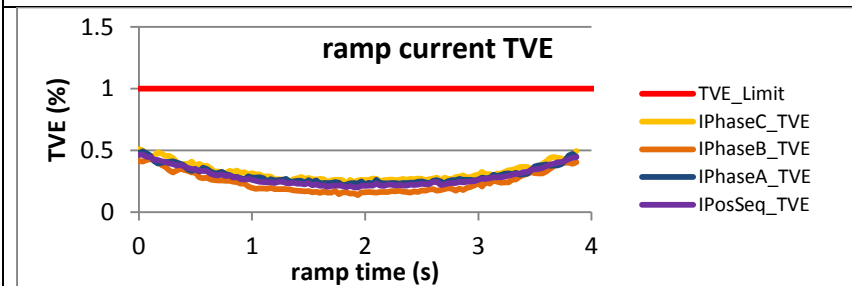


Figure 2849:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

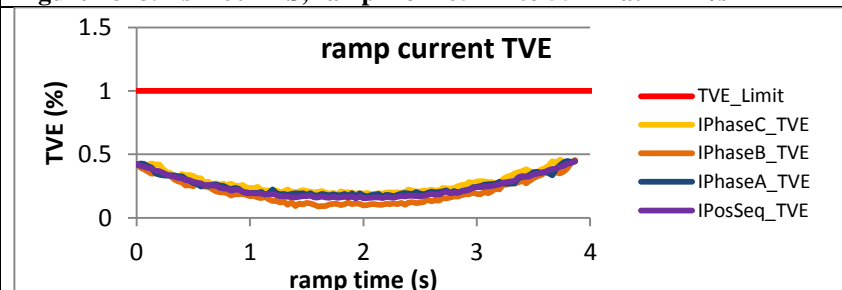


Figure 2850:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

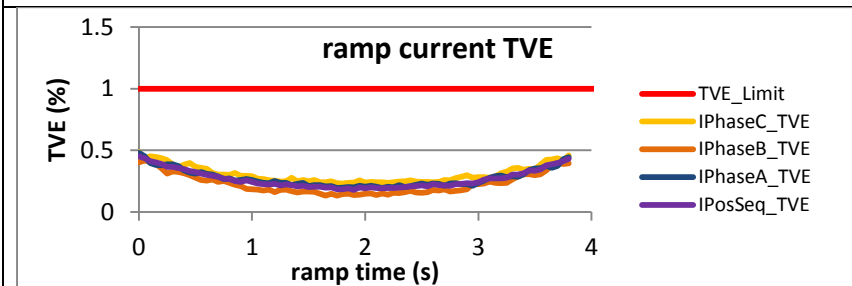


Figure 2851:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

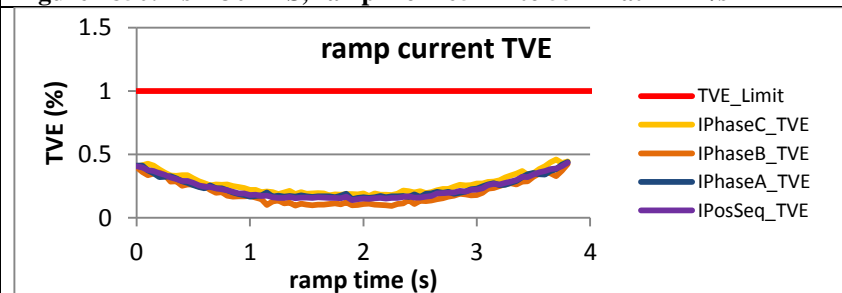


Figure 2852:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

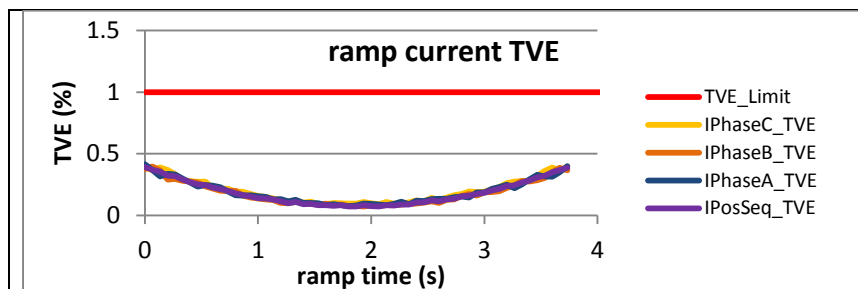


Figure 2853:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

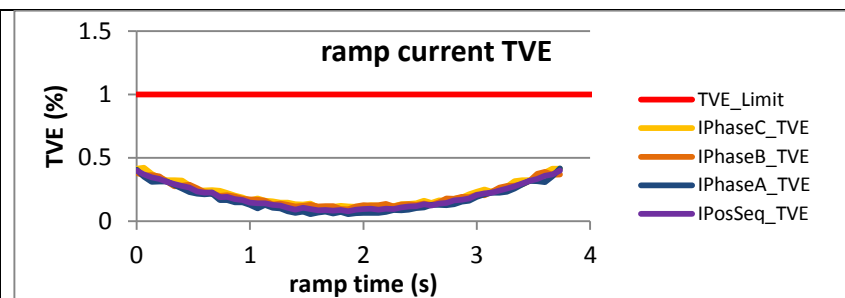


Figure 2854:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

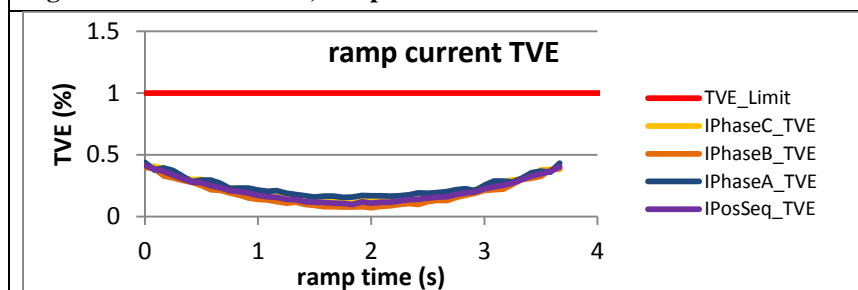


Figure 2855:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

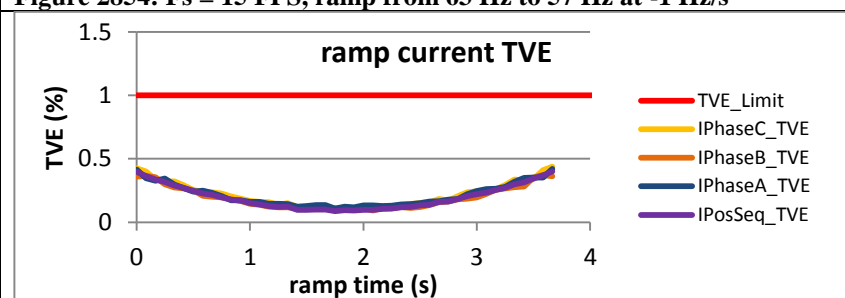


Figure 2856:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

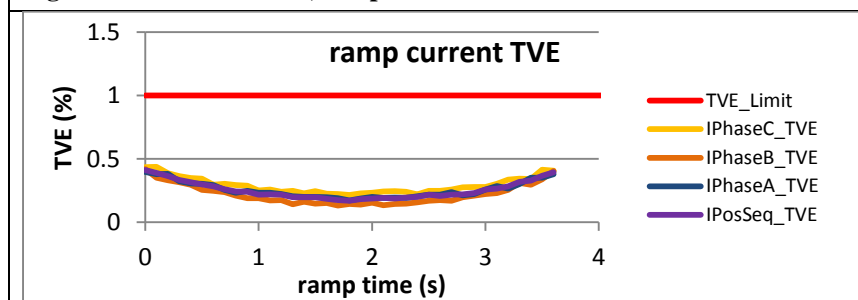


Figure 2857:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

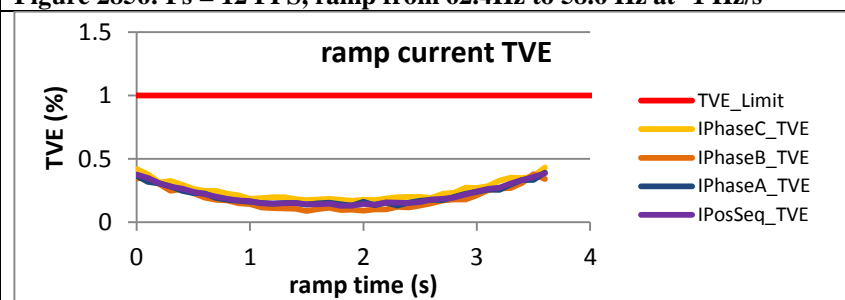
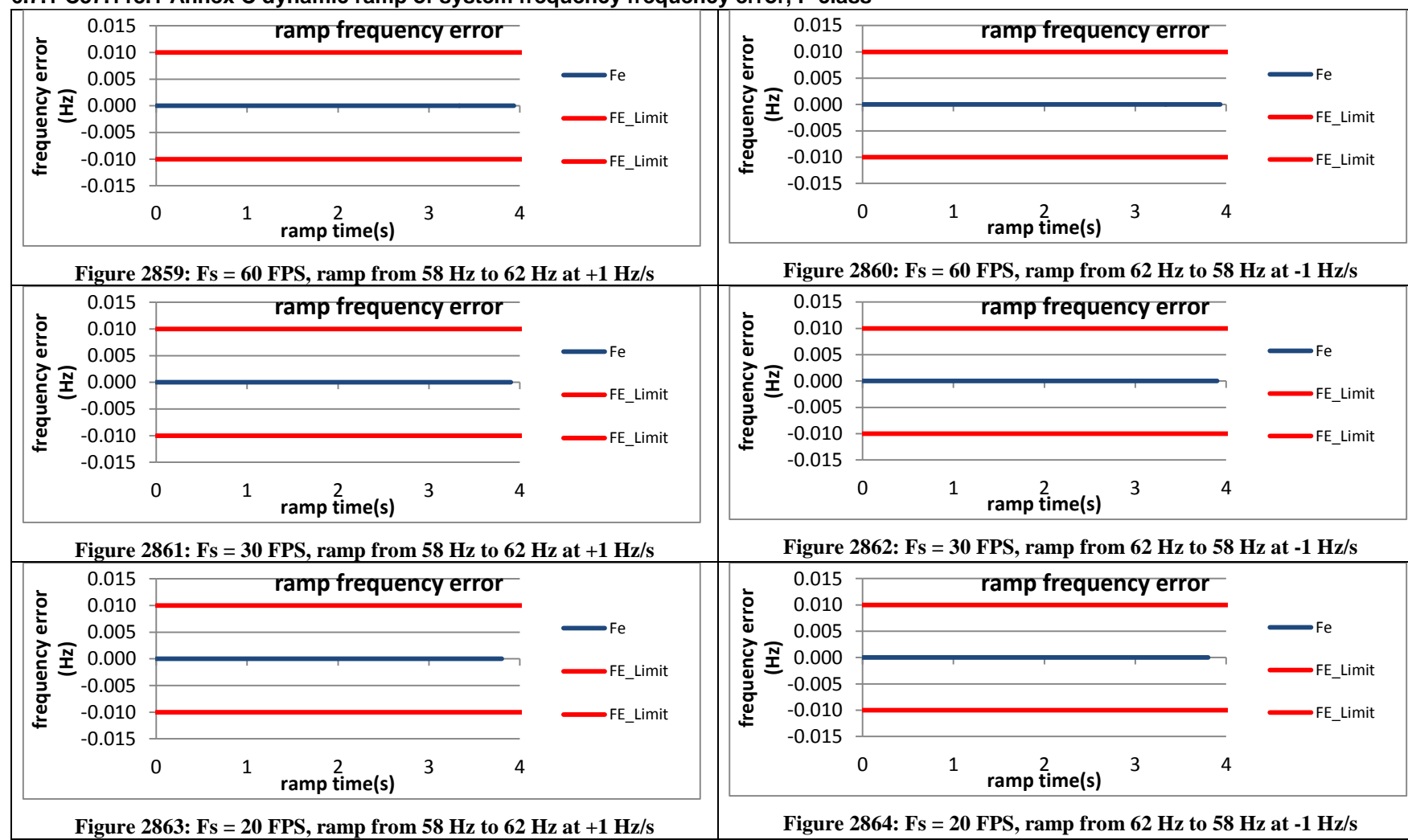


Figure 2858:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.7 Dynamic ramp of system frequency frequency, P class

### 6.7.1 C37.118.1 Annex C dynamic ramp of system frequency frequency error, P class



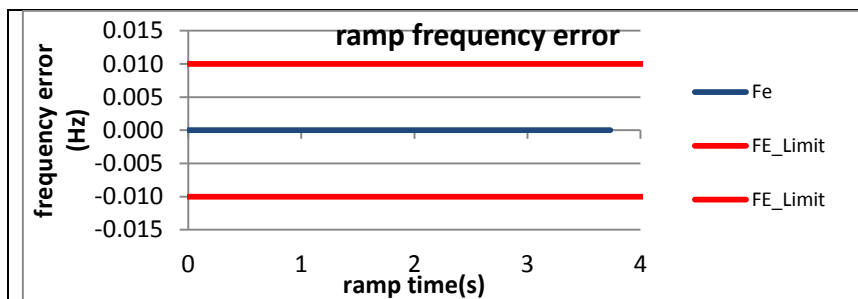


Figure 2865:  $F_s = 15$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

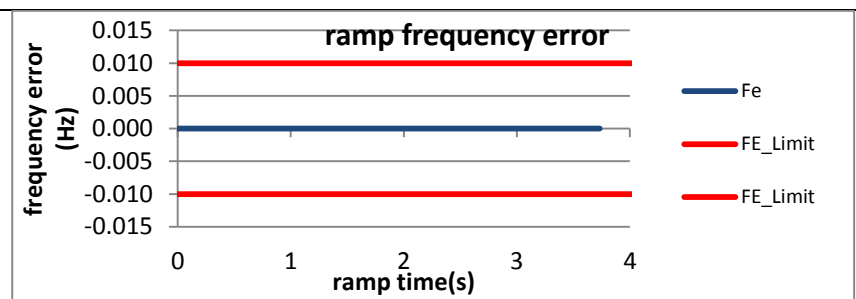


Figure 2866:  $F_s = 15$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

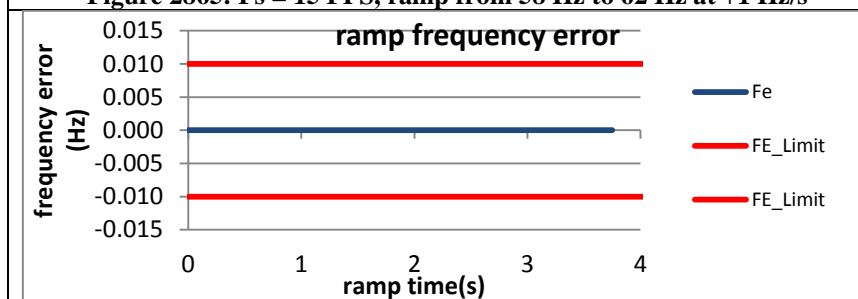


Figure 2867:  $F_s = 12$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

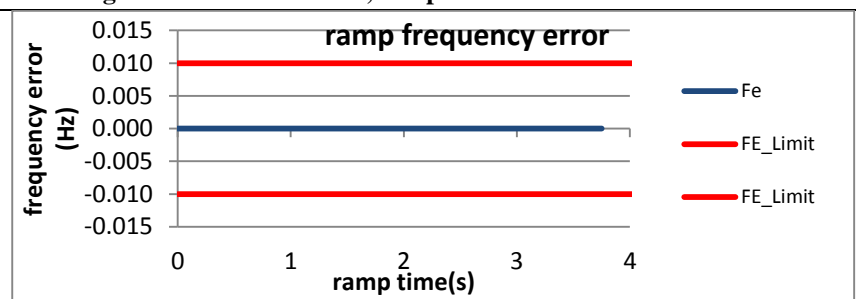


Figure 2868:  $F_s = 12$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

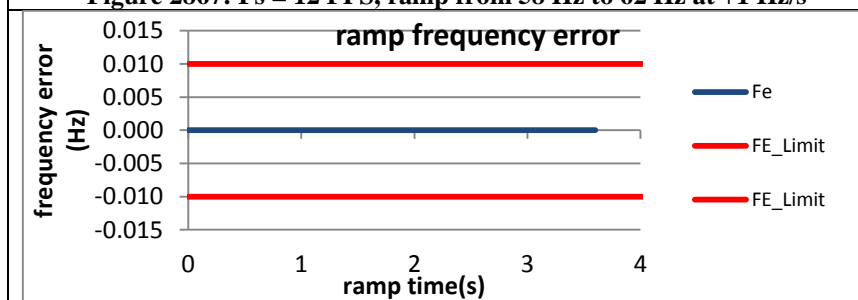


Figure 2869:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

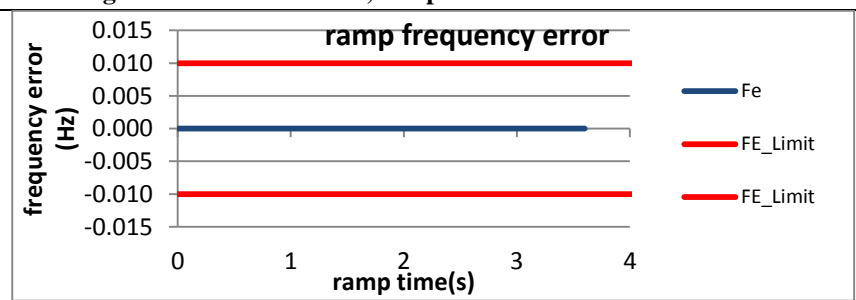


Figure 2870:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s



### 6.7.2 PMU A dynamic ramp of system frequency frequency error, P class

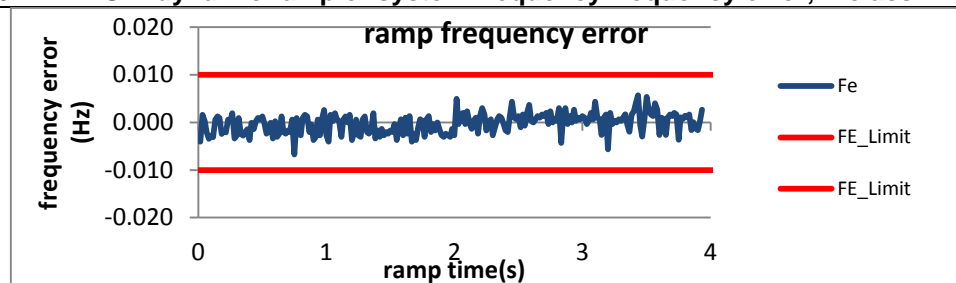


Figure 2871:  $F_s = 60$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

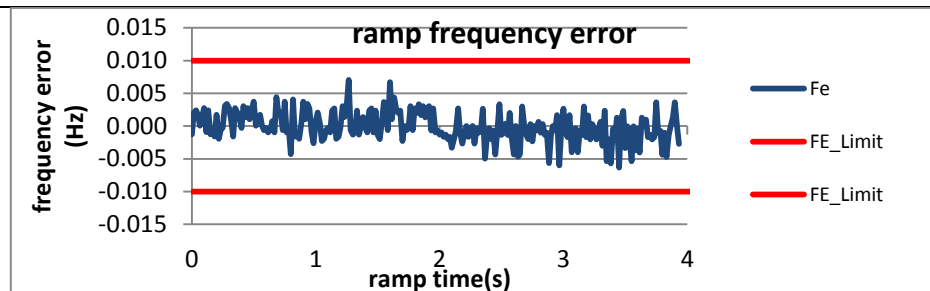


Figure 2872:  $F_s = 60$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

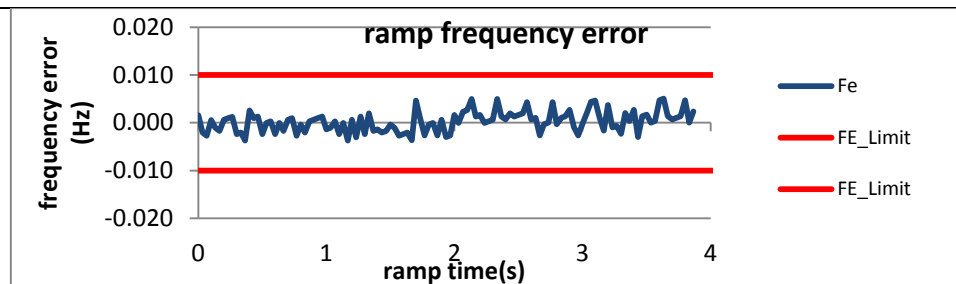


Figure 2873:  $F_s = 30$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

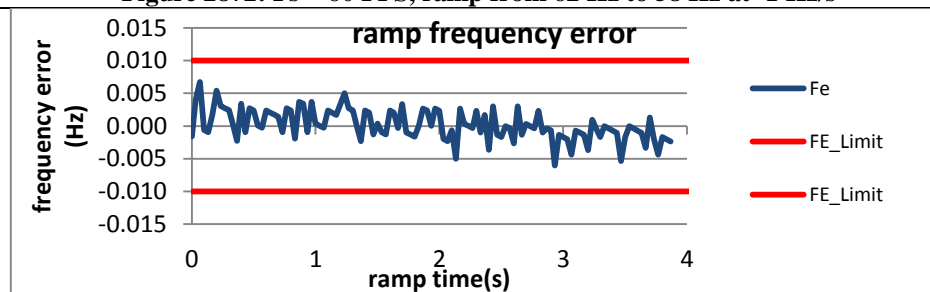


Figure 2874:  $F_s = 30$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

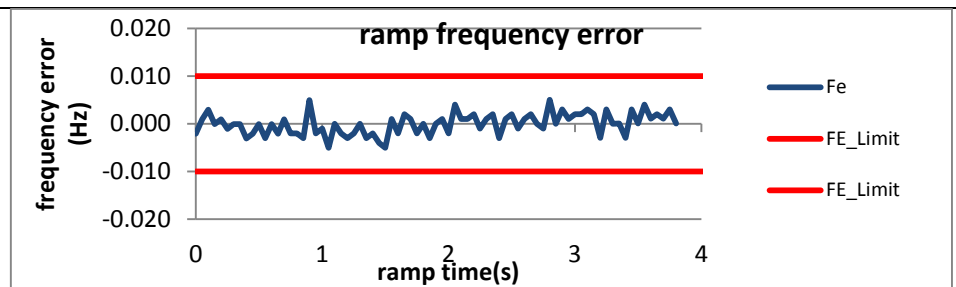


Figure 2875:  $F_s = 20$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

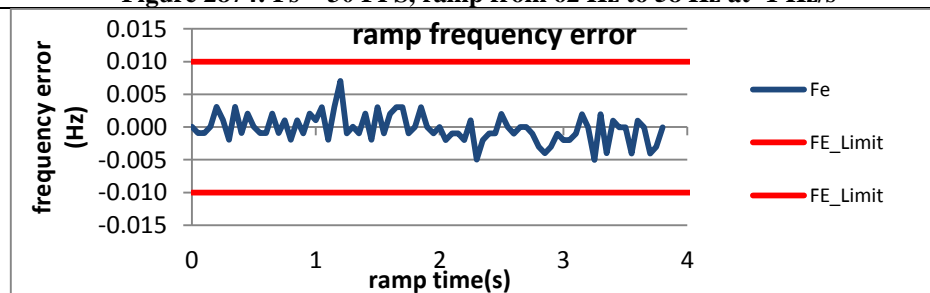
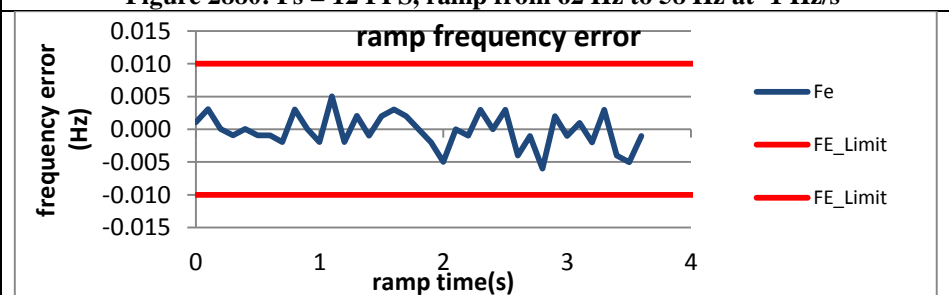
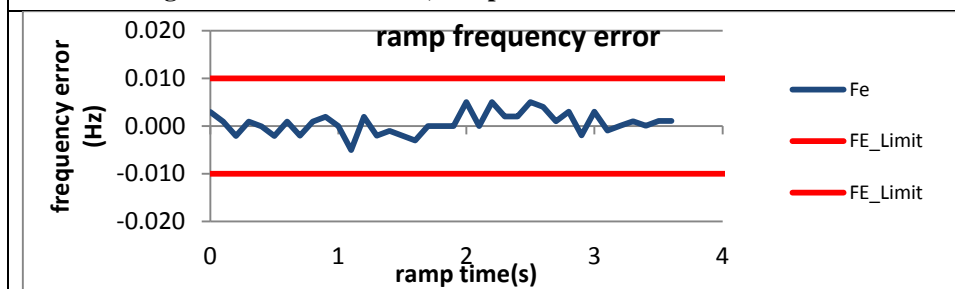
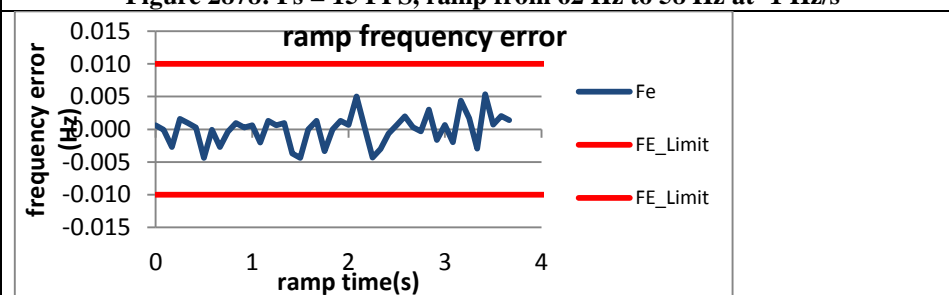
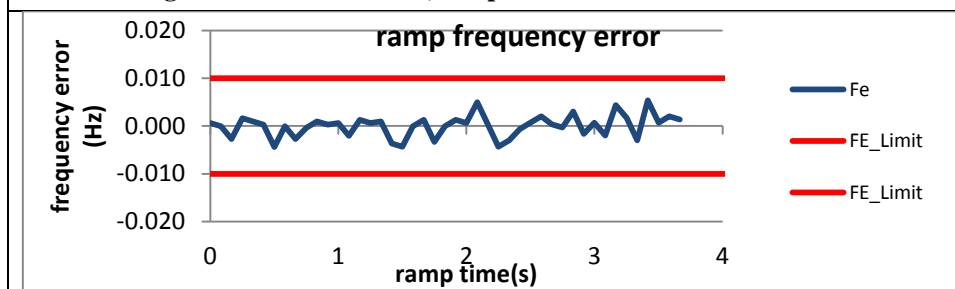
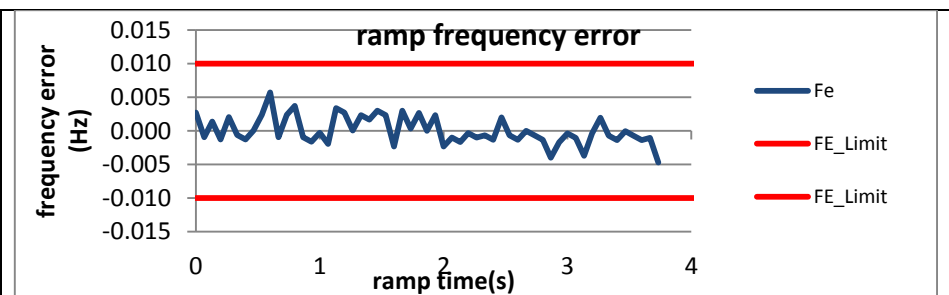
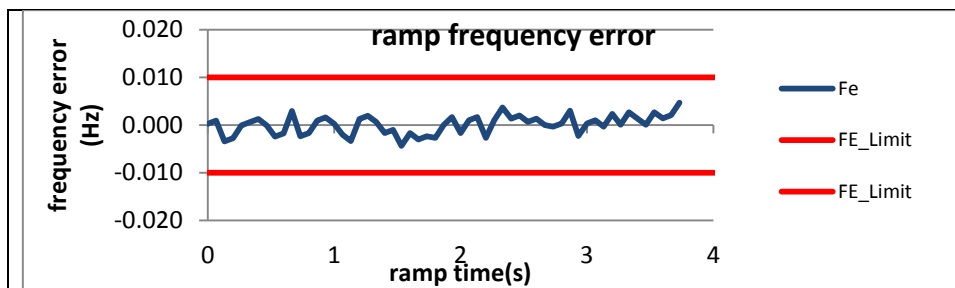


Figure 2876:  $F_s = 20$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s



### 6.7.3 PMU B dynamic ramp of system frequency frequency error, P class

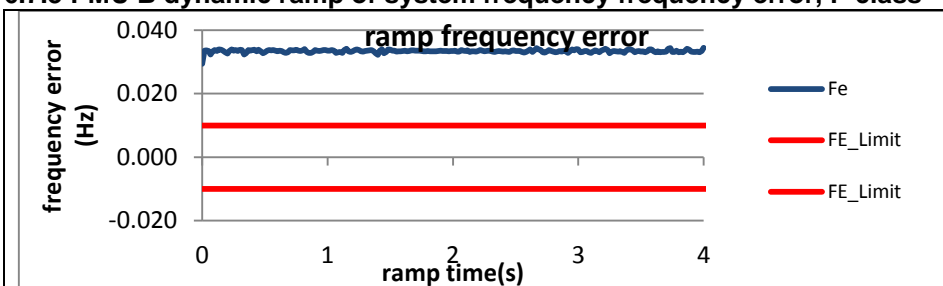


Figure 2883:  $F_s = 60$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

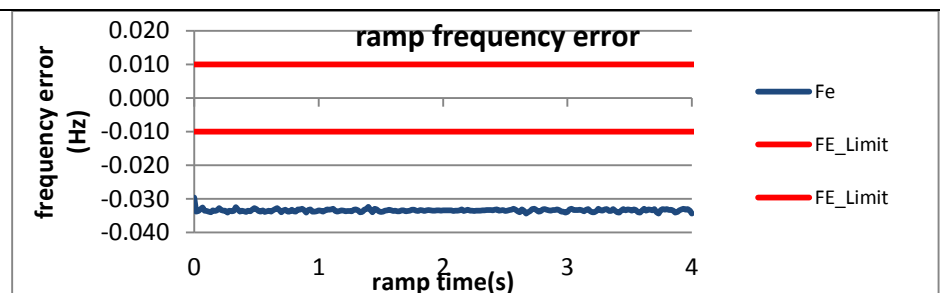


Figure 2884:  $F_s = 60$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

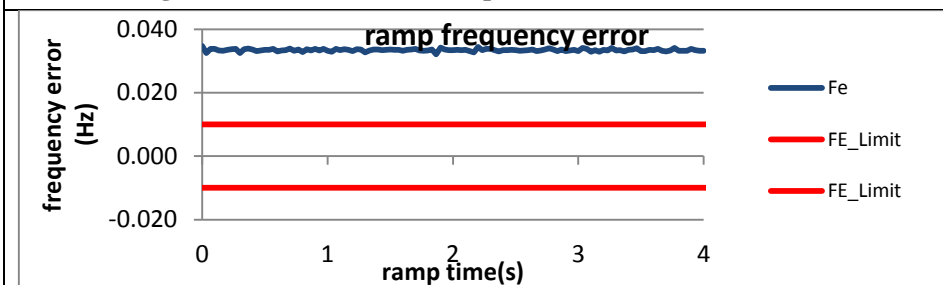


Figure 2885:  $F_s = 30$  FPS, ramp from 55 Hz to 65 Hz at +1 Hz/s

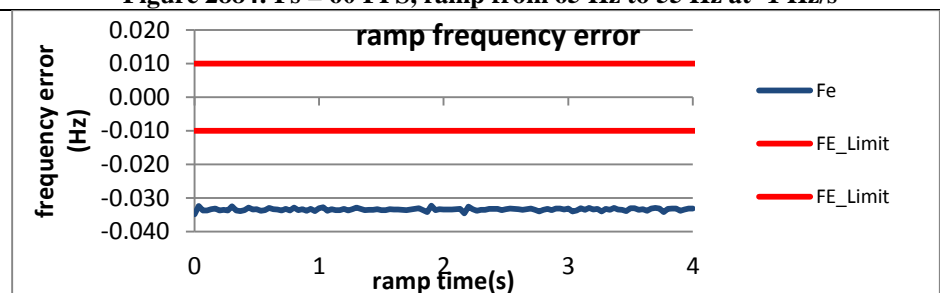


Figure 2886:  $F_s = 30$  FPS, ramp from 65 Hz to 55 Hz at -1 Hz/s

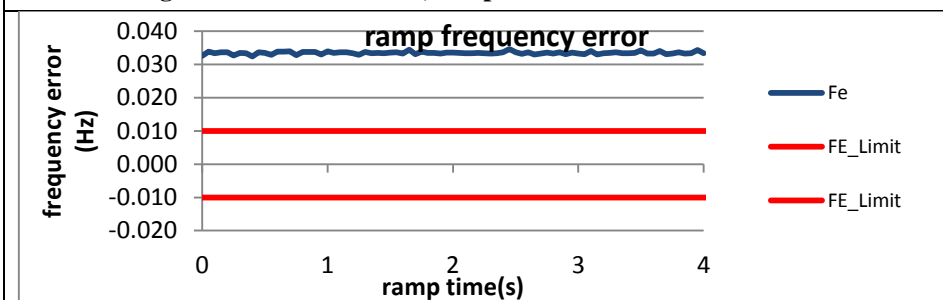


Figure 2887:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

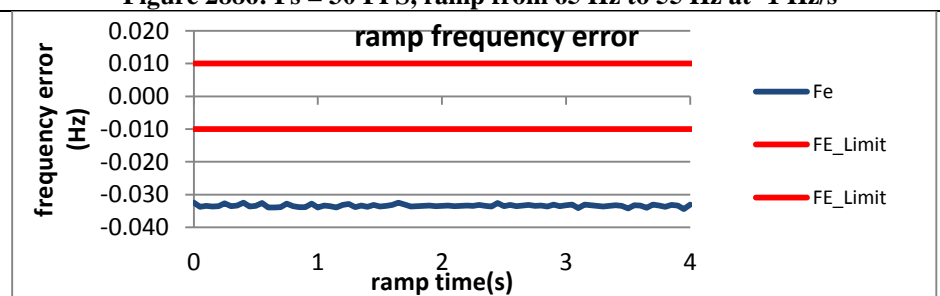


Figure 2888:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

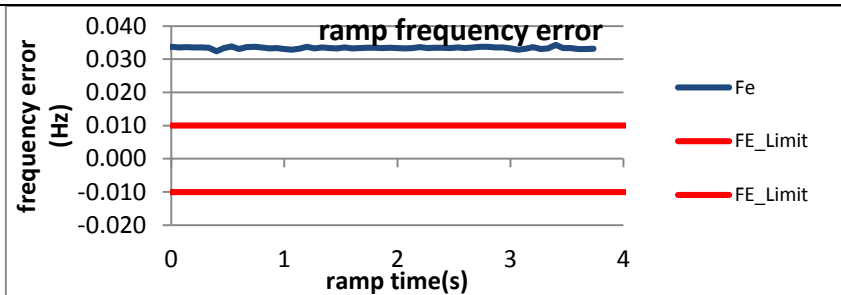


Figure 2889:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

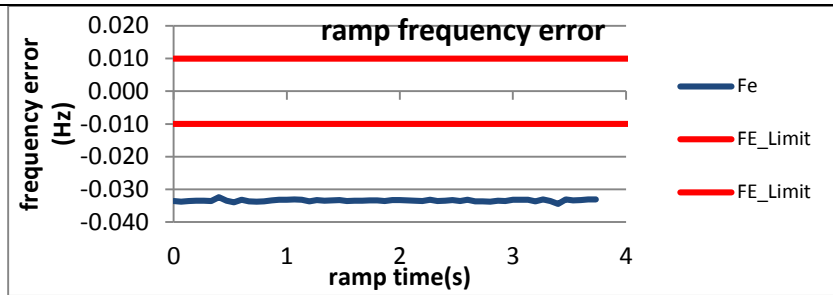


Figure 2890:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

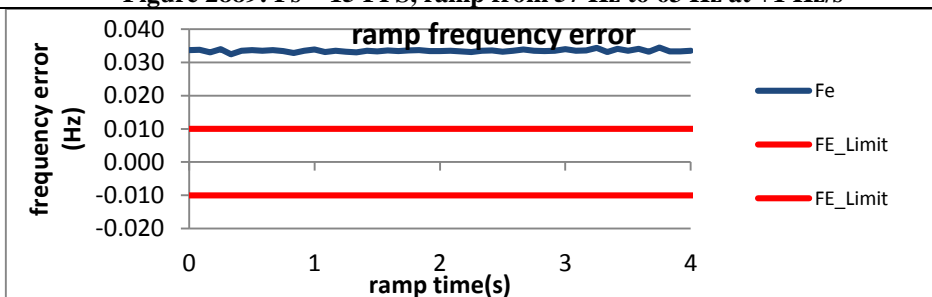


Figure 2891:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

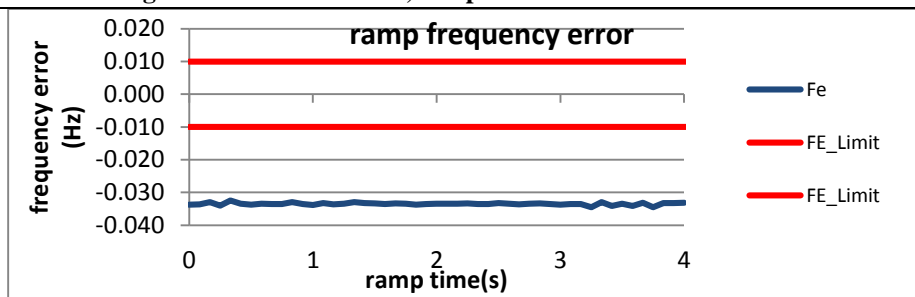


Figure 2892:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

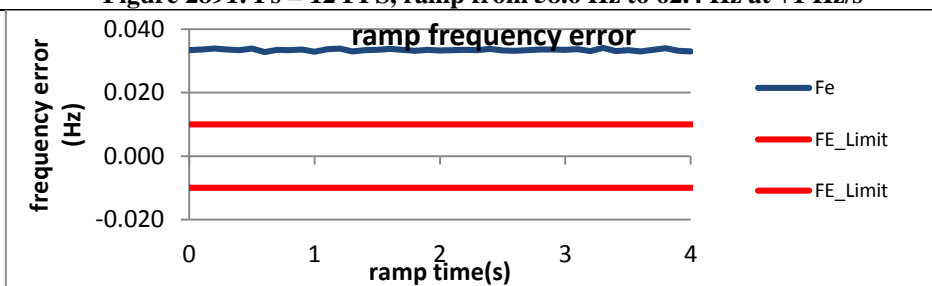


Figure 2893:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

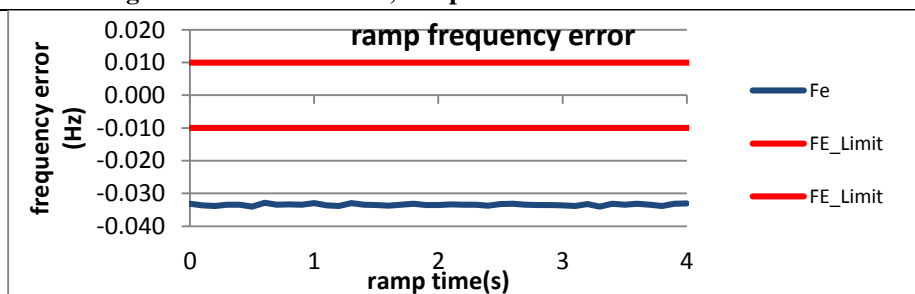
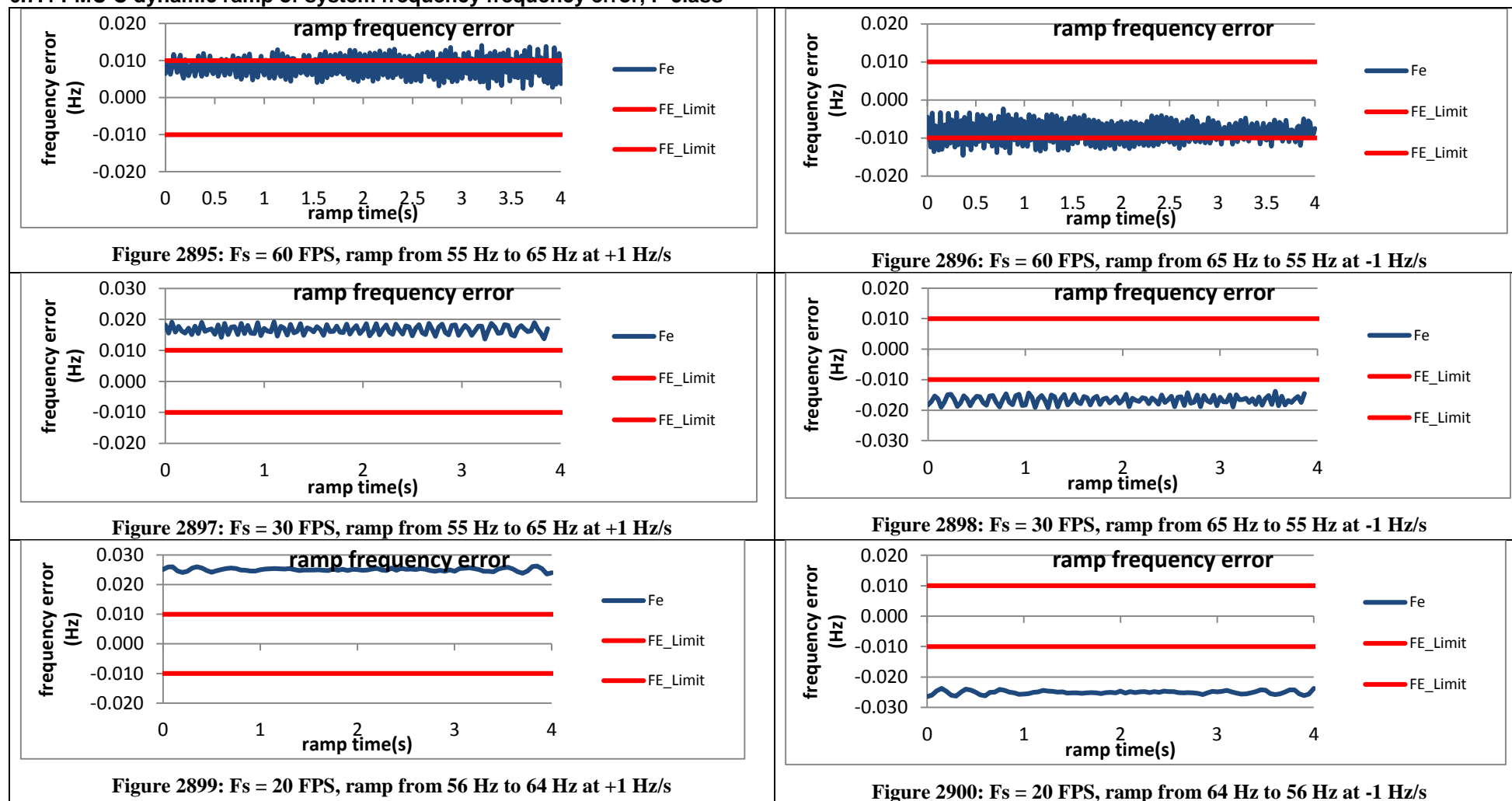
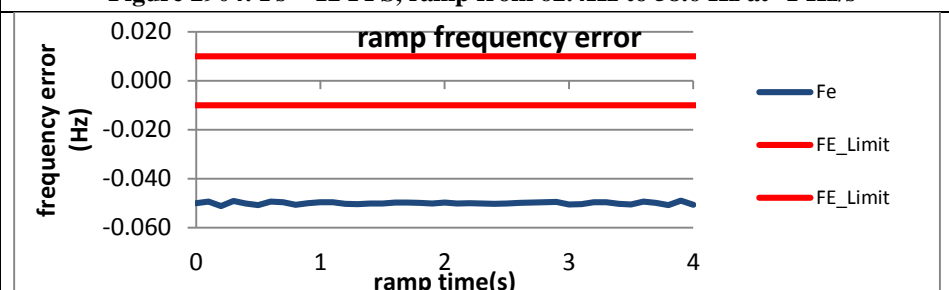
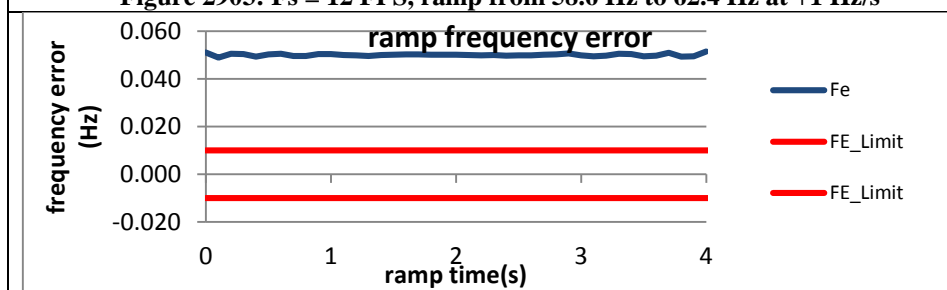
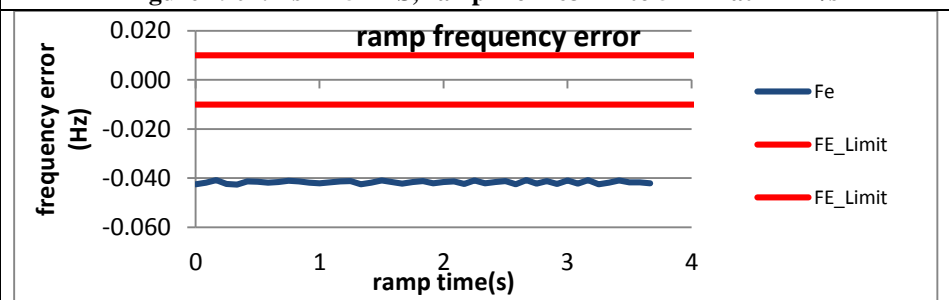
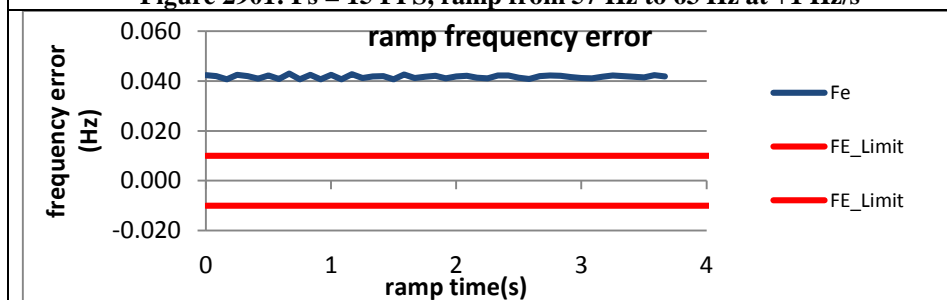
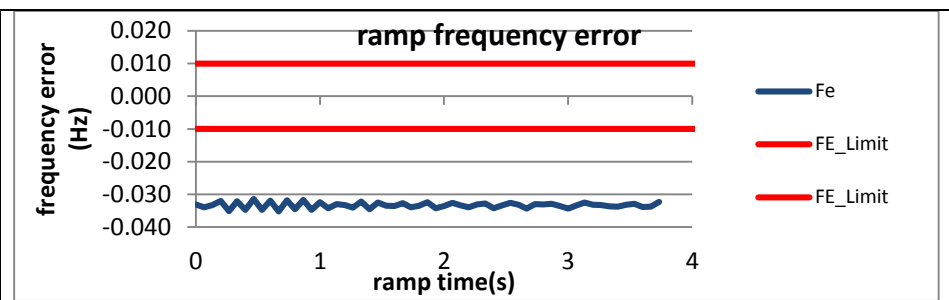
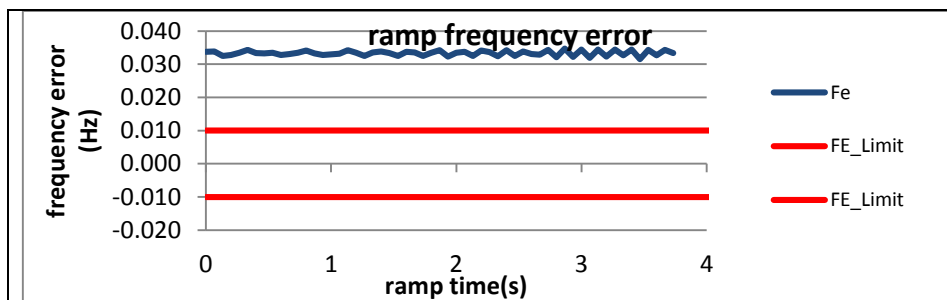


Figure 2894:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.7.4 PMU C dynamic ramp of system frequency frequency error, P class





### 6.7.5 PMU D dynamic ramp of system frequency frequency error, P class

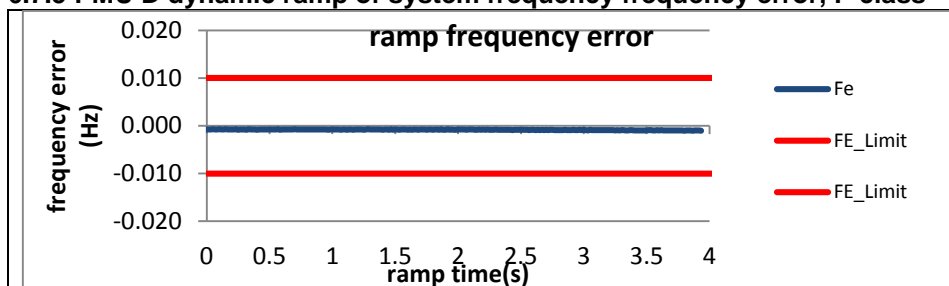


Figure 2907:  $F_s = 60$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

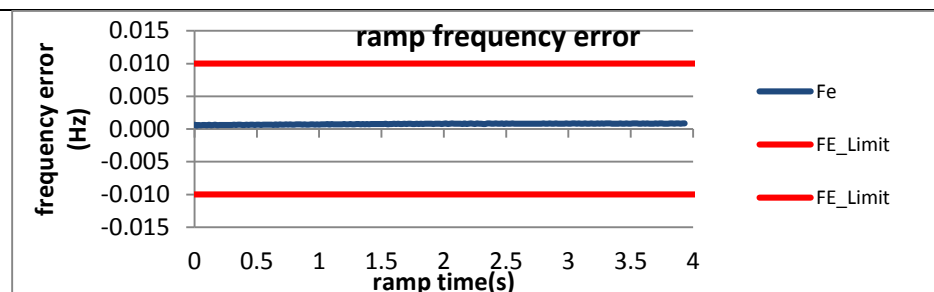


Figure 2908:  $F_s = 60$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

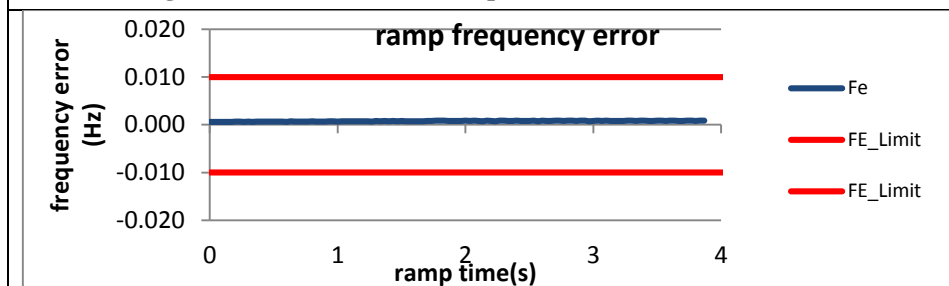


Figure 2909:  $F_s = 30$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

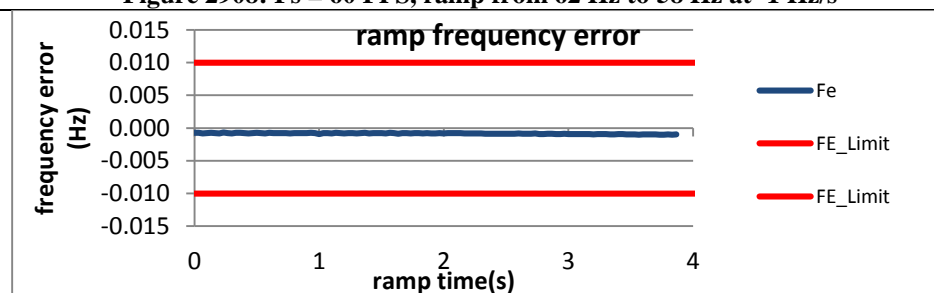


Figure 2910:  $F_s = 30$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

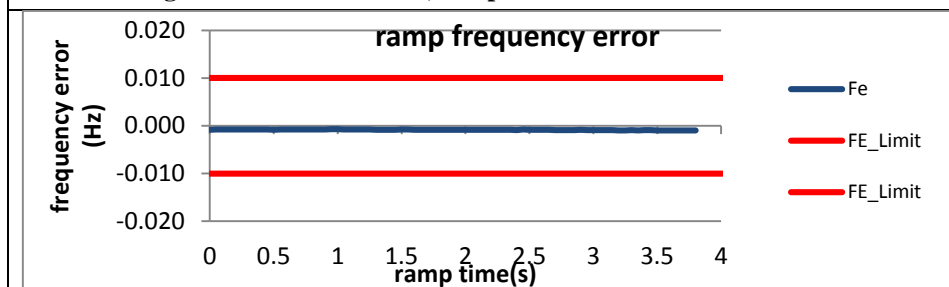


Figure 2911:  $F_s = 20$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

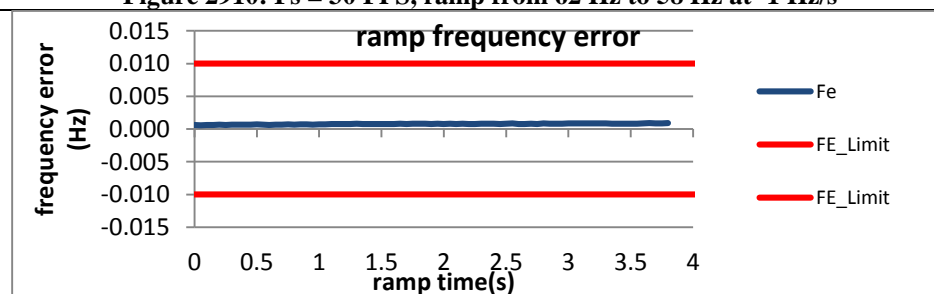


Figure 2912:  $F_s = 20$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

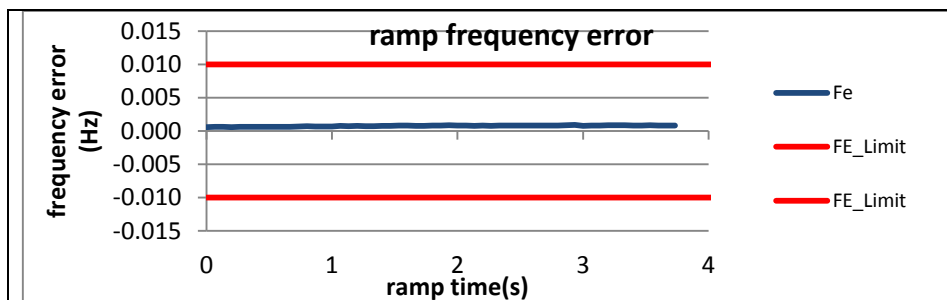


Figure 2913:  $F_s = 15$  FPS, ramp from 58 Hz to 62 Hz at  $+1$  Hz/s

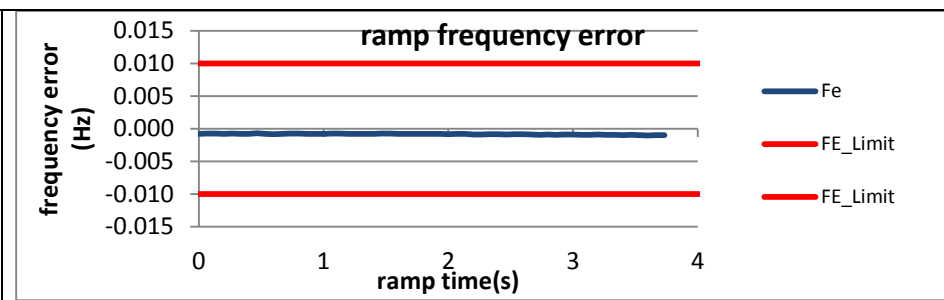


Figure 2914:  $F_s = 15$  FPS, ramp from 62 Hz to 58 Hz at  $-1$  Hz/s

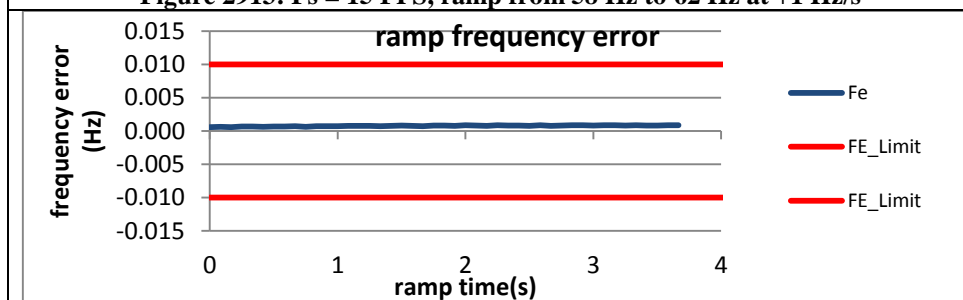


Figure 2915:  $F_s = 12$  FPS, ramp from 58 Hz to 62 Hz at  $+1$  Hz/s

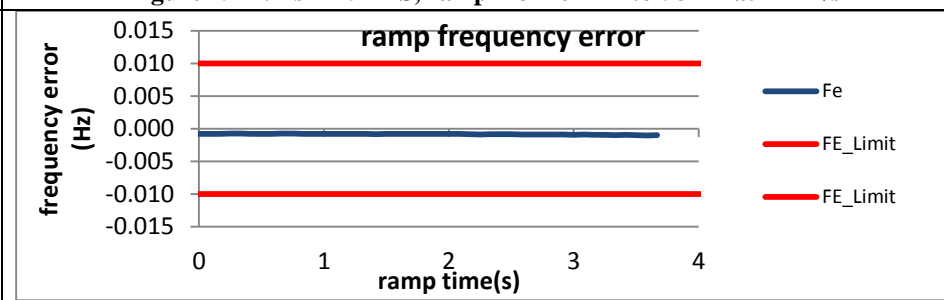


Figure 2916:  $F_s = 12$  FPS, ramp from 62 Hz to 58 Hz at  $-1$  Hz/s

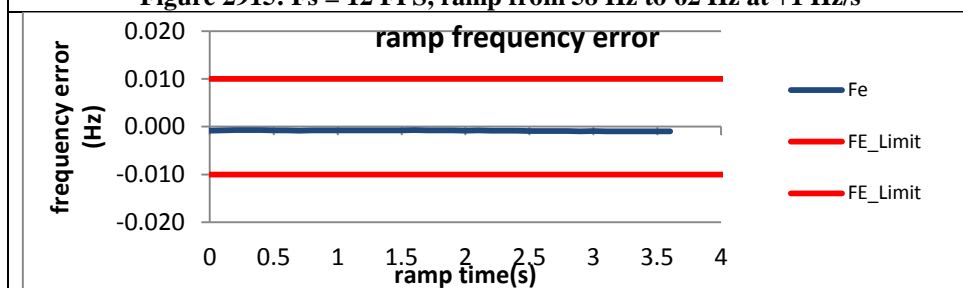


Figure 2917:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at  $+1$  Hz/s

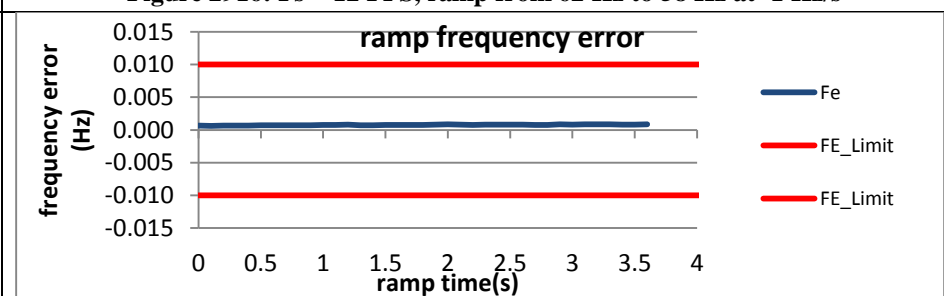


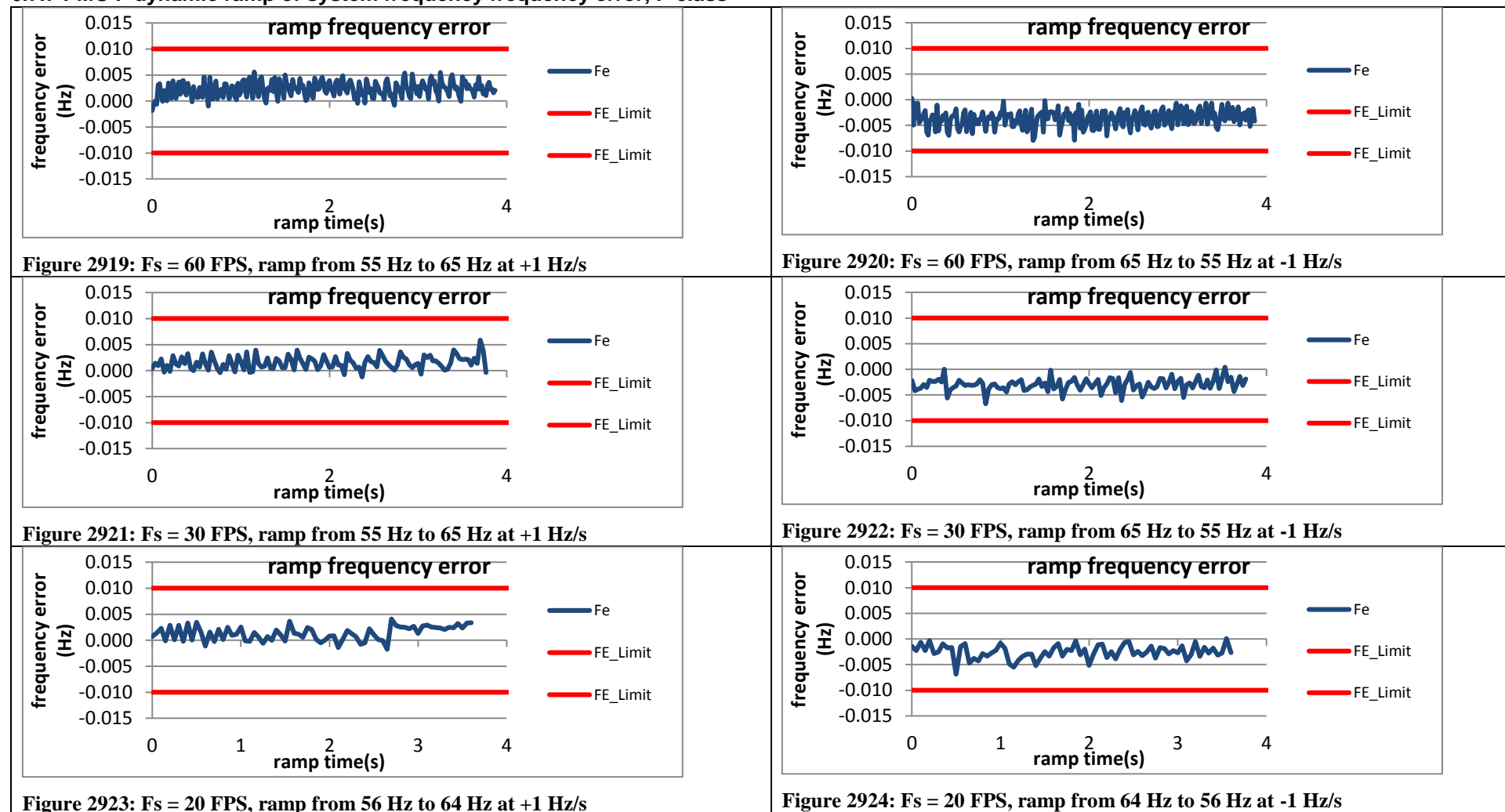
Figure 2918:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at  $-1$  Hz/s



## 6.7.6 PMU E dynamic ramp of system frequency frequency error, P class

PMU E does not support P class.

## 6.7.7 PMU F dynamic ramp of system frequency frequency error, P class



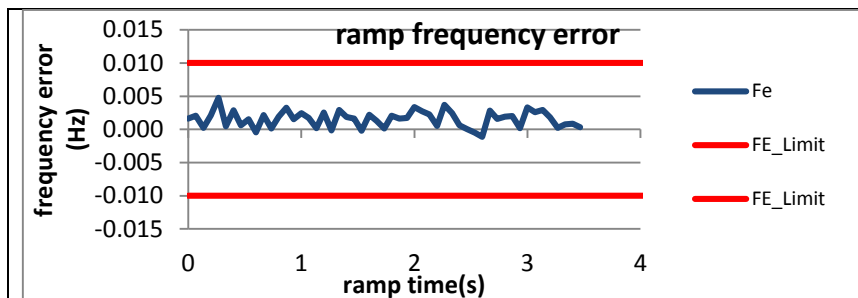


Figure 2925:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

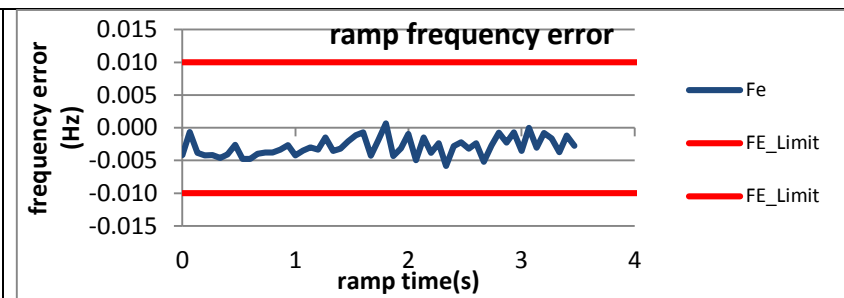


Figure 2926:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

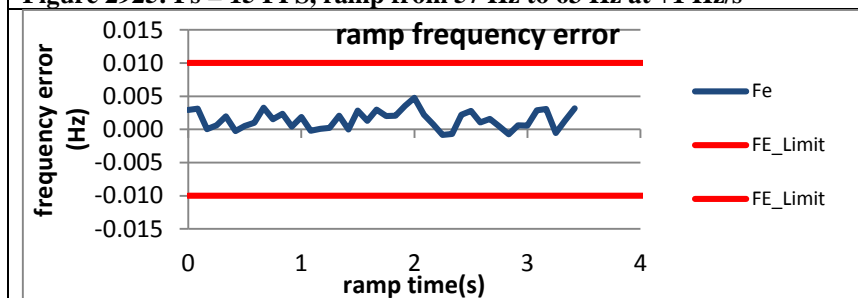


Figure 2927:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

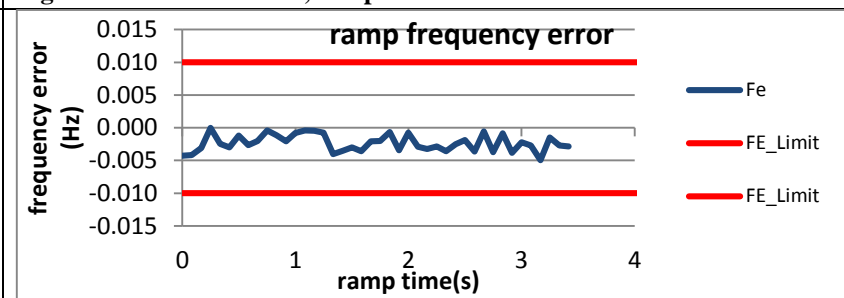


Figure 2928:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

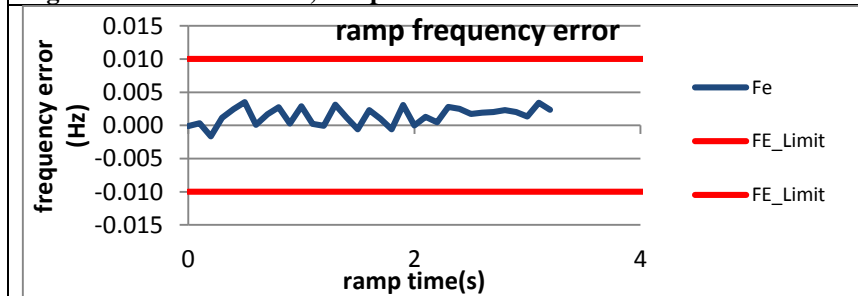


Figure 2929:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

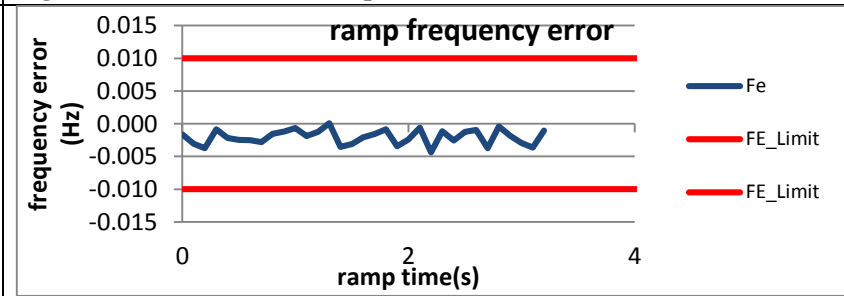
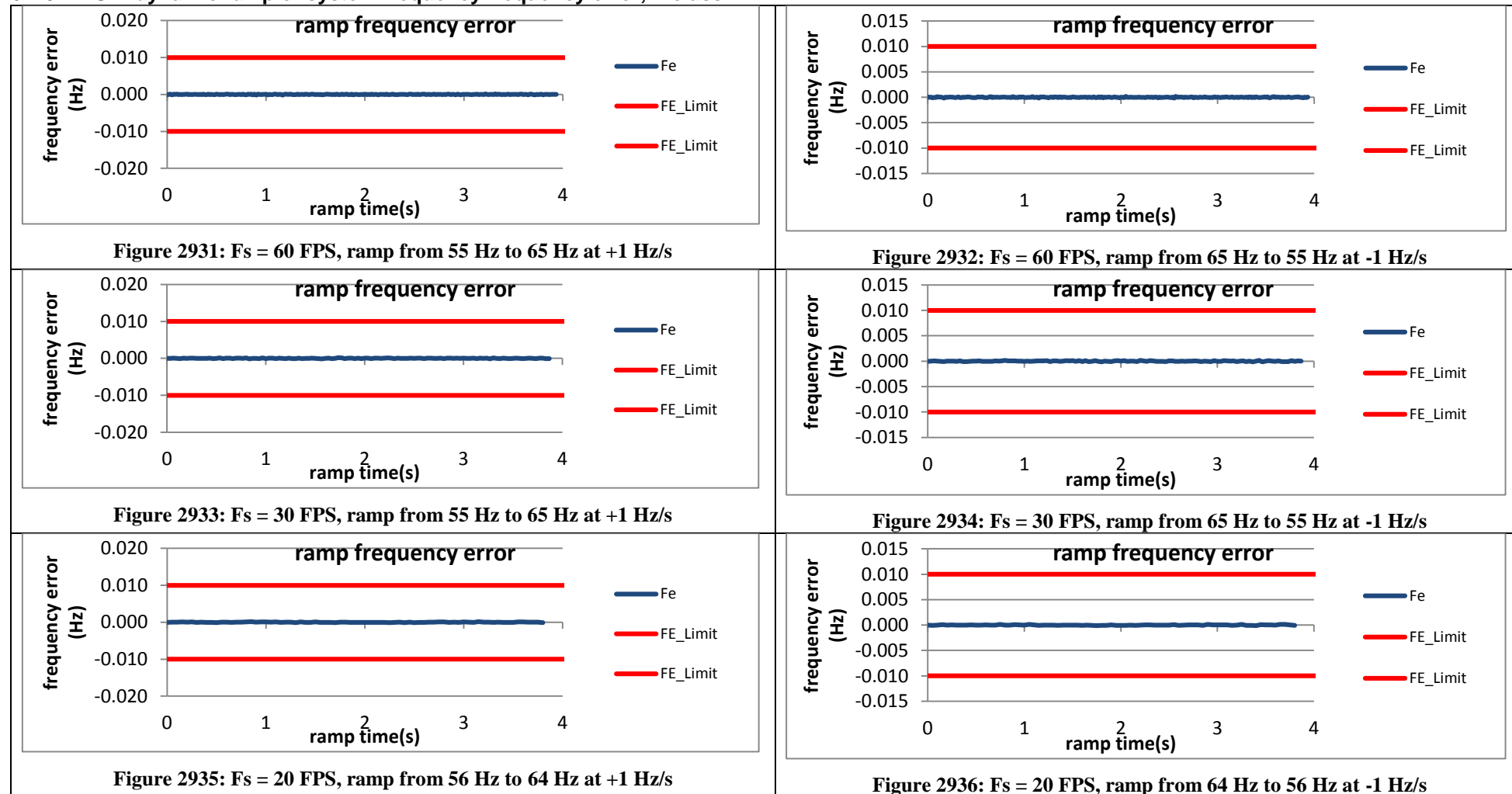


Figure 2930:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.7.8 PMU G dynamic ramp of system frequency frequency error, P class

PMU G does not support P class.

### 6.7.9 PMU H dynamic ramp of system frequency frequency error, P class



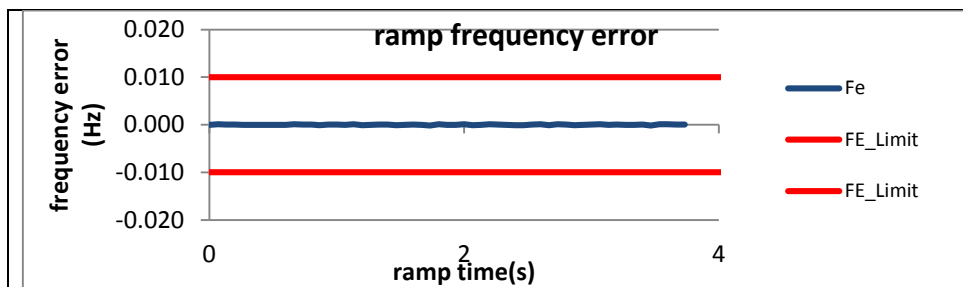


Figure 2937:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

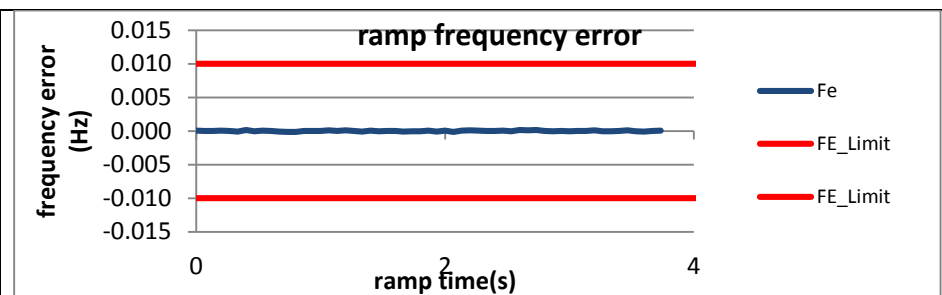


Figure 2938:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

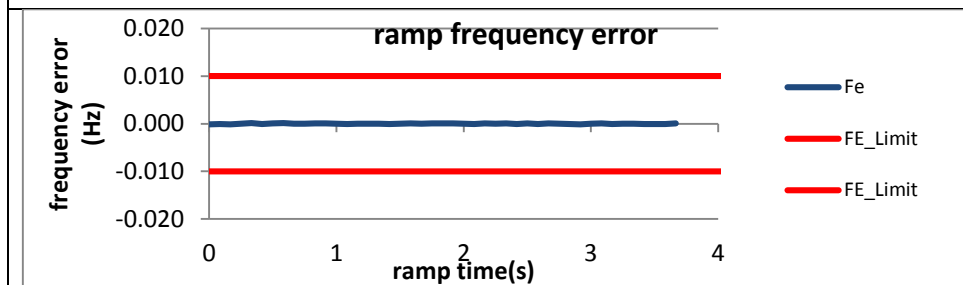


Figure 2939:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

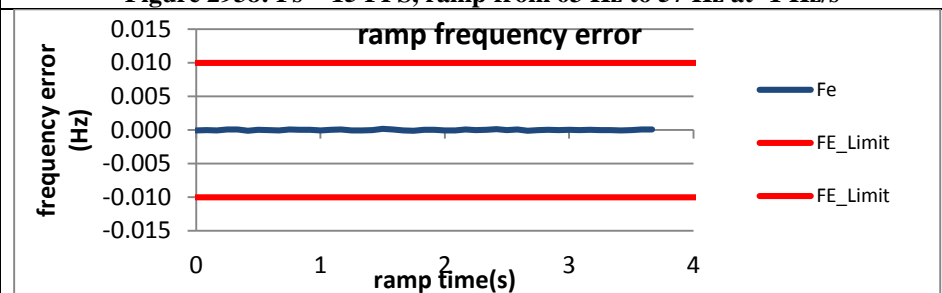


Figure 2940:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

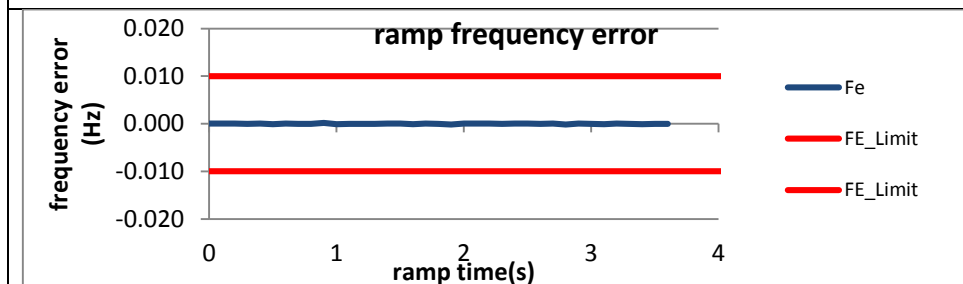


Figure 2941:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

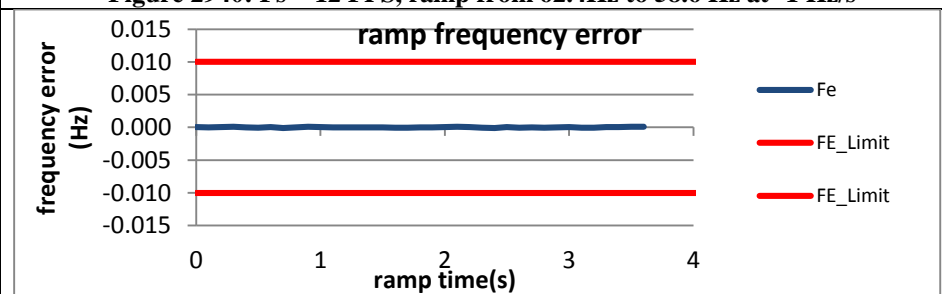
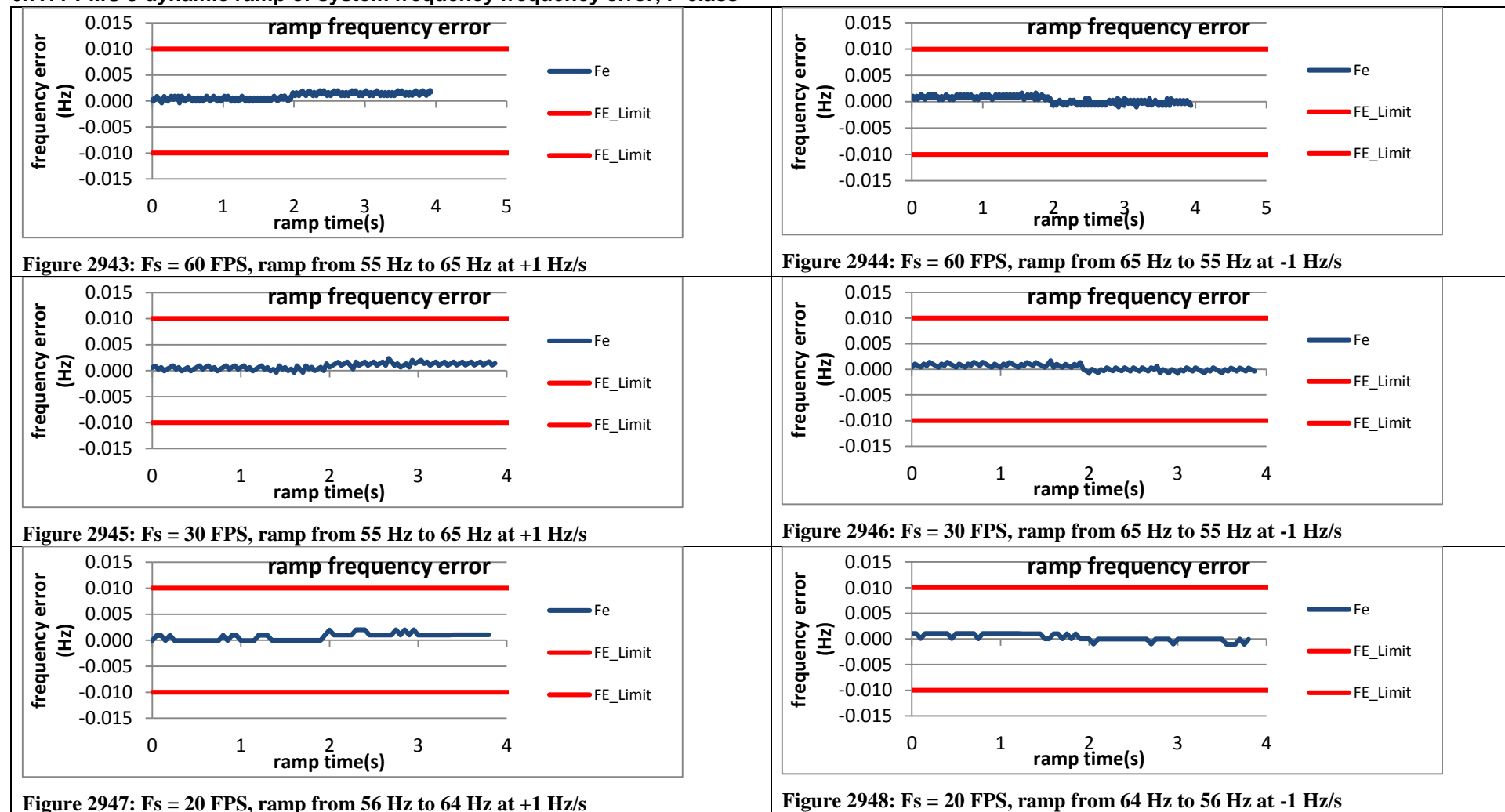


Figure 2942:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.7.10 PMU I dynamic ramp of system frequency frequency error, P class

PMU I does not support P class

#### 6.7.11 PMU J dynamic ramp of system frequency frequency error, P class



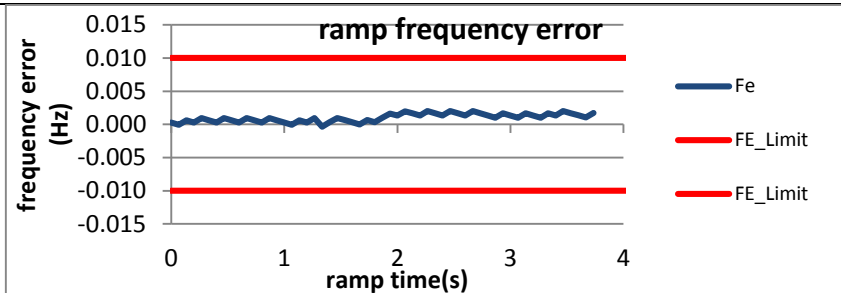


Figure 2949:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

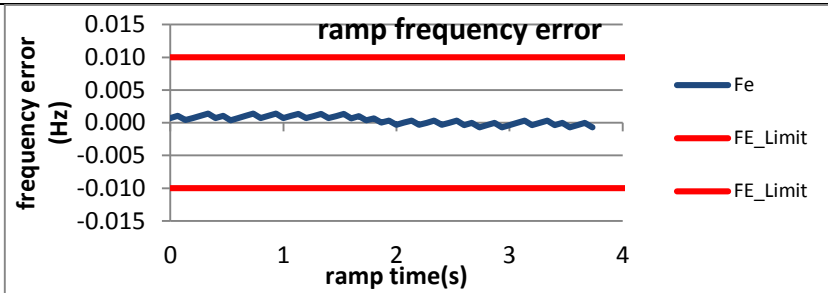


Figure 2950:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

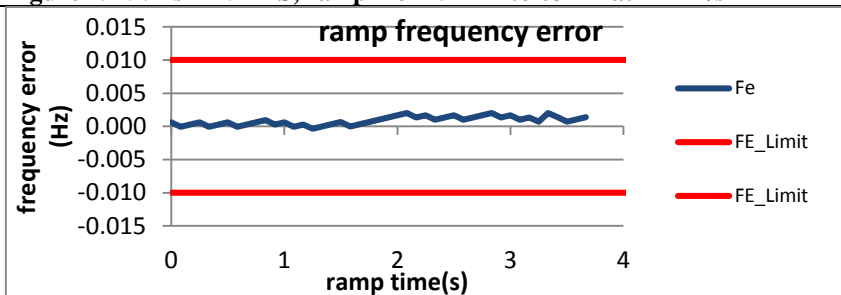


Figure 2951:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

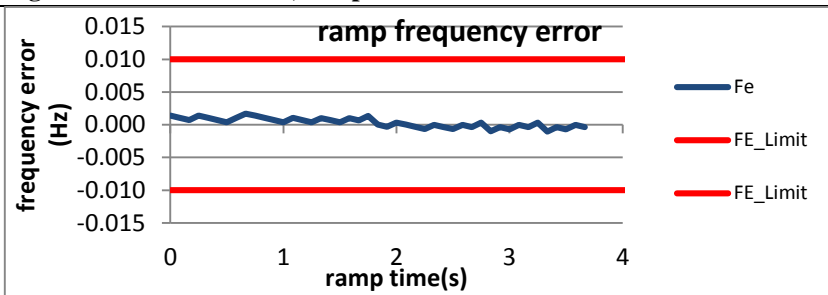


Figure 2952:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

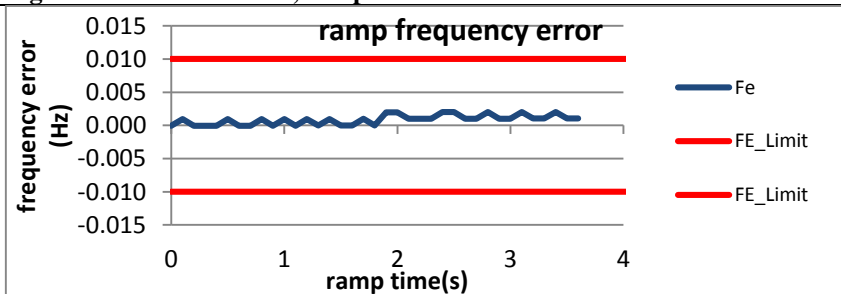


Figure 2953:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

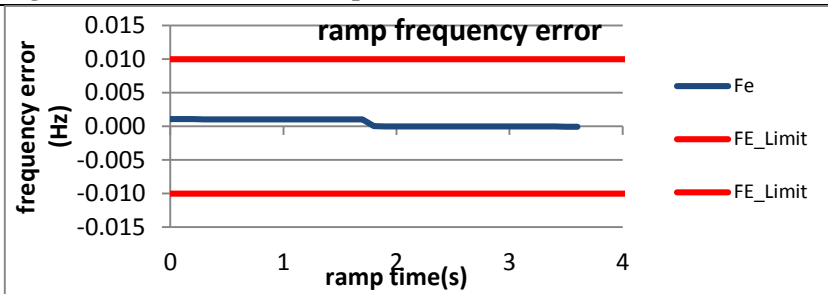


Figure 2954:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 6.8 Dynamic ramp of system frequency ROCOF, P class

### 6.8.1 C37.118.1 Annex C dynamic ramp of system frequency ROCOF error, P class

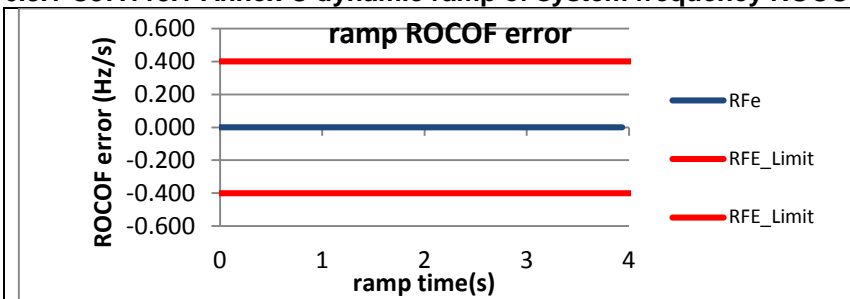


Figure 2955:  $F_s = 60$  FPS, ram from 58 Hz to 62 Hz at +1 Hz/s

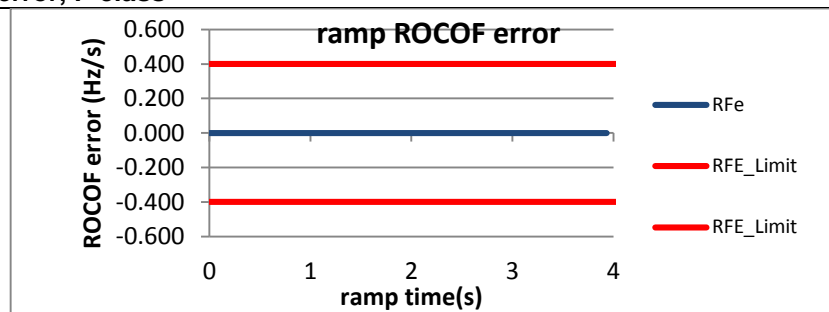


Figure 2956:  $F_s = 60$  FPS, ram from 62 Hz to 58 Hz at -1 Hz/s

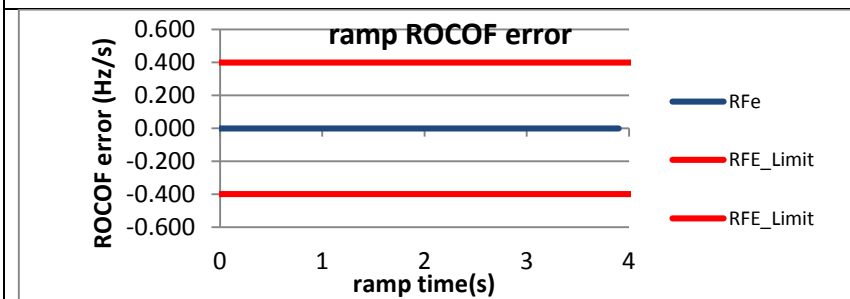


Figure 2957:  $F_s = 30$  FPS, ram from 58 Hz to 62 Hz at +1 Hz/s

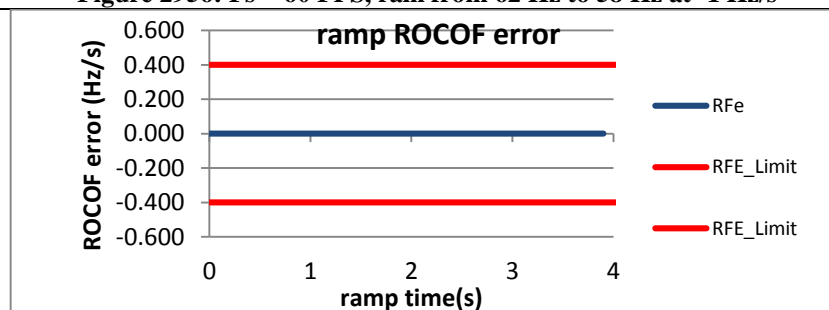


Figure 2958:  $F_s = 30$  FPS, ram from 62 Hz to 58 Hz at -1 Hz/s

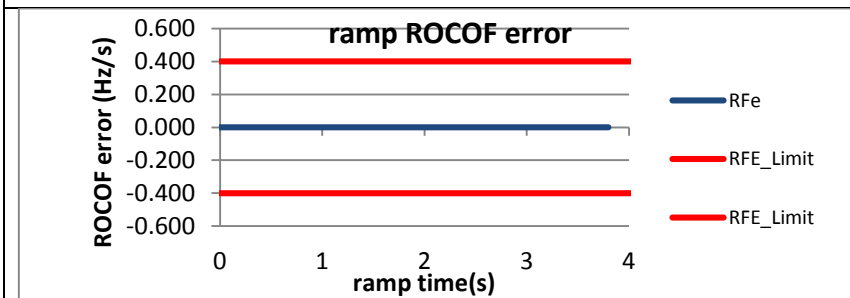


Figure 2959:  $F_s = 20$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

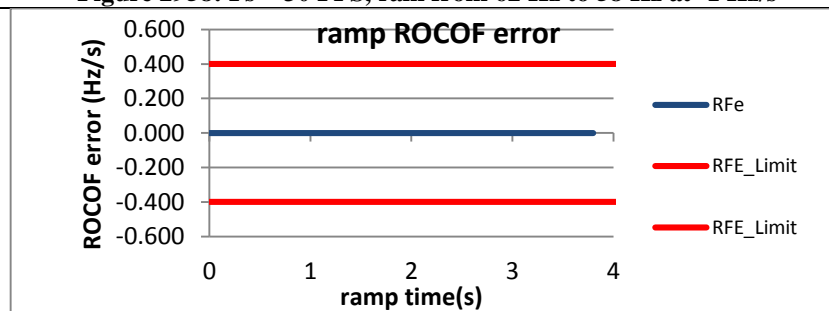


Figure 2960:  $F_s = 20$  FPS, ramp from 62 Hz to 58 Hz at =1 Hz/s

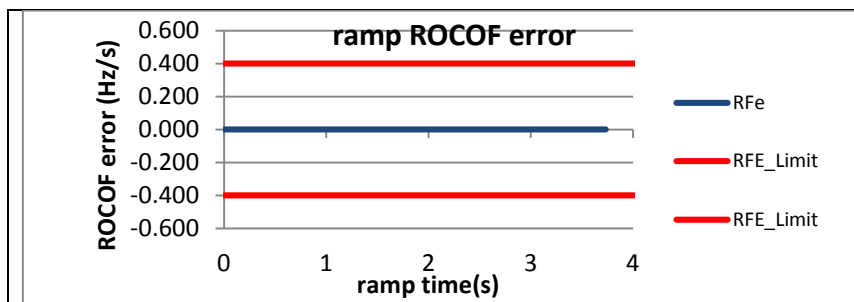


Figure 2961:  $F_s = 15$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

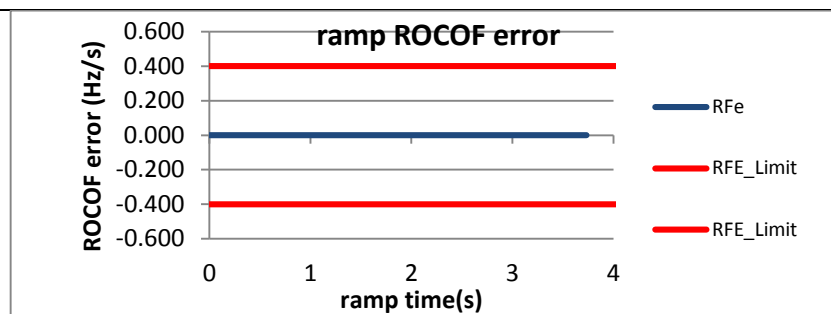


Figure 2962:  $F_s = 15$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

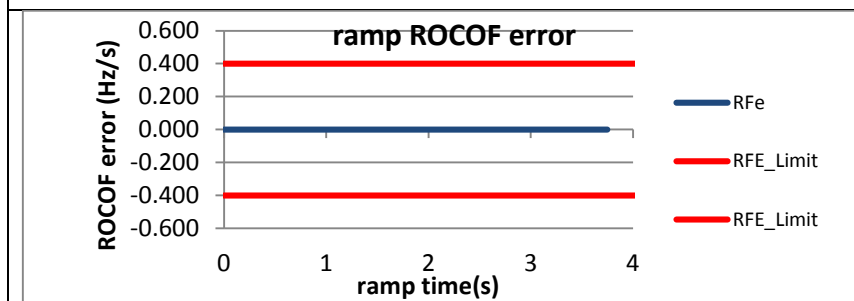


Figure 2963:  $F_s = 12$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

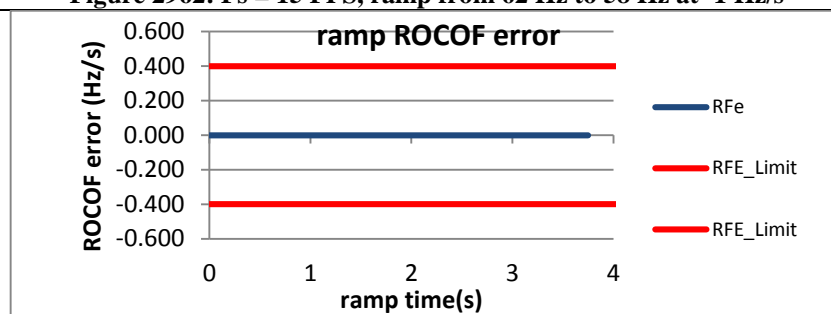


Figure 2964:  $F_s = 12$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

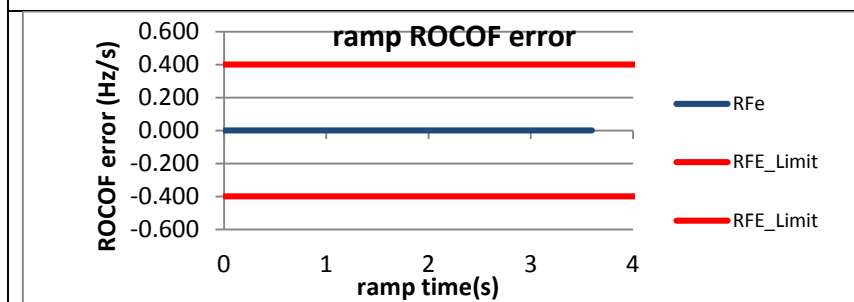


Figure 2965:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

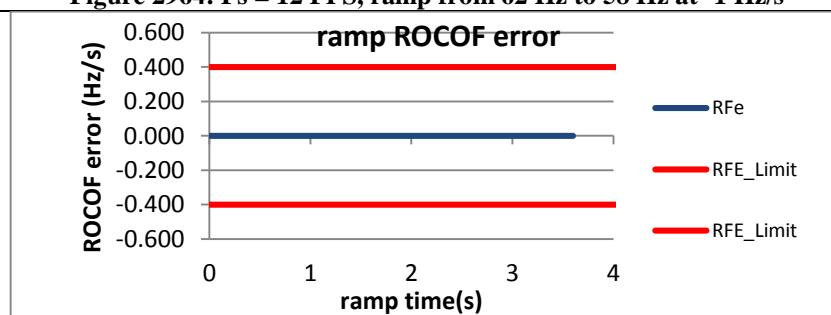


Figure 2966:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s



## 6.8.2 PMU A dynamic ramp of system frequency ROCOF error, P class

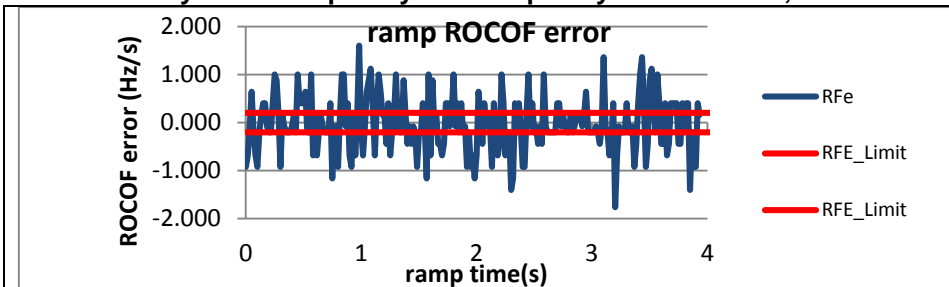


Figure 2967:  $F_s = 60$  FPS, ram from 58 Hz to 62 Hz at +1 Hz/s

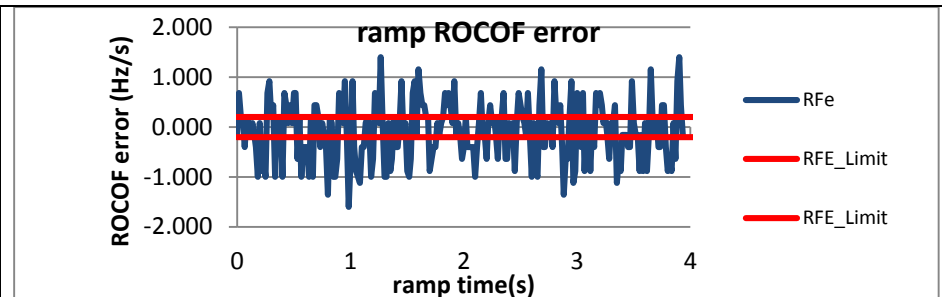


Figure 2968:  $F_s = 60$  FPS, ram from 62 Hz to 58 Hz at -1 Hz/s

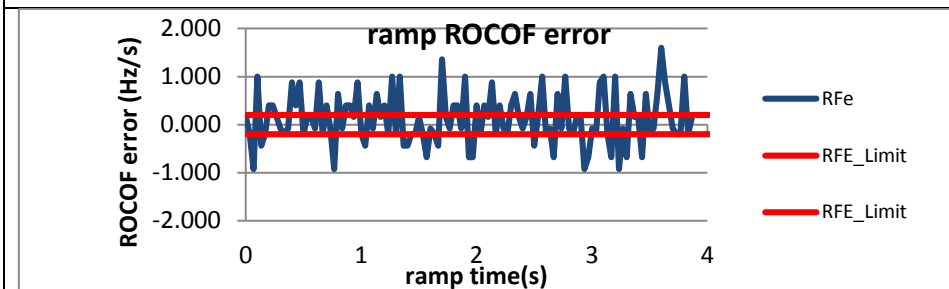


Figure 2969:  $F_s = 30$  FPS, ram from 58 Hz to 62 Hz at +1 Hz/s

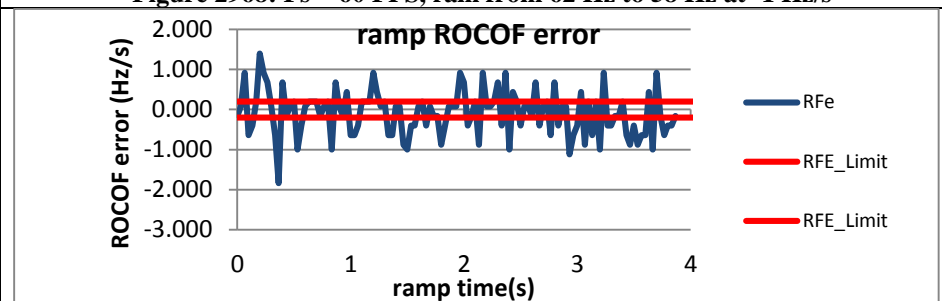


Figure 2970:  $F_s = 30$  FPS, ram from 62 Hz to 58 Hz at -1 Hz/s

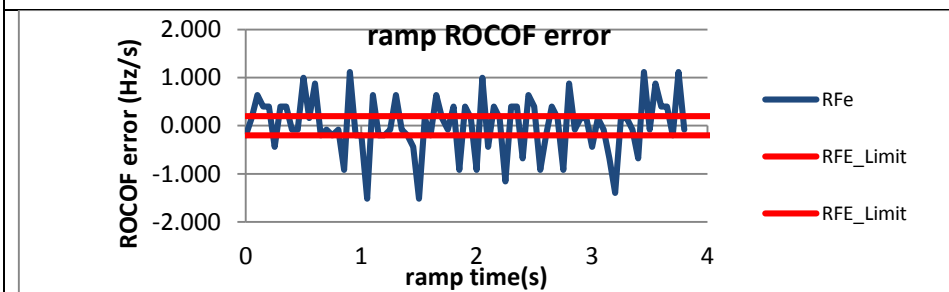


Figure 2971:  $F_s = 20$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

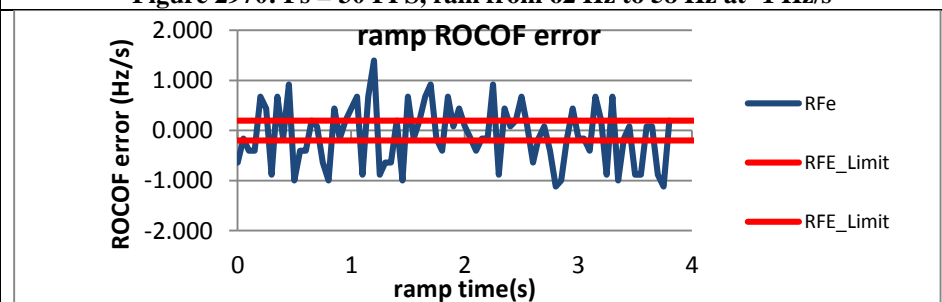


Figure 2972:  $F_s = 20$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

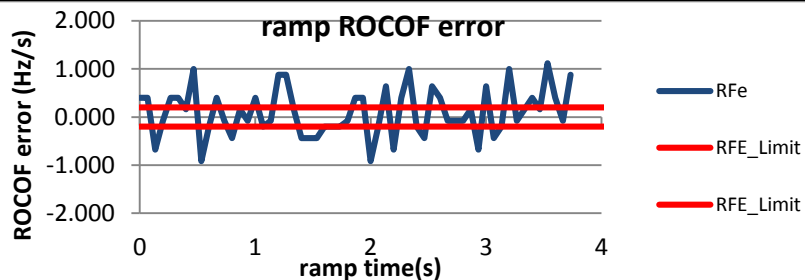


Figure 2973:  $F_s = 15$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

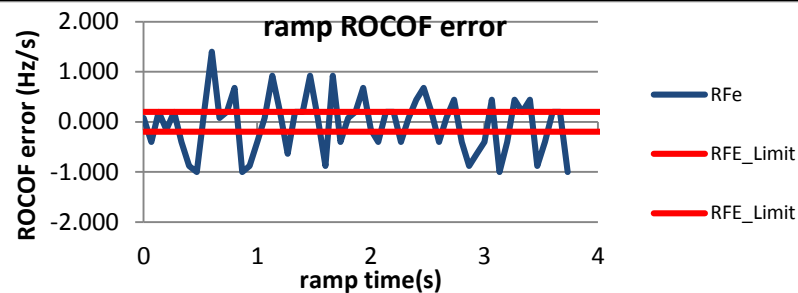


Figure 2974:  $F_s = 15$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

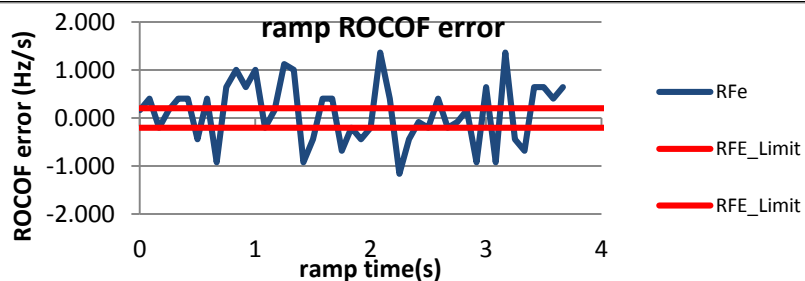


Figure 2975:  $F_s = 12$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

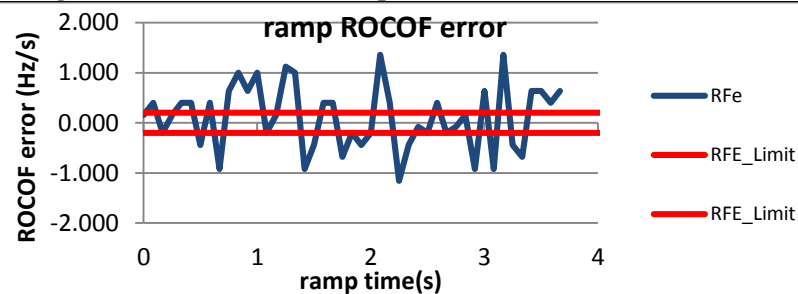


Figure 2976:  $F_s = 12$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

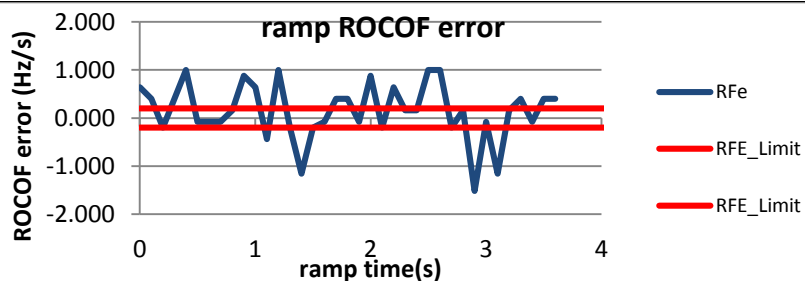


Figure 2977:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

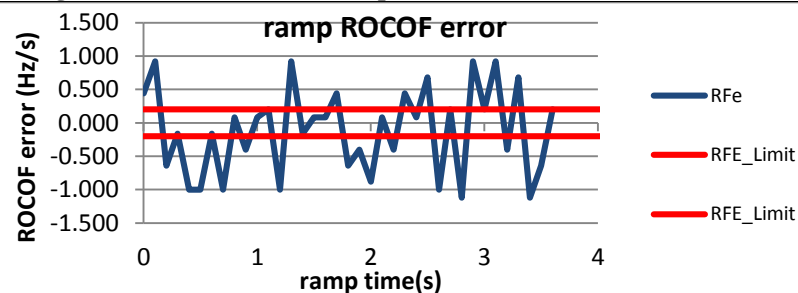


Figure 2978:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.8.3 PMU B dynamic ramp of system frequency ROCOF error, P class

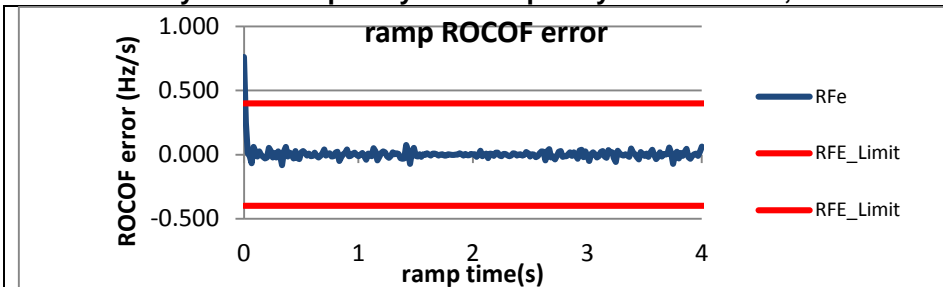


Figure 2979:  $F_s = 60$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

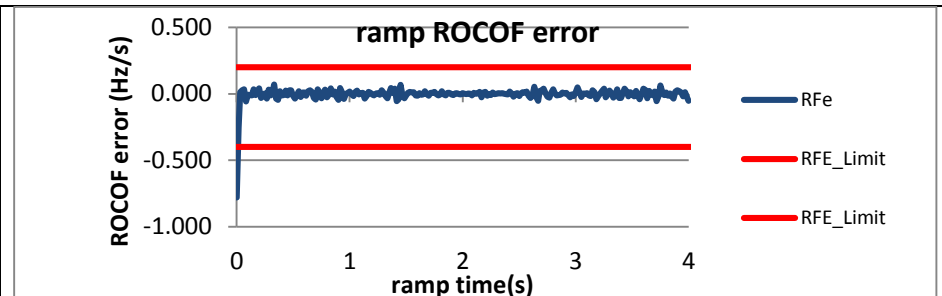


Figure 2980:  $F_s = 60$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

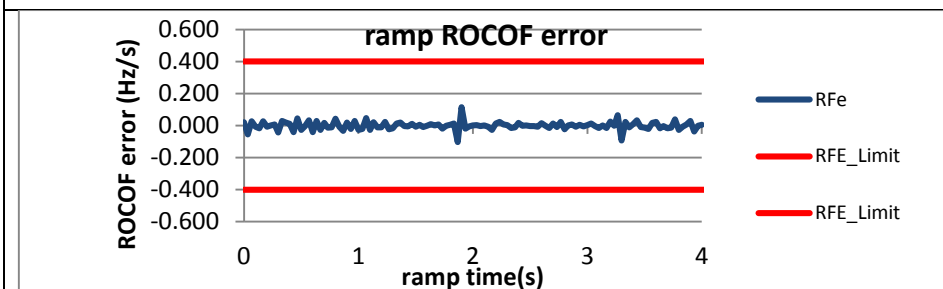


Figure 2981:  $F_s = 30$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

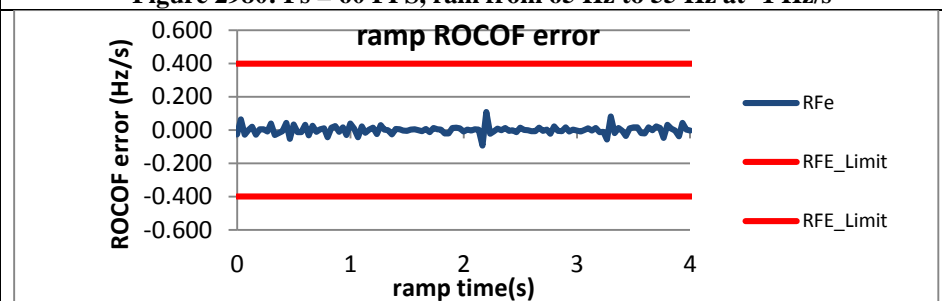


Figure 2982:  $F_s = 30$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

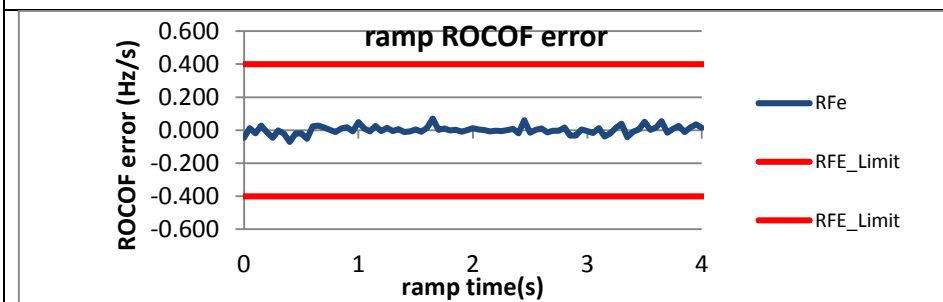


Figure 2983:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

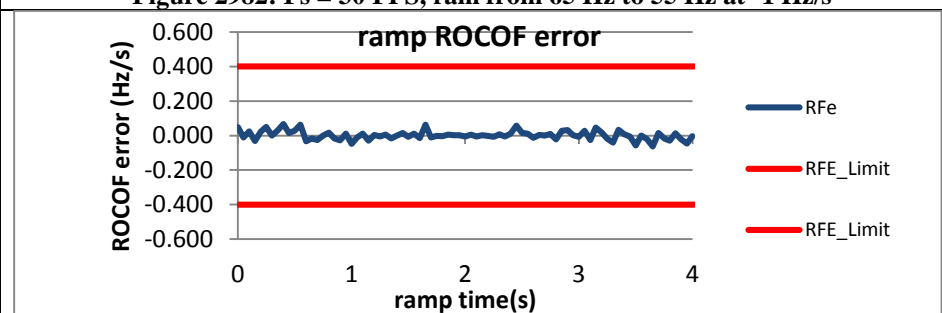


Figure 2984:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

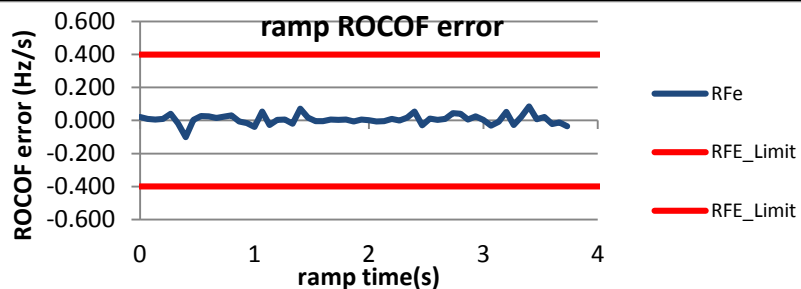


Figure 2985:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

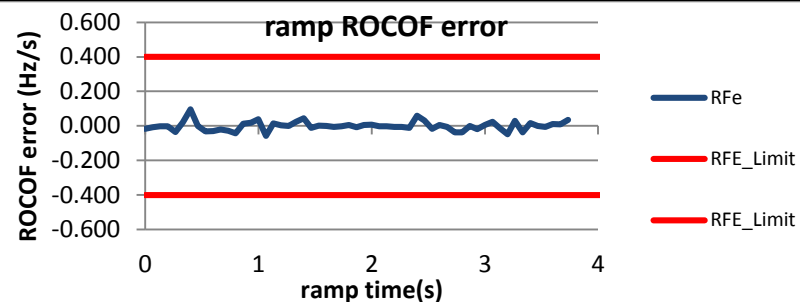


Figure 2986:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

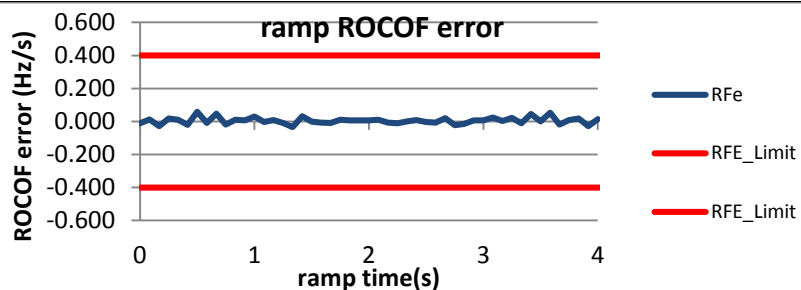


Figure 2987:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

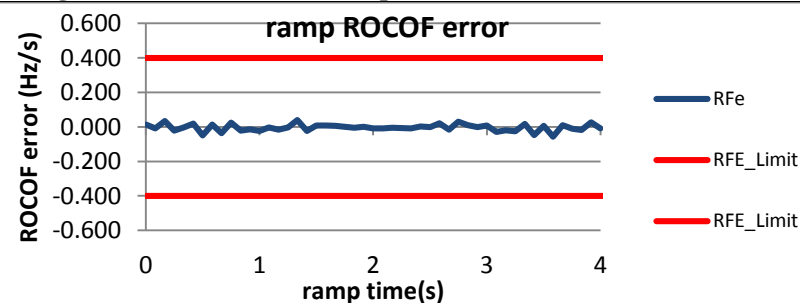


Figure 2988:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

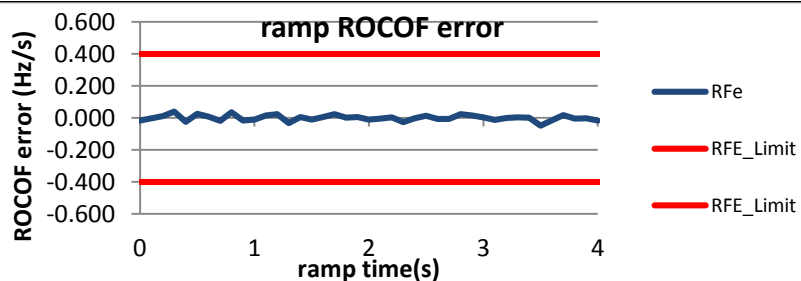


Figure 2989:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

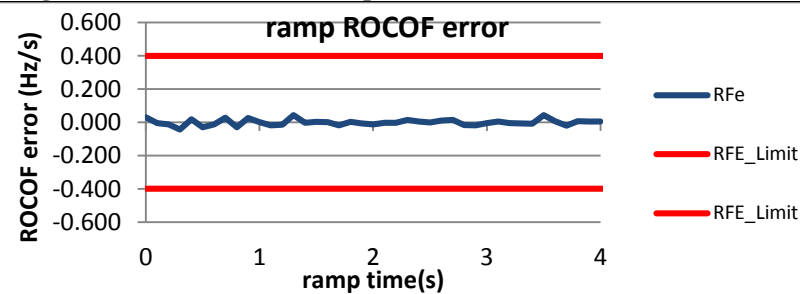


Figure 2990:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.8.4 PMU C dynamic ramp of system frequency ROCOF error, P class

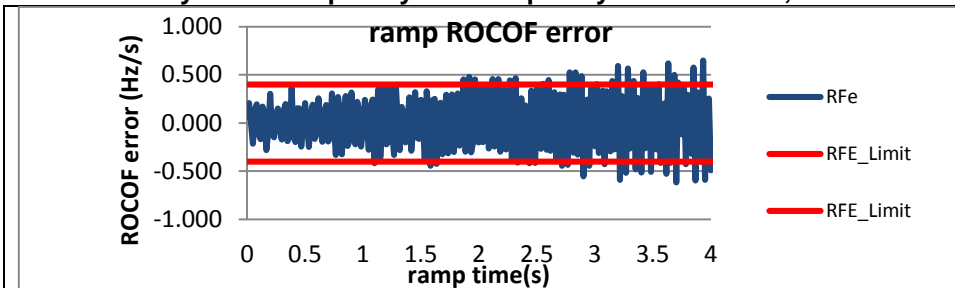


Figure 2991:  $F_s = 60$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

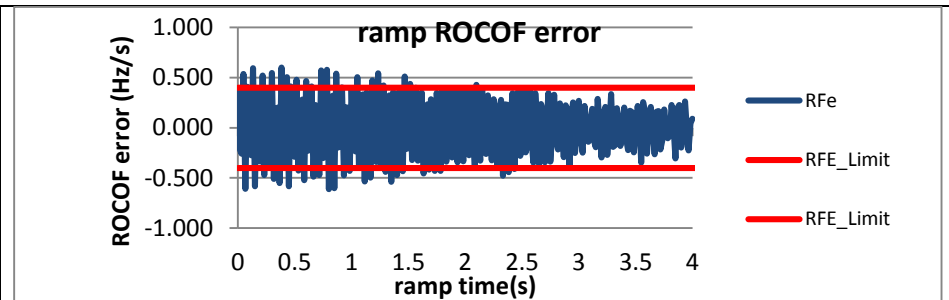


Figure 2992:  $F_s = 60$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

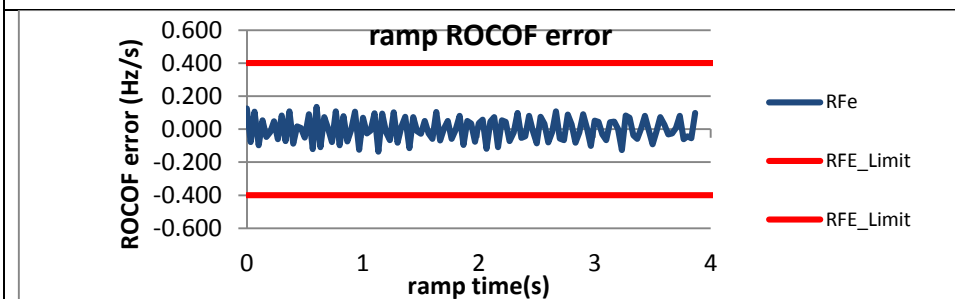


Figure 2993:  $F_s = 30$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

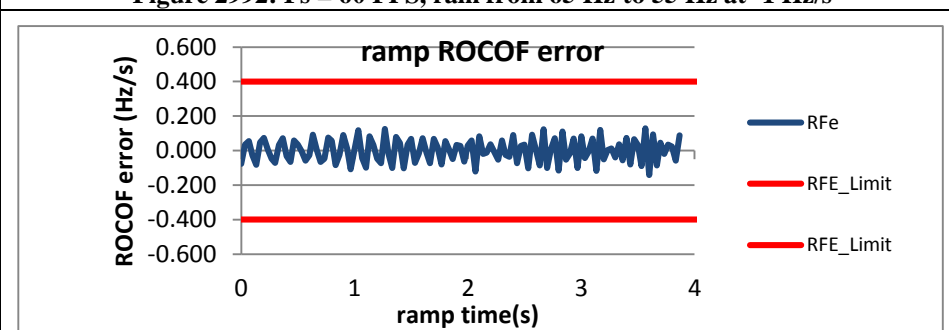


Figure 2994:  $F_s = 30$  FPS, ram from 65 Hz to 55 Hz at -1 Hz/s

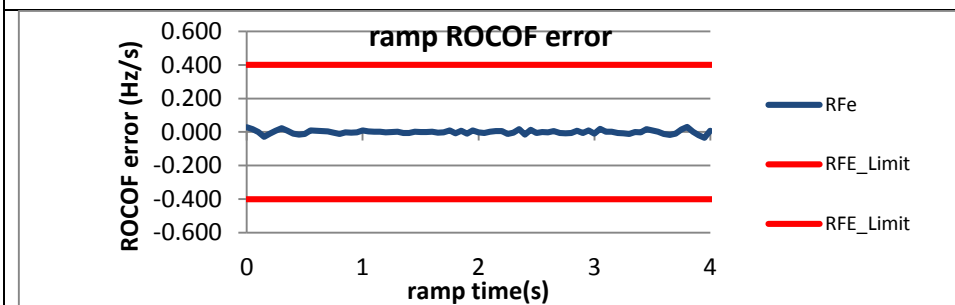


Figure 2995:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

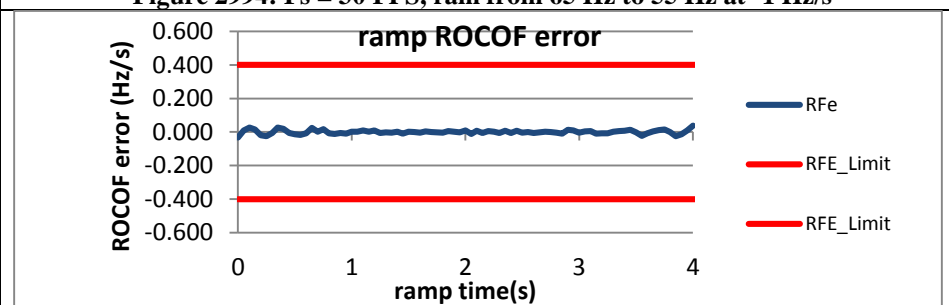


Figure 2996:  $F_s = 20$  FPS, ramp from 64 Hz to 56 Hz at -1 Hz/s

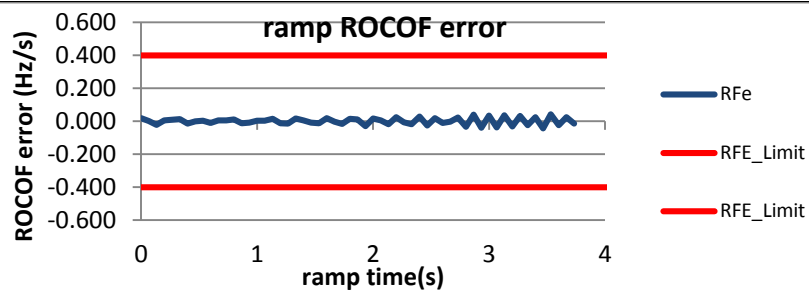


Figure 2997:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

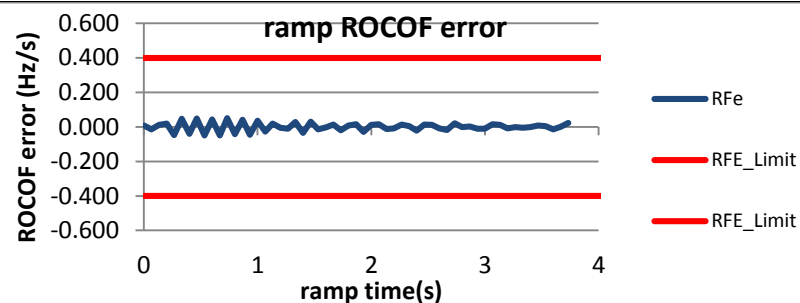


Figure 2998:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

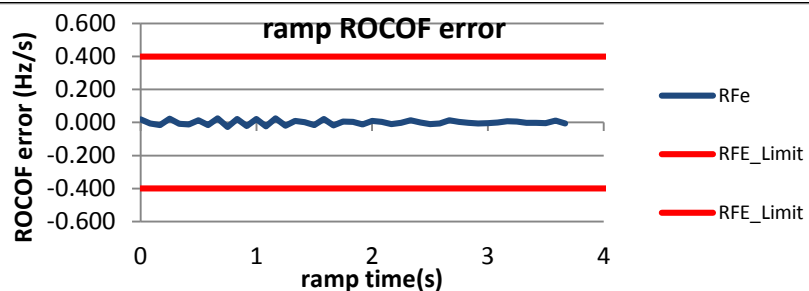


Figure 2999:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

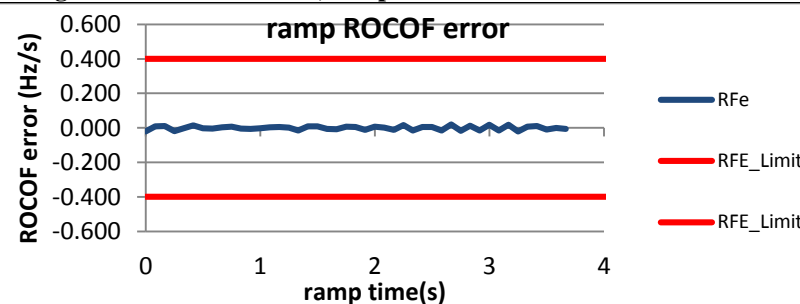


Figure 3000:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

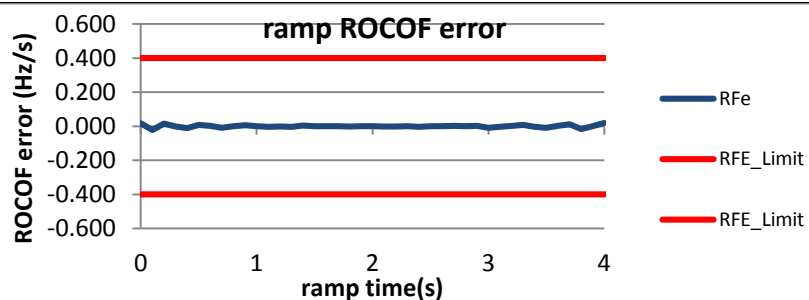


Figure 3001:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

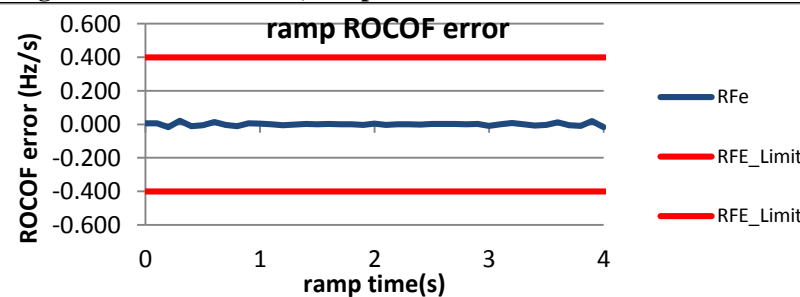


Figure 3002:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.8.5 PMU D dynamic ramp of system frequency ROCOF error, P class

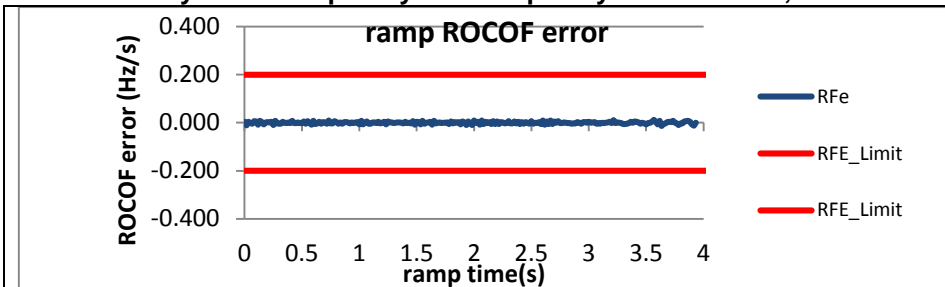


Figure 3003:  $F_s = 60$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

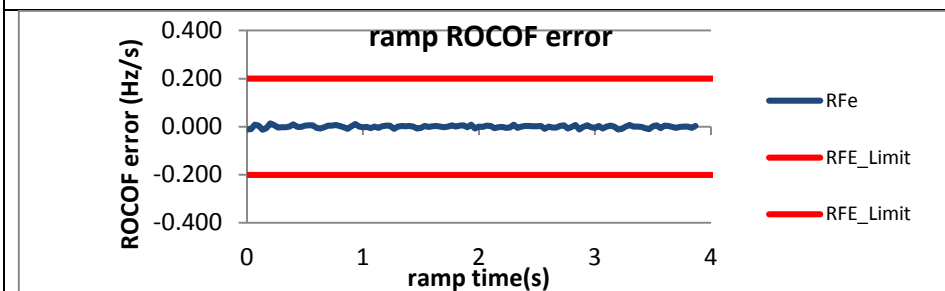


Figure 3005:  $F_s = 30$  FPS, ram from 55 Hz to 65 Hz at +1 Hz/s

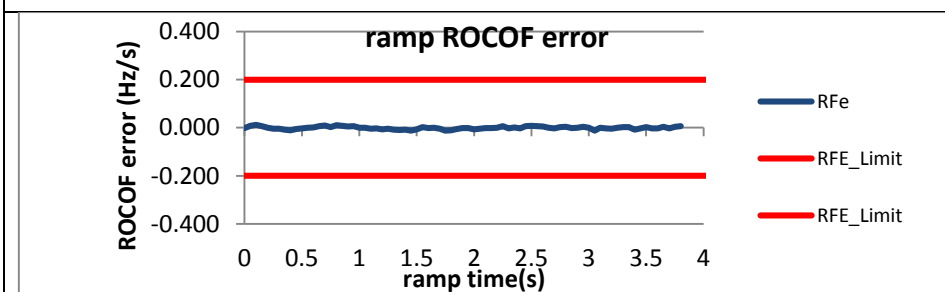


Figure 3007:  $F_s = 20$  FPS, ramp from 56 Hz to 64 Hz at +1 Hz/s

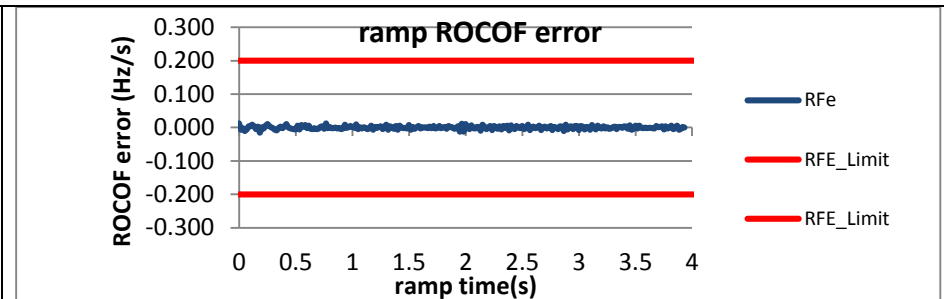


Figure 3004:  $F_s = 60$  FPS, ram from 62 Hz to 58 Hz at -1 Hz/s

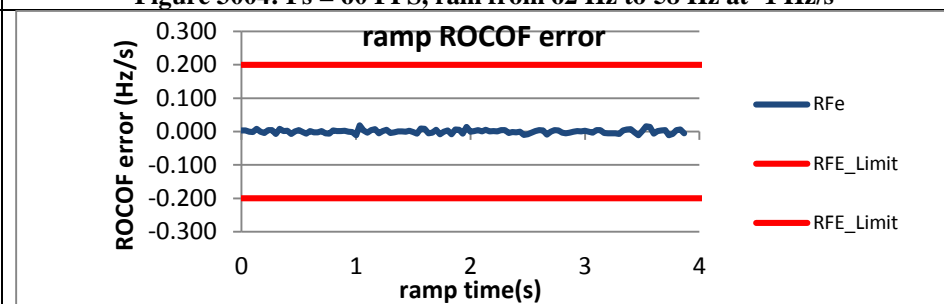


Figure 3006:  $F_s = 30$  FPS, ram from 62 Hz to 58 Hz at -1 Hz/s

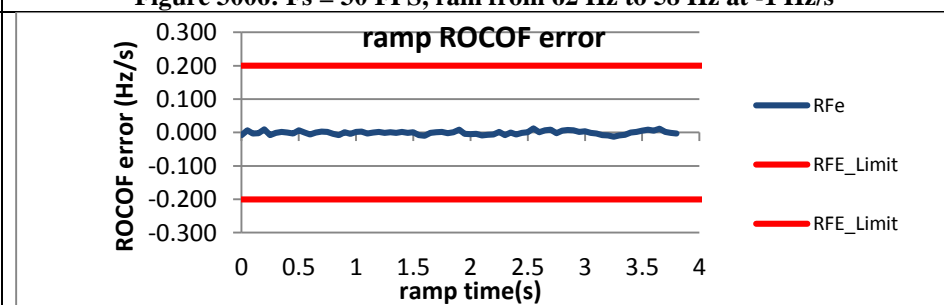


Figure 3008:  $F_s = 20$  FPS, ramp from 62 Hz to 58 Hz at =1 Hz/s

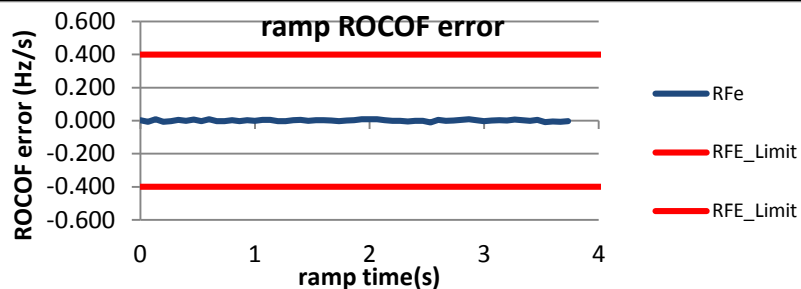


Figure 3009:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

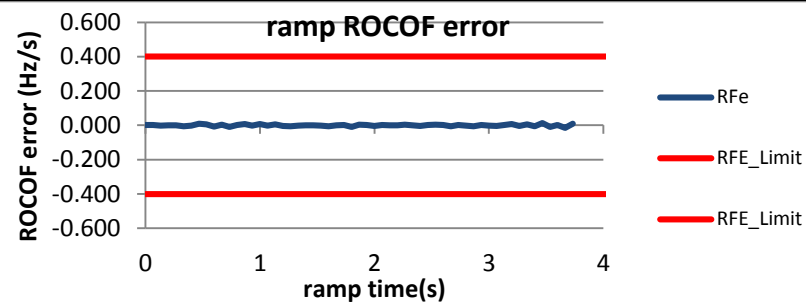


Figure 3010:  $F_s = 15$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

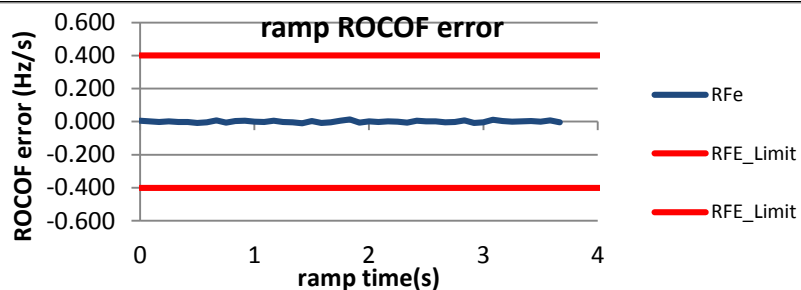


Figure 3011:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

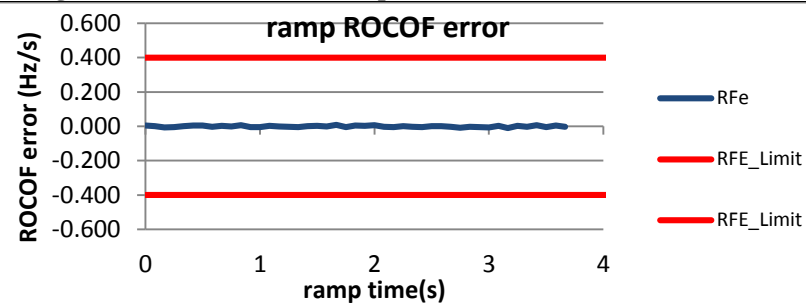


Figure 3012:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58 Hz at -1 Hz/s

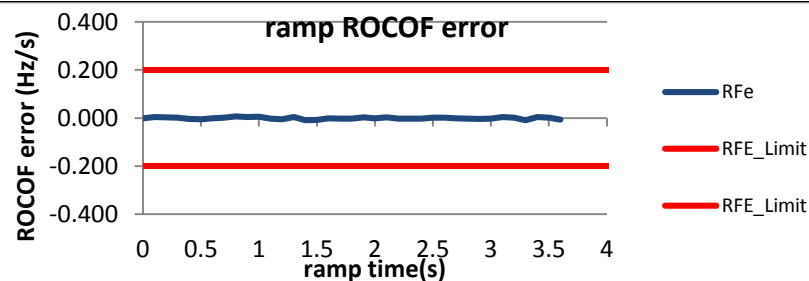


Figure 3013:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

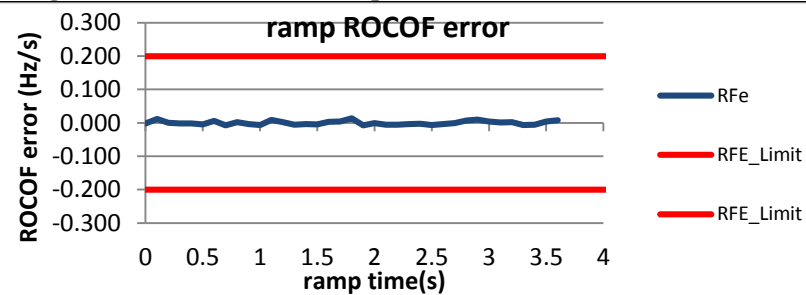


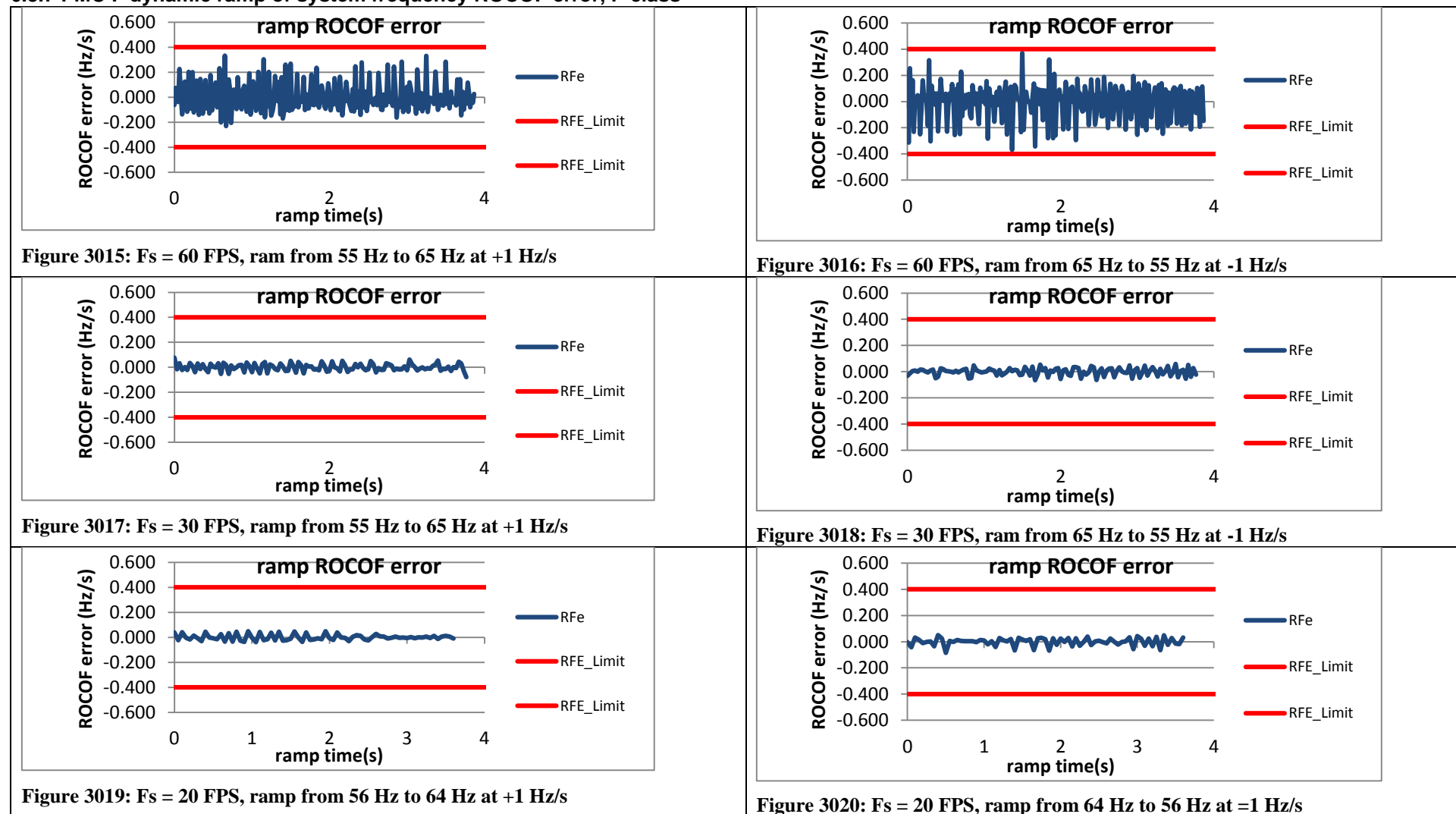
Figure 3014:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s



### 6.8.6 PMU E dynamic ramp of system frequency ROCOF error, P class

PMU E does not support P class.

### 6.8.7 PMU F dynamic ramp of system frequency ROCOF error, P class



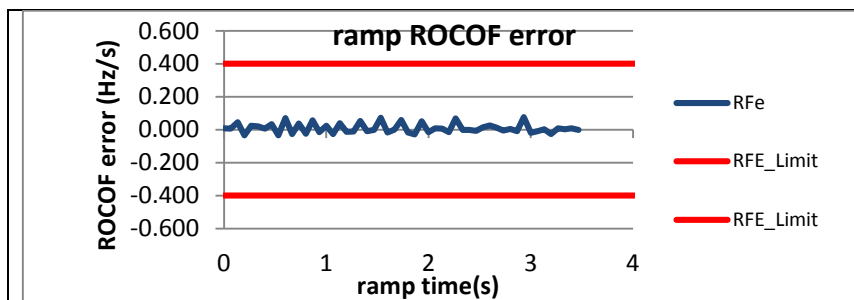


Figure 3021:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

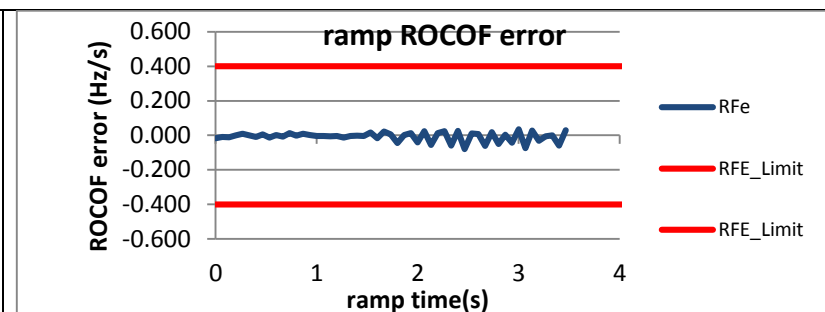


Figure 3022:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

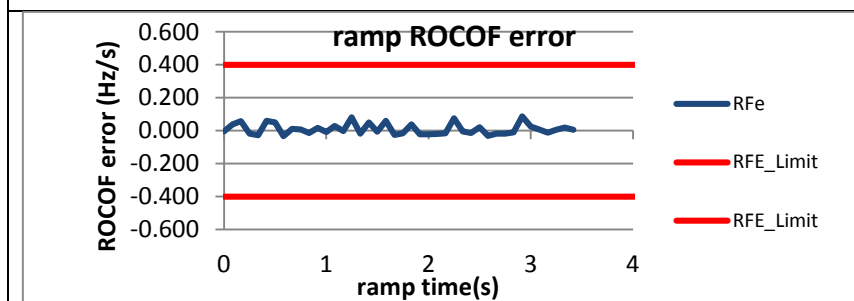


Figure 3023:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

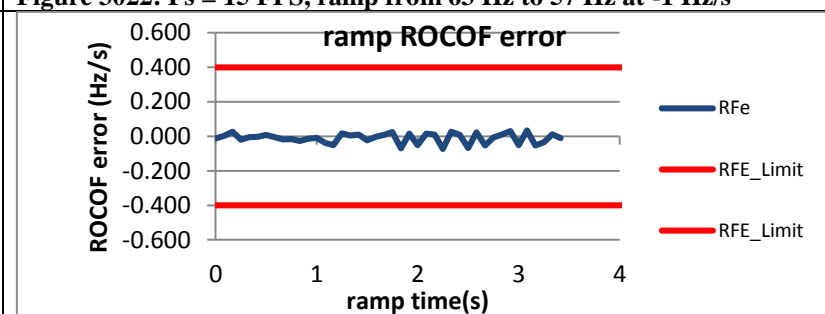


Figure 3024:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

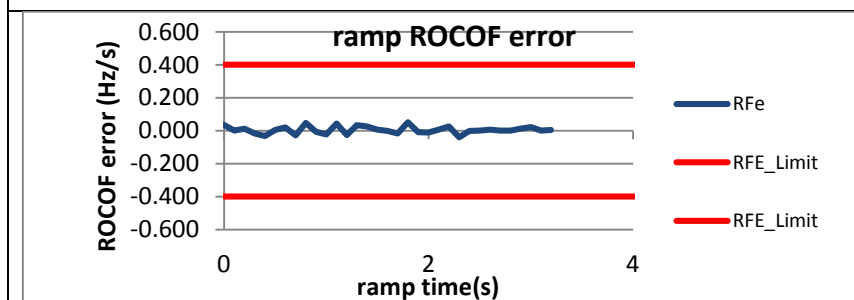


Figure 3025:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

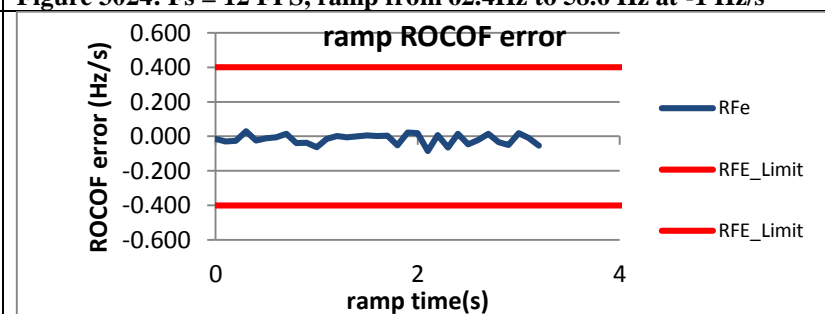
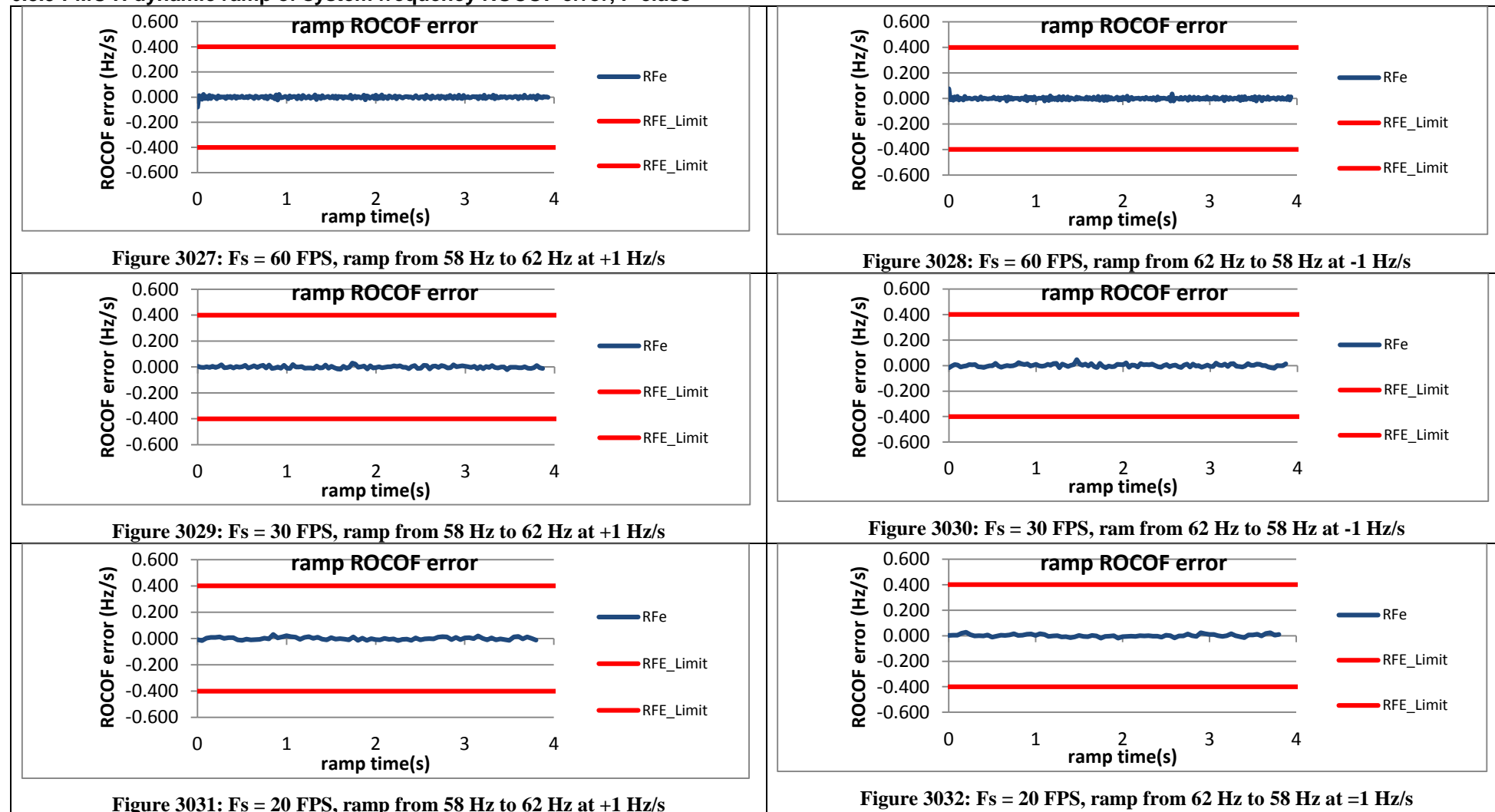


Figure 3026:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

### 6.8.8 PMU G dynamic ramp of system frequency ROCOF error, P class

PMU G does not support P class.

### 6.8.9 PMU H dynamic ramp of system frequency ROCOF error, P class



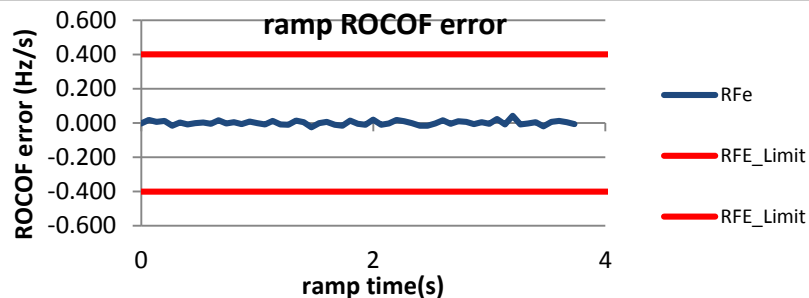


Figure 3033:  $F_s = 15$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

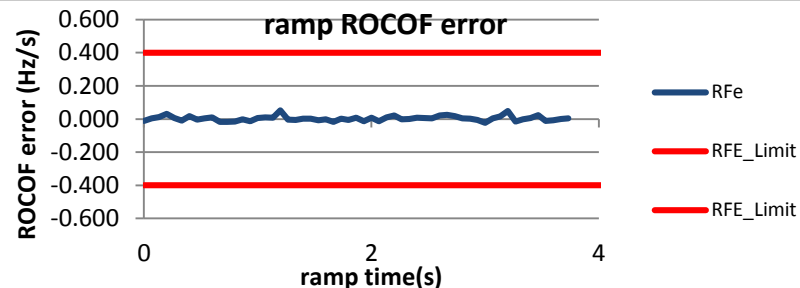


Figure 3034:  $F_s = 15$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

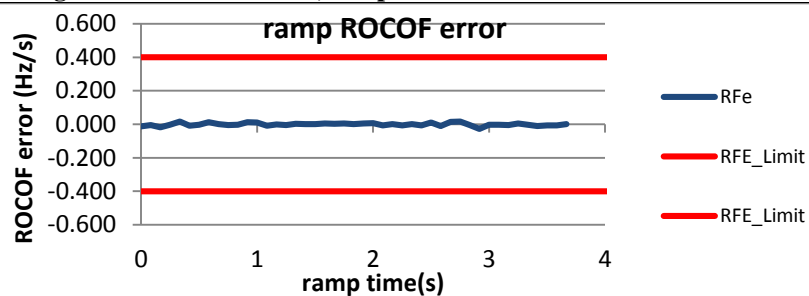


Figure 3035:  $F_s = 12$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

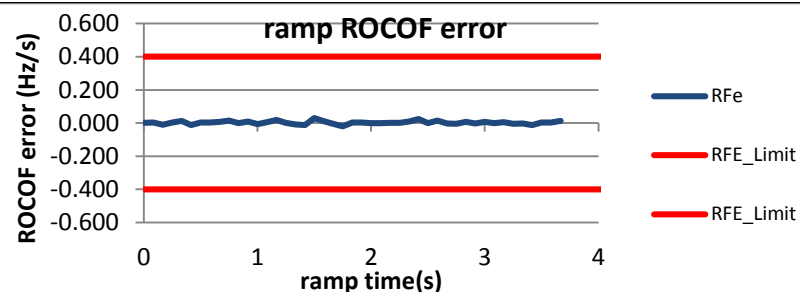


Figure 3036:  $F_s = 12$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

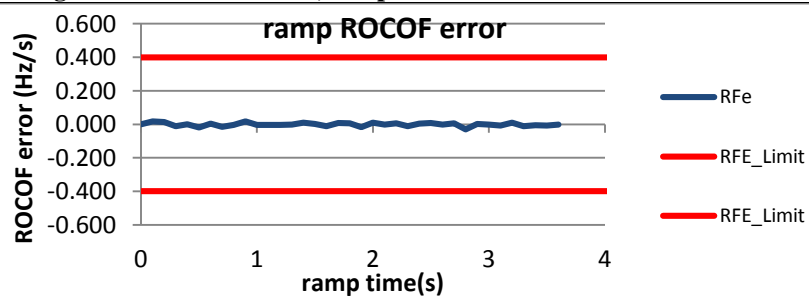


Figure 3037:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

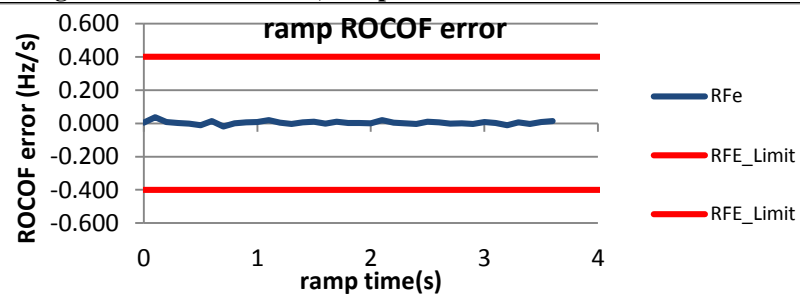
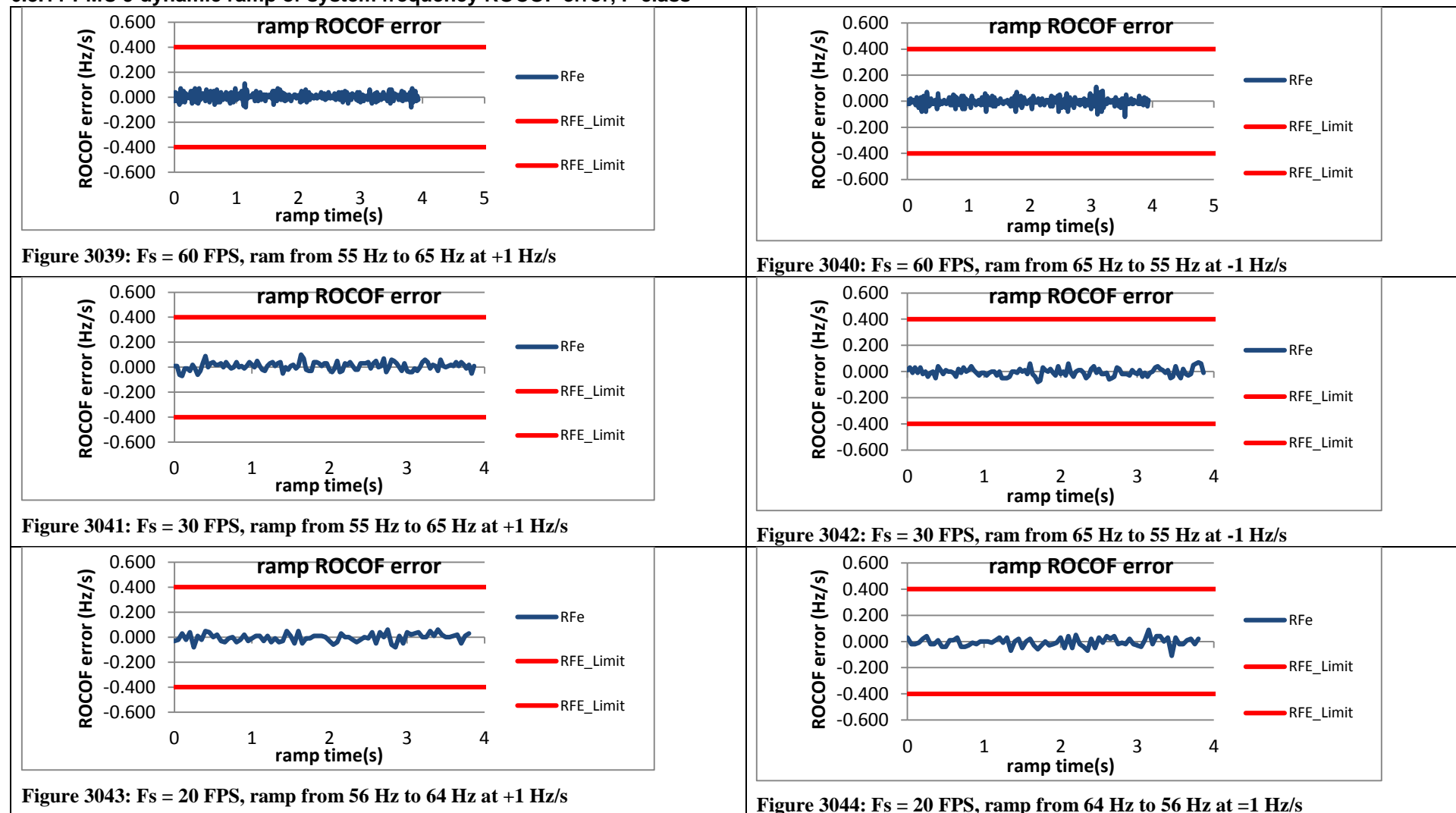


Figure 3038:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

#### 6.8.10 PMU I dynamic ramp of system frequency ROCOF error, P class

PMU I does not support P class

#### 6.8.11 PMU J dynamic ramp of system frequency ROCOF error, P class



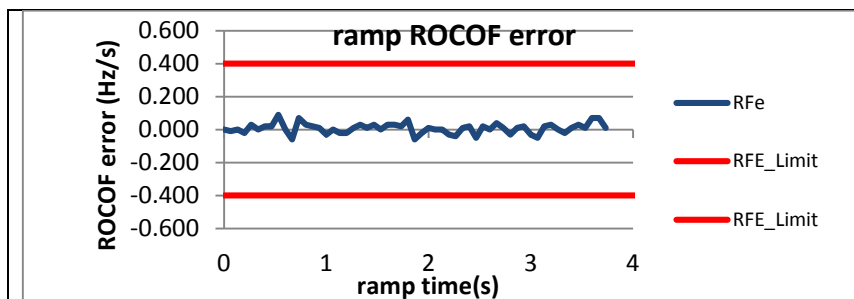


Figure 3045:  $F_s = 15$  FPS, ramp from 57 Hz to 63 Hz at +1 Hz/s

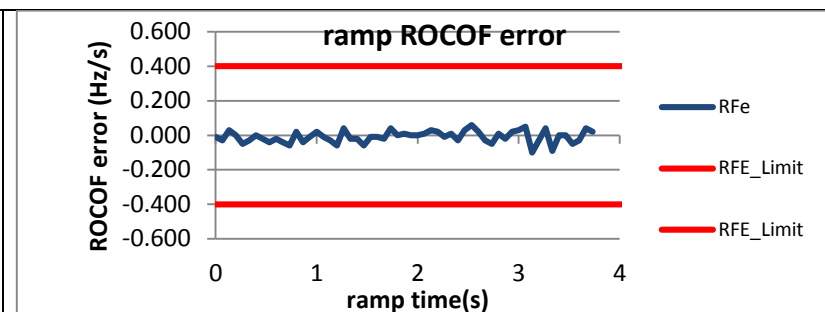


Figure 3046:  $F_s = 15$  FPS, ramp from 63 Hz to 57 Hz at -1 Hz/s

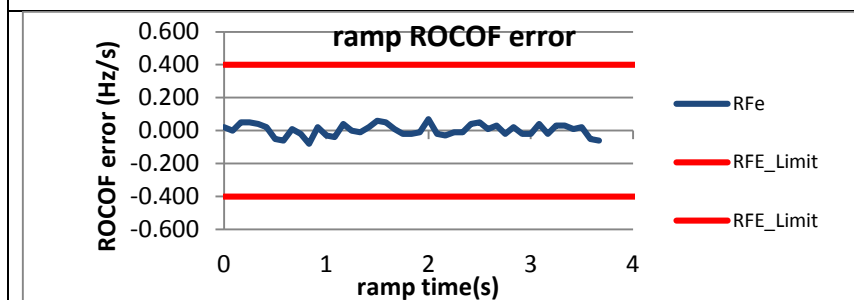


Figure 3047:  $F_s = 12$  FPS, ramp from 58.6 Hz to 62.4 Hz at +1 Hz/s

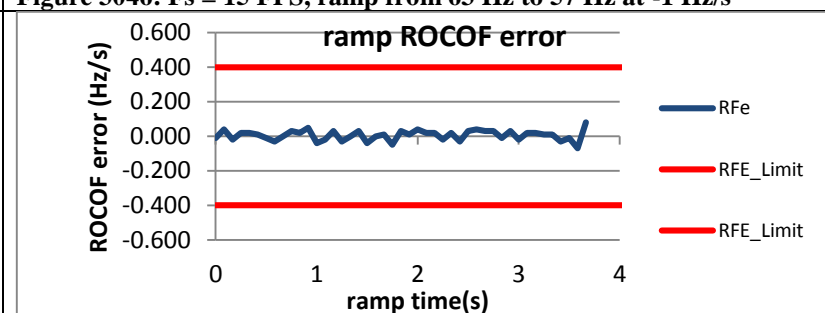


Figure 3048:  $F_s = 12$  FPS, ramp from 62.4 Hz to 58.6 Hz at -1 Hz/s

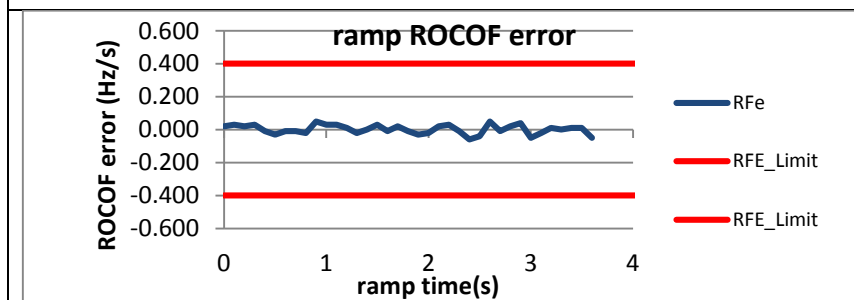


Figure 3049:  $F_s = 10$  FPS, ramp from 58 Hz to 62 Hz at +1 Hz/s

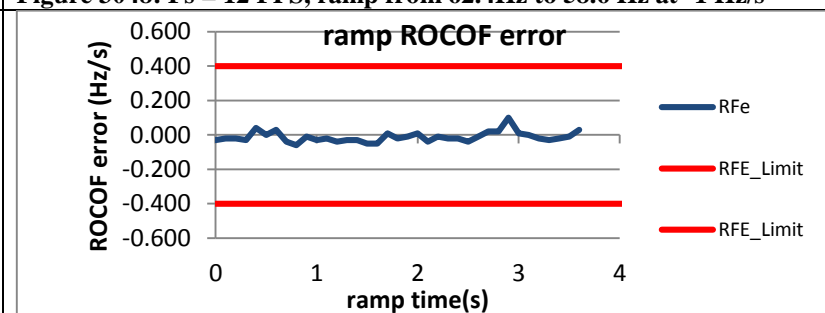


Figure 3050:  $F_s = 10$  FPS, ramp from 62 Hz to 58 Hz at -1 Hz/s

## 7. Dynamic bandwidth measurement: phase modulation

### Table of Contents

7. Dynamic bandwidth measurement: phase modulation .....	510
7.1 Phase modulation voltage TVE, M class .....	516
7.1.1 C37.118.1 Annex C phase modulation voltage TVE: M class .....	516
7.1.2 PMU A phase modulation voltage TVE: M class .....	517
7.1.3 PMU B phase modulation voltage TVE: M class .....	518
7.1.4 PMU C phase modulation voltage TVE: M class .....	519
7.1.5 PMU D phase modulation voltage TVE: M class .....	520
7.1.6 PMU E phase modulation voltage TVE: M class .....	521
7.1.7 PMU F phase modulation voltage TVE: M class .....	522
7.1.8 PMU G phase modulation voltage TVE: M class .....	523
7.1.9 PMU H phase modulation voltage TVE: M class .....	524
7.1.10 PMU I phase modulation voltage TVE: M class .....	525
7.1.11 PMU J phase modulation voltage TVE: M class .....	526
7.2 Phase modulation current TVE, M class .....	527
7.2.1 C37.118.1 Annex C phase modulation current TVE: M class .....	527
7.2.2 PMU A phase modulation current TVE: M class .....	528
7.2.3 PMU B phase modulation current TVE: M class .....	529
7.2.4 PMU C phase modulation current TVE: M class .....	530
7.2.5 PMU D phase modulation current TVE: M class .....	531
7.2.6 PMU E phase modulation current TVE: M class .....	532
7.2.7 PMU F phase modulation current TVE: M class .....	533
7.2.8 PMU G phase modulation current TVE: M class .....	534
7.2.9 PMU H phase modulation current TVE: M class .....	535
7.2.10 PMU I phase modulation current TVE: M class .....	536
7.2.11 PMU J phase modulation current TVE: M class .....	537
7.3 Dynamic bandwidth measurement: phase modulation frequency error, M class .....	538
7.3.1 C37.118.1 Annex C dynamic bandwidth measurement: phase modulation frequency error: M class .....	538
7.3.2 PMU A dynamic bandwidth measurement: phase modulation frequency error: M class .....	539
7.3.3 PMU B dynamic bandwidth measurement: phase modulation frequency error: M class .....	540
7.3.4 PMU C dynamic bandwidth measurement: phase modulation frequency error: M class .....	541
7.3.5 PMU D dynamic bandwidth measurement: phase modulation frequency error: M class .....	542
7.3.6 PMU E dynamic bandwidth measurement: phase modulation frequency error: M class .....	543
7.3.7 PMU F dynamic bandwidth measurement: phase modulation frequency error: M class .....	544
7.3.8 PMU G dynamic bandwidth measurement: phase modulation frequency error: M class .....	545

7.3.9 PMU H dynamic bandwidth measurement: phase modulation frequency error: M class .....	546
7.3.10 PMU I dynamic bandwidth measurement: phase modulation frequency error: M class .....	547
7.3.11 PMU J dynamic bandwidth measurement: phase modulation frequency error: M class .....	548
7.4 Dynamic bandwidth measurement: phase modulation ROCOF error .....	549
7.4.1 C37.118.1 Annex C dynamic bandwidth measurement: phase modulation ROCOF error: M class .....	549
7.4.2 PMU A dynamic bandwidth measurement: phase modulation ROCOF error: M class .....	550
7.4.3 PMU B dynamic bandwidth measurement: phase modulation ROCOF error: M class .....	551
7.4.4 PMU C dynamic bandwidth measurement: phase modulation ROCOF error: M class .....	552
7.4.5 PMU D dynamic bandwidth measurement: phase modulation ROCOF error: M class .....	553
7.4.6 PMU E dynamic bandwidth measurement: phase modulation ROCOF error: M class .....	554
7.4.7 PMU F dynamic bandwidth measurement: phase modulation ROCOF error: M class.....	555
7.4.8 PMU G * dynamic bandwidth measurement: phase modulation ROCOF error: M class .....	556
7.4.9 PMU H dynamic bandwidth measurement: phase modulation ROCOF error: M class .....	557
7.4.10 PMU I dynamic bandwidth measurement: phase modulation ROCOF error: M class .....	558
7.4.11 PMU J dynamic bandwidth measurement: phase modulation ROCOF error: M class .....	559
7.5 Phase modulation voltage TVE, P class .....	560
7.5.1 C37.118.1 Annex C dynamic bandwidth measurement: phase modulation voltage TVE: P class .....	560
7.5.2 PMU A dynamic bandwidth measurement: phase modulation voltage TVE: P class .....	561
7.5.3 PMU B dynamic bandwidth measurement: phase modulation voltage TVE: P class .....	562
7.5.4 PMU C dynamic bandwidth measurement: phase modulation voltage TVE: P class .....	563
7.5.5 PMU D dynamic bandwidth measurement: phase modulation voltage TVE: P class .....	564
7.5.6 PMU E dynamic bandwidth measurement: phase modulation voltage TVE: P class .....	564
7.5.7 PMU F dynamic bandwidth measurement: phase modulation voltage TVE: P class .....	565
7.5.8 PMU G dynamic bandwidth measurement: phase modulation voltage TVE: P class.....	565
7.5.9 PMU H dynamic bandwidth measurement: phase modulation voltage TVE: P class.....	566
7.5.10 PMU I dynamic bandwidth measurement: phase modulation voltage TVE: P class .....	566
7.5.11 PMU J dynamic bandwidth measurement: phase modulation voltage TVE: P class .....	567
7.6 Phase modulation current TVE, P class .....	568
7.6.1 C37.118.1 Annex C dynamic bandwidth measurement: phase modulation current TVE: P class .....	568
7.6.2 PMU A dynamic bandwidth measurement: phase modulation current TVE: P class .....	569
7.6.3 PMU B dynamic bandwidth measurement: phase modulation current TVE: P class .....	570
7.6.4 PMU C dynamic bandwidth measurement: phase modulation current TVE: P class .....	571
7.6.5 PMU D dynamic bandwidth measurement: phase modulation current TVE: P class .....	572
7.6.6 PMU E dynamic bandwidth measurement: phase modulation current TVE: P class .....	572
7.6.7 PMU F dynamic bandwidth measurement: phase modulation current TVE: P class .....	573
7.6.8 PMU G dynamic bandwidth measurement: phase modulation current TVE: P class.....	573
7.6.9 PMU H dynamic bandwidth measurement: phase modulation current TVE: P class.....	574
7.6.10 PMU I dynamic bandwidth measurement: phase modulation current TVE: P class .....	574
7.6.11 PMU J dynamic bandwidth measurement: phase modulation current TVE: P class .....	575
7.7 Dynamic bandwidth measurement: phase modulation frequency error: P class .....	576
7.7.1 C37.118.1 Annex C dynamic bandwidth measurement: phase modulation frequency error: P class .....	576



7.7.2 PMU A dynamic bandwidth measurement: phase modulation frequency error: P class .....	577
7.7.3 PMU B dynamic bandwidth measurement: phase modulation frequency error: P class.....	578
7.7.4 PMU C dynamic bandwidth measurement: phase modulation frequency error: P class.....	579
7.7.5 PMU D dynamic bandwidth measurement: phase modulation frequency error: P class .....	580
7.7.6 PMU E dynamic bandwidth measurement: phase modulation frequency error: P class .....	580
7.7.7 PMU F dynamic bandwidth measurement: phase modulation frequency error: P class .....	581
7.7.8 PMU G dynamic bandwidth measurement: phase modulation frequency error: P class .....	581
7.7.9 PMU H dynamic bandwidth measurement: phase modulation frequency error: P class .....	582
7.7.10 PMU I dynamic bandwidth measurement: phase modulation frequency error: P class.....	582
7.7.11 PMU J dynamic bandwidth measurement: phase modulation frequency error: P class .....	583
7.8 Dynamic bandwidth measurement: phase modulation ROCOF error: P class.....	584
7.8.1 C37.118.1 Annex C dynamic bandwidth measurement: phase modulation ROCOF error: P class .....	584
7.8.2 PMU A dynamic bandwidth measurement: phase modulation ROCOF error: P class .....	585
7.8.3 PMU B dynamic bandwidth measurement: phase modulation ROCOF error: P class.....	586
7.8.4 PMU C dynamic bandwidth measurement: phase modulation ROCOF error: P class.....	587
7.8.5 PMU D dynamic bandwidth measurement: phase modulation ROCOF error: P class .....	588
7.8.6 PMU E dynamic bandwidth measurement: phase modulation ROCOF error: P class .....	588
7.8.7 PMU F dynamic bandwidth measurement: phase modulation ROCOF error: P class .....	589
7.8.8 PMU G dynamic bandwidth measurement: phase modulation ROCOF error: P class .....	589
7.8.9 PMU H dynamic bandwidth measurement: phase modulation ROCOF error: P class .....	590
7.8.10 PMU I dynamic bandwidth measurement: phase modulation ROCOF error: P class.....	590
7.8.11 PMU J dynamic bandwidth measurement: phase modulation ROCOF error: P class .....	591

The measurement bandwidth tests apply modulated input signals to the PMU to ensure that the in-band performance is within limits. The phase modulation tests are a series of individual dynamic tests where the input signal phase is modulated at a 10% index of modulation. Individual tests are run with 0.2 Hz modulation frequency increments beginning at 0.1 Hz until the modulation frequency has reached the lesser of  $F_s/5$  Hz or 5 Hz for M class and 2 Hz for P class PMUs.

The maximum TVE, Fe and RFe of all tests are compared against the limits for TVE, Fe, and RFe to determine if the unit passes or fails the test.

C37.118.1-2011 amended by C37.118.1a-2014 specifies the limits as:

- max TVE: 3%
- max Fe:
  - M class:  $0.06 \times \min(F_s/5, 5)$
  - P class:  $0.03 \times \min(F_s/10, 2)$
- max RFe:
  - M class:  $0.18 \times \pi \times (\min(F_s/5, 5))^2$
  - P class:  $0.18 \times \pi \times (\min(F_s/10, 2))^2$

The test plan for measurement bandwidth is as follows:

$X_m$  is the peak amplitude of the input signal

$\omega_0$  is the nominal power system frequency in radians/second ( $2\pi F_0$ )

$\omega$  is the modulation frequency in radians/second

$k_x$  is the amplitude modulation index

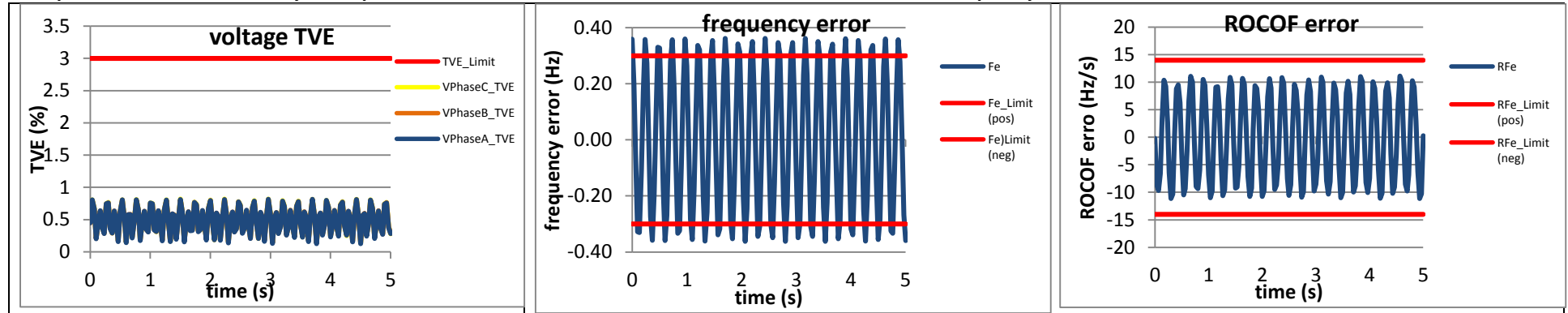
$k_a$  is the phase angle modulation index

$t$  is time

- a) Begin with phase modulated input at  $\omega/2\pi = 0.1$  Hz,  $k_x = 0.1$ ,  $k_a = 0$ .
- b) Wait for the system to settle.
- c) Capture the PMU output for at least 2 full cycles of modulation or 5 seconds, whichever is greater.
- d) Calculate the errors: TVE, FE, RFE for each report.
- e) Calculate the Max TVE, FE and RFE.
- f) Increase the modulation frequency  $\omega/2\pi$  by 0.2 Hz.
- g) Repeat steps b through f until the upper frequency range limit is reached.

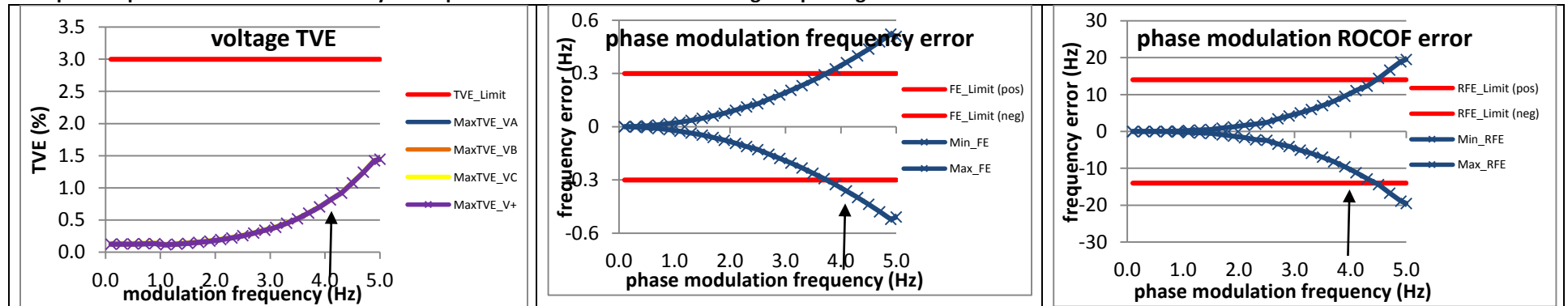
To illustrate an example of one PMU's response to one test, the below plots of TVE, Fe and RFe are shown from the test run on PMU B at  $F_s = 30$  FPS and a phase modulation frequency of 4.1 Hz:

Example data from one run of dynamic phase modulation test: PMU B at  $F_s = 30$  FPS, 4.1 Hz modulation frequency



The plots in the body of this section are a compilation of data for all tests made at 0.2 Hz modulation frequency intervals from each reporting rate. The X axis is the modulation frequency and the Y axis is TVE, Fe or RFe respectively. In the example below, an arrow indicates the maximum value from the example above.

Example compiled data from all runs of dynamic phase modulation tests from a single reporting rate: PMU B at  $F_s = 30$  FPS



# Results from the dynamic phase modulation tests

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R			
	V	E		V	E		V	E		V	E		V	E		V	E		V	E		V	E		V	E		V	E		V	E				
	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E		E	E					
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			
PMU A	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	F	P	P	P	P	P	F	P	P	P	P	P	P	P		
PMU B	P	P	P	P	P	P	P	P	P	P	P	P	P	F	P	P	P	P	P	F	F	P	P	P	P	F	F	P	P	P	P	F	F	P	P	P
PMU C	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	P	P	P	
PMU D	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
PMU E	P	I	P	-	-	-	-	-	-	-	-	-	P	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-
PMU F	P	P	F	P	P	P	P	P	F	P	P	P	F	P	F	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
PMU G*	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	F	F	F	-	-	-	F	F	P	-	-	-	-	-	-	-	-	
PMU H	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
PMU I	F	I	I	-	-	-	F	I	I	-	-	-	F	I	I	-	-	-	F	I	I	-	-	-	F	P	I	-	-	-	P	P	P	-	-	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		

P = Pass (measurement is within the limits), F = Fail (measurement is outside the limits), I = Indeterminate (measurement is within the uncertainty of the test instrument of the limits)

\* PMU G ROCOF output is always 0.

## 7.1 Phase modulation voltage TVE, M class

### 7.1.1 C37.118.1 Annex C phase modulation voltage TVE: M class

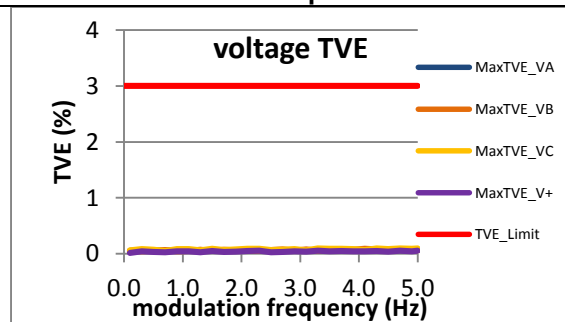


Figure 3051:  $F_s = 60$  FPS

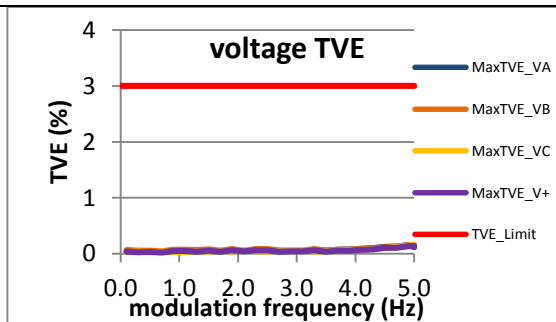


Figure 3052:  $F_s = 30$  FPS

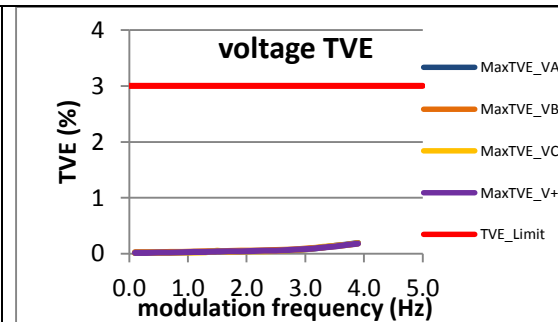


Figure 3053:  $F_s = 20$  FPS

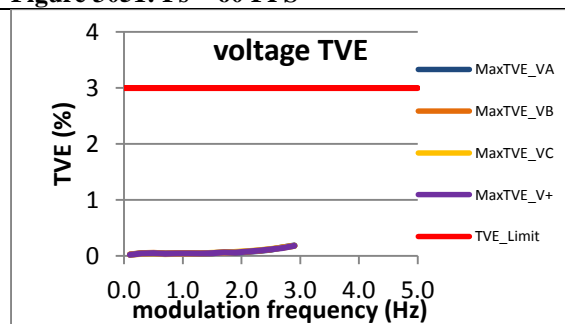


Figure 3054:  $F_s = 15$  FPS

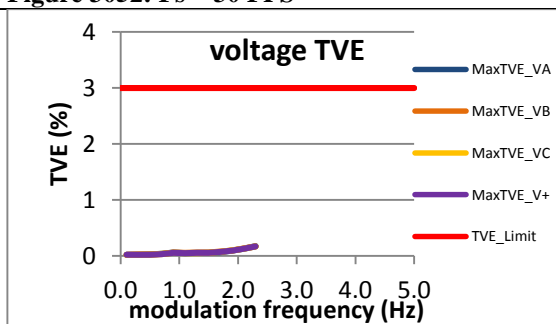


Figure 3055:  $F_s = 12$  FPS

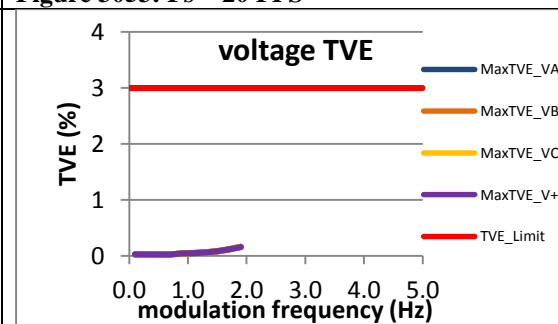
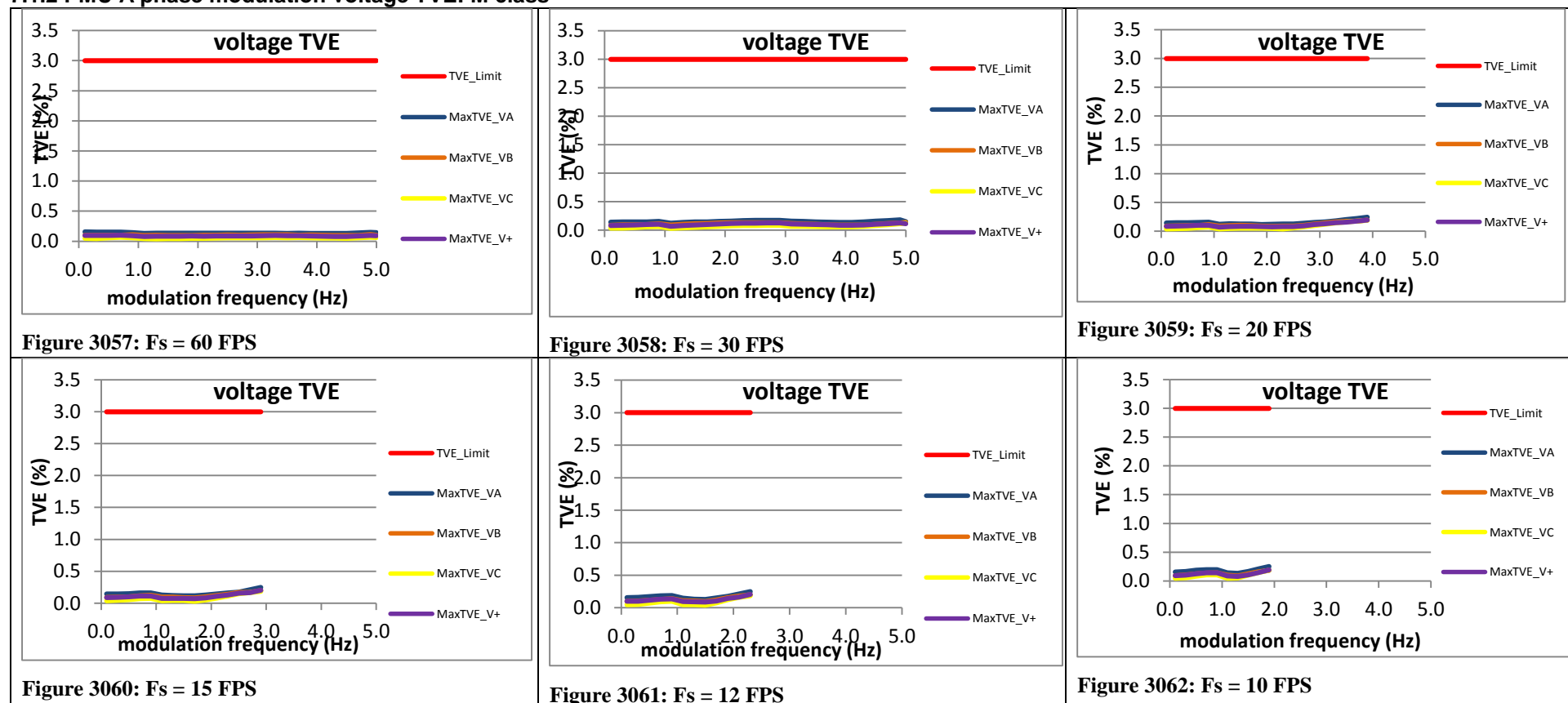


Figure 3056:  $F_s = 10$  FPS

### 7.1.2 PMU A phase modulation voltage TVE: M class



### 7.1.3 PMU B phase modulation voltage TVE: M class

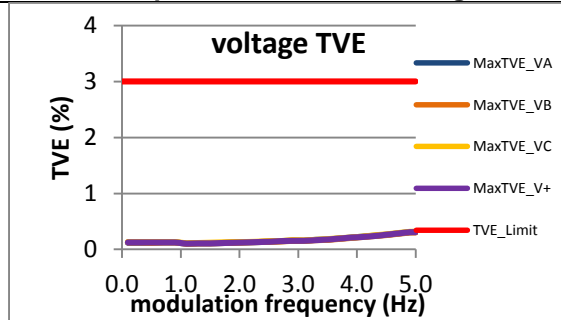


Figure 3063:  $F_s = 60$  FPS

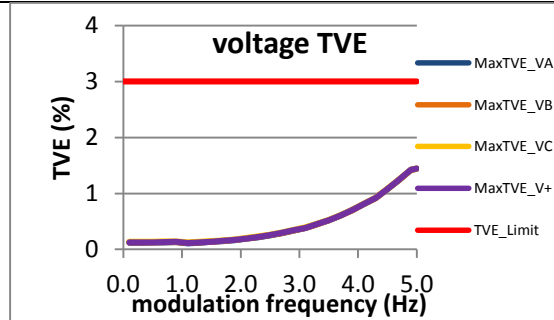


Figure 3064:  $F_s = 30$  FPS

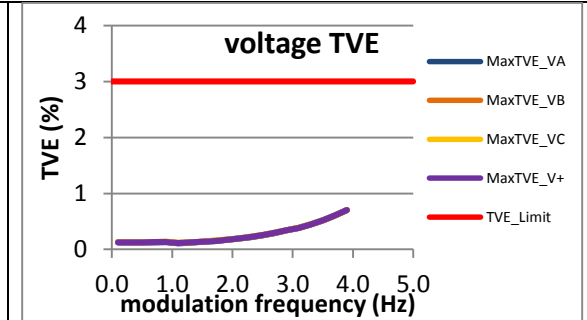


Figure 3065:  $F_s = 20$  FPS

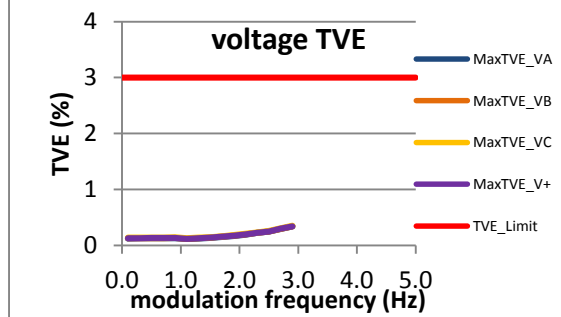


Figure 3066:  $F_s = 15$  FPS

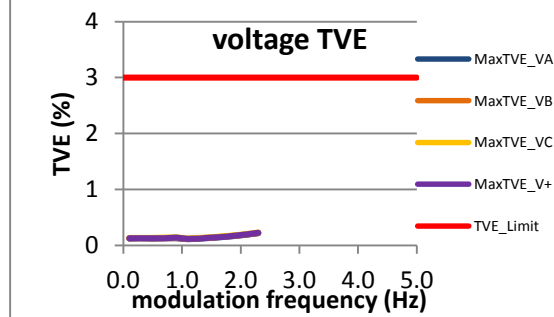


Figure 3067:  $F_s = 12$  FPS

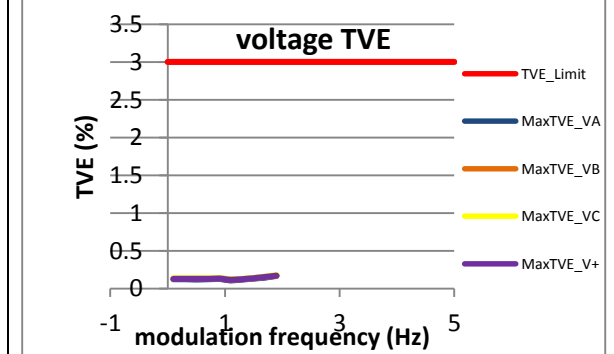


Figure 3068:  $F_s = 10$  FPS

#### 7.1.4 PMU C phase modulation voltage TVE: M class

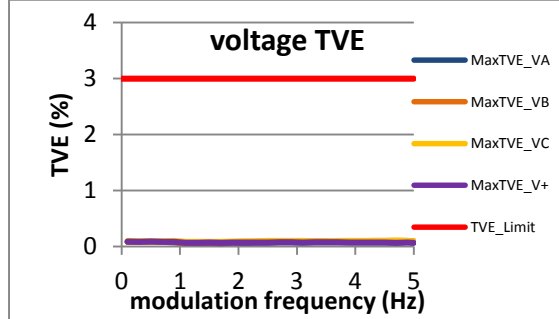


Figure 3069:  $F_s = 60$  FPS

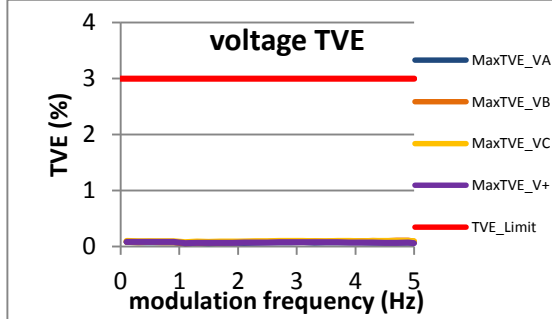


Figure 3070:  $F_s = 30$  FPS

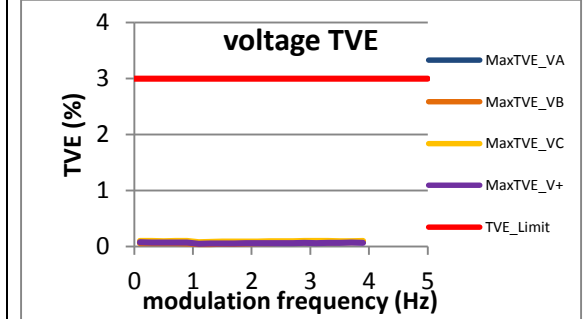


Figure 3071:  $F_s = 20$  FPS

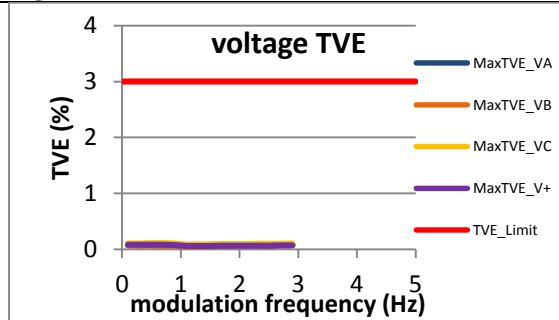


Figure 3072:  $F_s = 15$  FPS

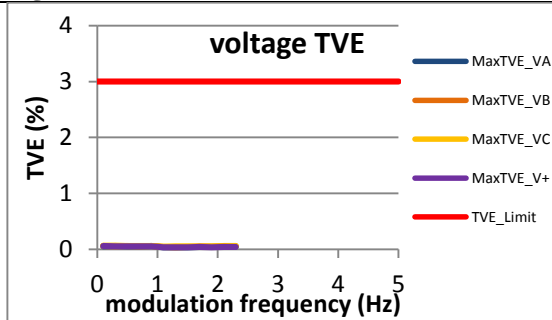


Figure 3073:  $F_s = 12$  FPS

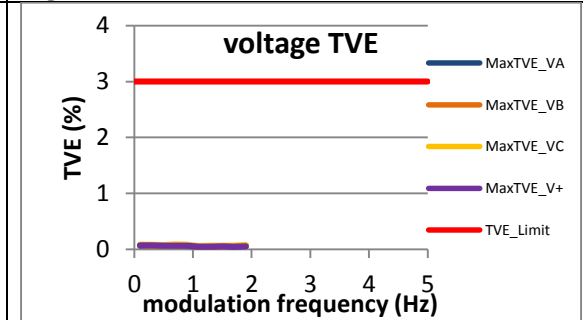


Figure 3074:  $F_s = 10$  FPS



### 7.1.5 PMU D phase modulation voltage TVE: M class

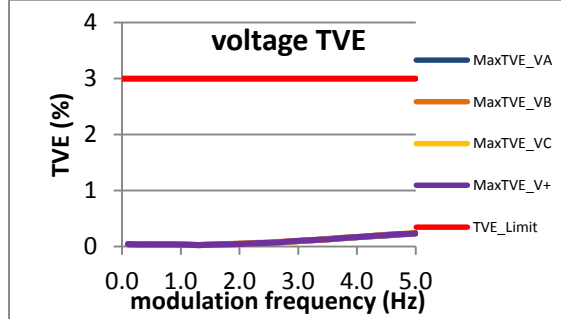


Figure 3075:  $F_s = 60$  FPS

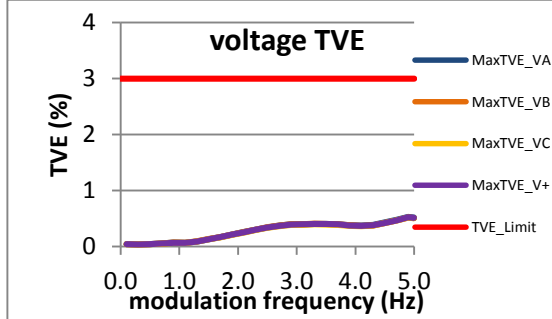


Figure 3076:  $F_s = 30$  FPS

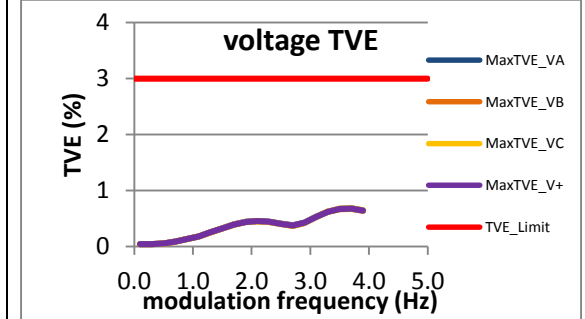


Figure 3077:  $F_s = 20$  FPS

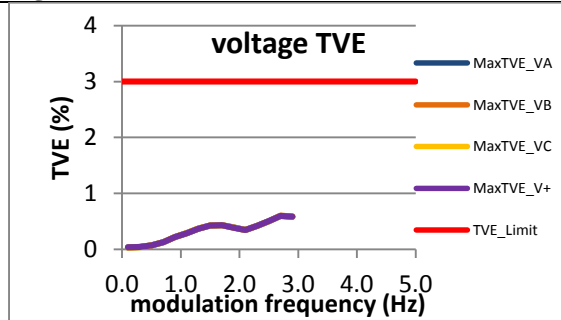


Figure 3078:  $F_s = 15$  FPS

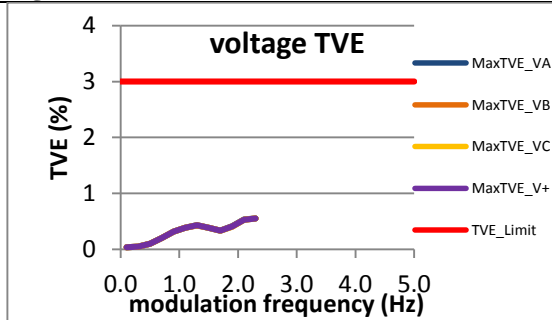


Figure 3079:  $F_s = 12$  FPS

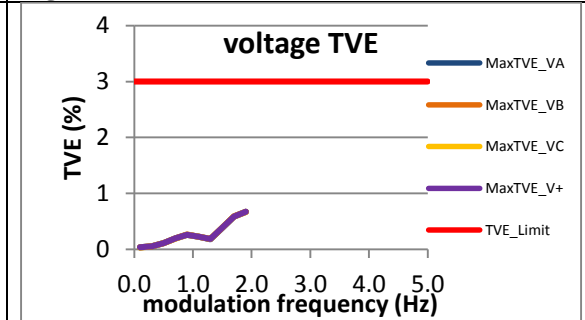


Figure 3080:  $F_s = 10$  FPS

### 7.1.6 PMU E phase modulation voltage TVE: M class

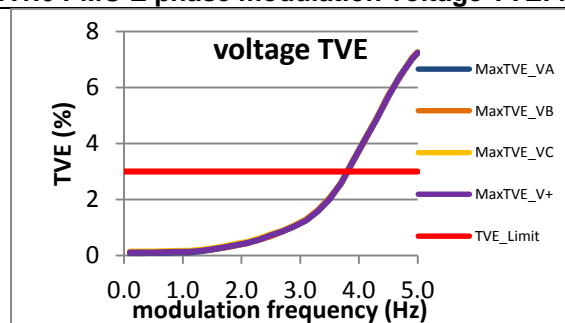


Figure 3081:  $F_s = 60$  FPS

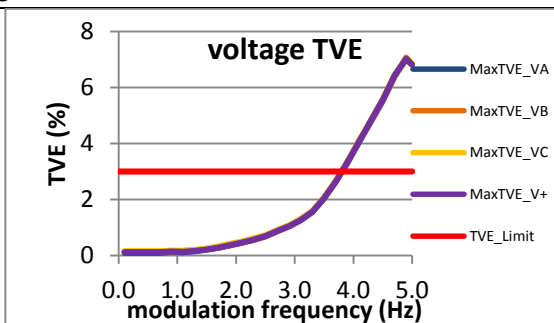


Figure 3082:  $F_s = 30$  FPS

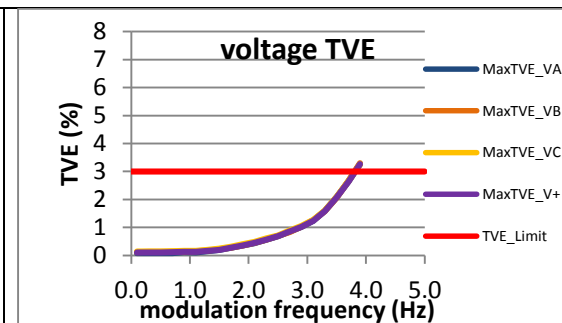


Figure 3083:  $F_s = 20$  FPS

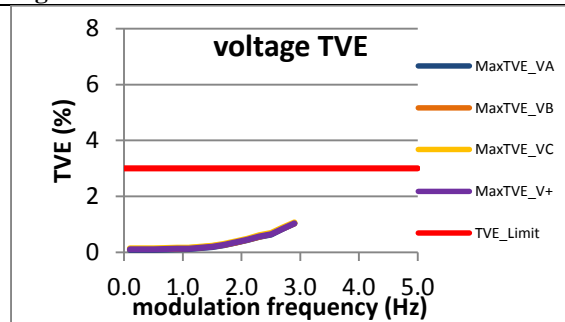


Figure 3084:  $F_s = 15$  FPS

MISSING DATA

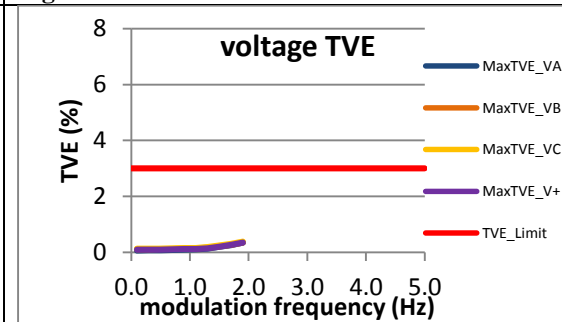


Figure 3085:  $F_s = 10$  FPS

### 7.1.7 PMU F phase modulation voltage TVE: M class

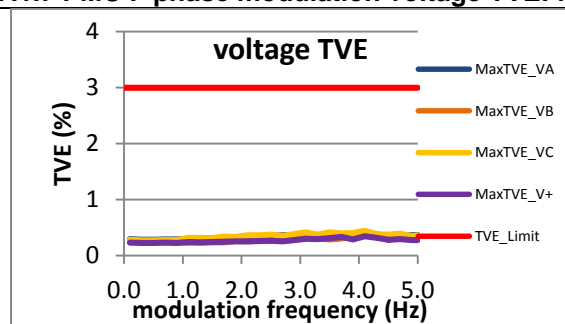


Figure 3086:  $F_s = 60$  FPS

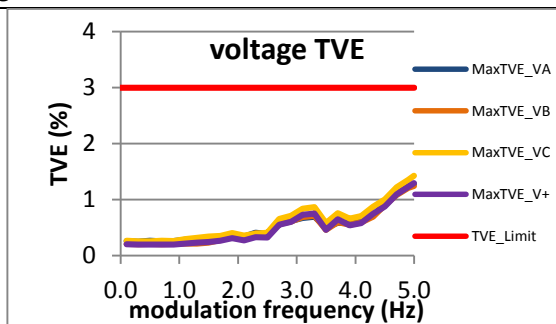


Figure 3087:  $F_s = 30$  FPS

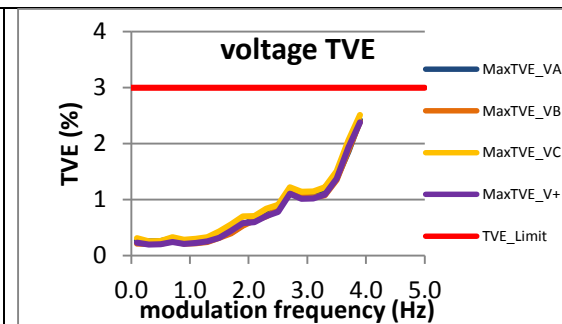


Figure 3088:  $F_s = 20$  FPS

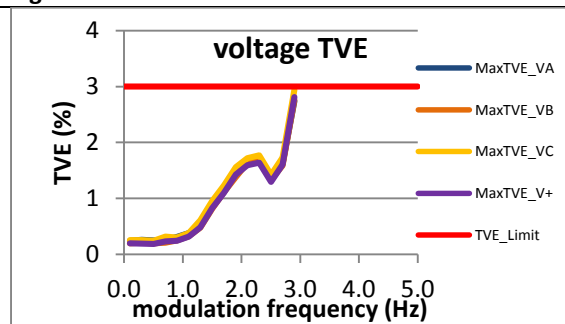


Figure 3089:  $F_s = 15$  FPS

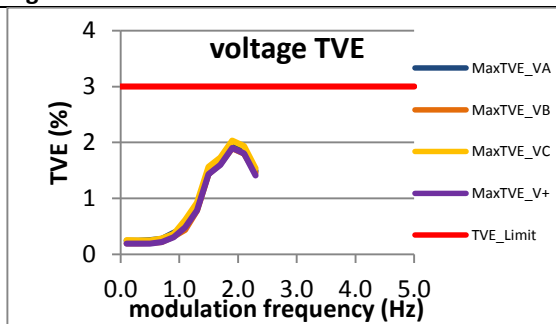


Figure 3090:  $F_s = 12$  FPS

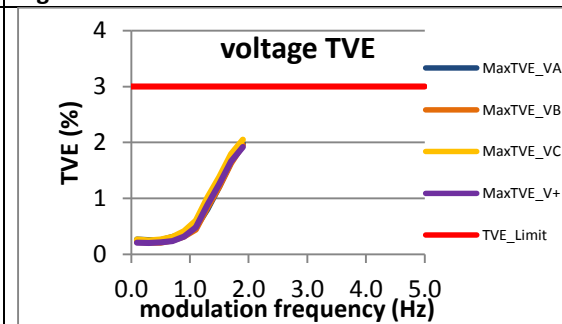
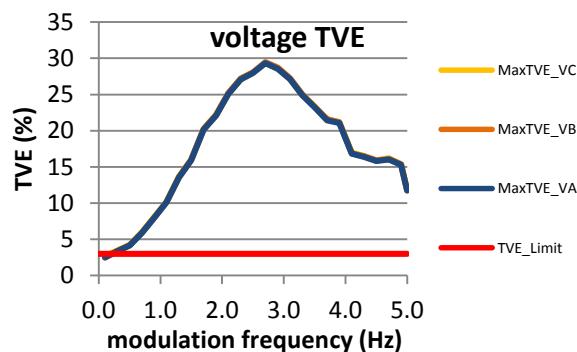


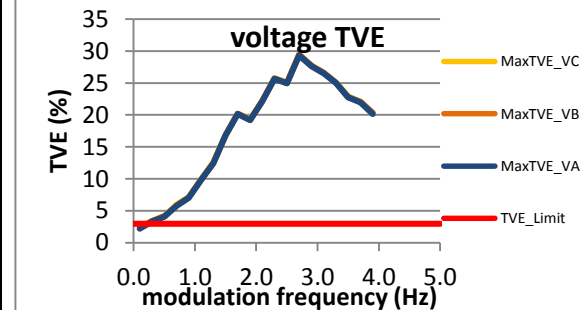
Figure 3091:  $F_s = 10$  FPS

### 7.1.8 PMU G phase modulation voltage TVE: M class

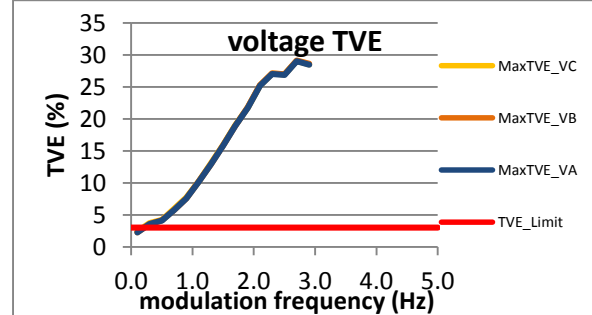
**Figure 3092:  $F_s = 60$  FPS is not supported by this PMU**



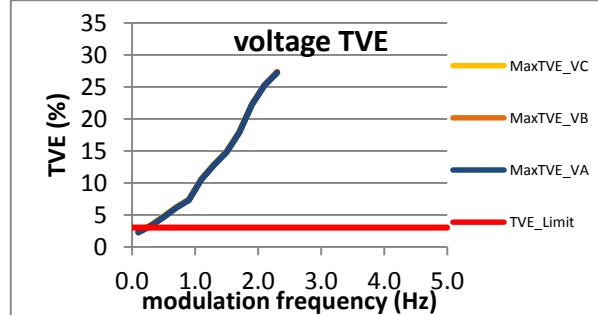
**Figure 3093:  $F_s = 30$  FPS**



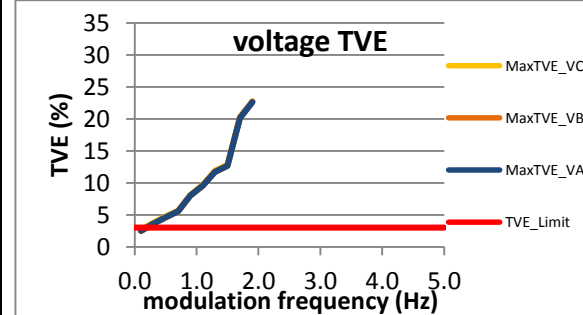
**Figure 3094:  $F_s = 20$  FPS**



**Figure 3095:  $F_s = 15$  FPS**



**Figure 3096:  $F_s = 12$  FPS**



**Figure 3097:  $F_s = 10$  FPS**

### 7.1.9 PMU H phase modulation voltage TVE: M class

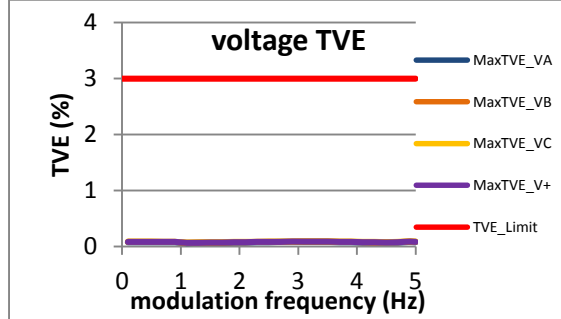


Figure 3098:  $F_s = 60$  FPS

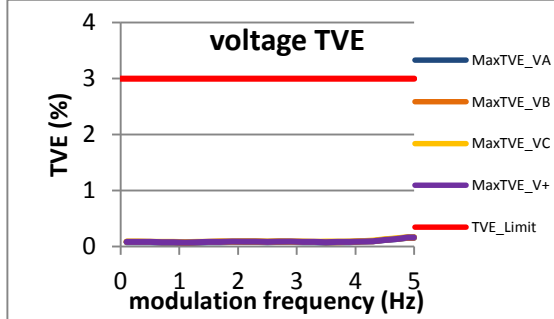


Figure 3099:  $F_s = 30$  FPS

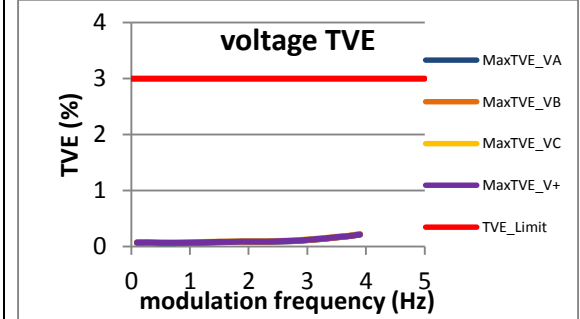


Figure 3100:  $F_s = 20$  FPS

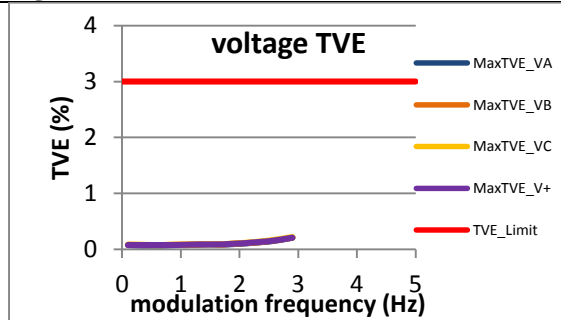


Figure 3101:  $F_s = 15$  FPS

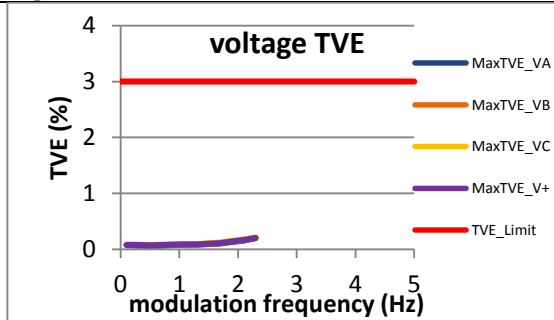


Figure 3102:  $F_s = 12$  FPS

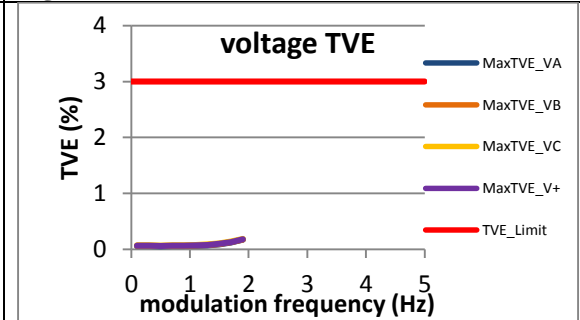


Figure 3103:  $F_s = 10$  FPS

### 7.1.10 PMU I phase modulation voltage TVE: M class

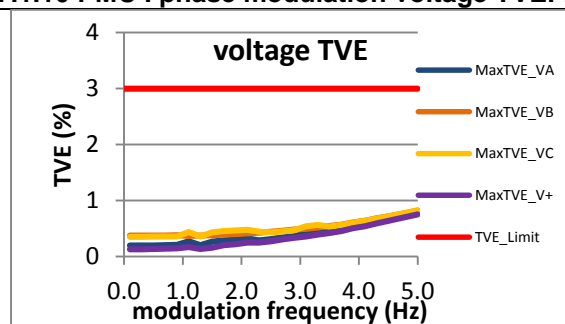


Figure 3104:  $F_s = 60$  FPS

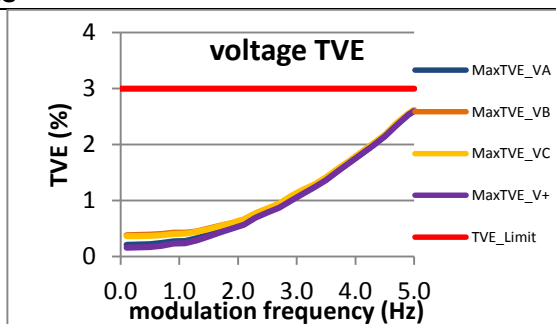


Figure 3105:  $F_s = 30$  FPS

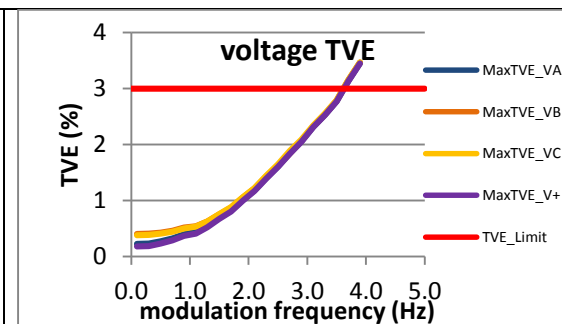


Figure 3106:  $F_s = 20$  FPS

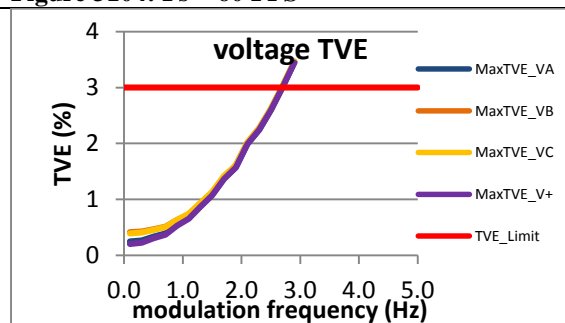


Figure 3107:  $F_s = 15$  FPS

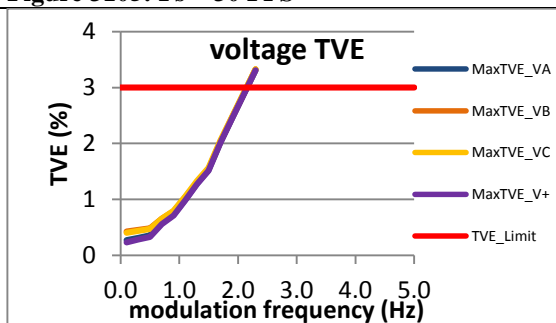


Figure 3108:  $F_s = 12$  FPS

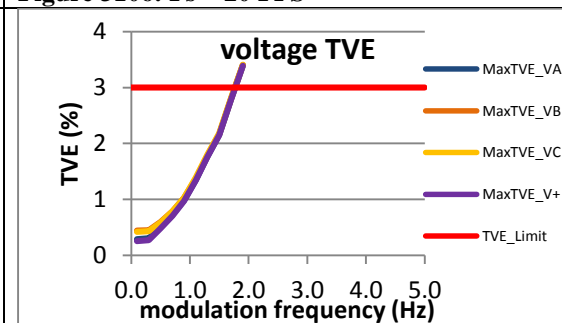


Figure 3109:  $F_s = 10$  FPS

### 7.1.11 PMU J phase modulation voltage TVE: M class

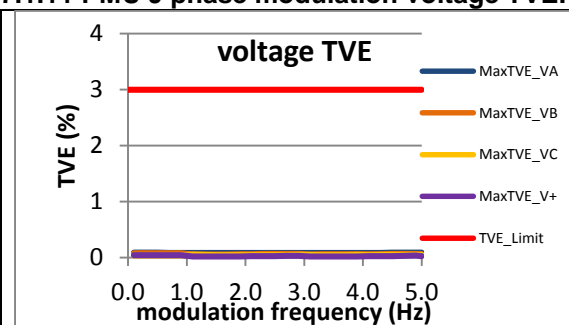


Figure 3110:  $F_s = 60$  FPS

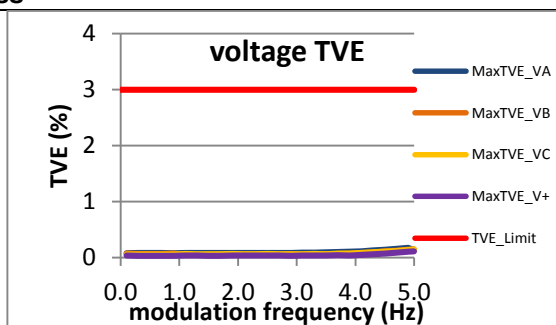


Figure 3111:  $F_s = 30$  FPS

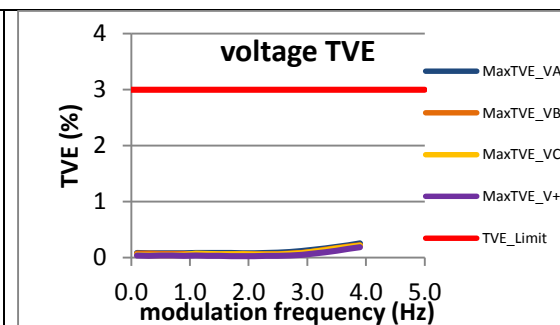


Figure 3112:  $F_s = 20$  FPS

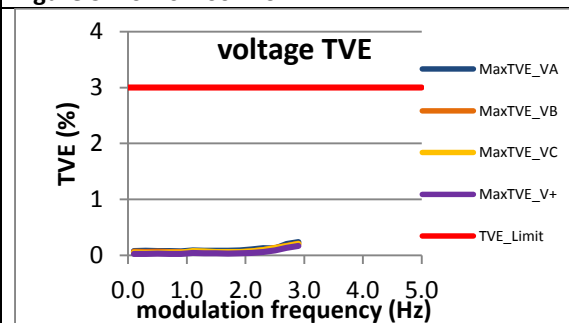


Figure 3113:  $F_s = 15$  FPS

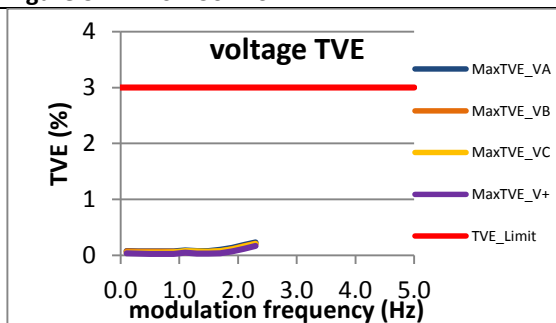


Figure 3114:  $F_s = 12$  FPS

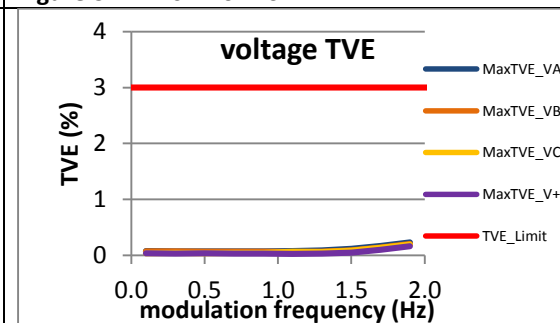
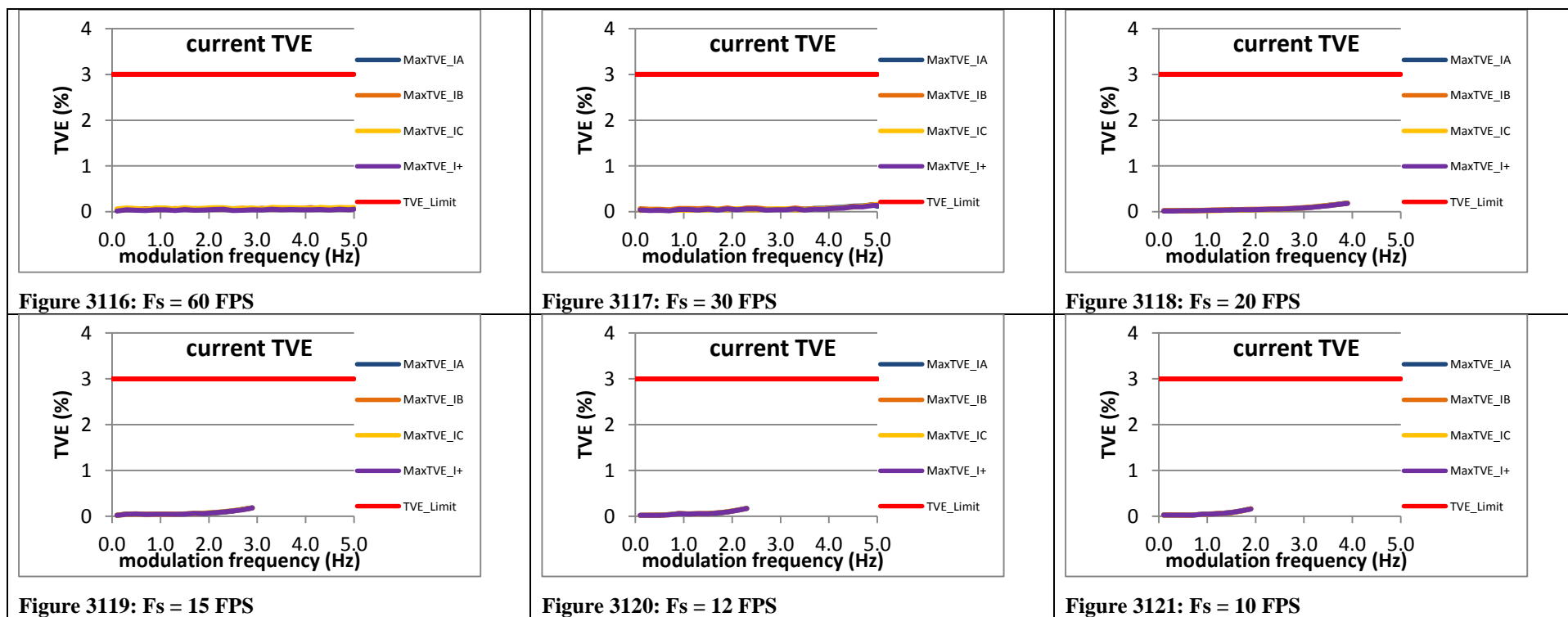


Figure 3115:  $F_s = 10$  FPS

## 7.2 Phase modulation current TVE, M class

### 7.2.1 C37.118.1 Annex C phase modulation current TVE: M class





## 7.2.2 PMU A phase modulation current TVE: M class

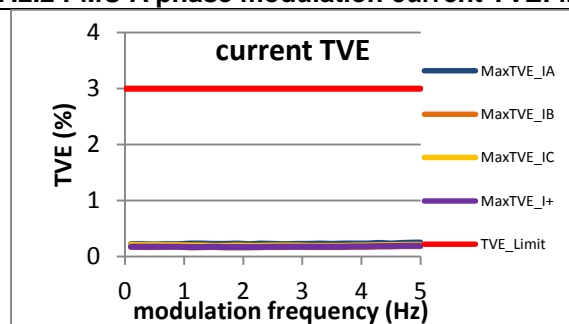


Figure 3122:  $F_s = 60$  FPS

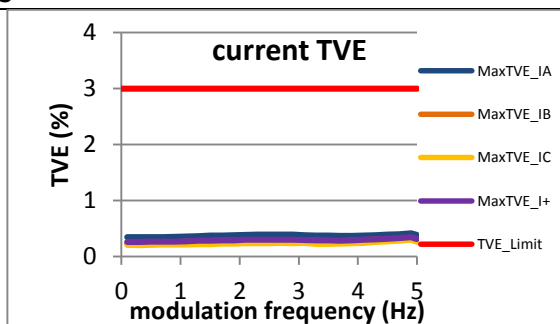


Figure 3123:  $F_s = 30$  FPS

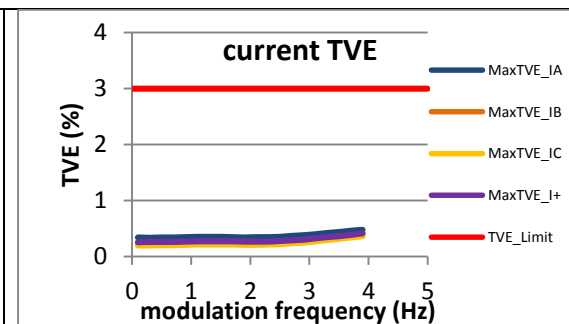


Figure 3124:  $F_s = 20$  FPS

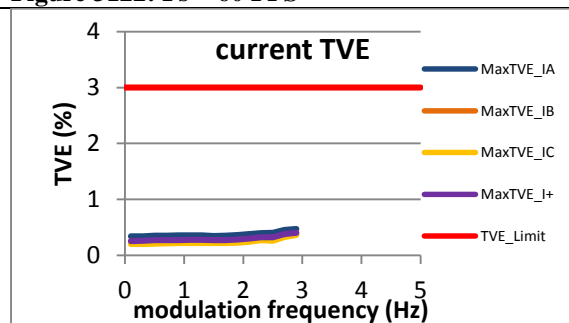


Figure 3125:  $F_s = 15$  FPS

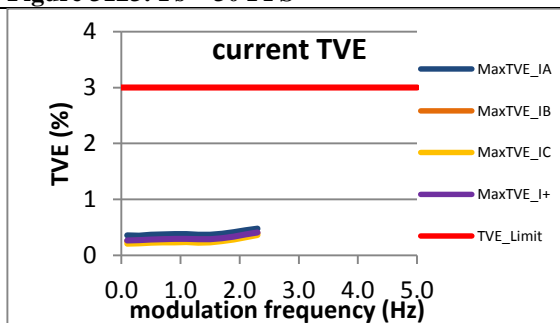


Figure 3126:  $F_s = 12$  FPS

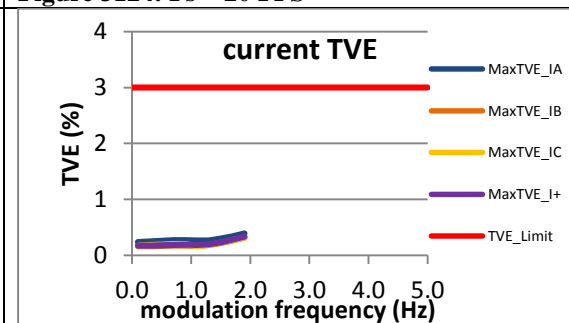


Figure 3127:  $F_s = 10$  FPS

### 7.2.3 PMU B phase modulation current TVE: M class

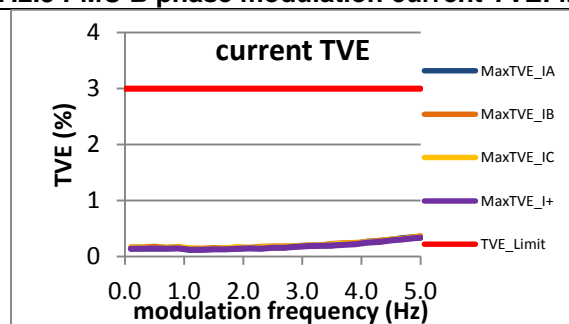


Figure 3128:  $F_s = 60$  FPS

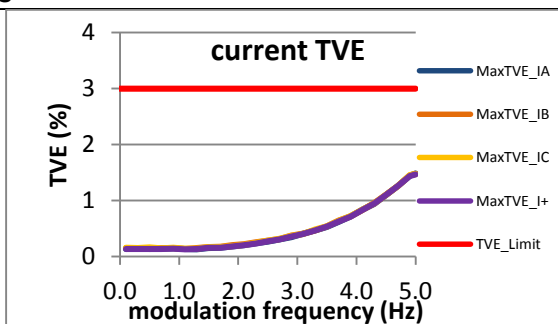


Figure 3129:  $F_s = 30$  FPS

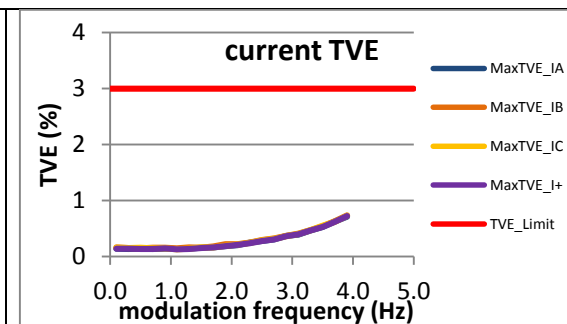


Figure 3130:  $F_s = 20$  FPS

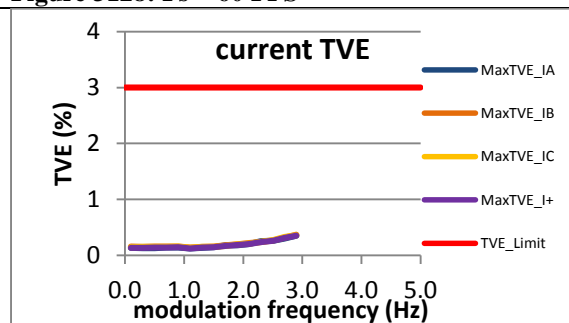


Figure 3131:  $F_s = 15$  FPS

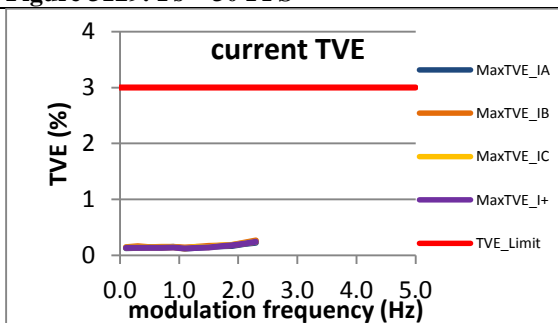


Figure 3132:  $F_s = 12$  FPS

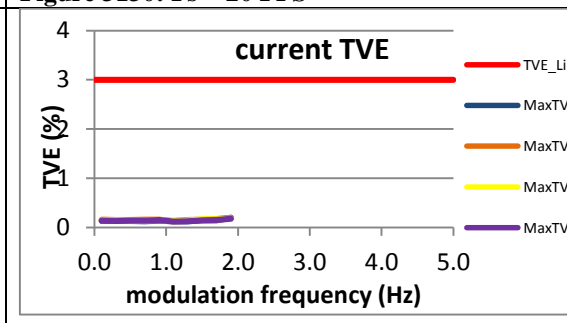


Figure 3133:  $F_s = 10$  FPS

#### 7.2.4 PMU C phase modulation current TVE: M class

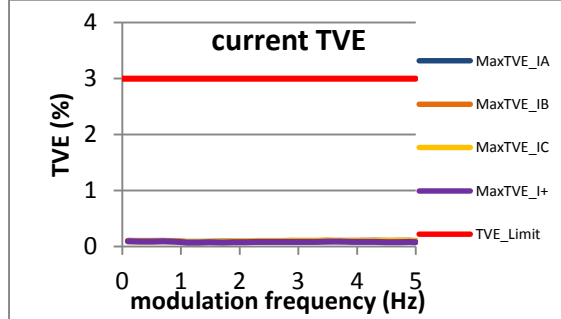


Figure 3134:  $F_s = 60$  FPS

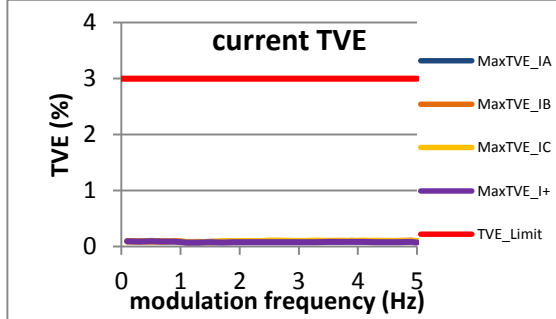


Figure 3135:  $F_s = 30$  FPS

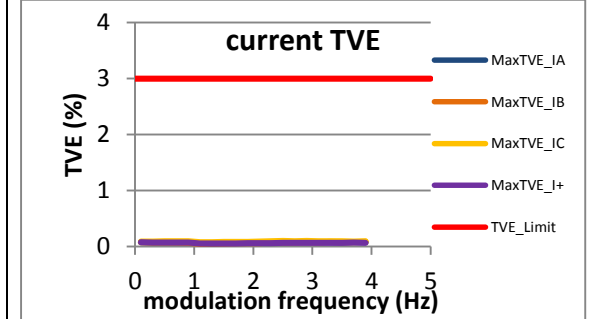


Figure 3136:  $F_s = 20$  FPS

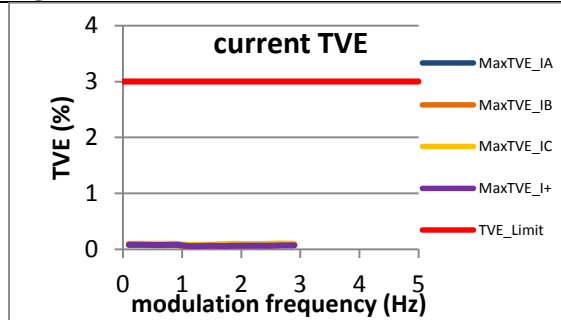


Figure 3137:  $F_s = 15$  FPS

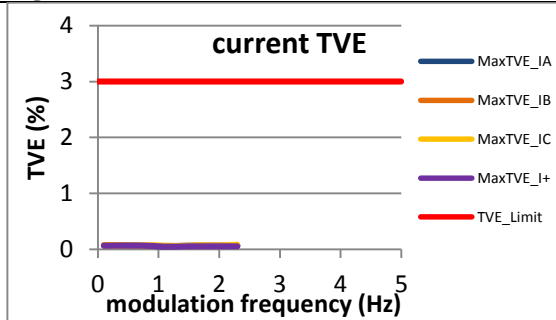


Figure 3138:  $F_s = 12$  FPS

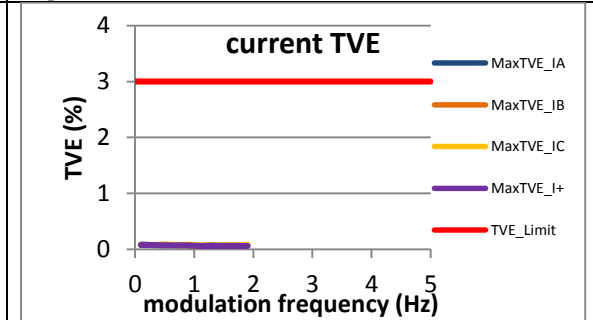


Figure 3139:  $F_s = 10$  FPS

### 7.2.5 PMU D phase modulation current TVE: M class

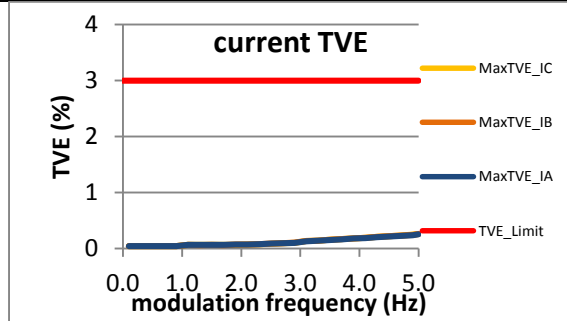


Figure 3140:  $F_s = 60$  FPS

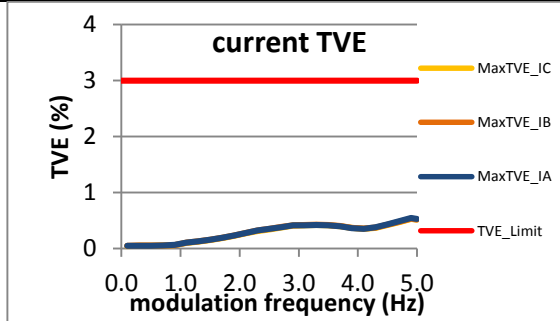


Figure 3141:  $F_s = 30$  FPS

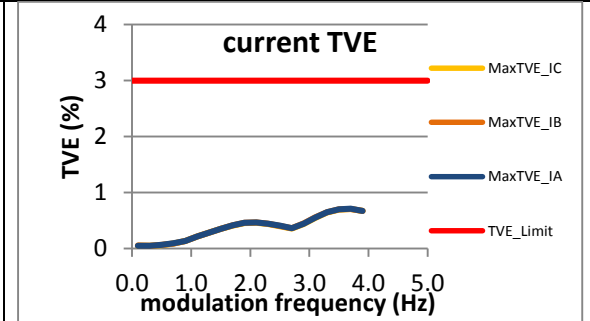


Figure 3142:  $F_s = 20$  FPS

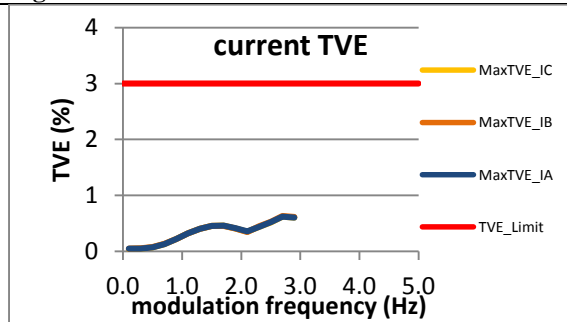


Figure 3143:  $F_s = 15$  FPS

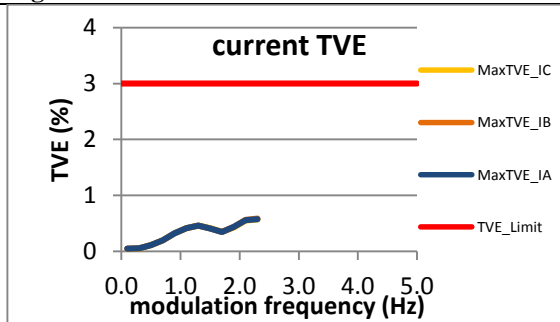


Figure 3144:  $F_s = 12$  FPS

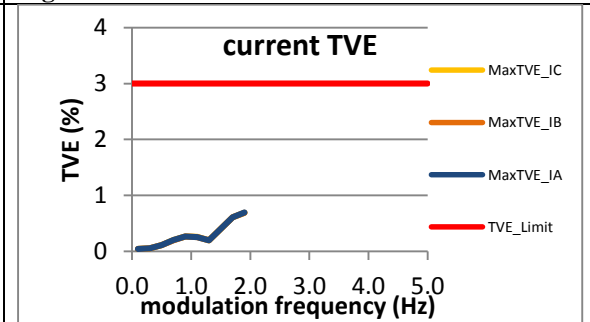
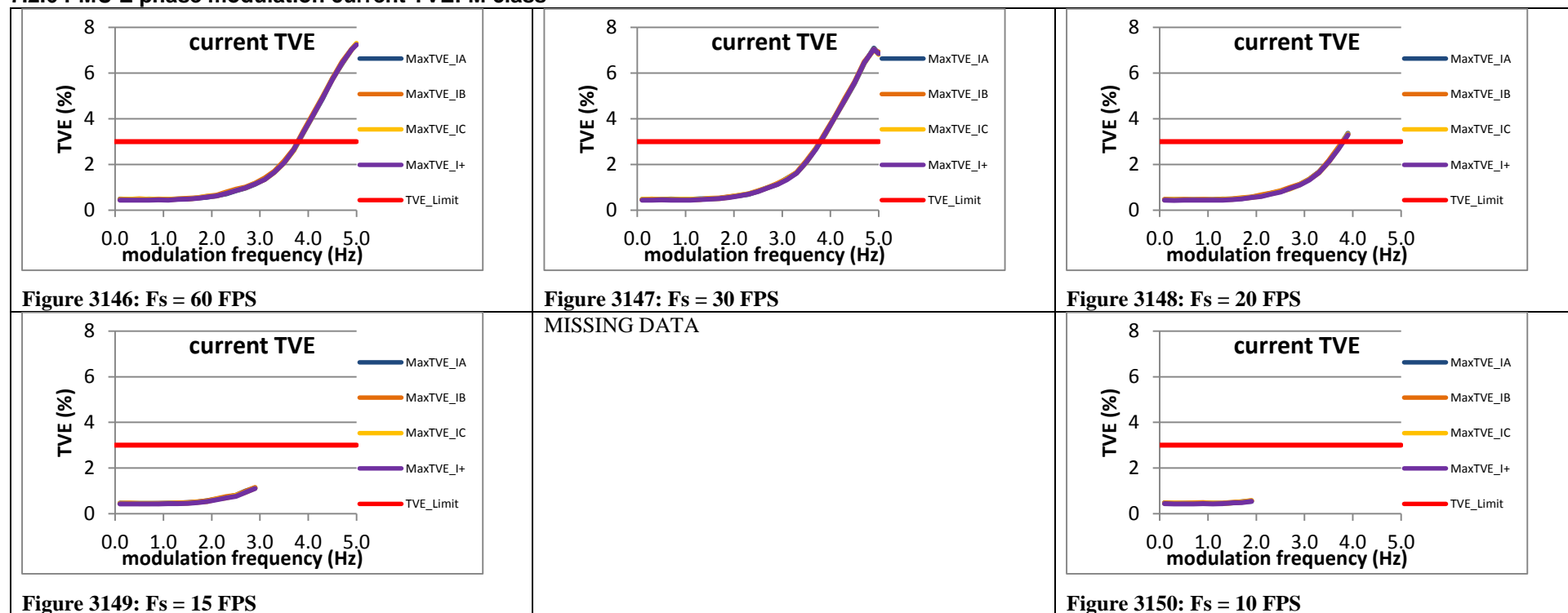


Figure 3145:  $F_s = 10$  FPS

## 7.2.6 PMU E phase modulation current TVE: M class



### 7.2.7 PMU F phase modulation current TVE: M class

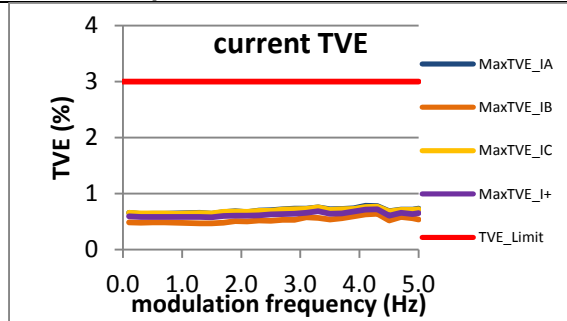


Figure 3151:  $F_s = 60$  FPS

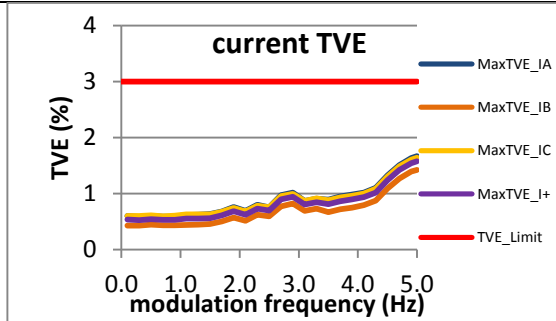


Figure 3152:  $F_s = 30$  FPS

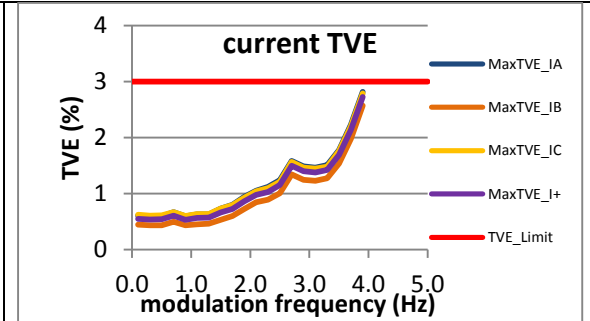


Figure 3153:  $F_s = 20$  FPS

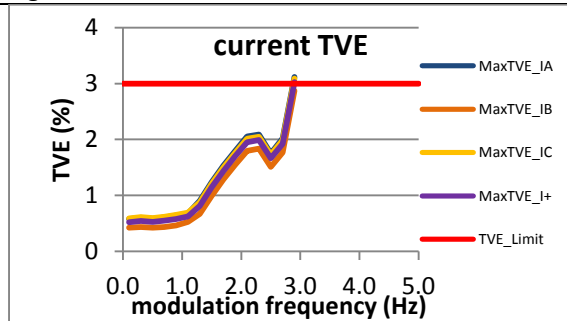


Figure 3154:  $F_s = 15$  FPS

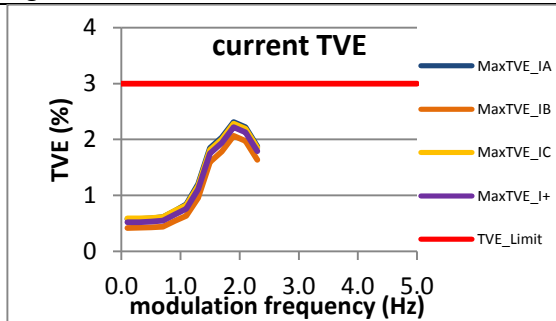


Figure 3155:  $F_s = 12$  FPS

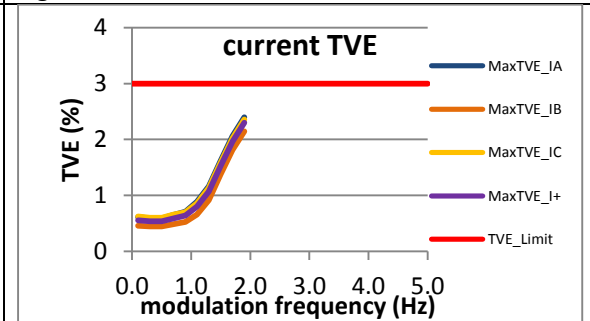


Figure 3156:  $F_s = 10$  FPS

## 7.2.8 PMU G phase modulation current TVE: M class

Figure 3157:  $F_s = 60$  FPS is not supported by this PMU

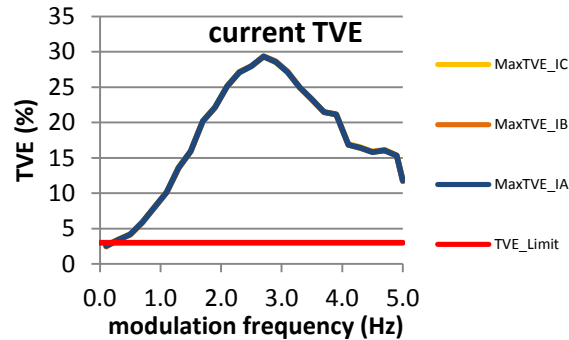


Figure 3158:  $F_s = 30$  FPS

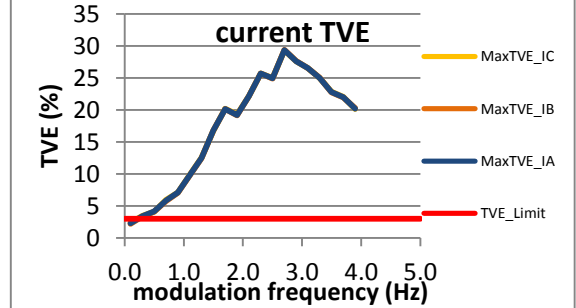


Figure 3159:  $F_s = 20$  FPS

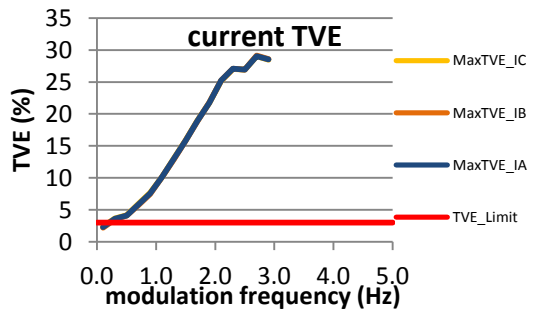


Figure 3160:  $F_s = 15$  FPS

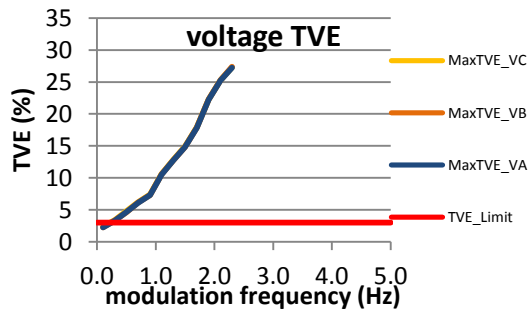


Figure 3161:  $F_s = 12$  FPS

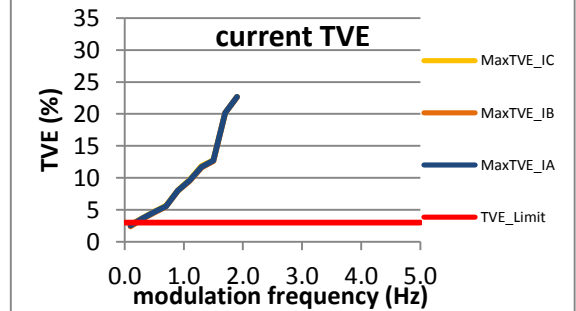


Figure 3162:  $F_s = 10$  FPS

### 7.2.9 PMU H phase modulation current TVE: M class

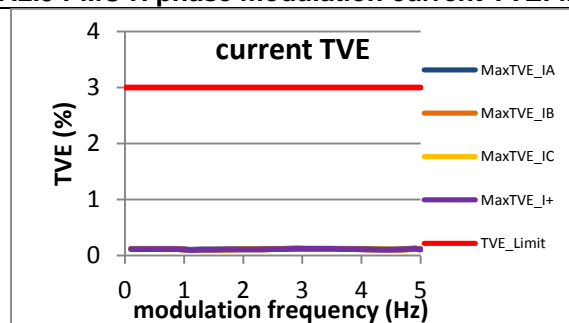


Figure 3163:  $F_s = 60$  FPS

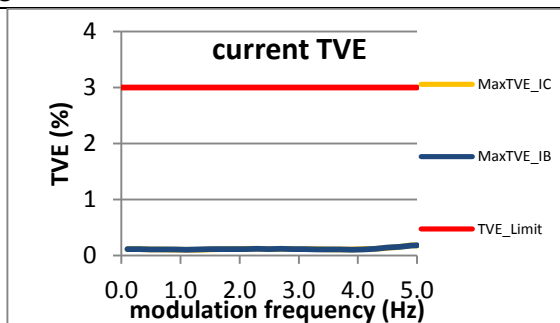


Figure 3164:  $F_s = 30$  FPS

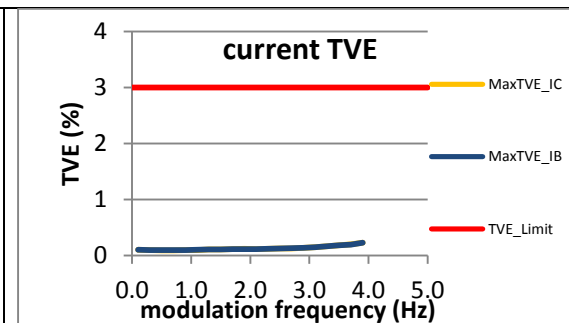


Figure 3165:  $F_s = 20$  FPS

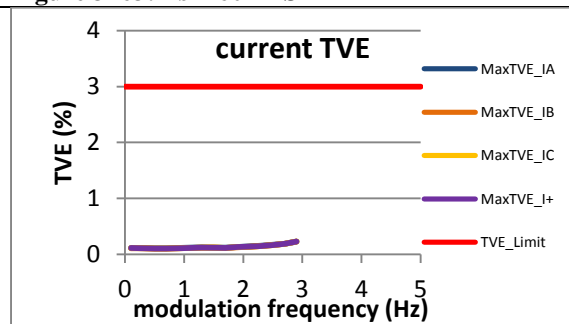


Figure 3166:  $F_s = 15$  FPS

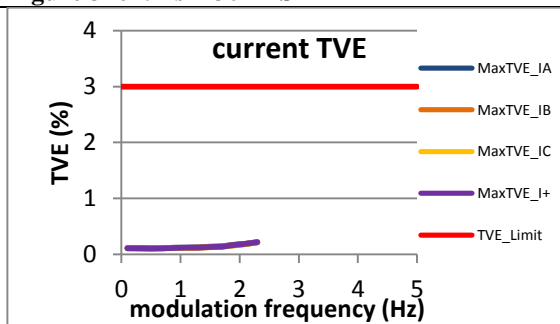


Figure 3167:  $F_s = 12$  FPS

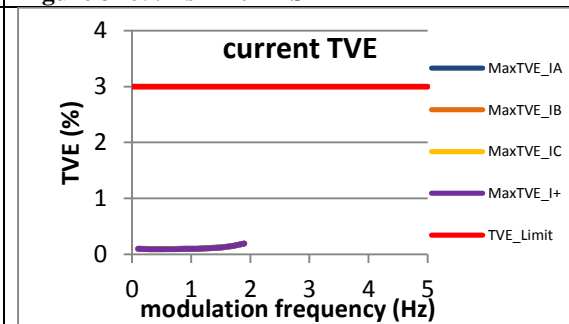


Figure 3168:  $F_s = 10$  FPS



## 7.2.10 PMU I phase modulation current TVE: M class

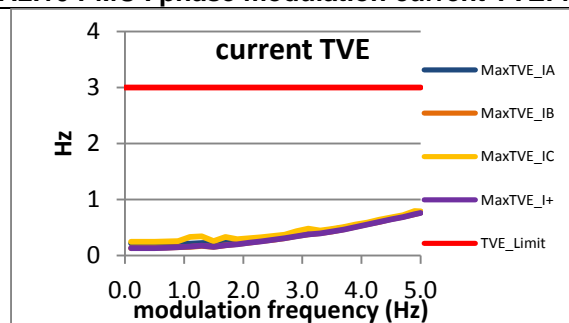


Figure 3169:  $F_s = 60$  FPS

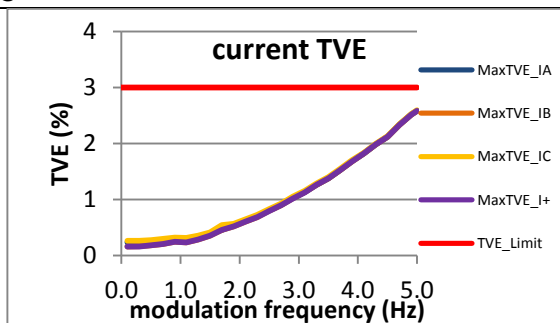


Figure 3170:  $F_s = 30$  FPS

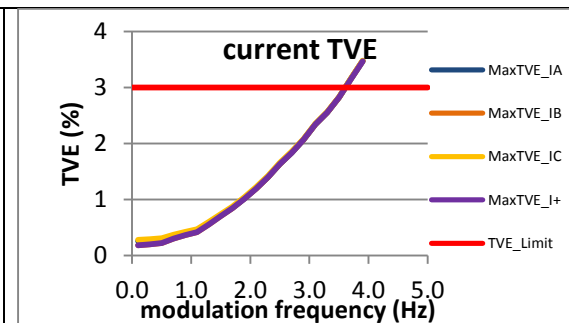


Figure 3171:  $F_s = 20$  FPS

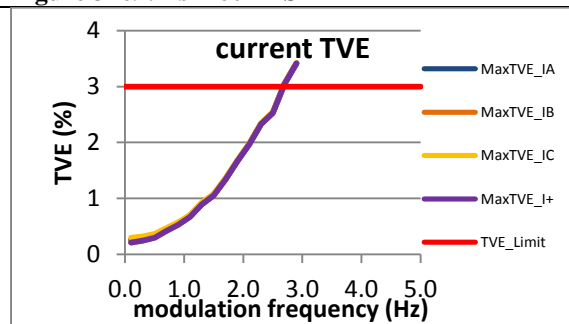


Figure 3172:  $F_s = 15$  FPS

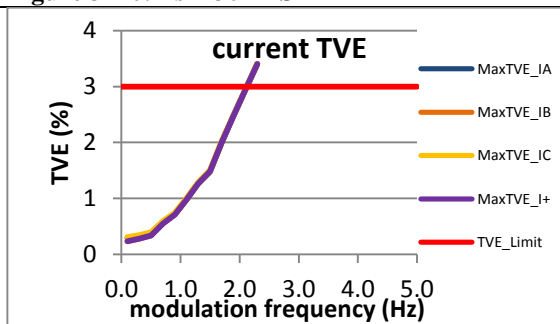


Figure 3173:  $F_s = 12$  FPS

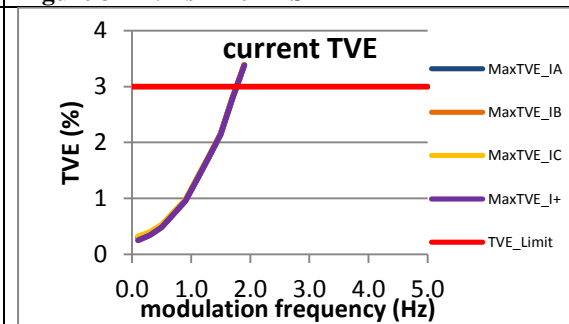


Figure 3174:  $F_s = 10$  FPS

## 7.2.11 PMU J phase modulation current TVE: M class

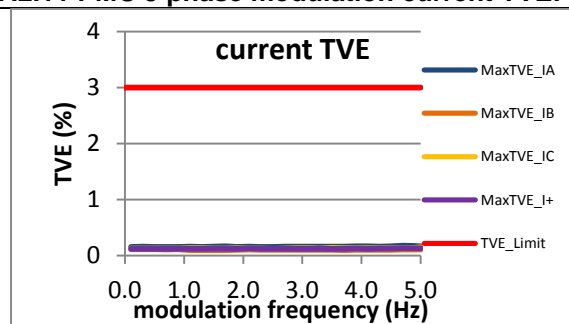


Figure 3175:  $F_s = 60$  FPS

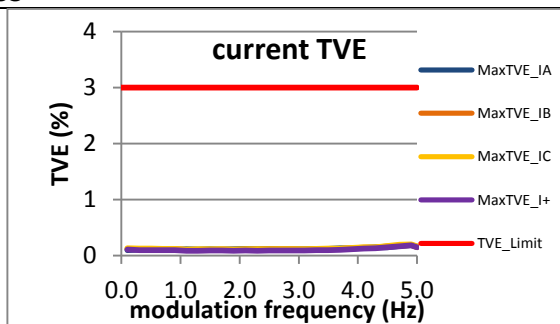


Figure 3176:  $F_s = 30$  FPS

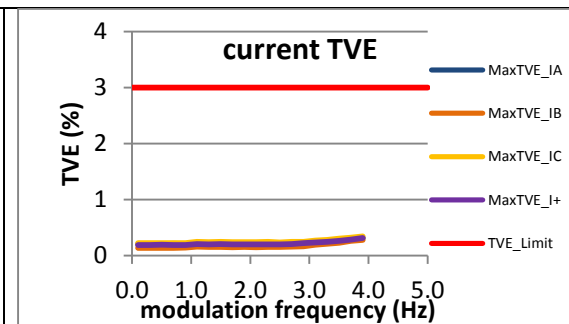


Figure 3177:  $F_s = 20$  FPS

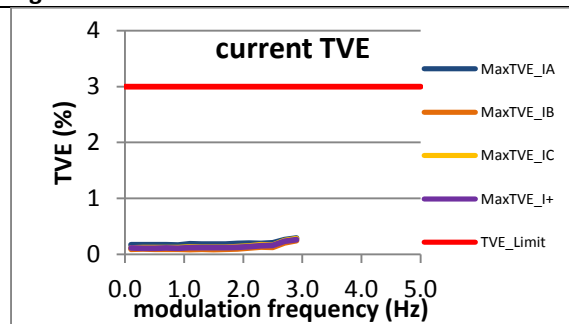


Figure 3178:  $F_s = 15$  FPS

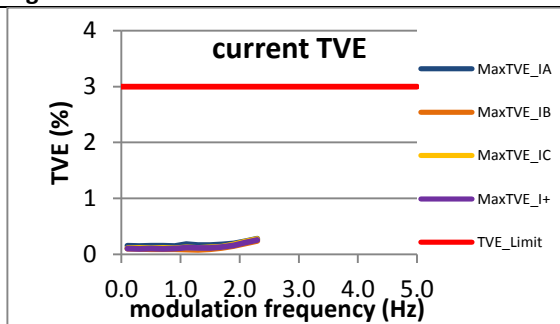


Figure 3179:  $F_s = 12$  FPS

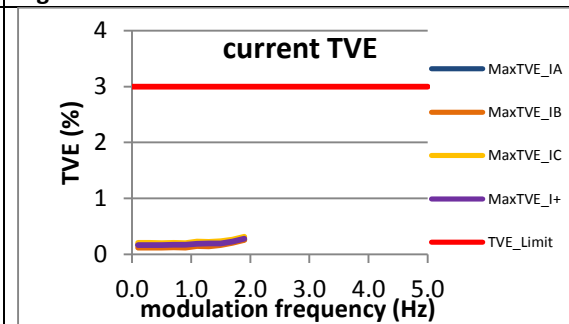
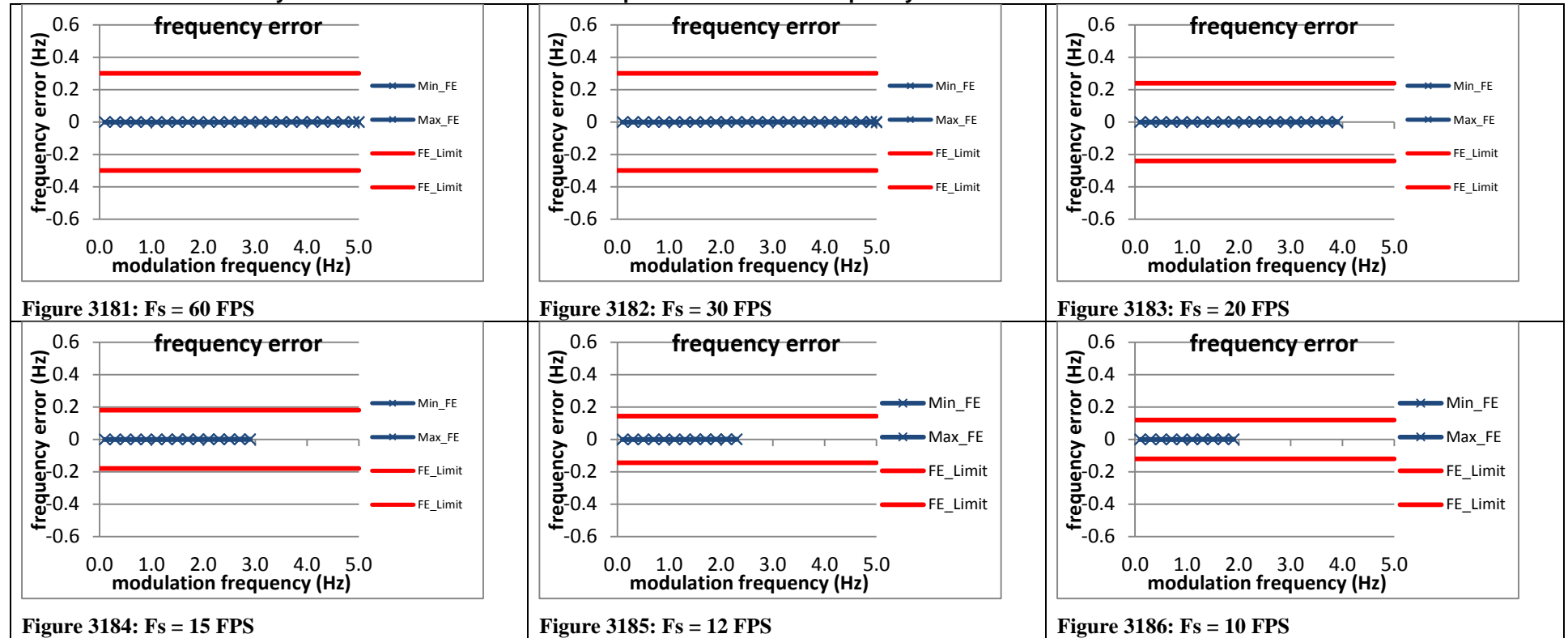


Figure 3180:  $F_s = 10$  FPS

### 7.3 Dynamic bandwidth measurement: phase modulation frequency error, M class

#### 7.3.1 C37.118.1 Annex C dynamic bandwidth measurement: phase modulation frequency error: M class



### 7.3.2 PMU A dynamic bandwidth measurement: phase modulation frequency error: M class

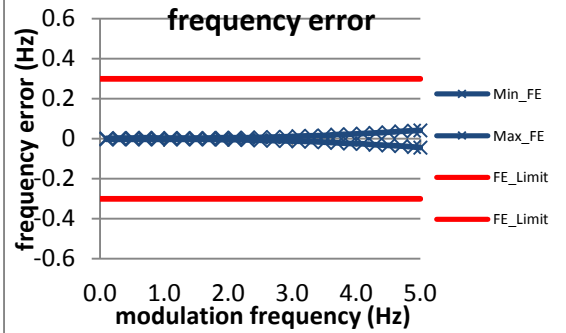


Figure 3187:  $F_s = 60$  FPS

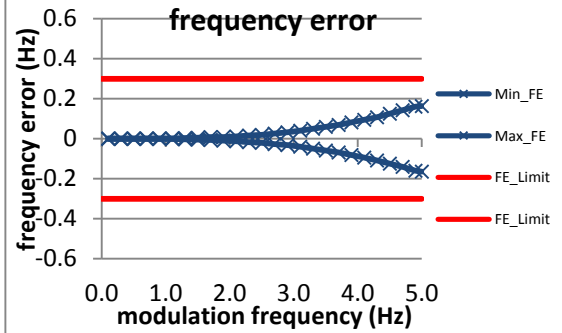


Figure 3188:  $F_s = 30$  FPS

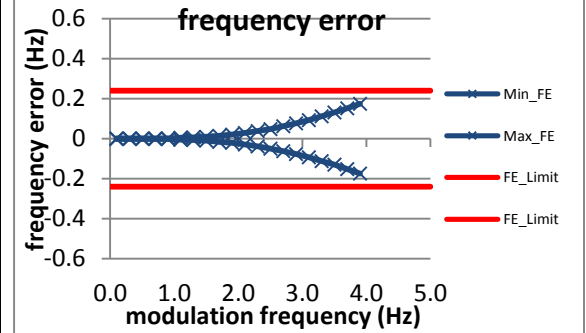


Figure 3189:  $F_s = 20$  FPS

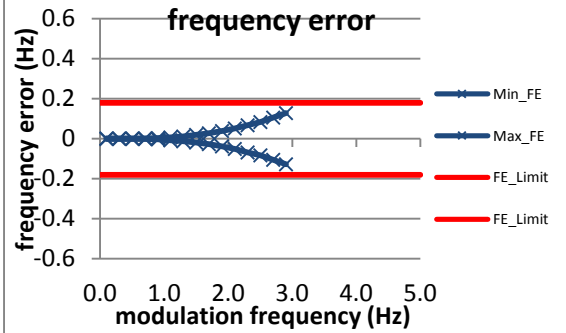


Figure 3190:  $F_s = 15$  FPS

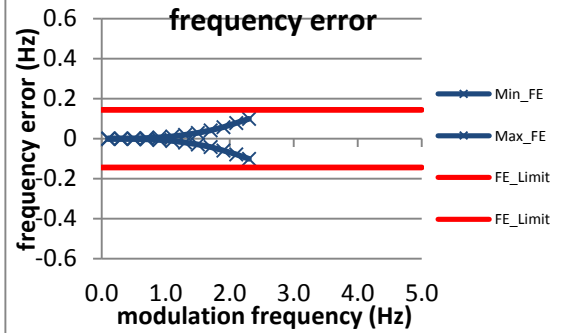


Figure 3191:  $F_s = 12$  FPS

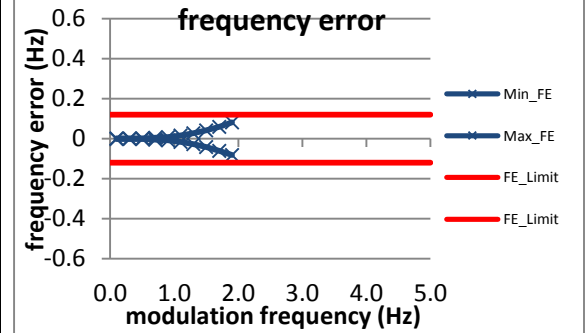


Figure 3192:  $F_s = 10$  FPS

### 7.3.3 PMU B dynamic bandwidth measurement: phase modulation frequency error: M class

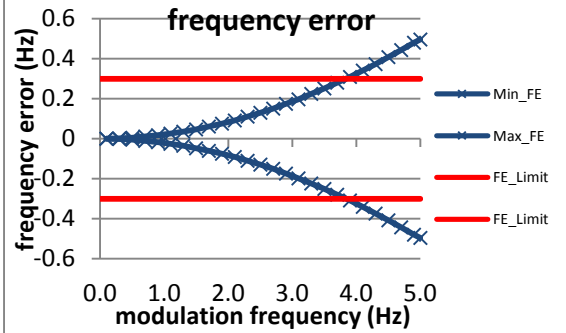


Figure 3193:  $F_s = 60$  FPS

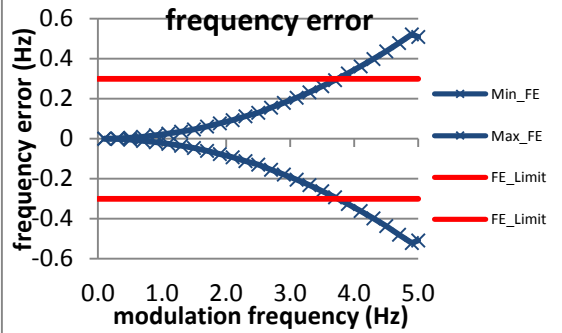


Figure 3194:  $F_s = 30$  FPS

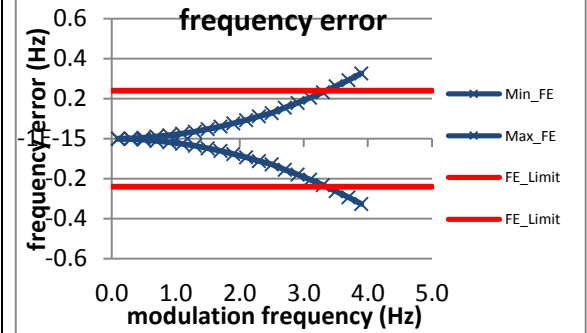


Figure 3195:  $F_s = 20$  FPS

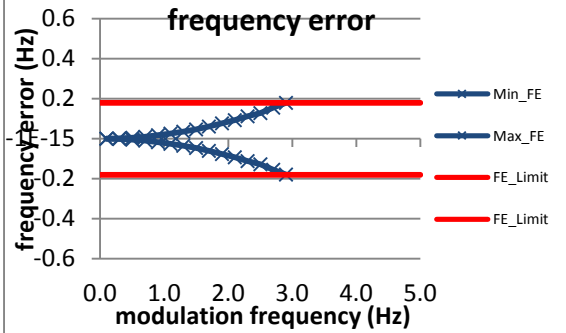


Figure 3196:  $F_s = 15$  FPS

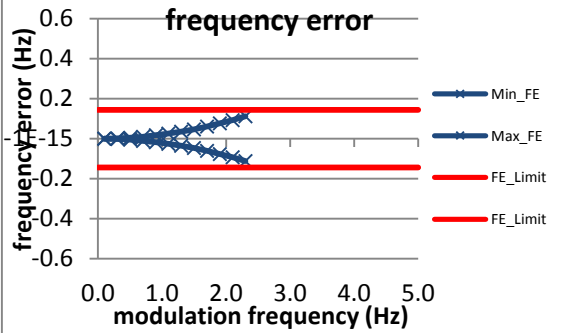


Figure 3197:  $F_s = 12$  FPS

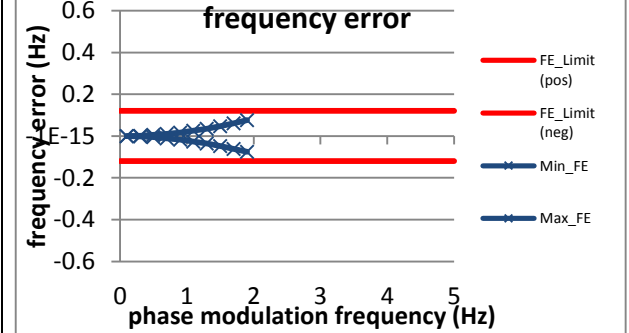


Figure 3198:  $F_s = 10$  FPS

### 7.3.4 PMU C dynamic bandwidth measurement: phase modulation frequency error: M class

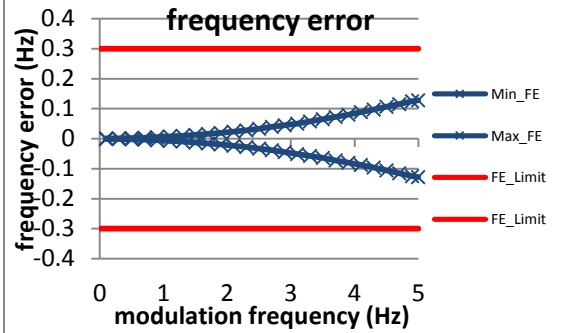


Figure 3199:  $F_s = 60$  FPS

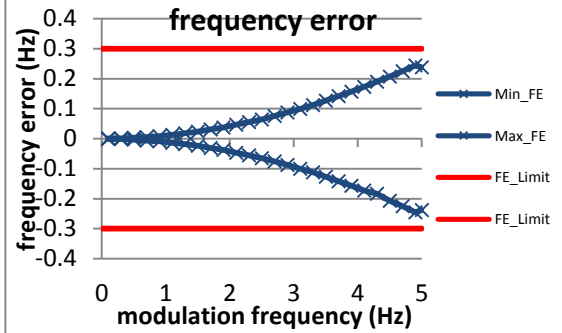


Figure 3200:  $F_s = 30$  FPS

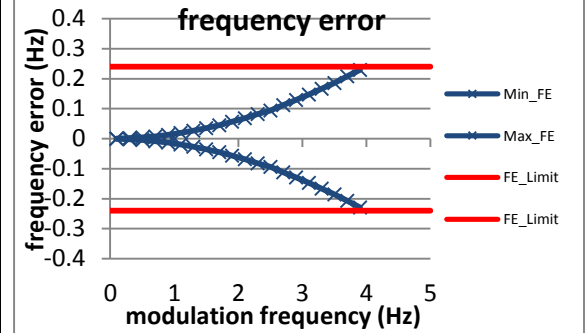


Figure 3201:  $F_s = 20$  FPS

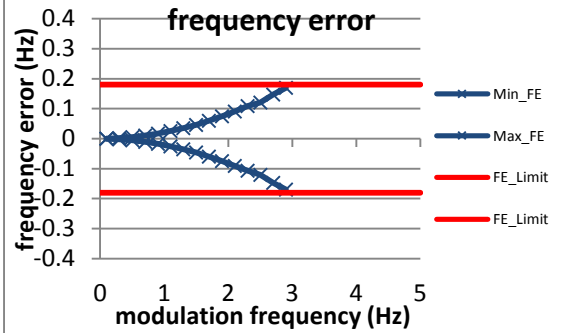


Figure 3202:  $F_s = 15$  FPS

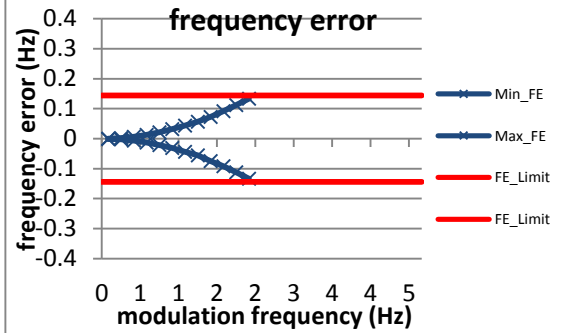


Figure 3203:  $F_s = 12$  FPS

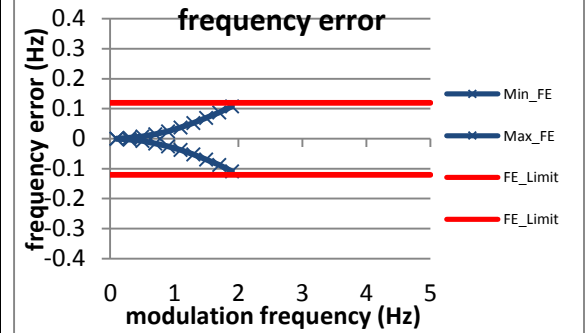
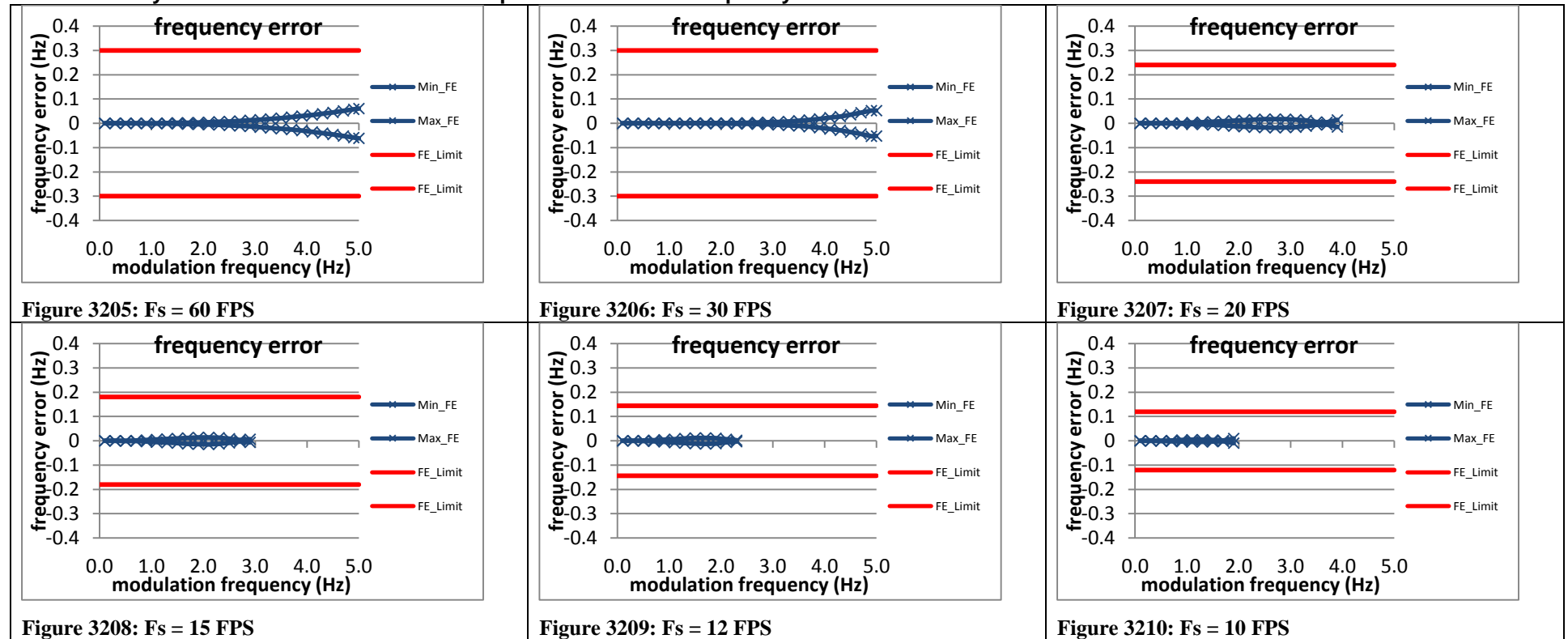
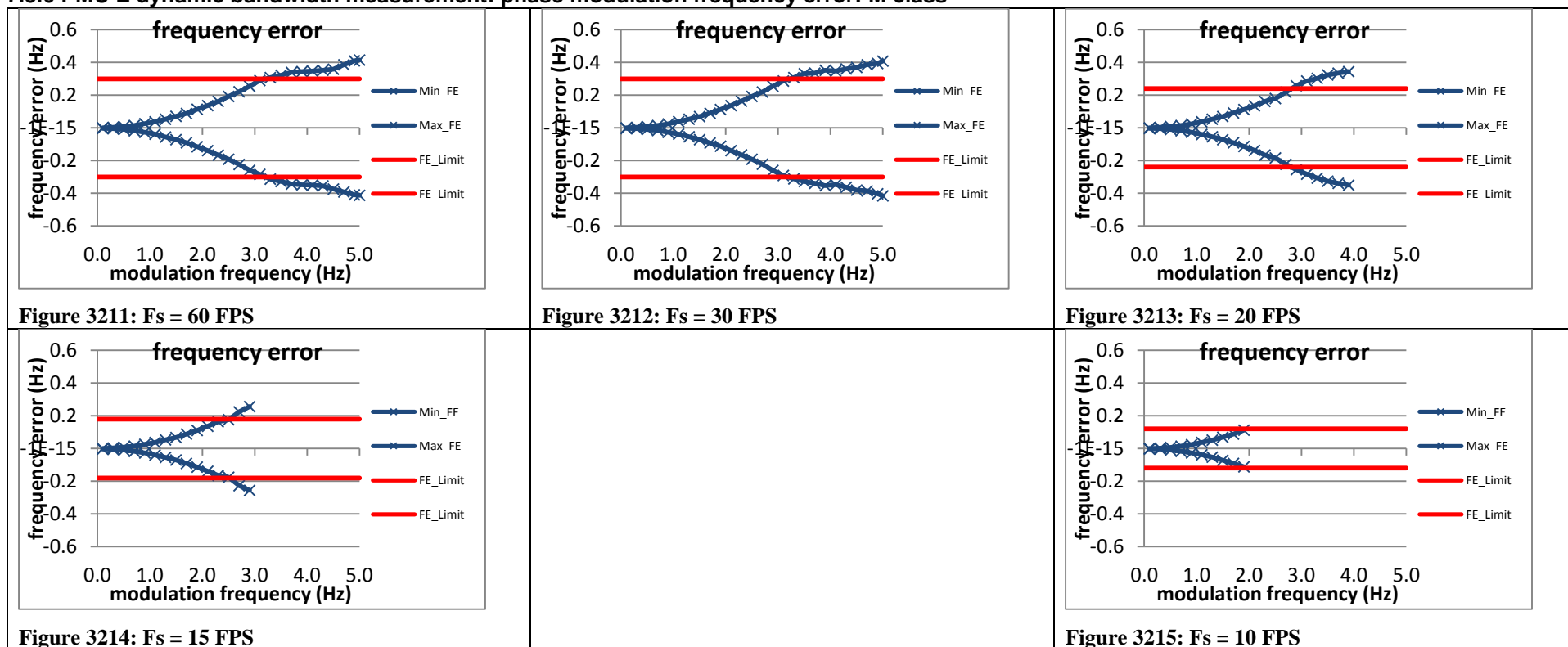


Figure 3204:  $F_s = 10$  FPS

### 7.3.5 PMU D dynamic bandwidth measurement: phase modulation frequency error: M class

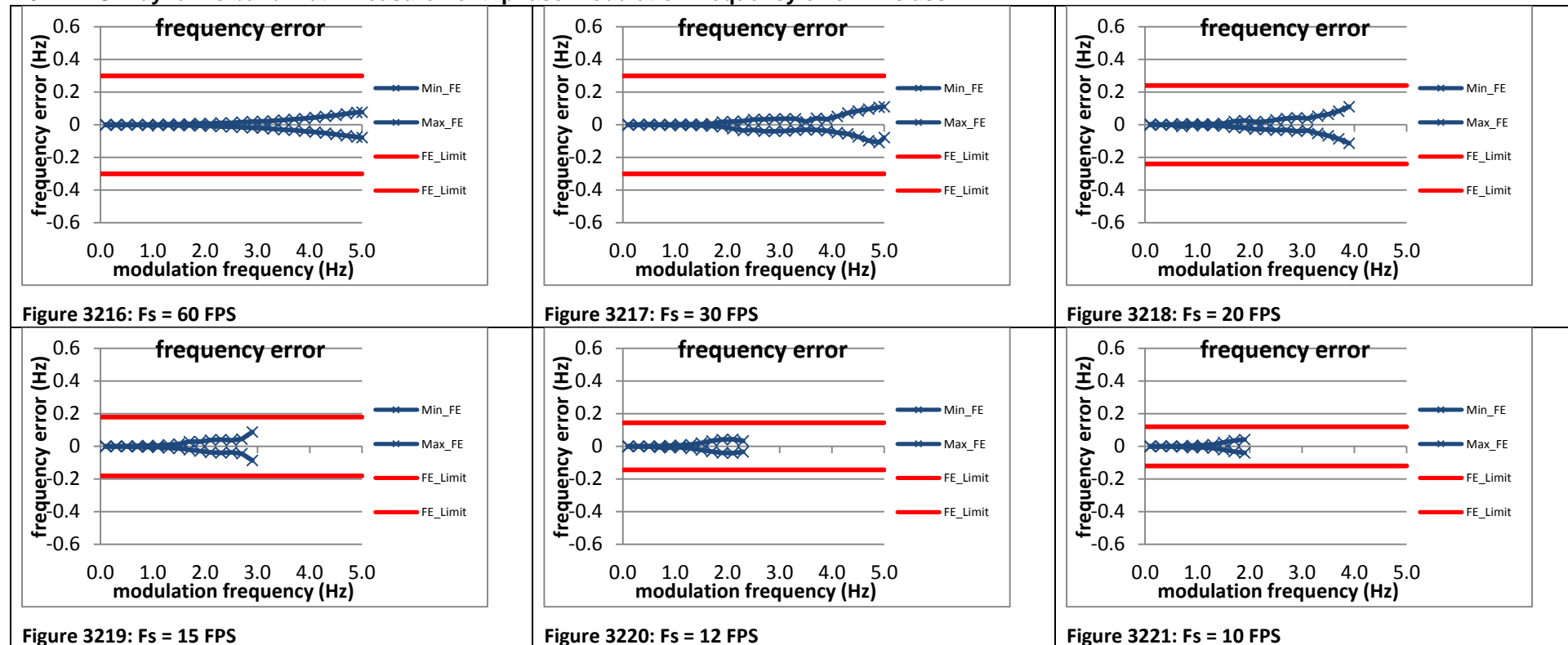


### 7.3.6 PMU E dynamic bandwidth measurement: phase modulation frequency error: M class





### 7.3.7 PMU F dynamic bandwidth measurement: phase modulation frequency error: M class



### 7.3.8 PMU G dynamic bandwidth measurement: phase modulation frequency error: M class

Figure 3222:  $F_s = 60$  FPS is not supported by this PMU

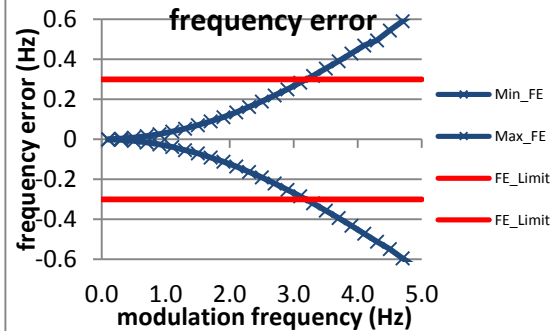


Figure 3223:  $F_s = 30$  FPS

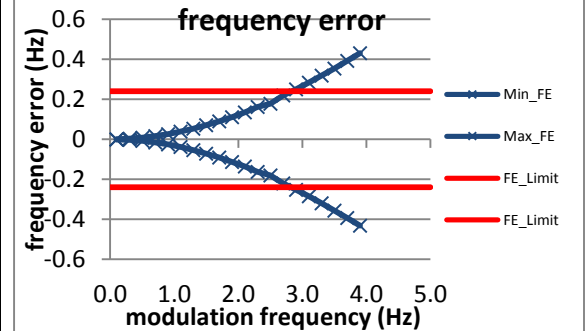


Figure 3224:  $F_s = 20$  FPS

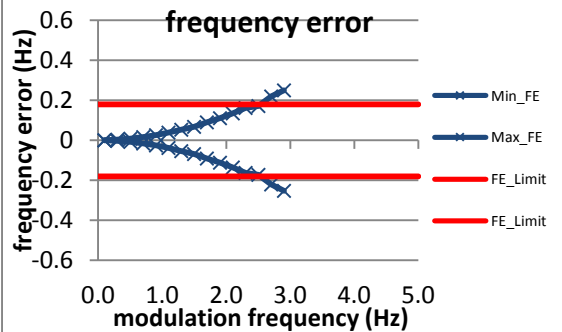


Figure 3225:  $F_s = 15$  FPS

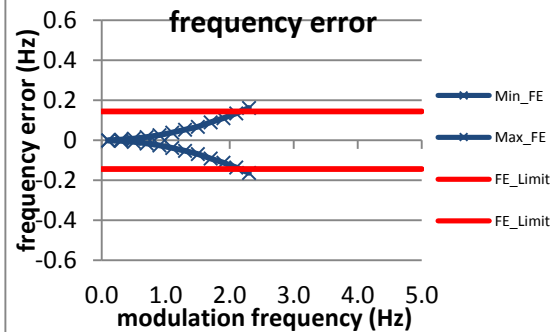


Figure 3226:  $F_s = 12$  FPS

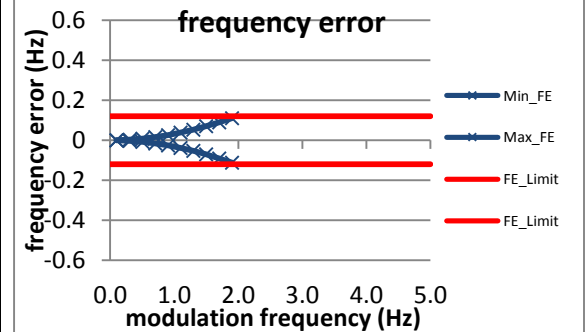
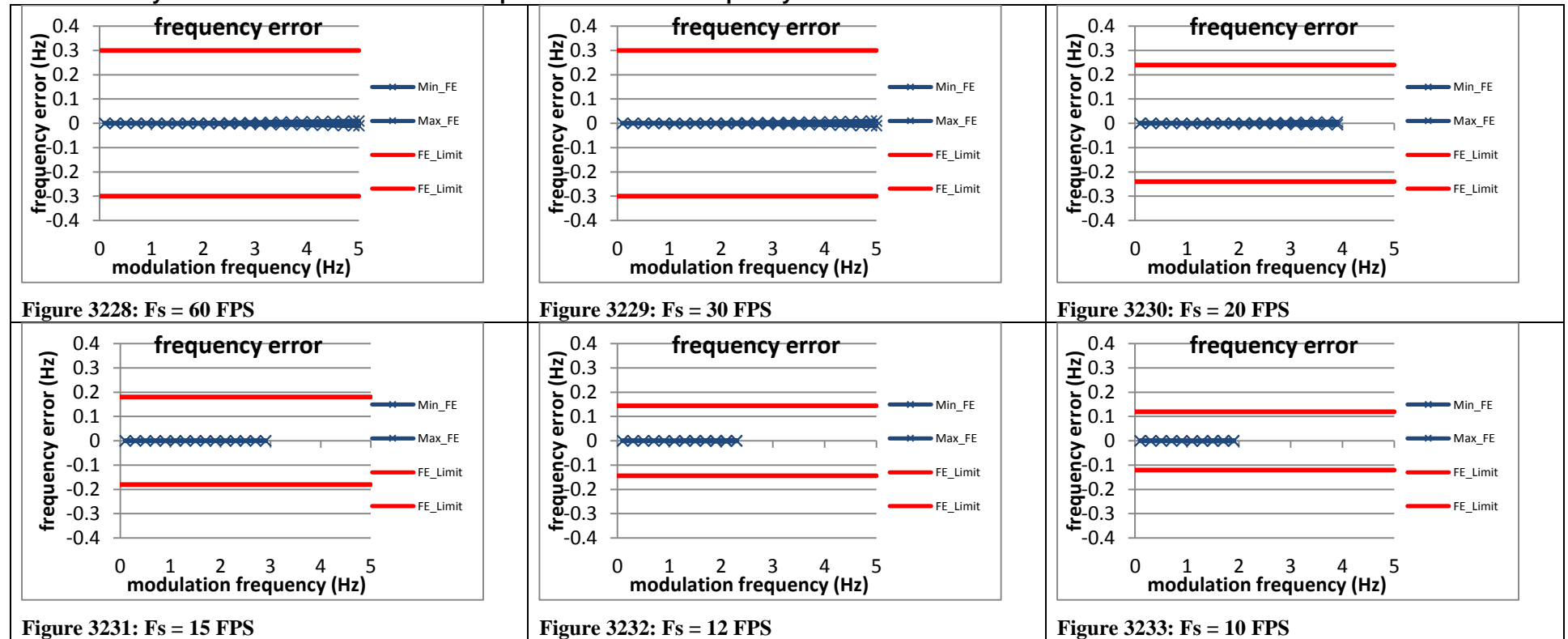
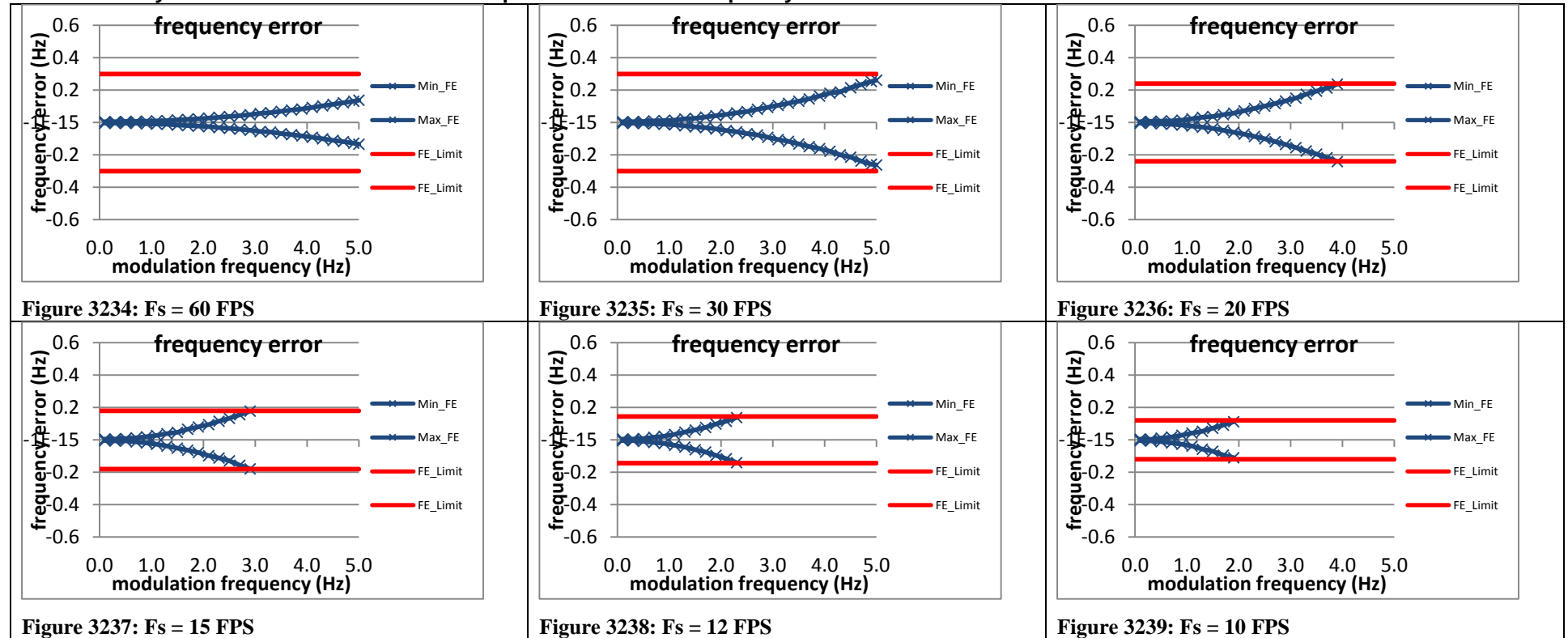


Figure 3227:  $F_s = 10$  FPS

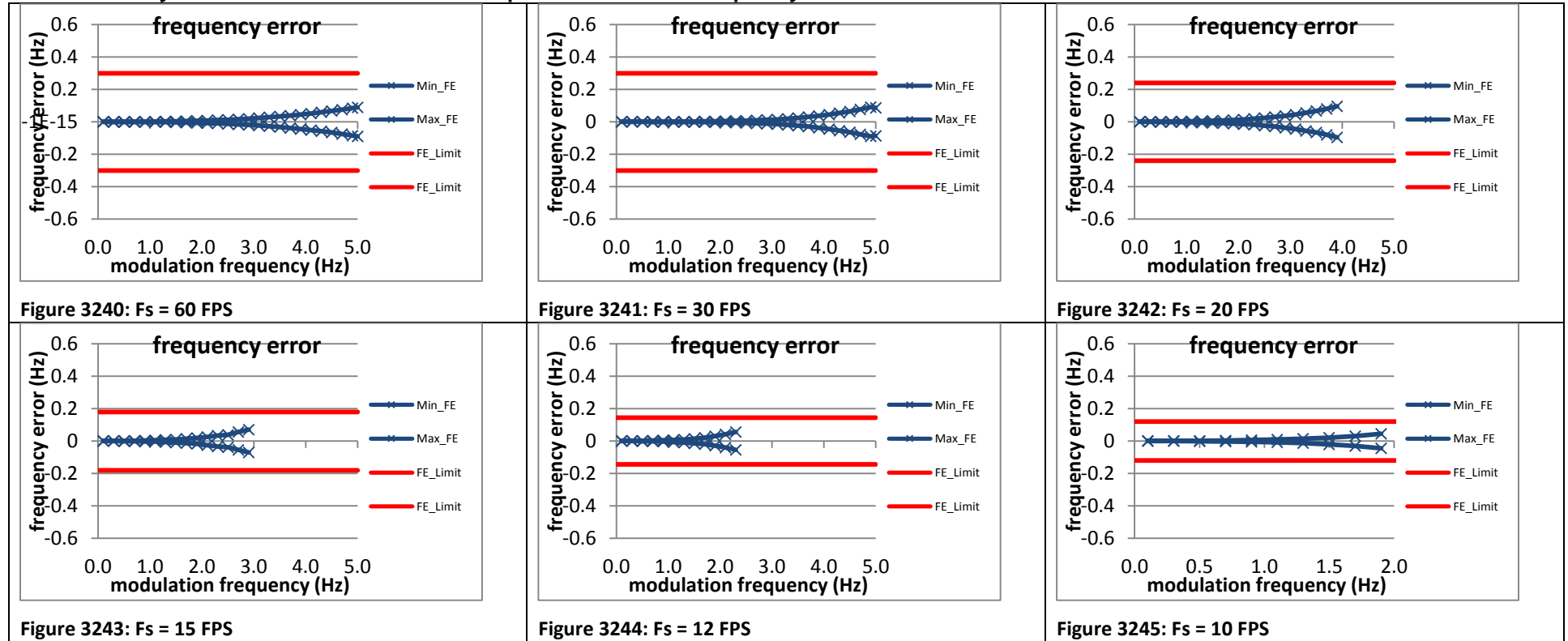
### 7.3.9 PMU H dynamic bandwidth measurement: phase modulation frequency error: M class



### 7.3.10 PMU I dynamic bandwidth measurement: phase modulation frequency error: M class

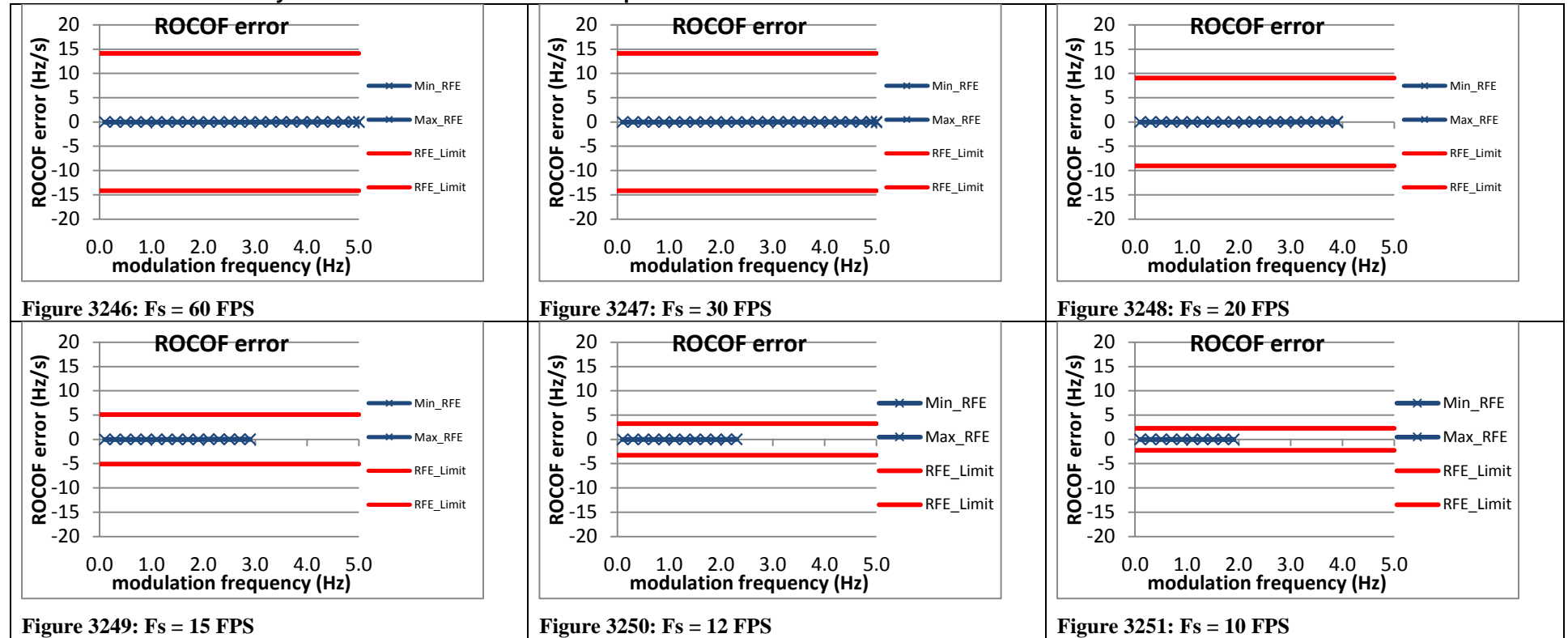


### 7.3.11 PMU J dynamic bandwidth measurement: phase modulation frequency error: M class

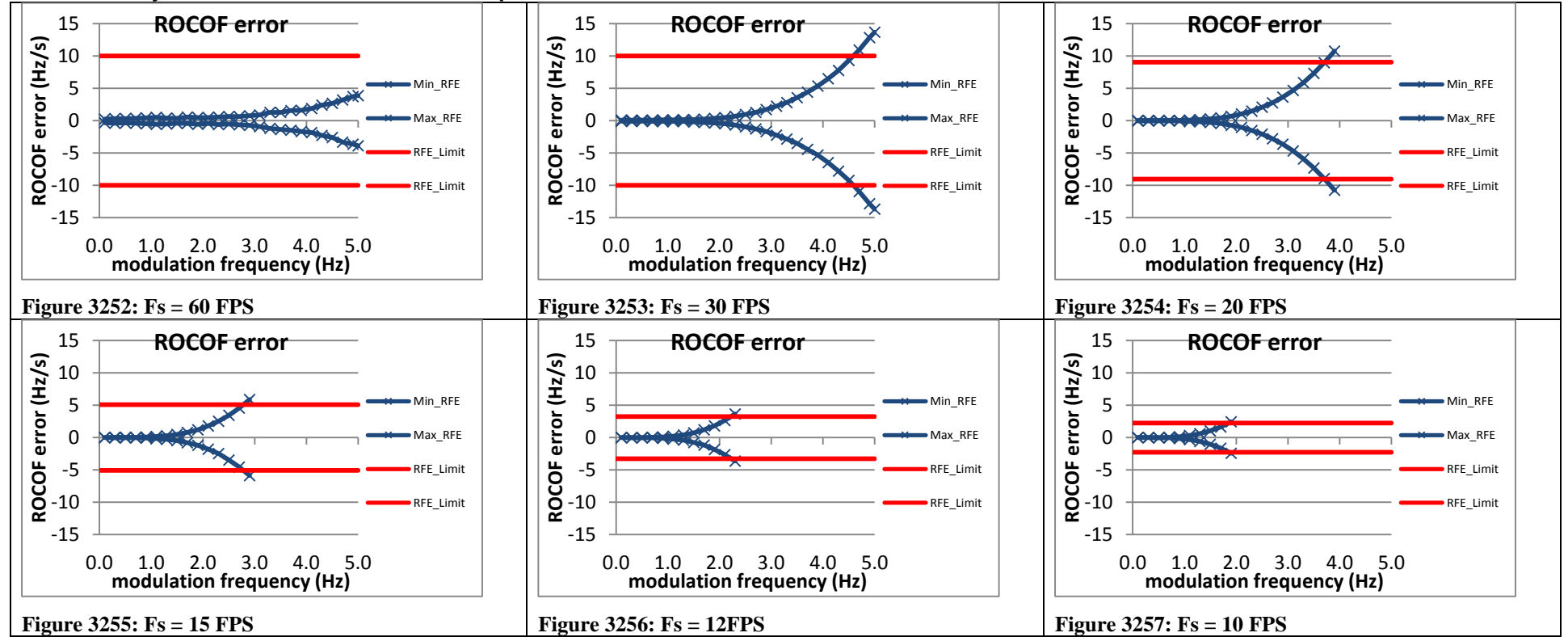


## 7.4 Dynamic bandwidth measurement: phase modulation ROCOF error

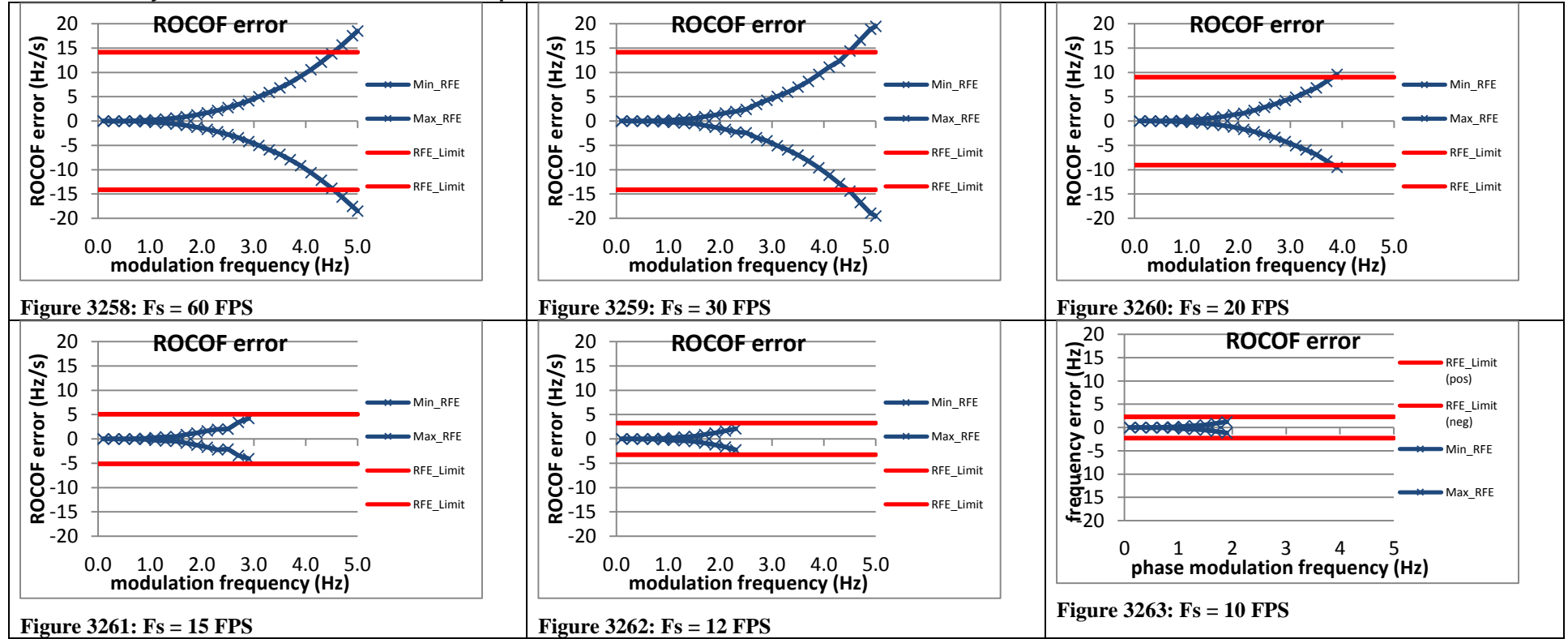
### 7.4.1 C37.118.1 Annex C dynamic bandwidth measurement: phase modulation ROCOF error: M class



#### 7.4.2 PMU A dynamic bandwidth measurement: phase modulation ROCOF error: M class

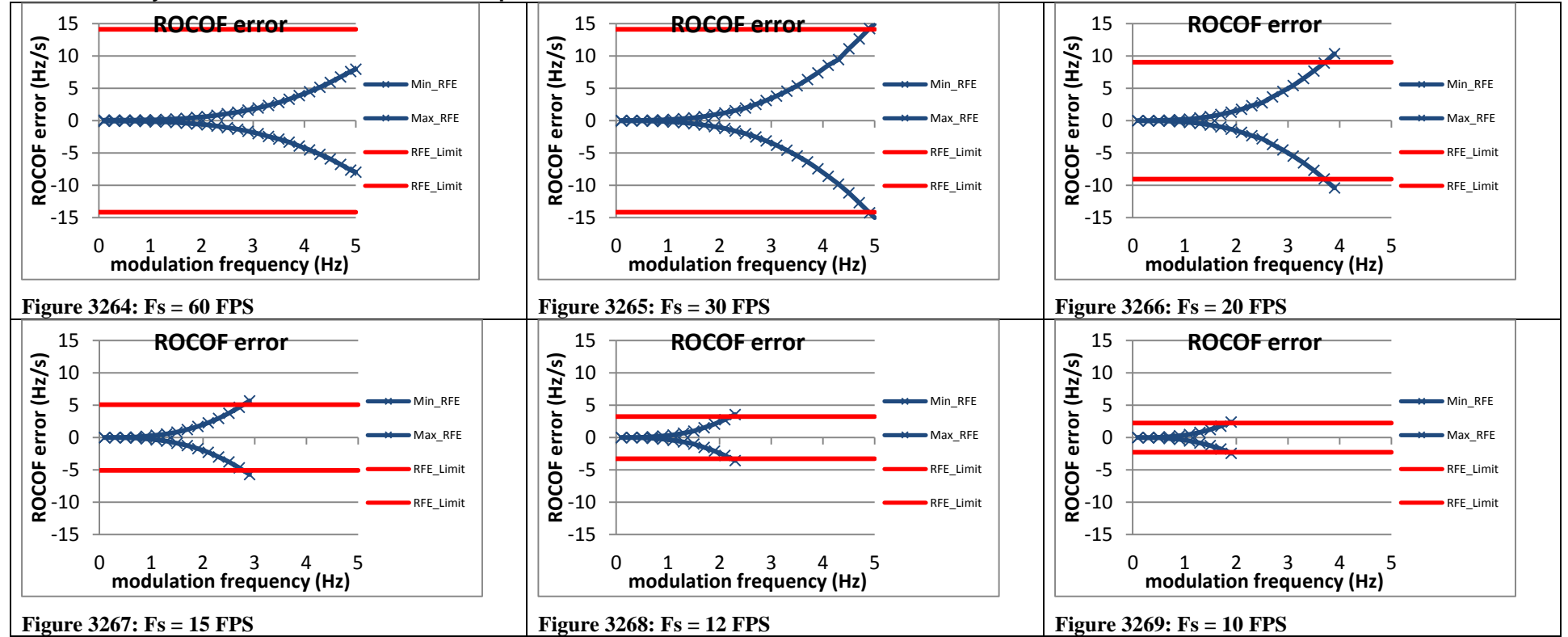


#### 7.4.3 PMU B dynamic bandwidth measurement: phase modulation ROCOF error: M class

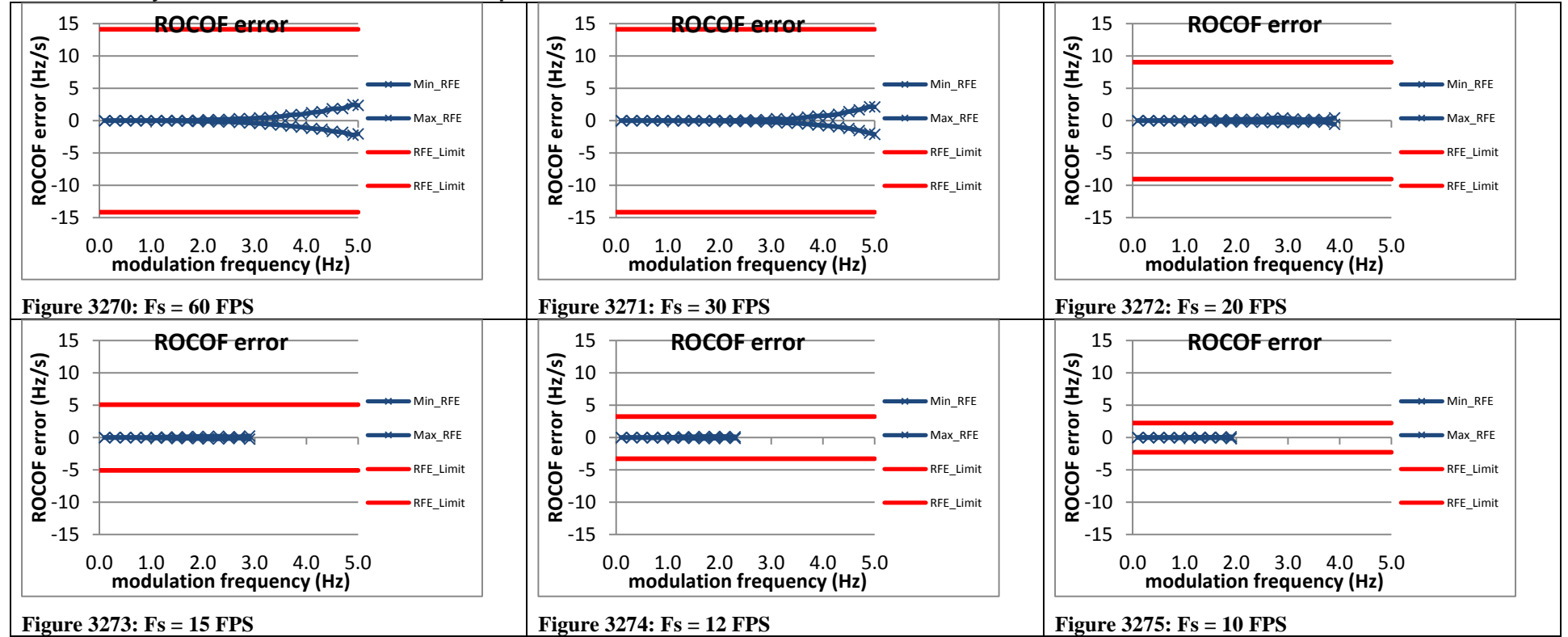




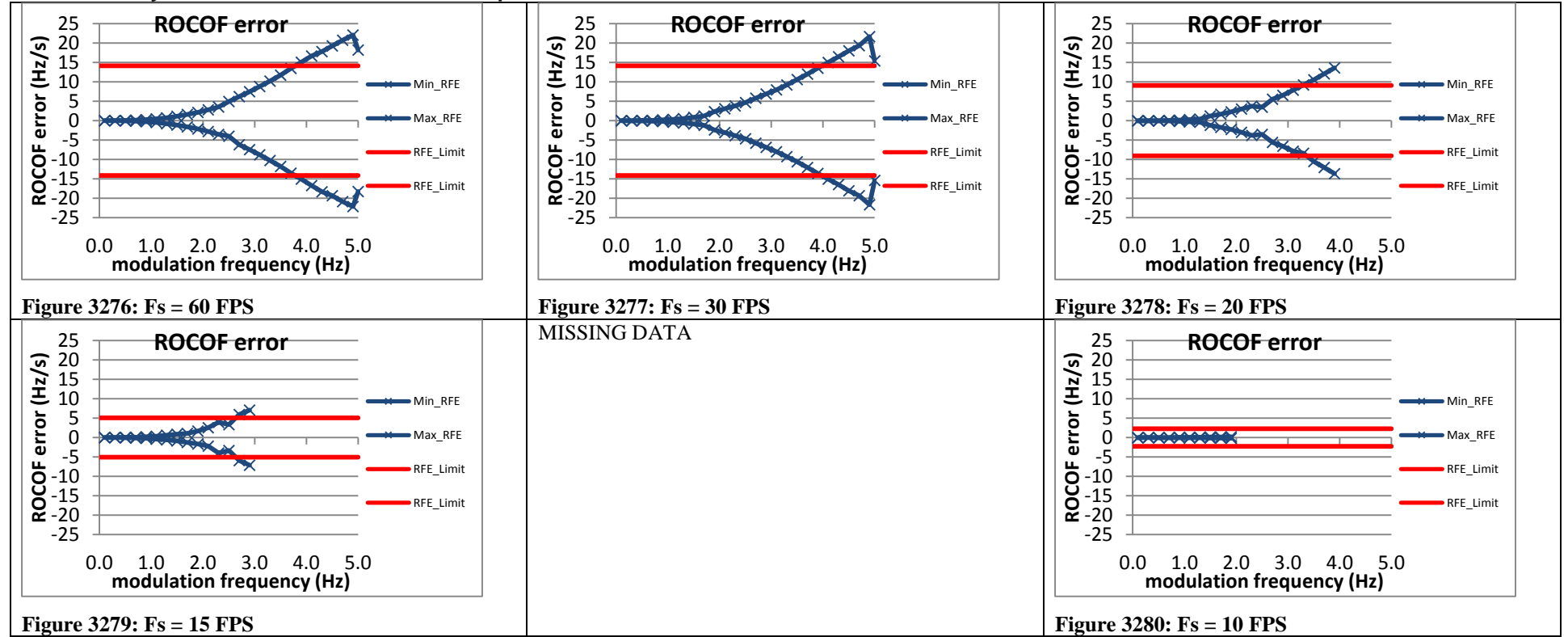
#### 7.4.4 PMU C dynamic bandwidth measurement: phase modulation ROCOF error: M class



#### 7.4.5 PMU D dynamic bandwidth measurement: phase modulation ROCOF error: M class



#### 7.4.6 PMU E dynamic bandwidth measurement: phase modulation ROCOF error: M class



#### 7.4.7 PMU F dynamic bandwidth measurement: phase modulation ROCOF error: M class

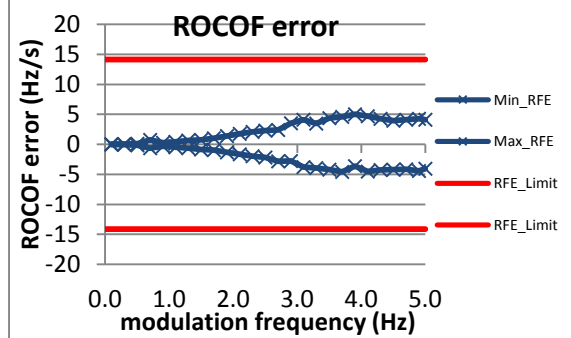


Figure 3281:  $F_s = 60$  FPS

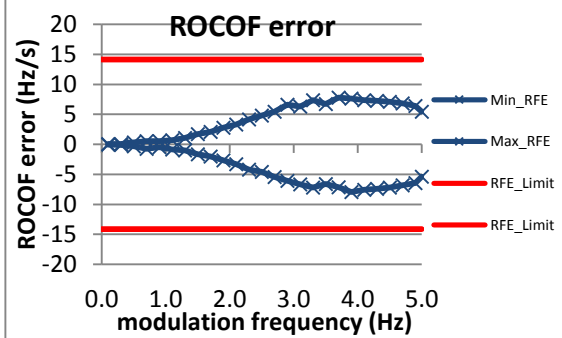


Figure 3282:  $F_s = 30$  FPS

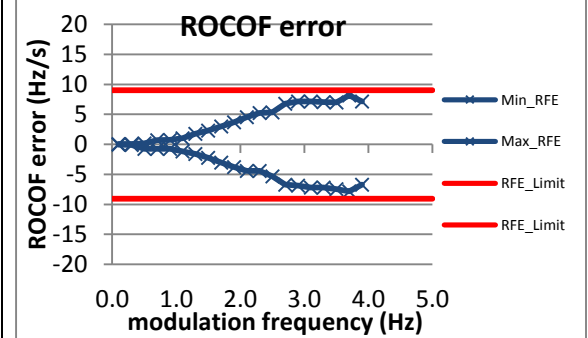


Figure 3283:  $F_s = 20$  FPS

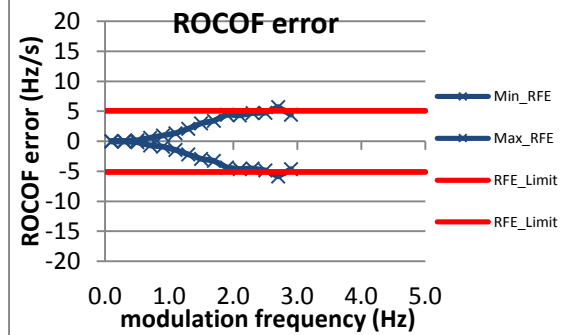


Figure 3284:  $F_s = 15$  FPS

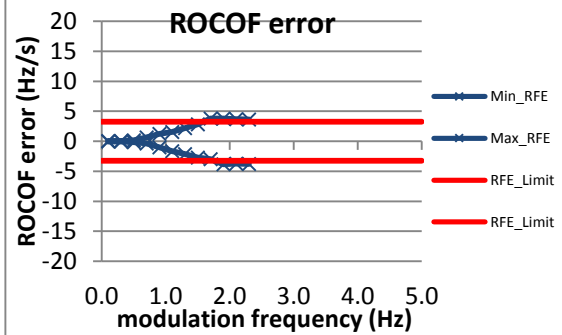


Figure 3285:  $F_s = 12$  FPS

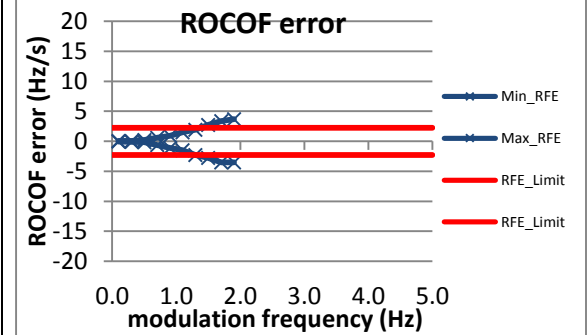


Figure 3286:  $F_s = 10$  FPS

#### 7.4.8 PMU G \* dynamic bandwidth measurement: phase modulation ROCOF error: M class

Figure 3287:  $F_s = 60$  FPS is not supported by this PMU

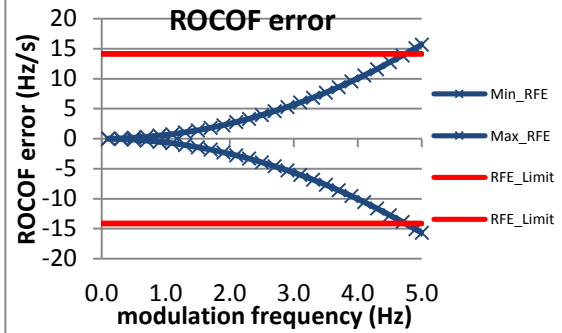


Figure 3288:  $F_s = 30$  FPS

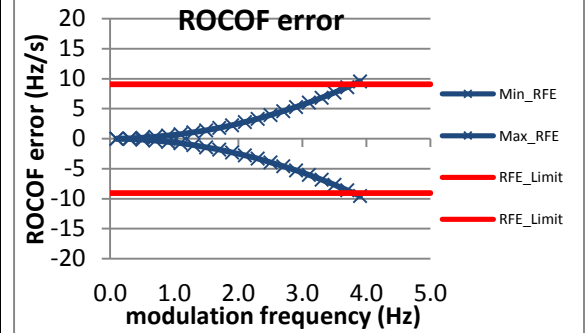


Figure 3289:  $F_s = 20$  FPS

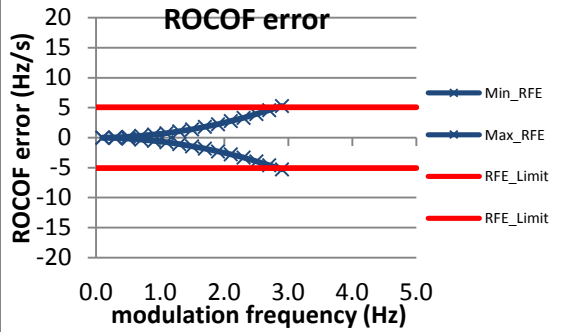


Figure 3290:  $F_s = 15$  FPS

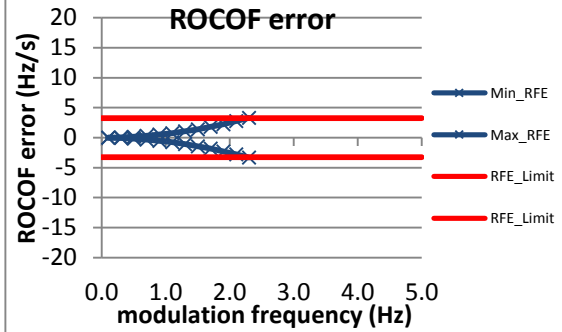


Figure 3291:  $F_s = 12$  FPS

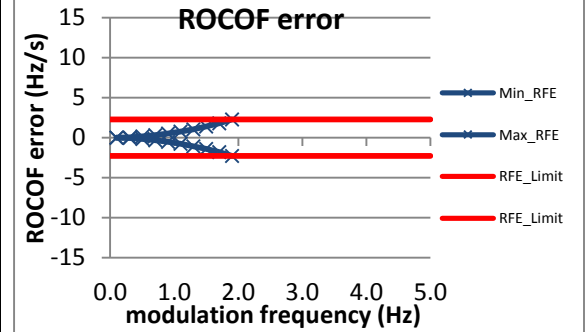


Figure 3292:  $F_s = 10$  FPS

\* This PMU always outputs ROCOF = 0

#### 7.4.9 PMU H dynamic bandwidth measurement: phase modulation ROCOF error: M class

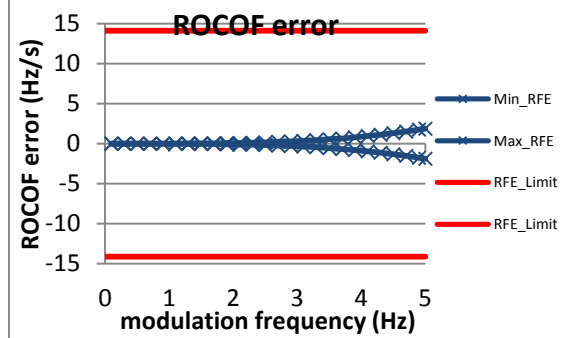


Figure 3293:  $F_s = 60$  FPS

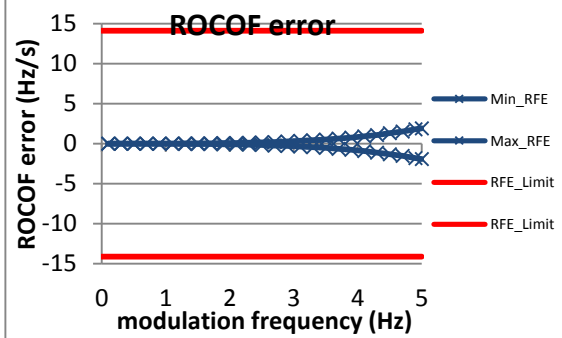


Figure 3294:  $F_s = 30$  FPS

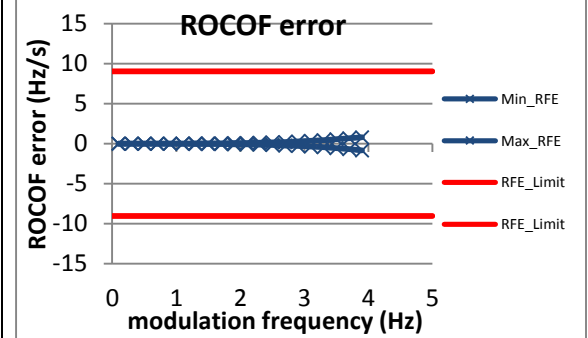


Figure 3295:  $F_s = 20$  FPS

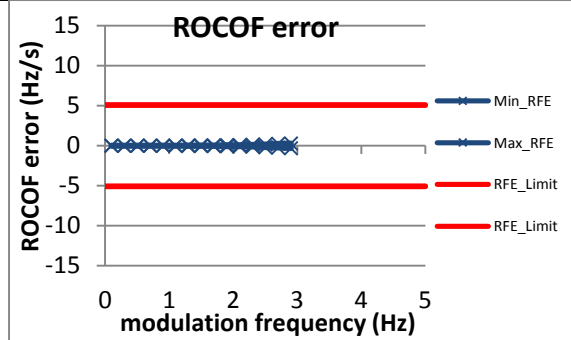


Figure 3296:  $F_s = 15$  FPS

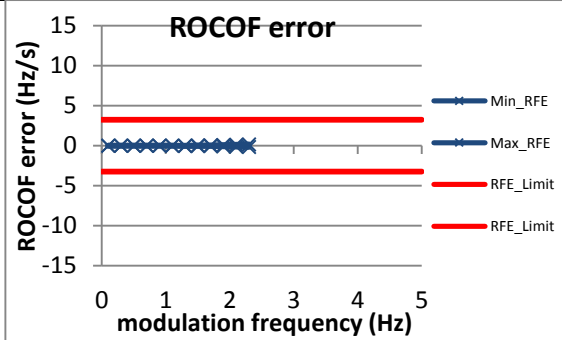


Figure 3297:  $F_s = 12$  FPS

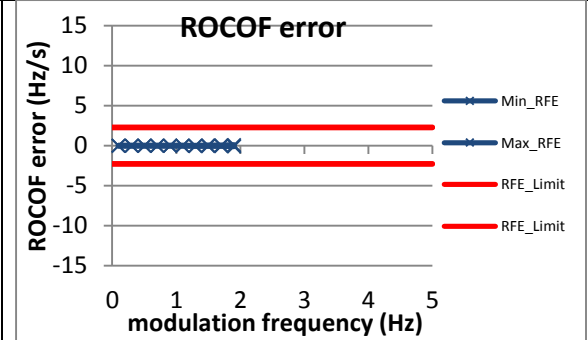
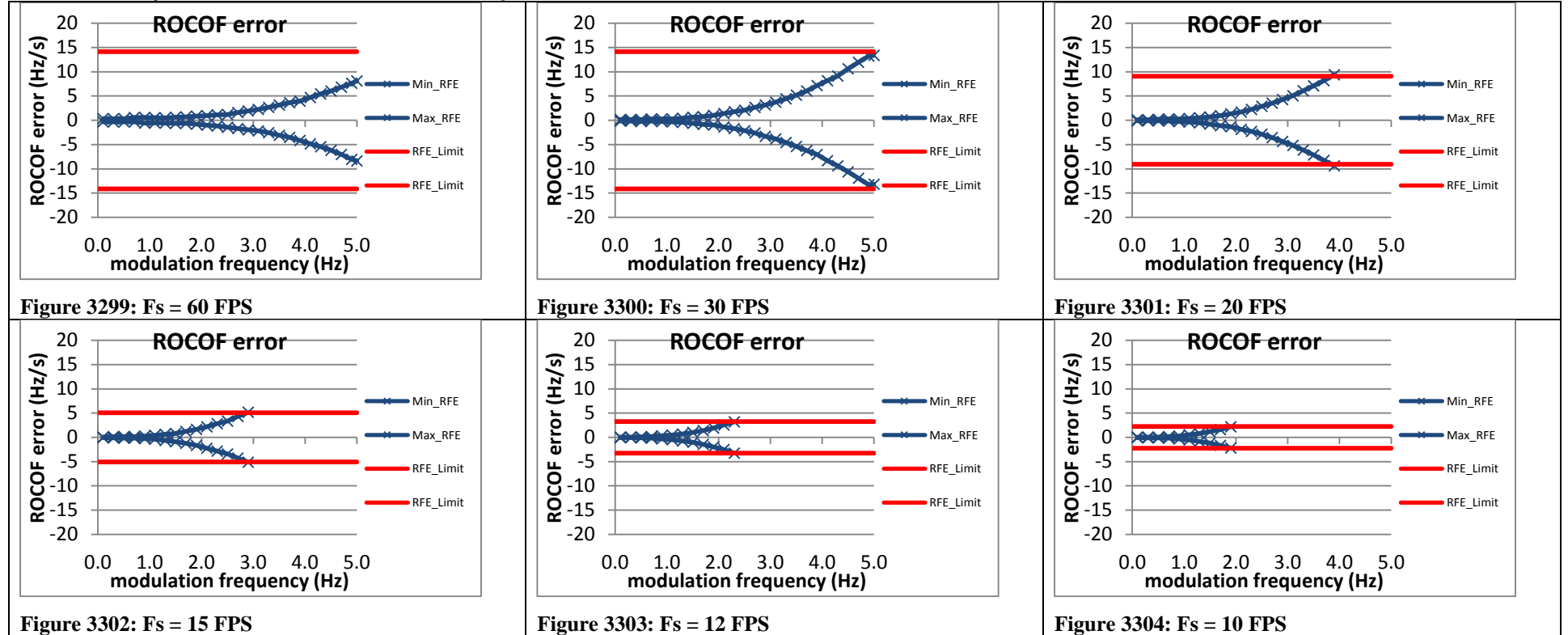


Figure 3298:  $F_s = 10$  FPS

#### 7.4.10 PMU I dynamic bandwidth measurement: phase modulation ROCOF error: M class



#### 7.4.11 PMU J dynamic bandwidth measurement: phase modulation ROCOF error: M class

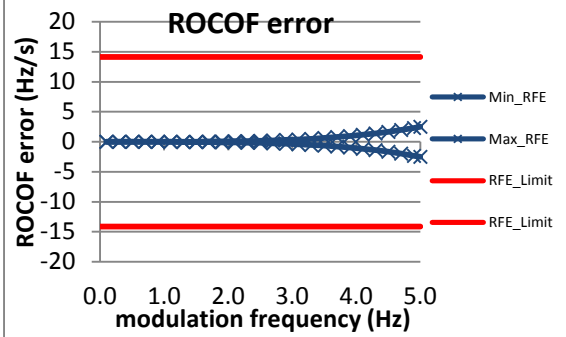


Figure 3305:  $F_s = 60$  FPS

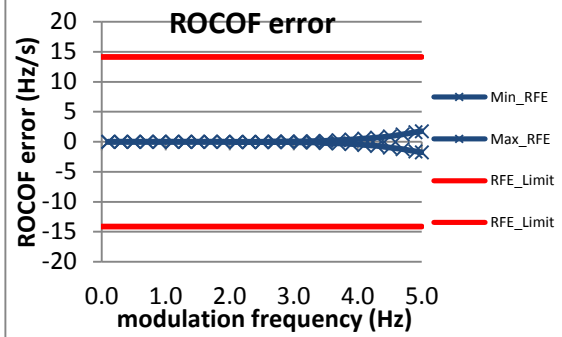


Figure 3306:  $F_s = 30$  FPS

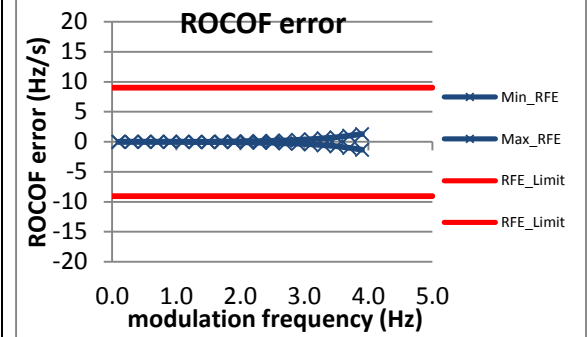


Figure 3307:  $F_s = 20$  FPS

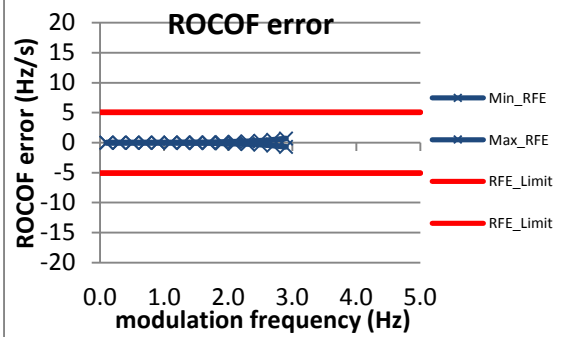


Figure 3308:  $F_s = 15$  FPS

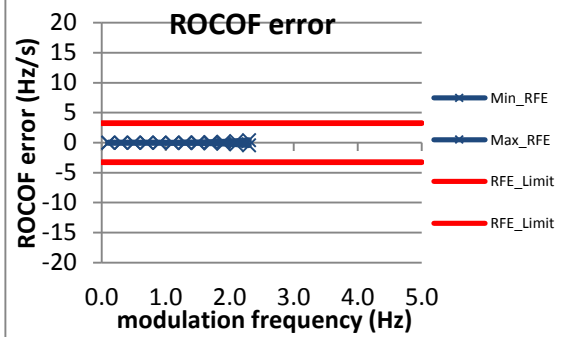


Figure 3309:  $F_s = 12$  FPS

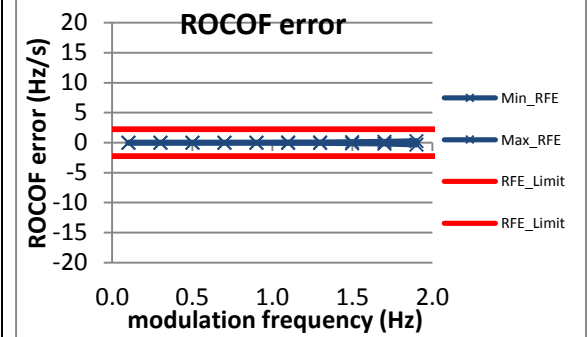


Figure 3310:  $F_s = 10$  FPS



## 7.5 Phase modulation voltage TVE, P class

### 7.5.1 C37.118.1 Annex C dynamic bandwidth measurement: phase modulation voltage TVE: P class

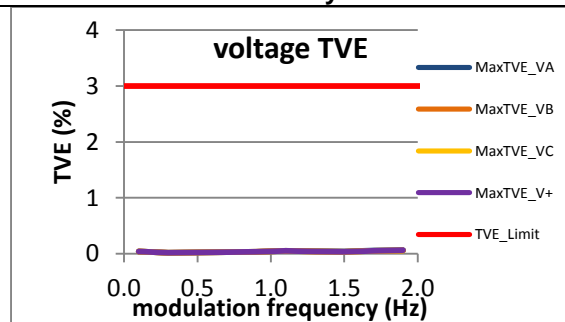


Figure 3311:  $F_s = 60$  FPS

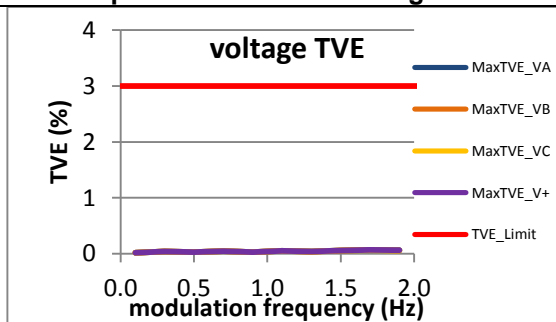


Figure 3312:  $F_s = 30$  FPS

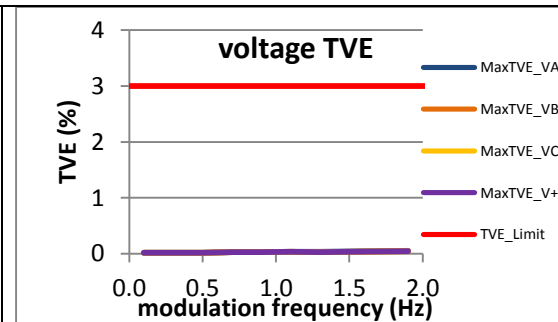


Figure 3313:  $F_s = 20$  FPS

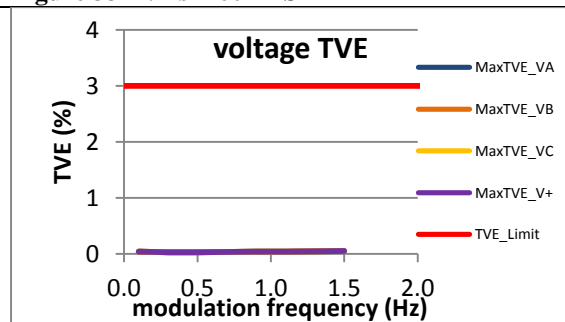


Figure 3314:  $F_s = 15$  FPS

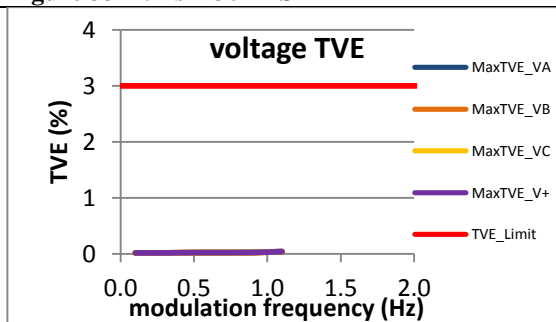


Figure 3315:  $F_s = 12$  FPS

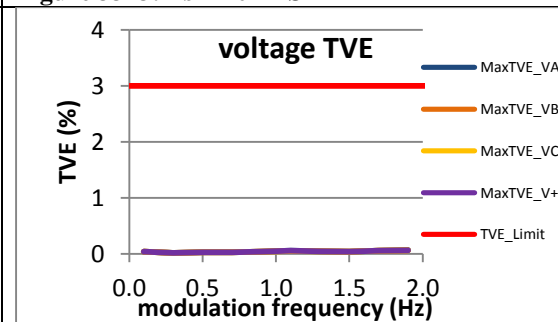


Figure 3316:  $F_s = 10$  FPS

## 7.5.2 PMU A dynamic bandwidth measurement: phase modulation voltage TVE: P class

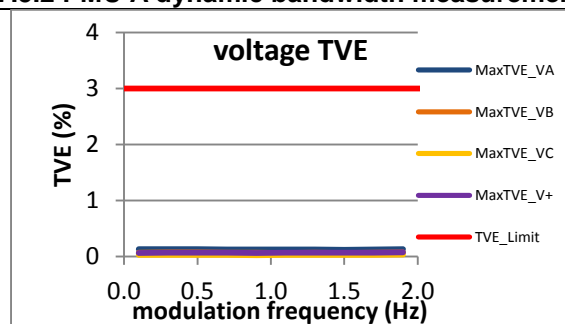


Figure 3317:  $F_s = 60$  FPS

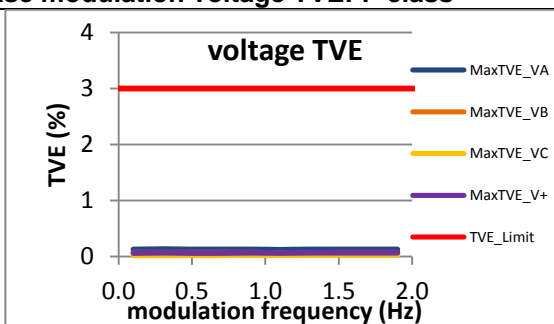


Figure 3318:  $F_s = 30$  FPS

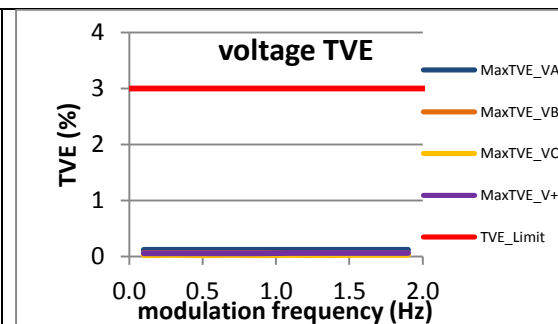


Figure 3319:  $F_s = 20$  FPS

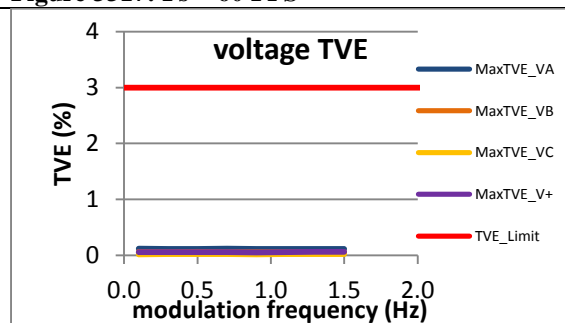


Figure 3320:  $F_s = 15$  FPS

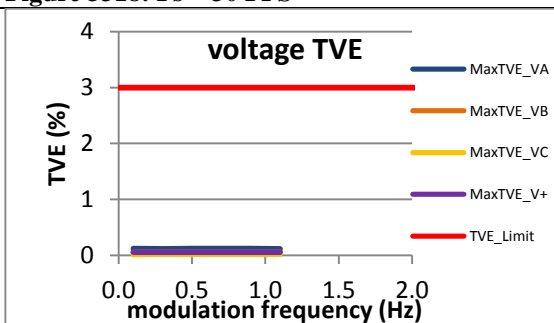


Figure 3321:  $F_s = 12$  FPS

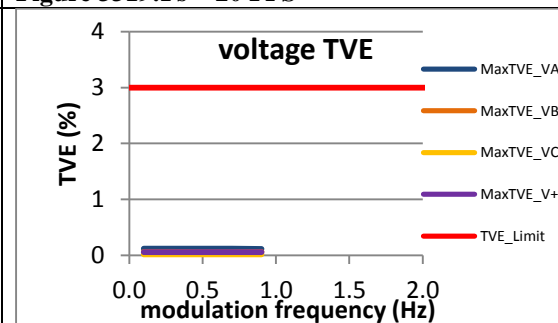


Figure 3322:  $F_s = 10$  FPS

### 7.5.3 PMU B dynamic bandwidth measurement: phase modulation voltage TVE: P class

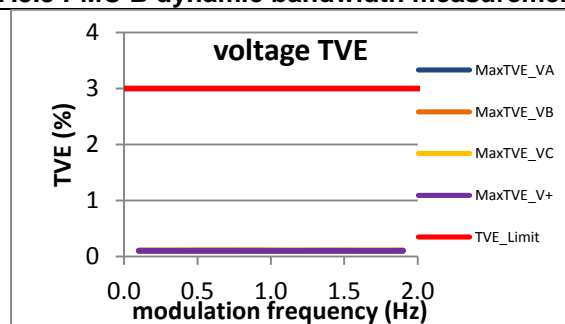


Figure 3323:  $F_s = 60$  FPS

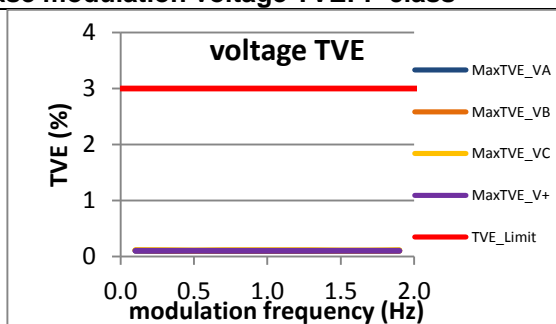


Figure 3324:  $F_s = 30$  FPS

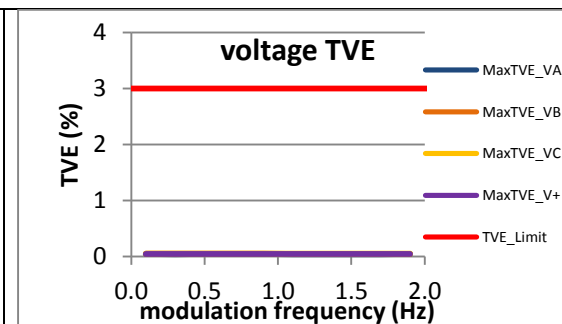


Figure 3325:  $F_s = 20$  FPS

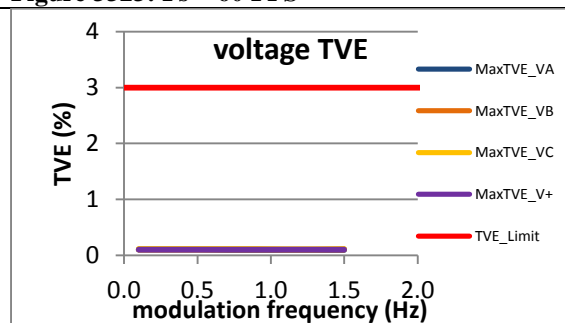


Figure 3326:  $F_s = 15$  FPS

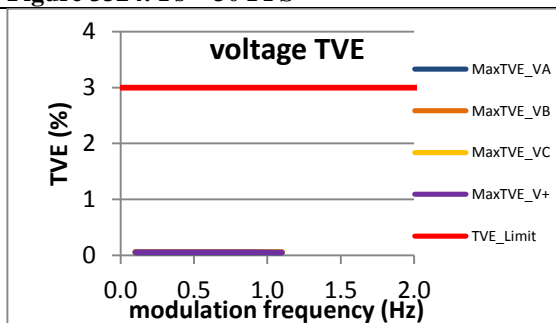


Figure 3327:  $F_s = 12$  FPS

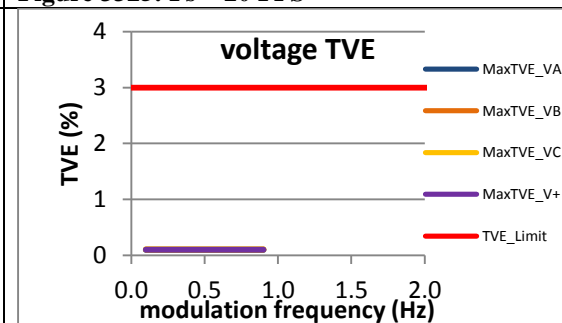


Figure 3328:  $F_s = 10$  FPS

#### 7.5.4 PMU C dynamic bandwidth measurement: phase modulation voltage TVE: P class

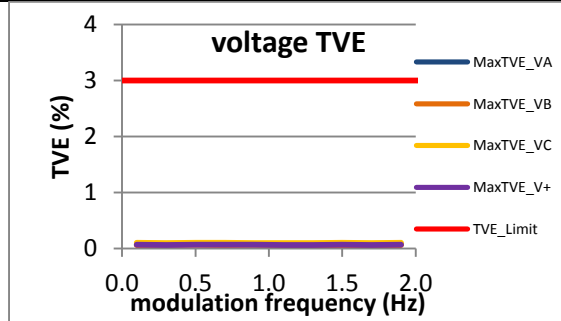


Figure 3329:  $F_s = 60$  FPS

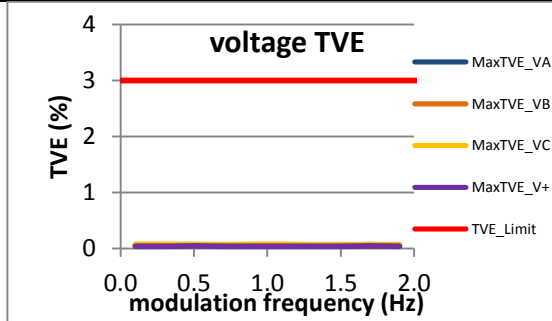


Figure 3330:  $F_s = 30$  FPS

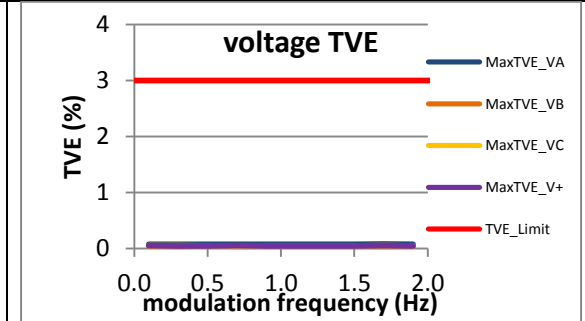


Figure 3331:  $F_s = 20$  FPS

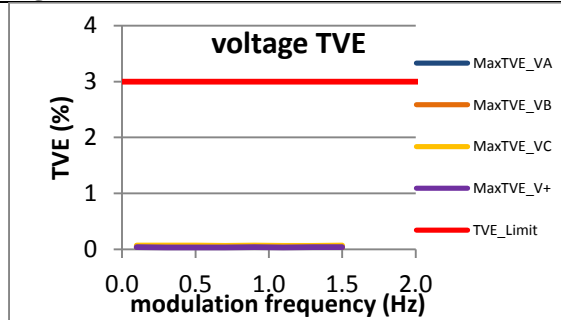


Figure 3332:  $F_s = 15$  FPS

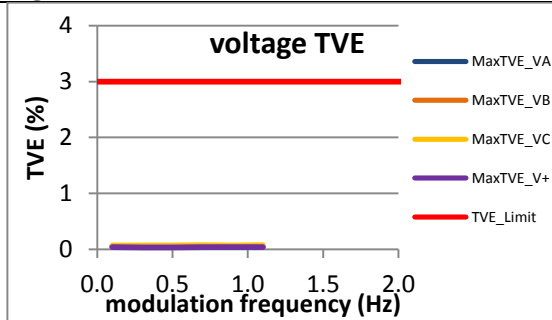


Figure 3333:  $F_s = 12$  FPS

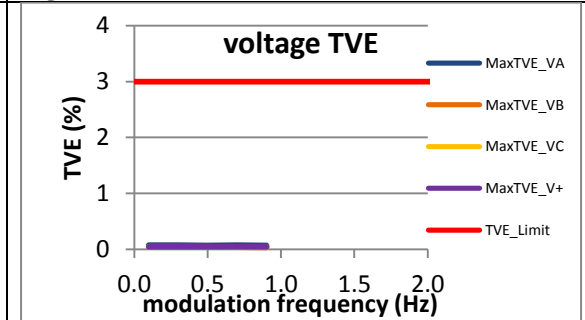
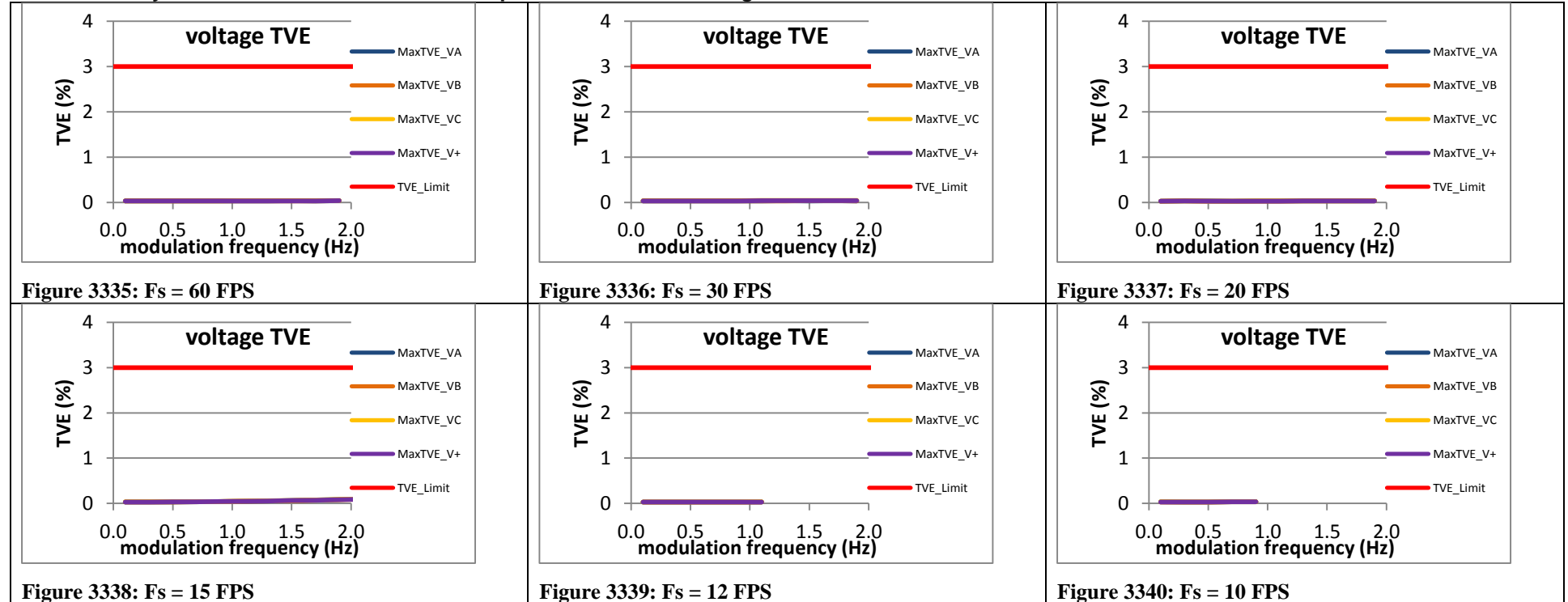


Figure 3334:  $F_s = 10$  FPS

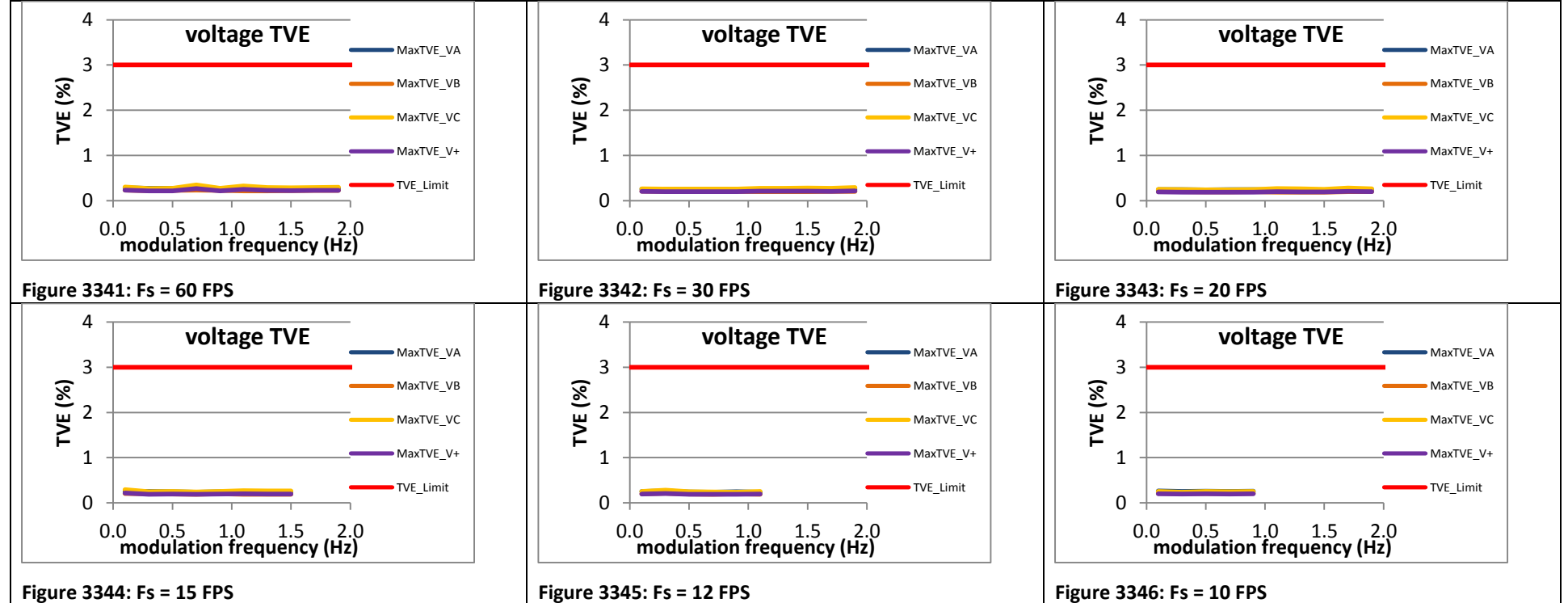
### 7.5.5 PMU D dynamic bandwidth measurement: phase modulation voltage TVE: P class



### 7.5.6 PMU E dynamic bandwidth measurement: phase modulation voltage TVE: P class

PMU E does not support P class

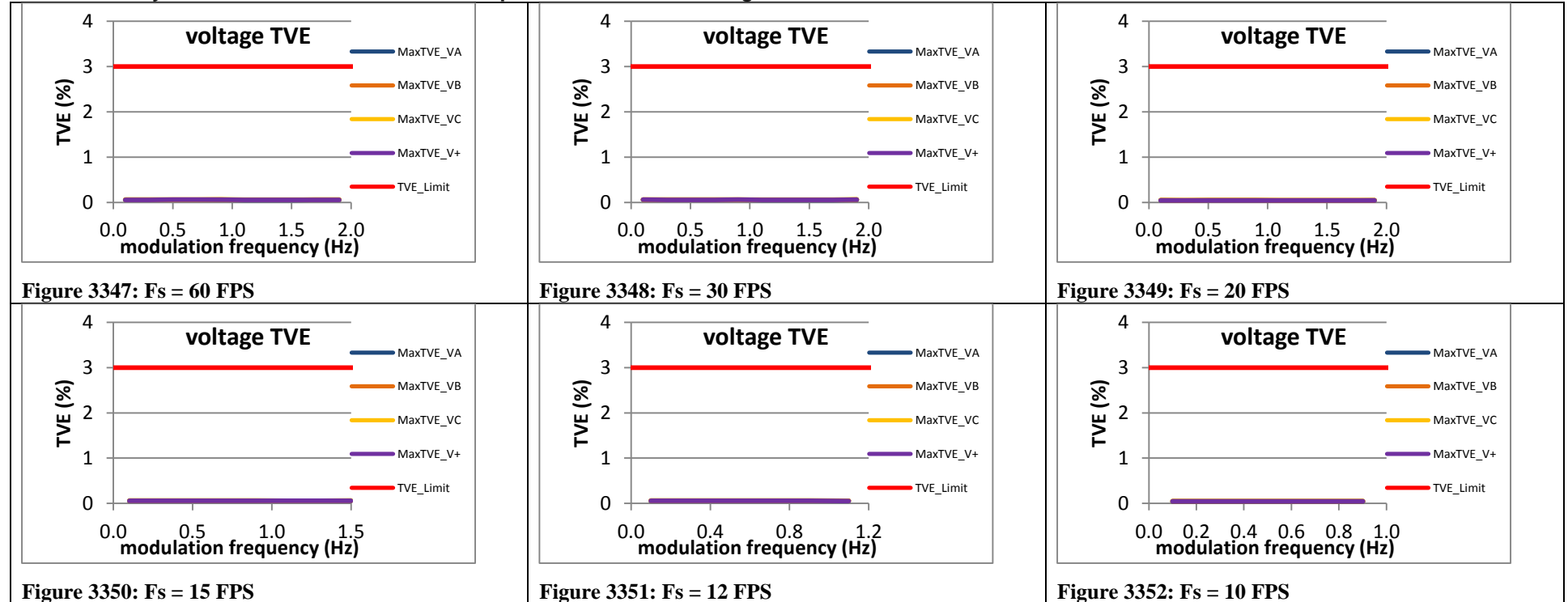
### 7.5.7 PMU F dynamic bandwidth measurement: phase modulation voltage TVE: P class



### 7.5.8 PMU G dynamic bandwidth measurement: phase modulation voltage TVE: P class

PMU G does not support P class.

### 7.5.9 PMU H dynamic bandwidth measurement: phase modulation voltage TVE: P class



### 7.5.10 PMU I dynamic bandwidth measurement: phase modulation voltage TVE: P class

PMU I does not support P class

### 7.5.11 PMU J dynamic bandwidth measurement: phase modulation voltage TVE: P class

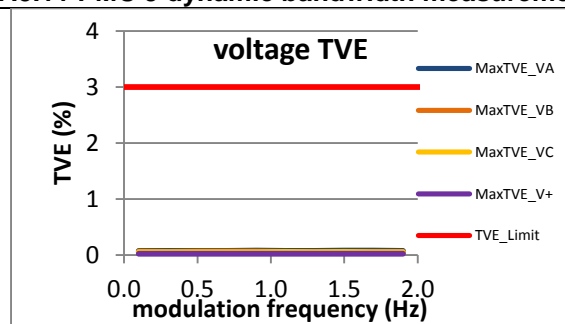


Figure 3353:  $F_s = 60$  FPS

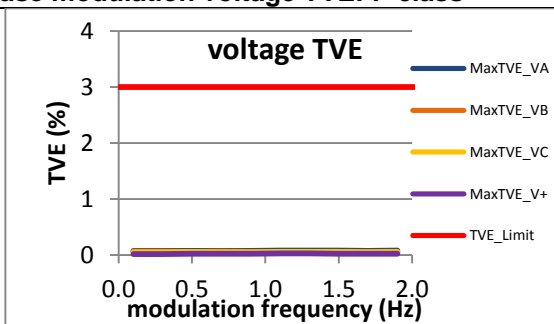


Figure 3354:  $F_s = 30$  FPS

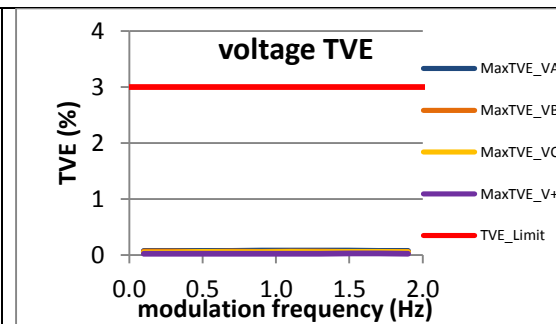


Figure 3355:  $F_s = 20$  FPS

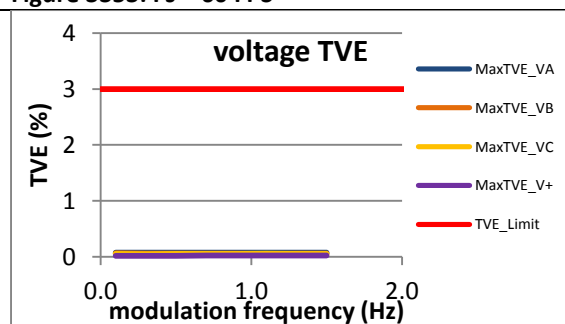


Figure 3356:  $F_s = 15$  FPS

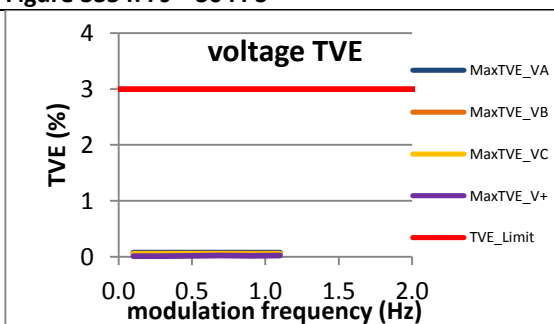


Figure 3357:  $F_s = 12$  FPS

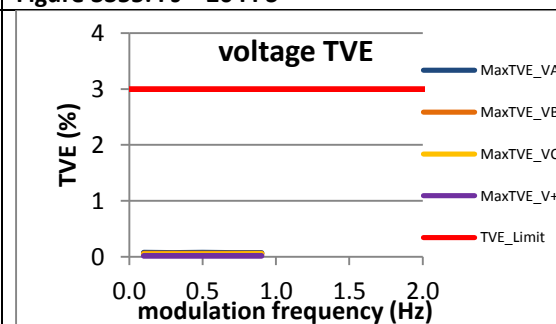


Figure 3358:  $F_s = 10$  FPS



## 7.6 Phase modulation current TVE, P class

### 7.6.1 C37.118.1 Annex C dynamic bandwidth measurement: phase modulation current TVE: P class

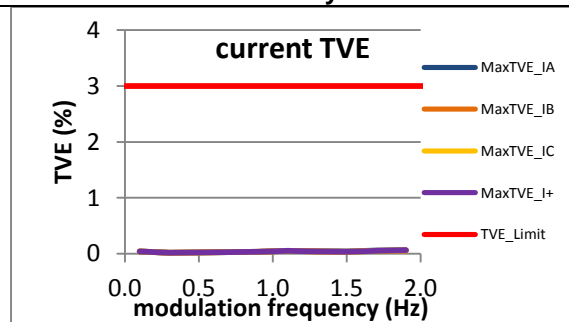


Figure 3359:  $F_s = 60$  FPS

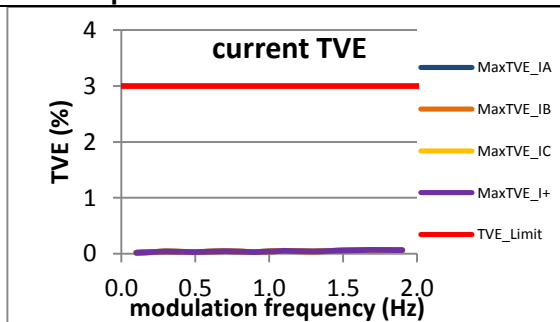


Figure 3360:  $F_s = 30$  FPS

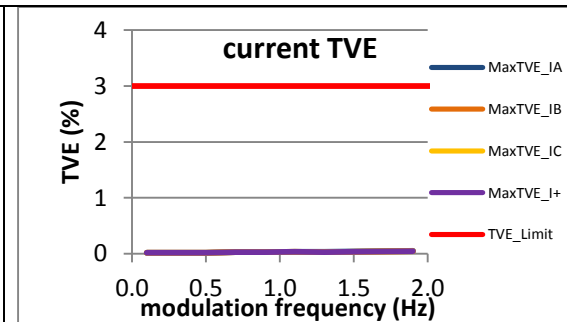


Figure 3361:  $F_s = 20$  FPS

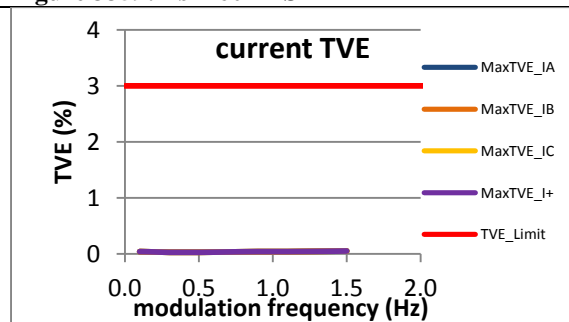


Figure 3362:  $F_s = 15$  FPS

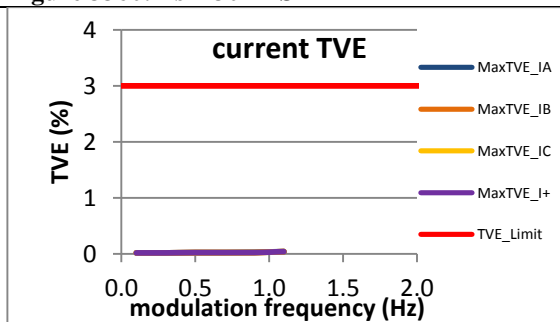


Figure 3363:  $F_s = 12$  FPS

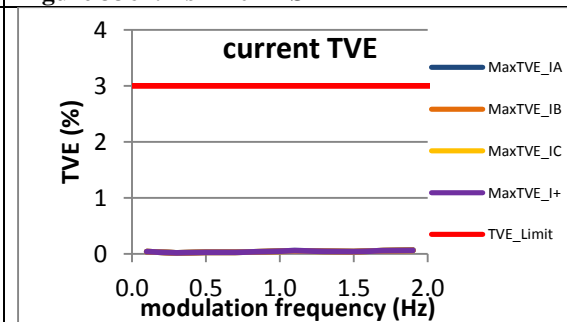


Figure 3364:  $F_s = 10$  FPS

## 7.6.2 PMU A dynamic bandwidth measurement: phase modulation current TVE: P class

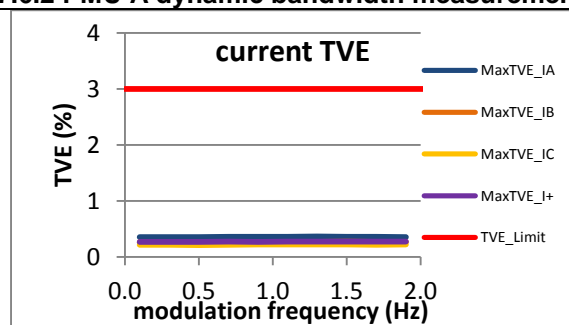


Figure 3365:  $F_s = 60$  FPS

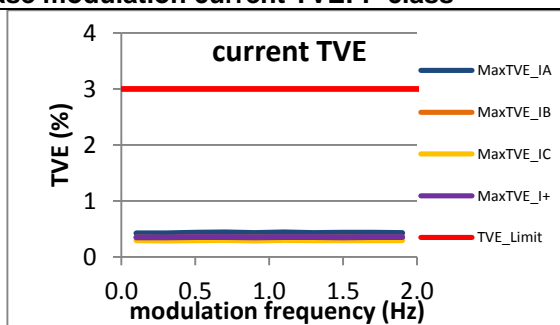


Figure 3366:  $F_s = 30$  FPS

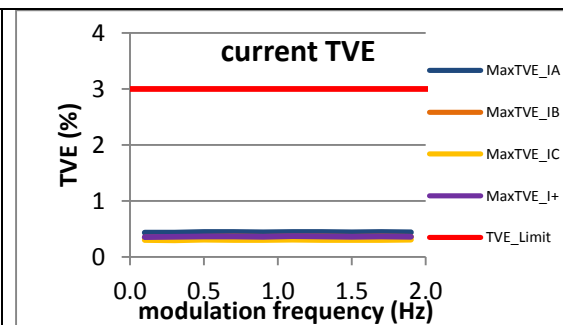


Figure 3367:  $F_s = 20$  FPS

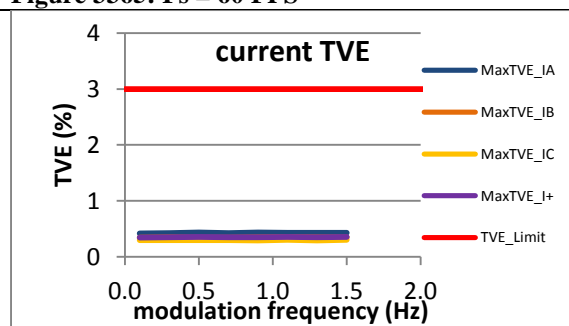


Figure 3368:  $F_s = 15$  FPS

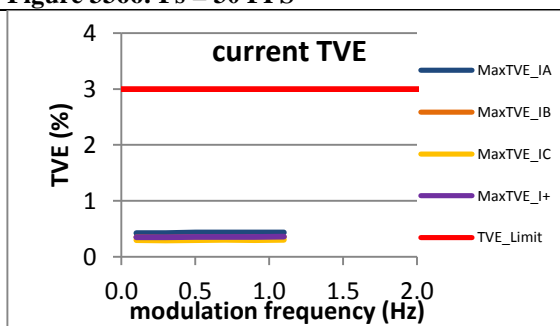


Figure 3369:  $F_s = 12$  FPS

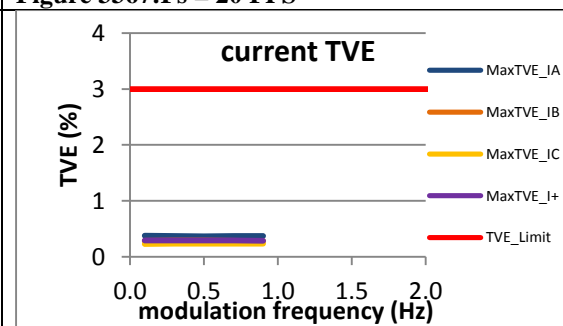


Figure 3370:  $F_s = 10$  FPS

### 7.6.3 PMU B dynamic bandwidth measurement: phase modulation current TVE: P class

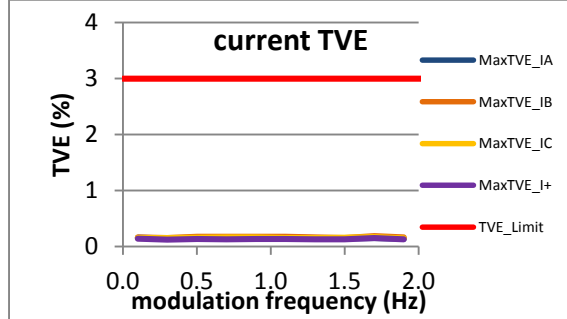


Figure 3371:  $F_s = 60$  FPS

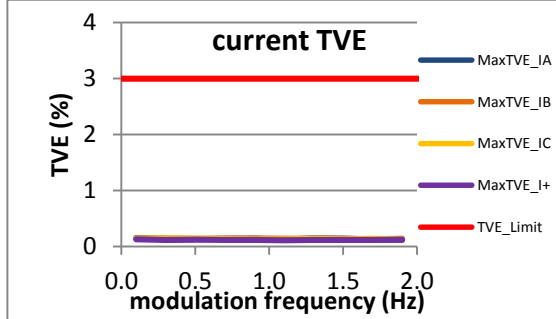


Figure 3372:  $F_s = 30$  FPS

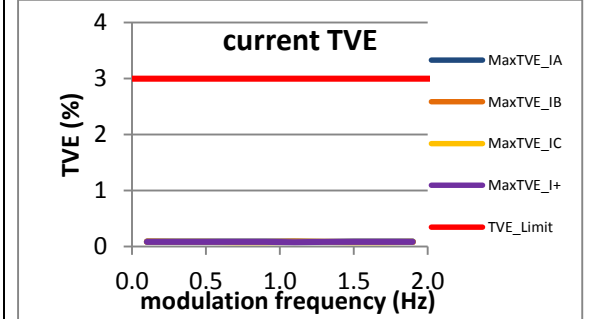


Figure 3373:  $F_s = 20$  FPS

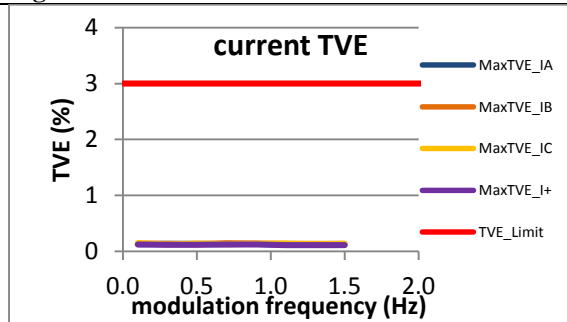


Figure 3374:  $F_s = 15$  FPS

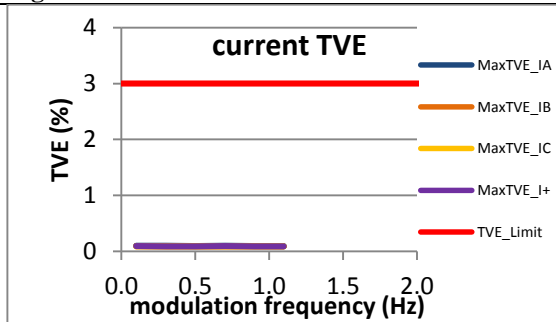


Figure 3375:  $F_s = 12$  FPS

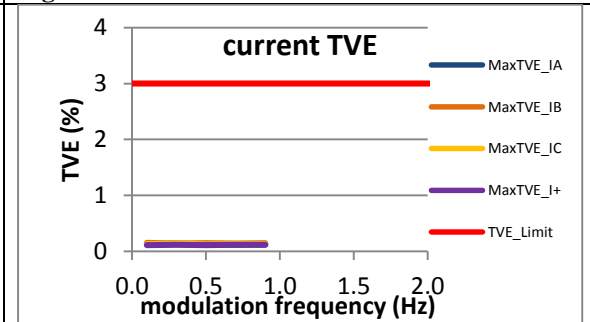


Figure 3376:  $F_s = 10$  FPS

#### 7.6.4 PMU C dynamic bandwidth measurement: phase modulation current TVE: P class

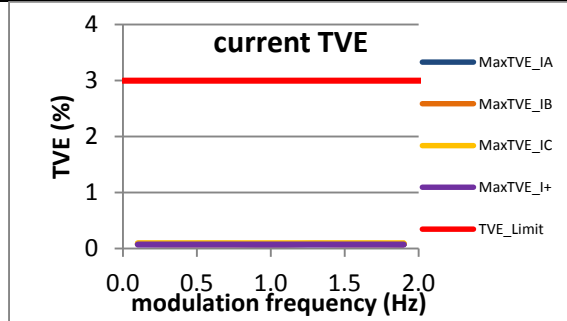


Figure 3377:  $F_s = 60$  FPS

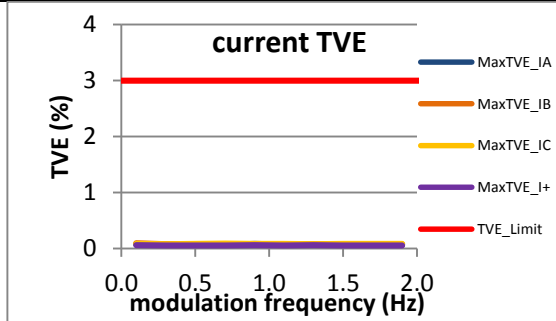


Figure 3378:  $F_s = 30$  FPS

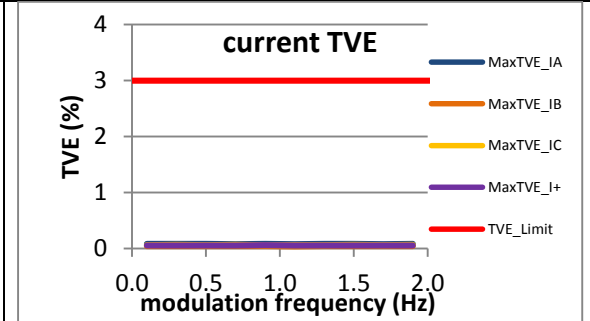


Figure 3379:  $F_s = 20$  FPS

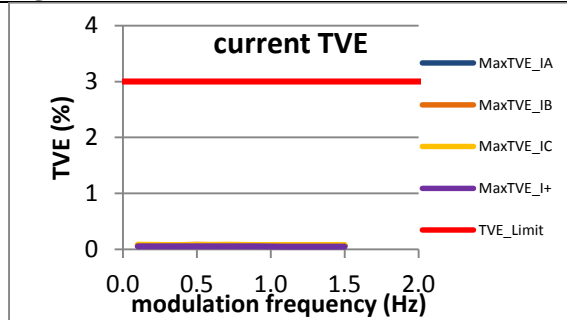


Figure 3380:  $F_s = 15$  FPS

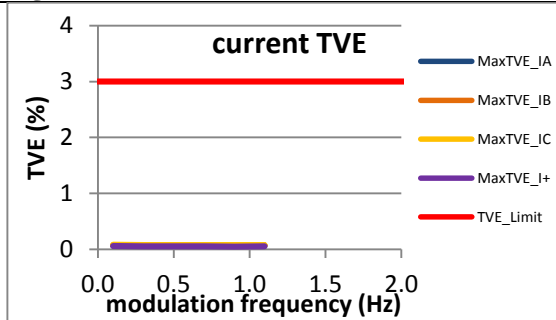


Figure 3381:  $F_s = 12$  FPS

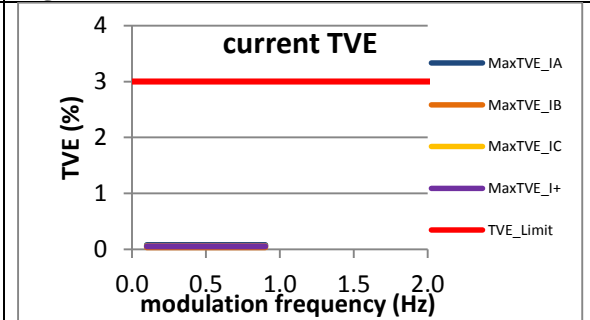


Figure 3382:  $F_s = 10$  FPS

### 7.6.5 PMU D dynamic bandwidth measurement: phase modulation current TVE: P class

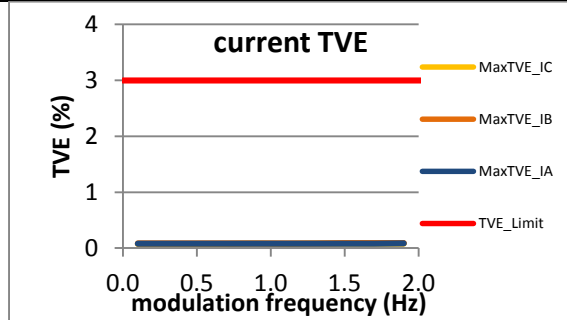


Figure 3383:  $F_s = 60$  FPS

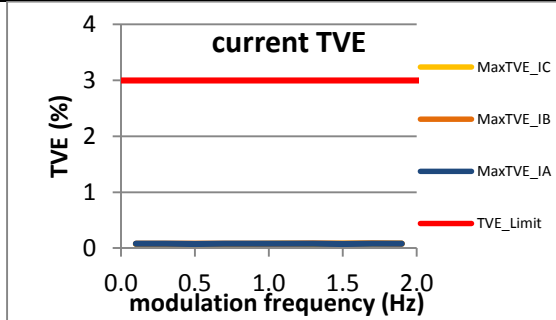


Figure 3384:  $F_s = 30$  FPS

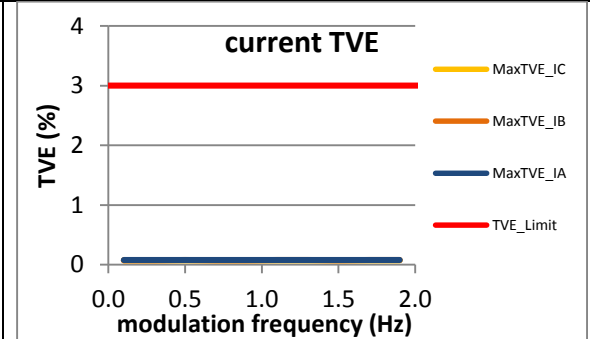


Figure 3385:  $F_s = 20$  FPS

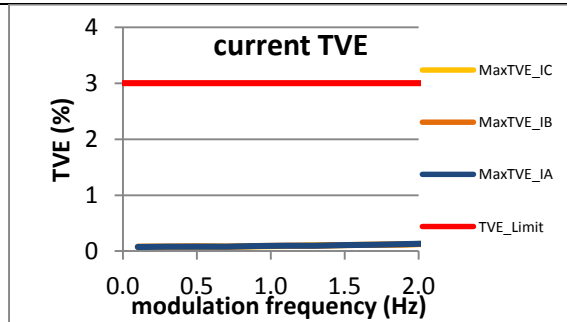


Figure 3386:  $F_s = 15$  FPS

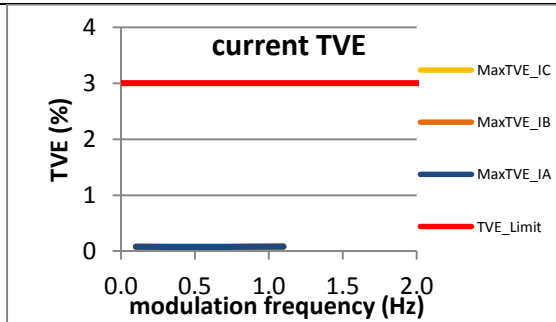


Figure 3387:  $F_s = 12$  FPS

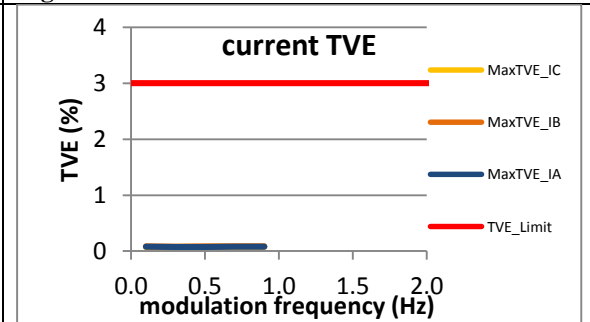
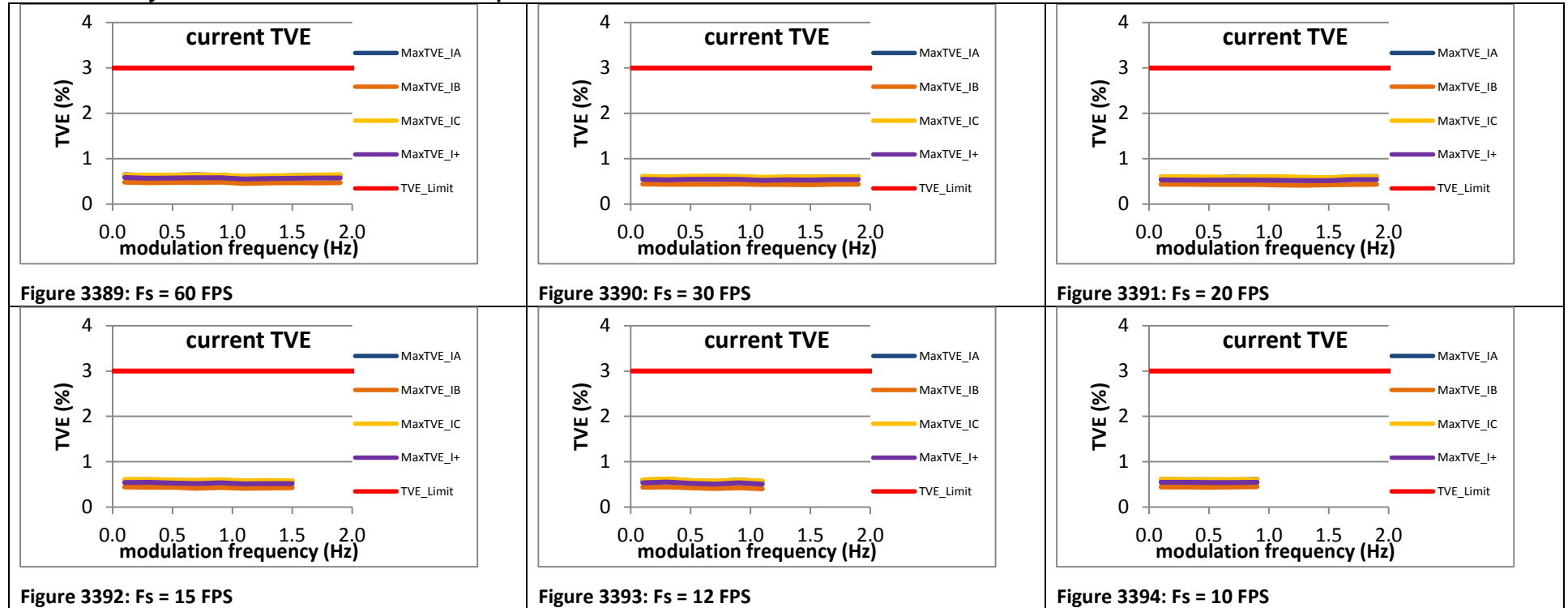


Figure 3388:  $F_s = 10$  FPS

### 7.6.6 PMU E dynamic bandwidth measurement: phase modulation current TVE: P class

PMU E does not support P class

### 7.6.7 PMU F dynamic bandwidth measurement: phase modulation current TVE: P class



### 7.6.8 PMU G dynamic bandwidth measurement: phase modulation current TVE: P class

PMU G does not support P class

### 7.6.9 PMU H dynamic bandwidth measurement: phase modulation current TVE: P class

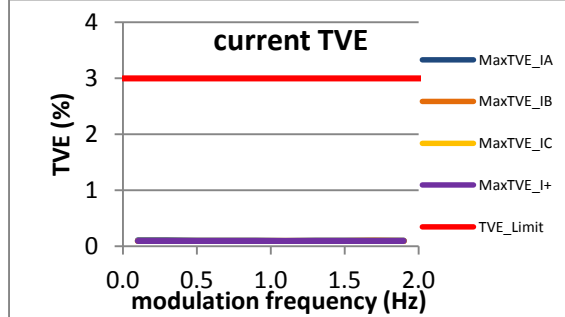


Figure 3395:  $F_s = 60$  FPS

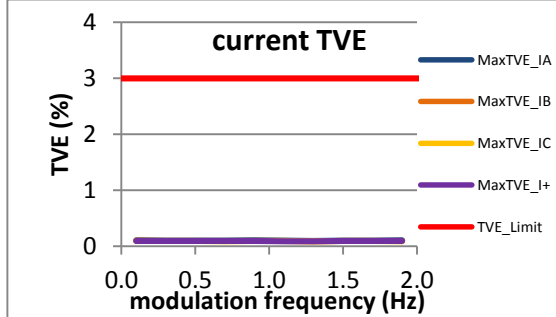


Figure 3396:  $F_s = 30$  FPS

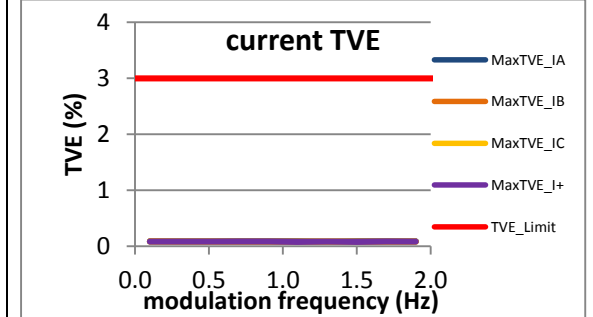


Figure 3397:  $F_s = 20$  FPS

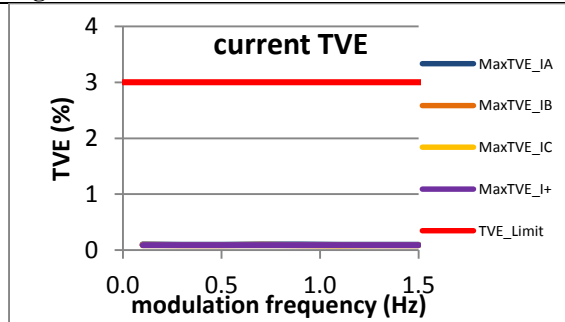


Figure 3398:  $F_s = 15$  FPS

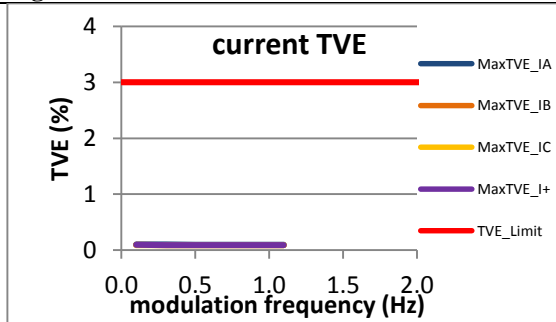


Figure 3399:  $F_s = 12$  FPS

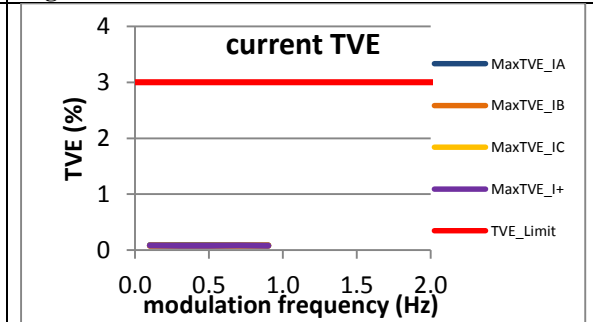


Figure 3400:  $F_s = 10$  FPS

### 7.6.10 PMU I dynamic bandwidth measurement: phase modulation current TVE: P class

PMU I does not support P class

### 7.6.11 PMU J dynamic bandwidth measurement: phase modulation current TVE: P class

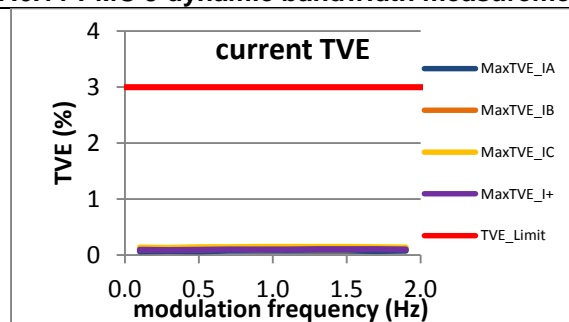


Figure 3401:  $F_s = 60$  FPS

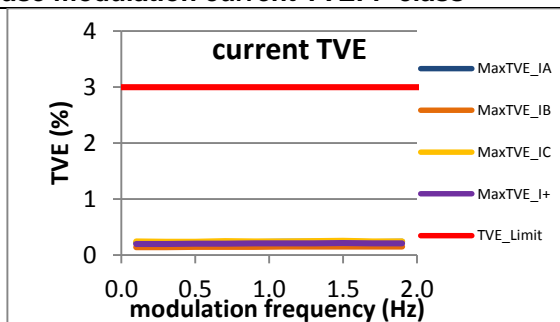


Figure 3402:  $F_s = 30$  FPS

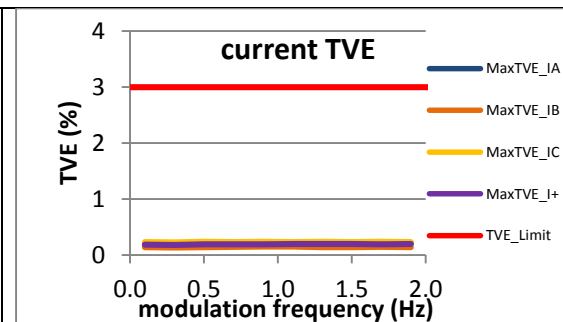


Figure 3403:  $F_s = 20$  FPS

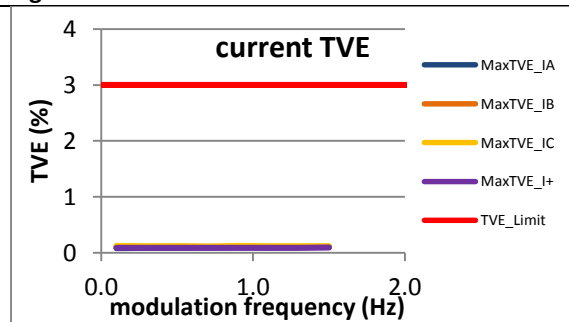


Figure 3404:  $F_s = 15$  FPS

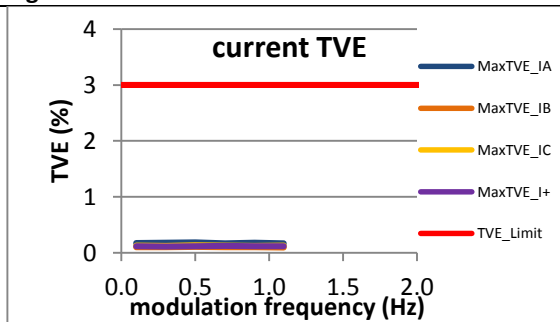


Figure 3405:  $F_s = 12$  FPS

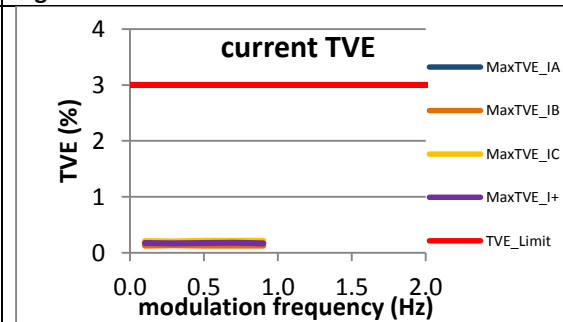
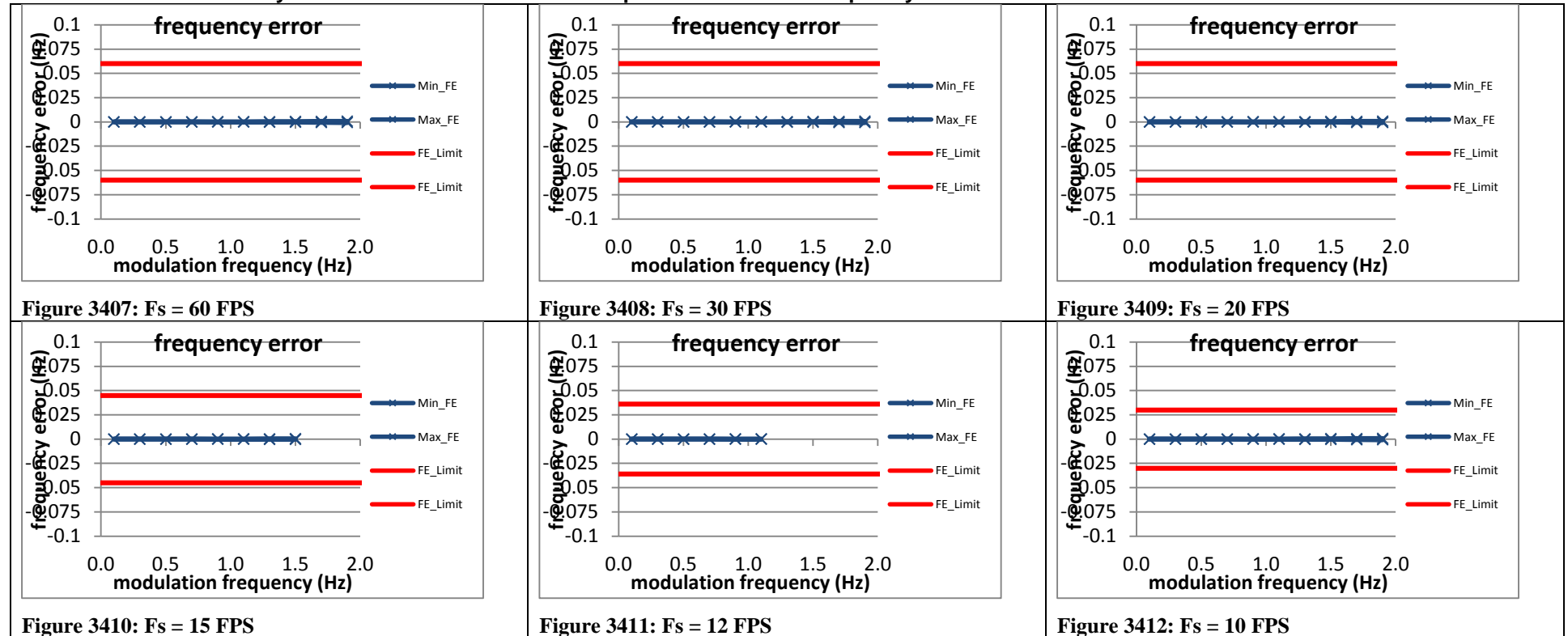


Figure 3406:  $F_s = 10$  FPS

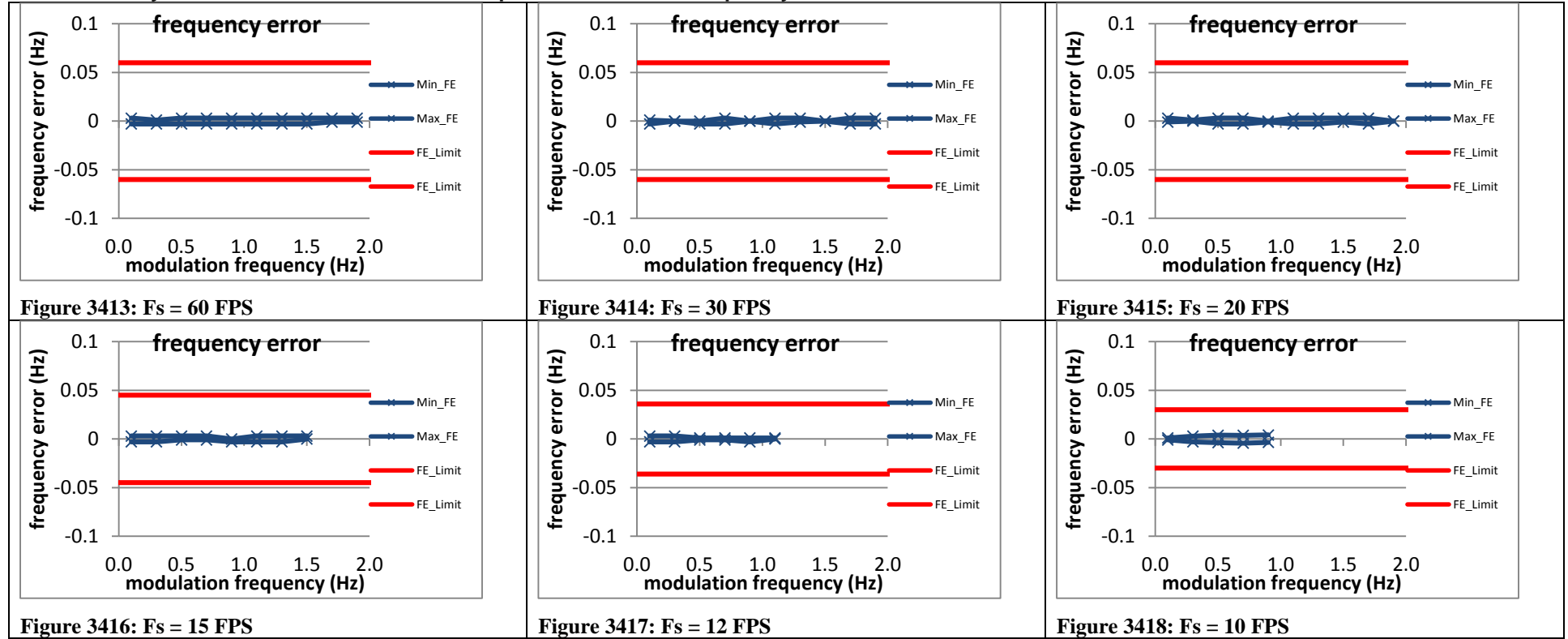


## 7.7 Dynamic bandwidth measurement: phase modulation frequency error: P class

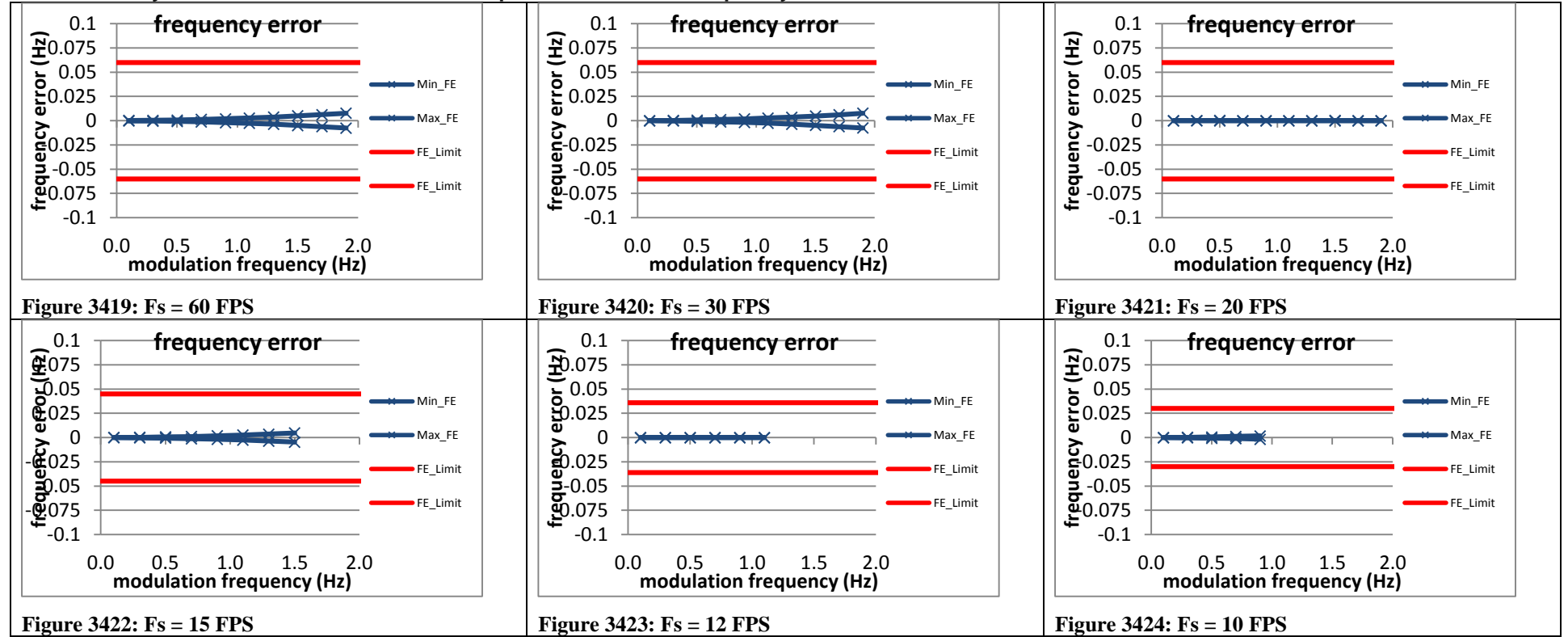
### 7.7.1 C37.118.1 Annex C dynamic bandwidth measurement: phase modulation frequency error: P class



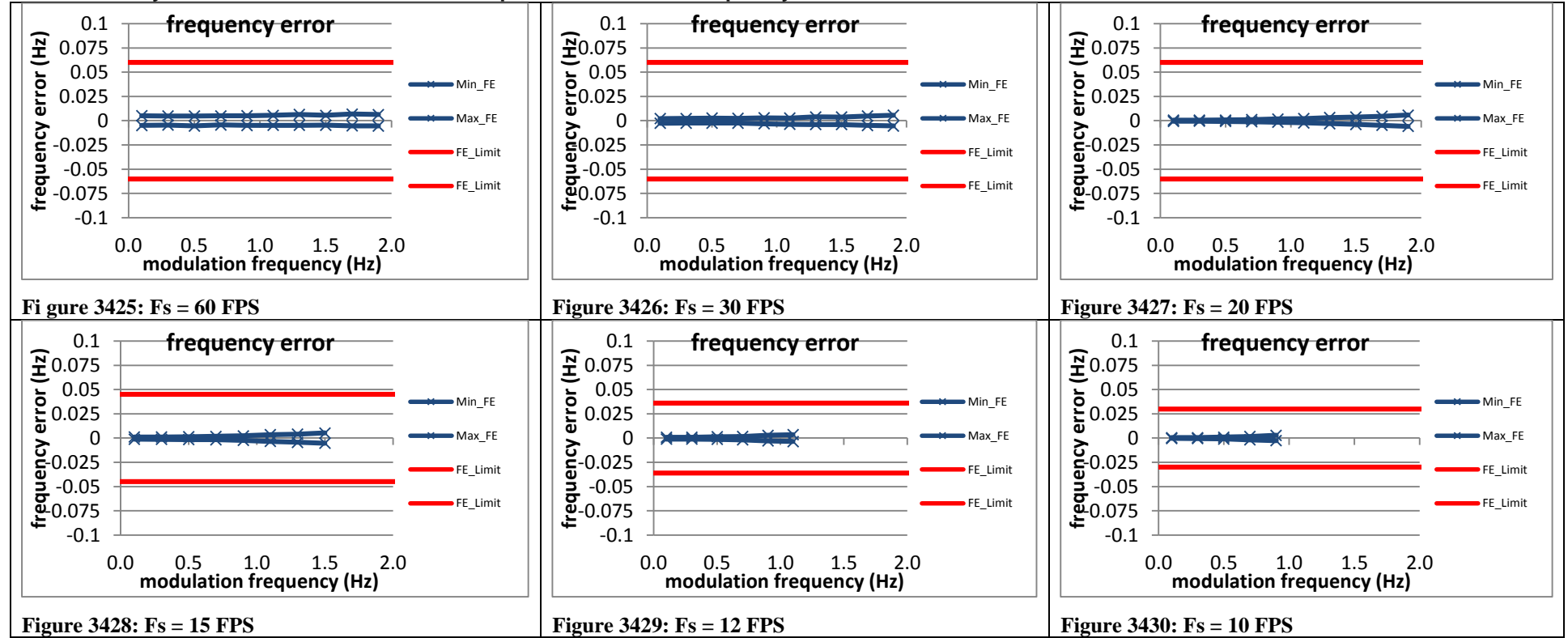
### 7.7.2 PMU A dynamic bandwidth measurement: phase modulation frequency error: P class



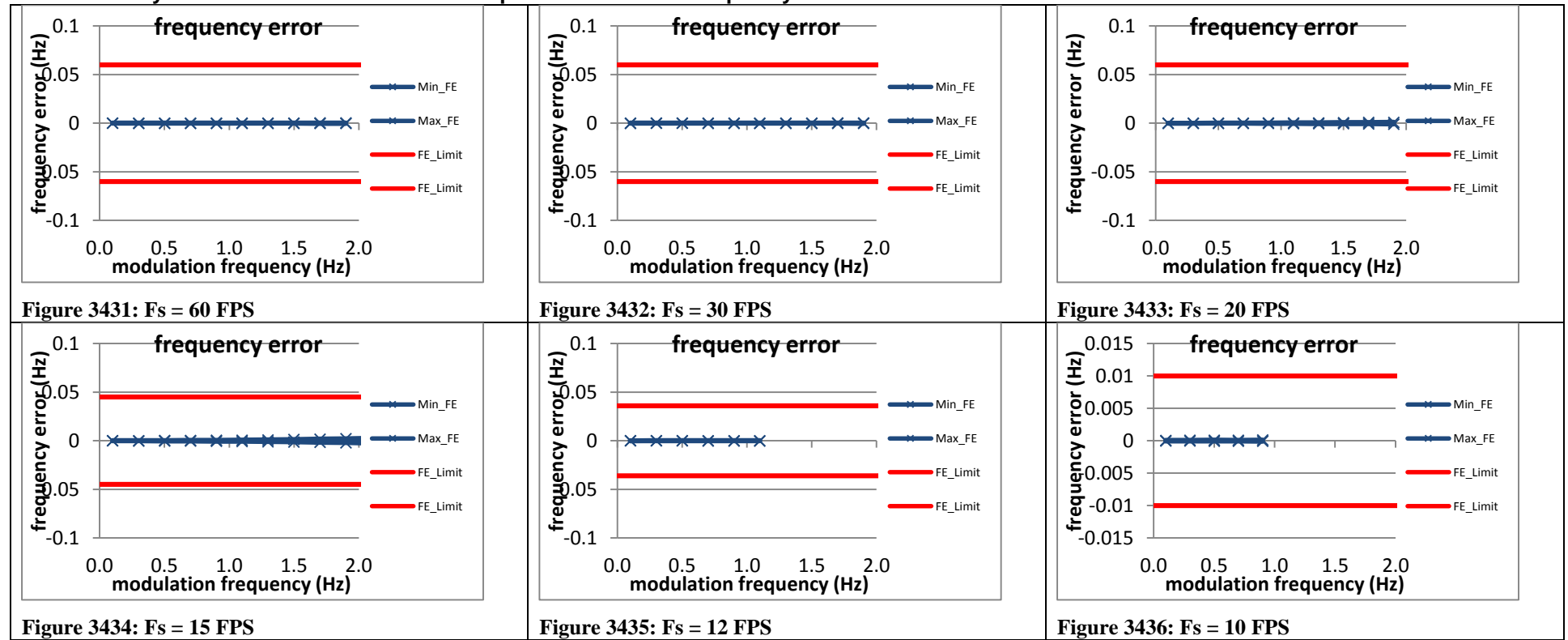
### 7.7.3 PMU B dynamic bandwidth measurement: phase modulation frequency error: P class



#### 7.7.4 PMU C dynamic bandwidth measurement: phase modulation frequency error: P class



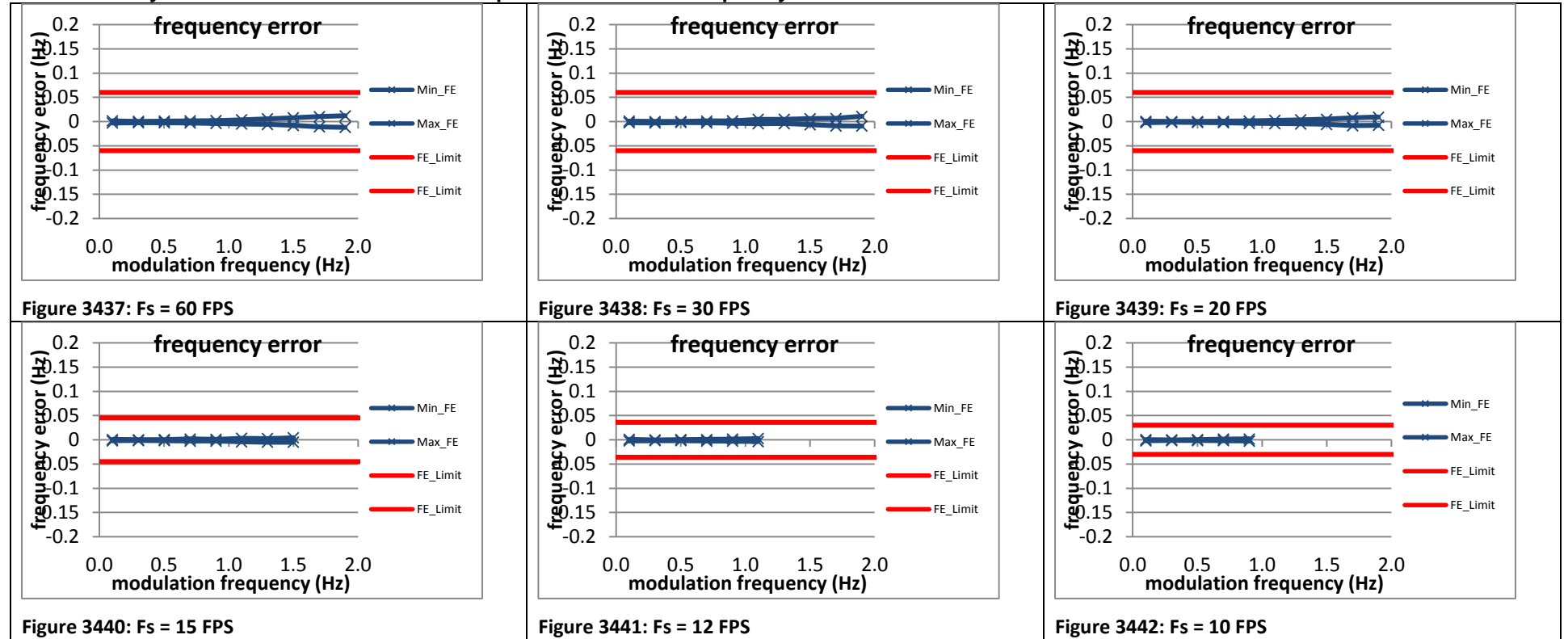
### 7.7.5 PMU D dynamic bandwidth measurement: phase modulation frequency error: P class



### 7.7.6 PMU E dynamic bandwidth measurement: phase modulation frequency error: P class

PMU E does not support P class

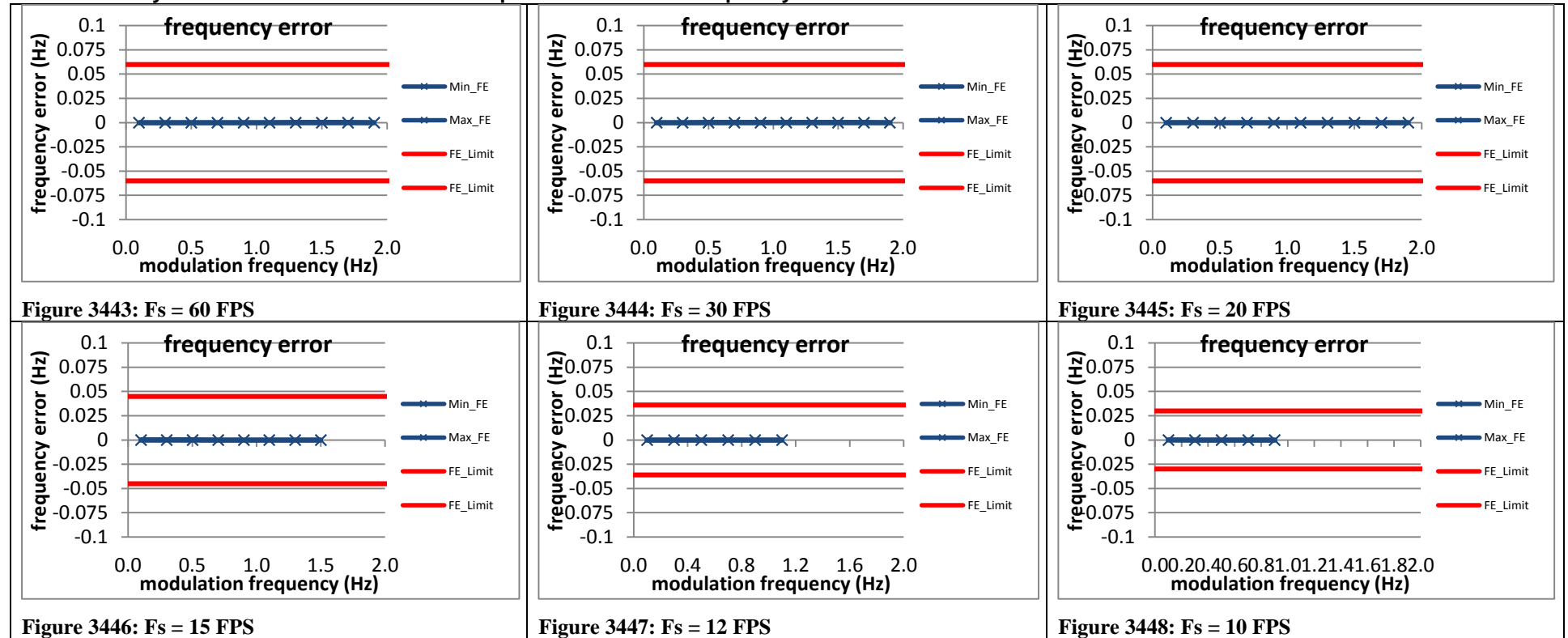
### 7.7.7 PMU F dynamic bandwidth measurement: phase modulation frequency error: P class



### 7.7.8 PMU G dynamic bandwidth measurement: phase modulation frequency error: P class

PMU G does not support P class.

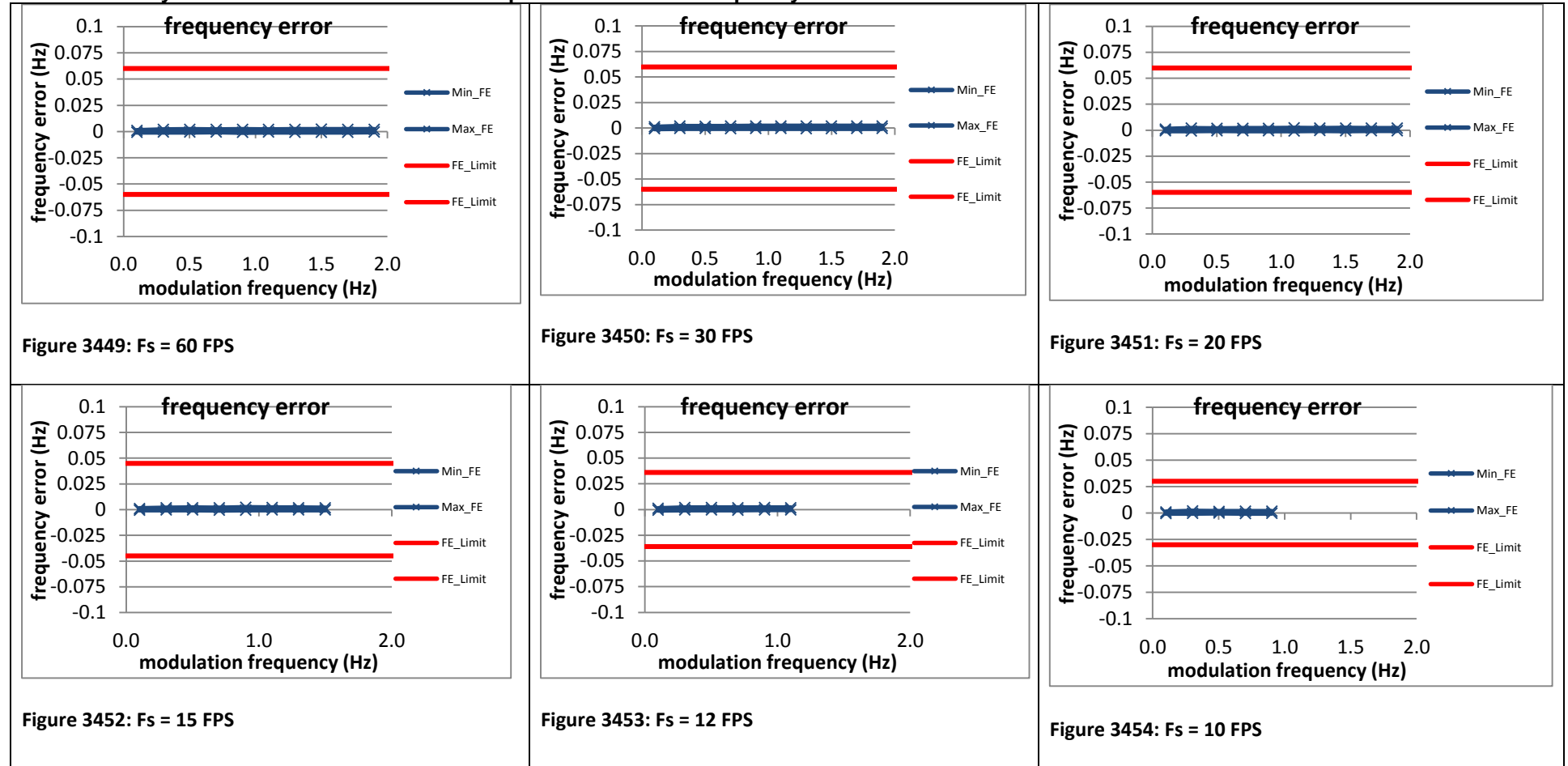
### 7.7.9 PMU H dynamic bandwidth measurement: phase modulation frequency error: P class



### 7.7.10 PMU I dynamic bandwidth measurement: phase modulation frequency error: P class

PMU I does not support P class

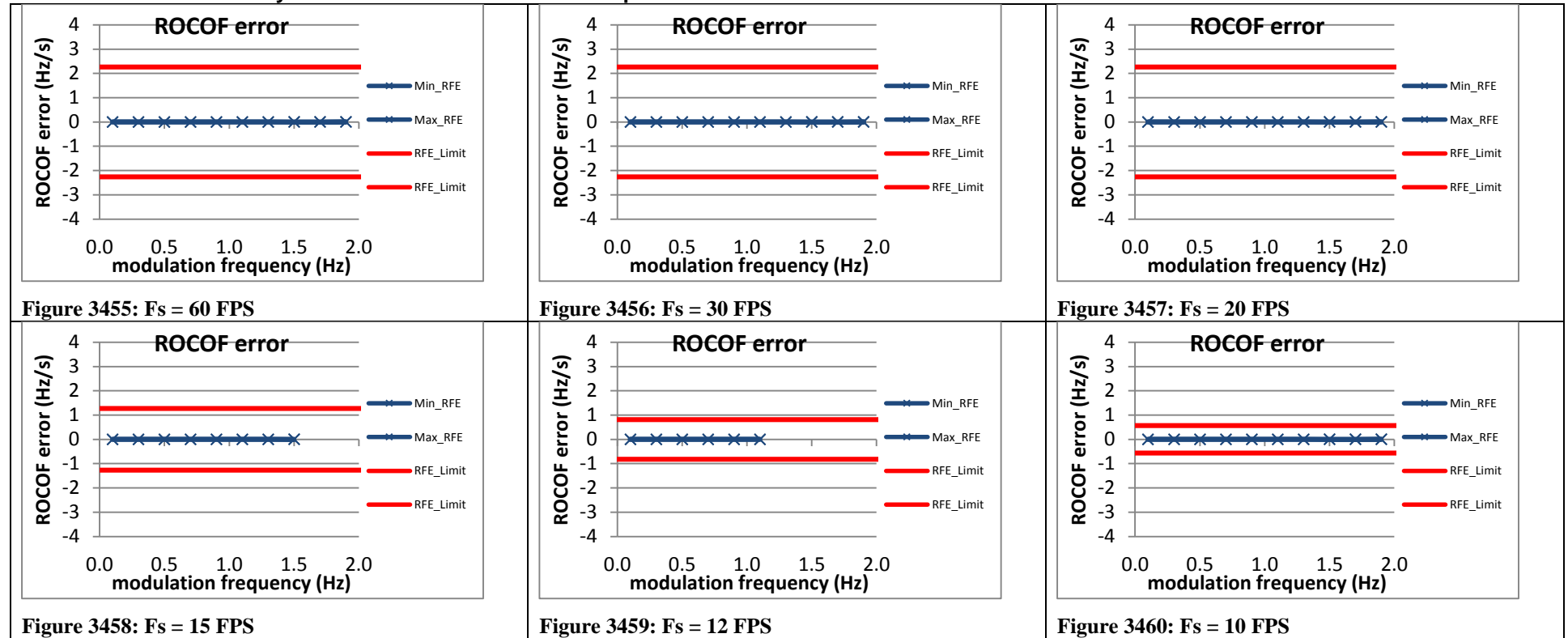
### 7.7.11 PMU J dynamic bandwidth measurement: phase modulation frequency error: P class





## 7.8 Dynamic bandwidth measurement: phase modulation ROCOF error: P class

### 7.8.1 C37.118.1 Annex C dynamic bandwidth measurement: phase modulation ROCOF error: P class



### 7.8.2 PMU A dynamic bandwidth measurement: phase modulation ROCOF error: P class

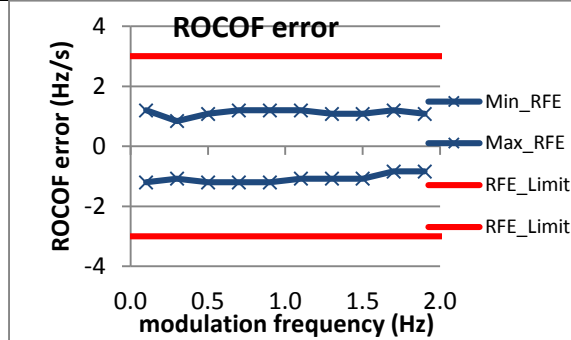


Figure 3461:  $F_s = 60$  FPS

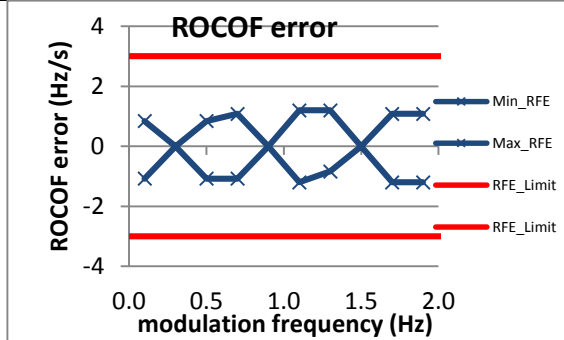


Figure 3462:  $F_s = 30$  FPS

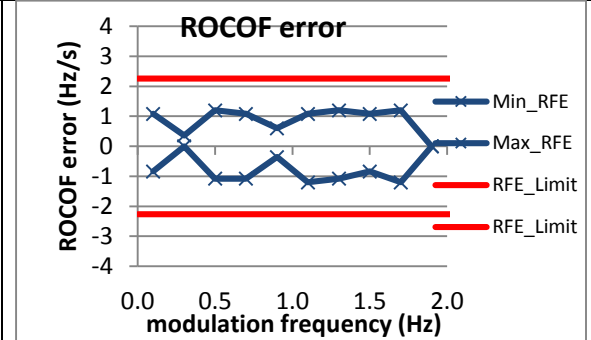


Figure 3463:  $F_s = 20$  FPS

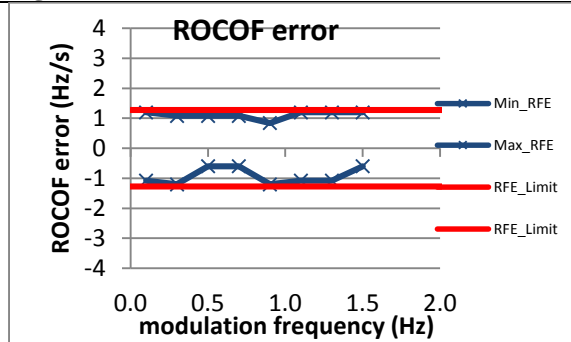


Figure 3464:  $F_s = 15$  FPS

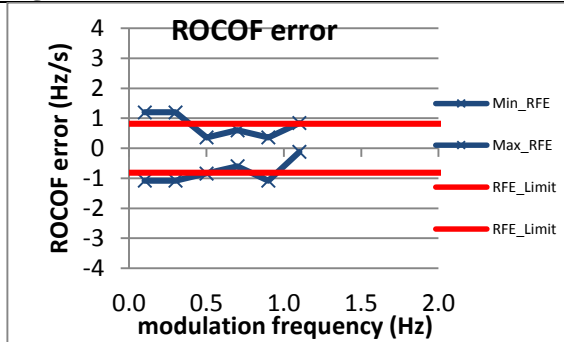


Figure 3465:  $F_s = 12$  FPS

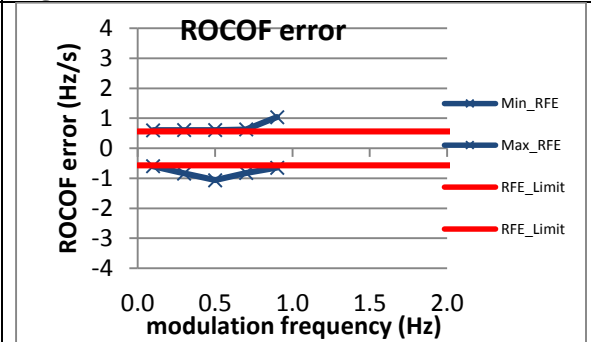
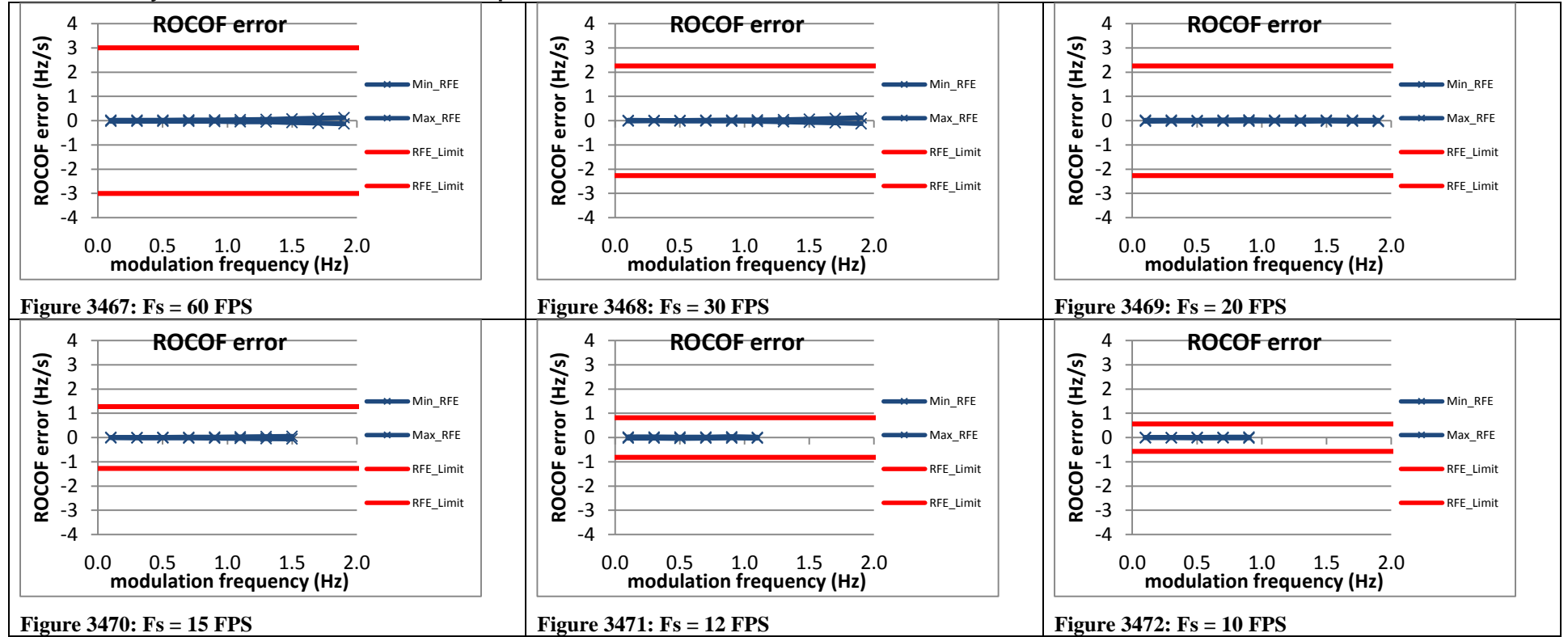


Figure 3466:  $F_s = 10$  FPS

### 7.8.3 PMU B dynamic bandwidth measurement: phase modulation ROCOF error: P class



#### 7.8.4 PMU C dynamic bandwidth measurement: phase modulation ROCOF error: P class

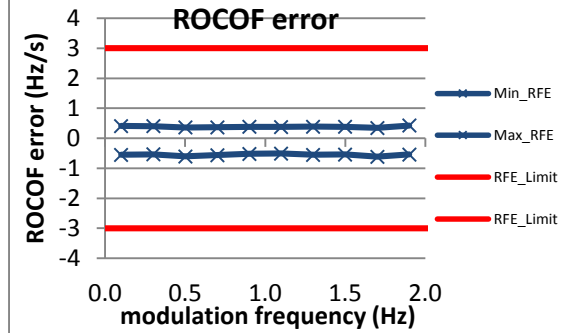


Figure 3473:  $F_s = 60$  FPS

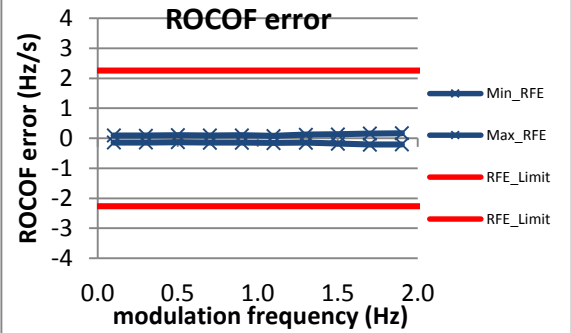


Figure 3474:  $F_s = 30$  FPS

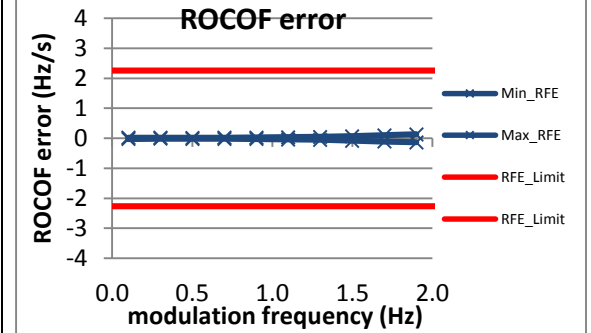


Figure 3475:  $F_s = 20$  FPS

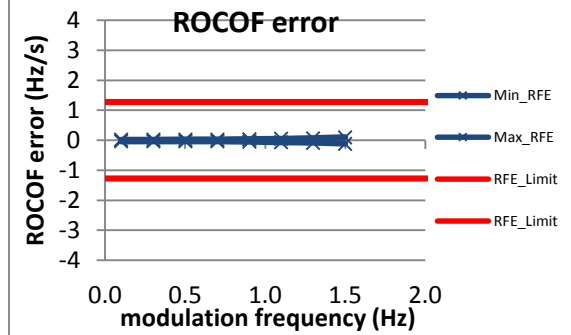


Figure 3476:  $F_s = 15$  FPS

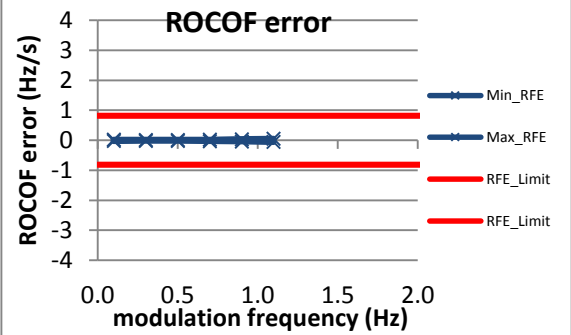


Figure 3477:  $F_s = 12$  FPS

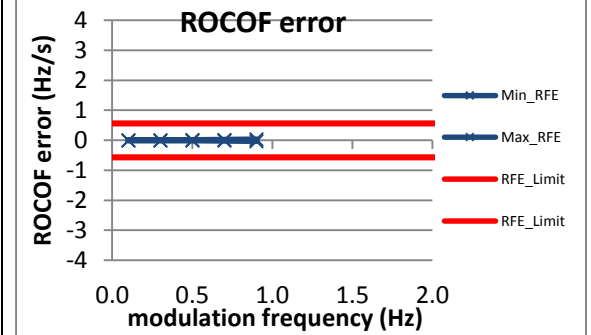
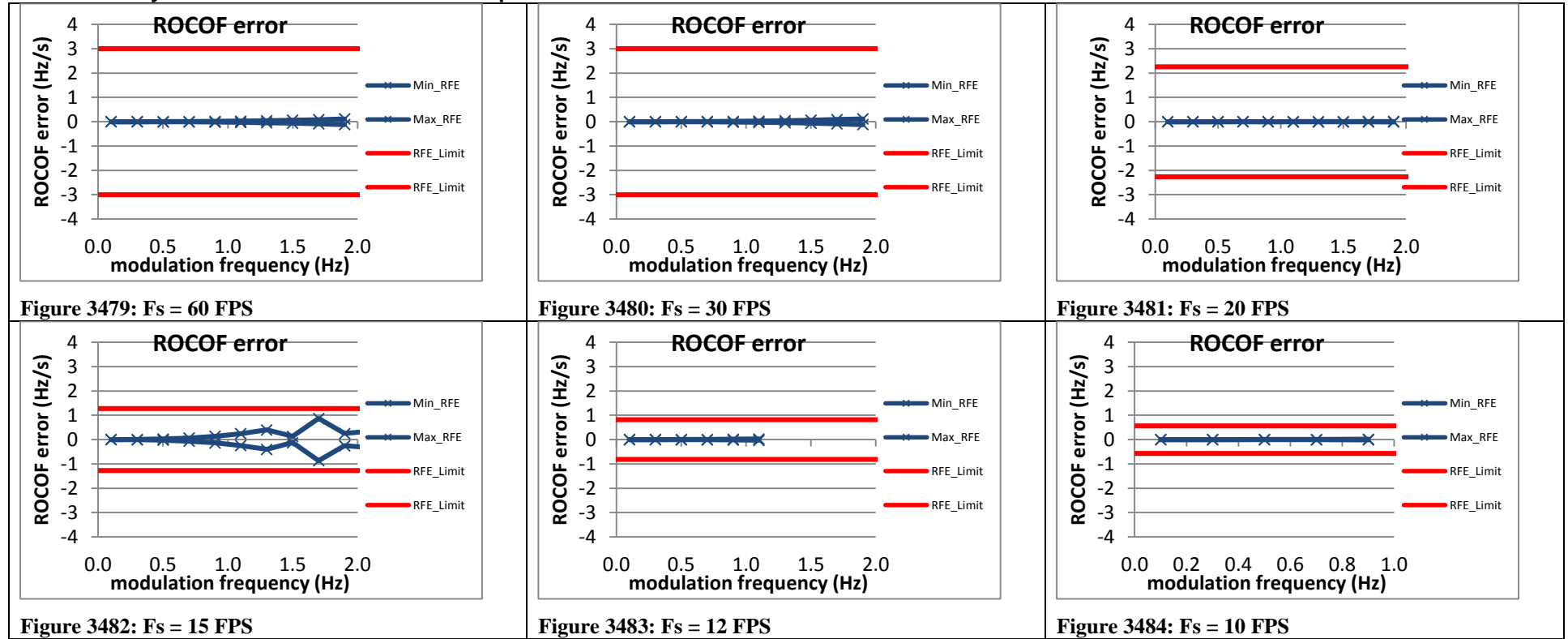


Figure 3478:  $F_s = 10$  FPS

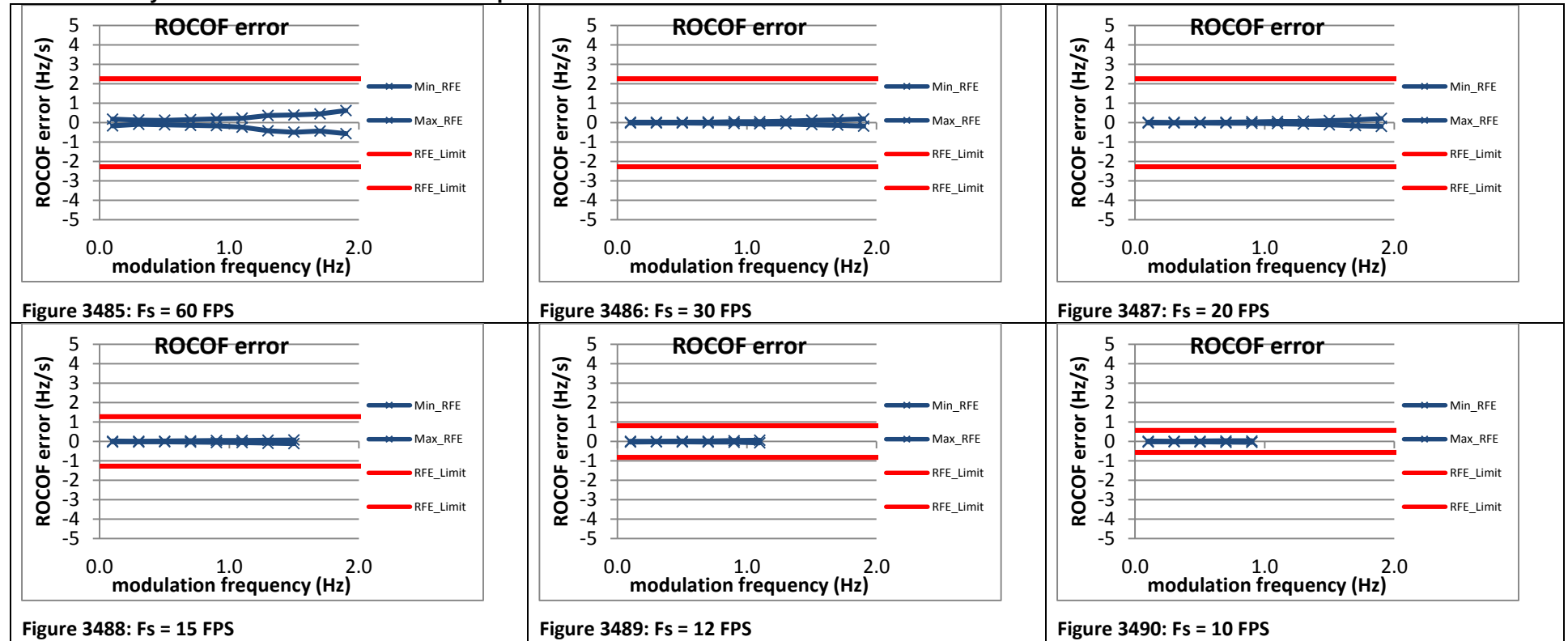
### 7.8.5 PMU D dynamic bandwidth measurement: phase modulation ROCOF error: P class



### 7.8.6 PMU E dynamic bandwidth measurement: phase modulation ROCOF error: P class

PMU E does not support P class

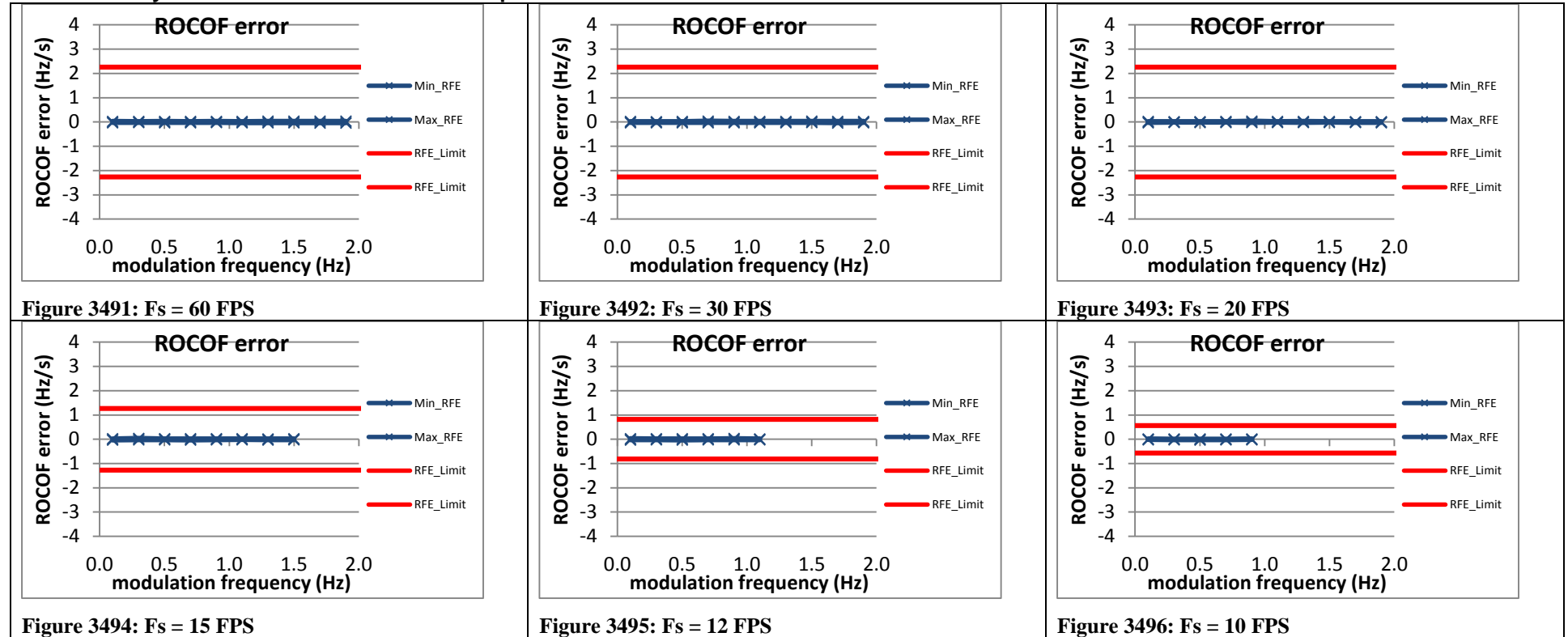
### 7.8.7 PMU F dynamic bandwidth measurement: phase modulation ROCOF error: P class



### 7.8.8 PMU G dynamic bandwidth measurement: phase modulation ROCOF error: P class

PMU G does not support P class

### 7.8.9 PMU H dynamic bandwidth measurement: phase modulation ROCOF error: P class



### 7.8.10 PMU I dynamic bandwidth measurement: phase modulation ROCOF error: P class

PMU I does not support P class

### 7.8.11 PMU J dynamic bandwidth measurement: phase modulation ROCOF error: P class

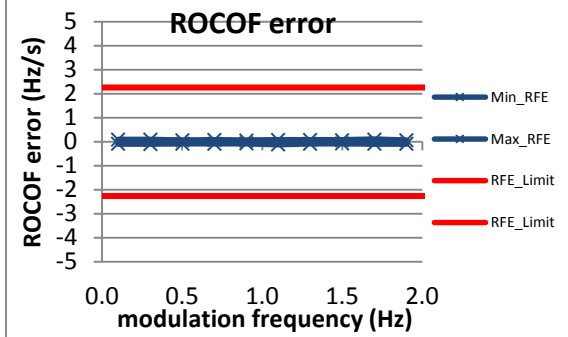


Figure 3497:  $F_s = 60$  FPS

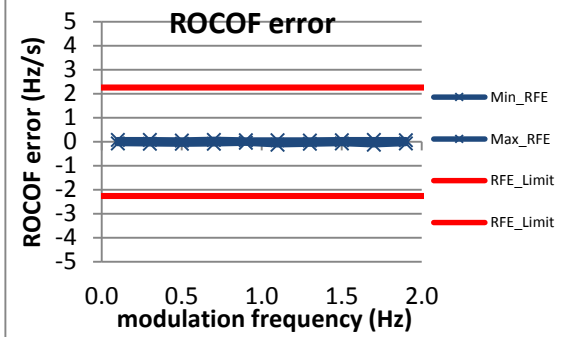


Figure 3498:  $F_s = 30$  FPS

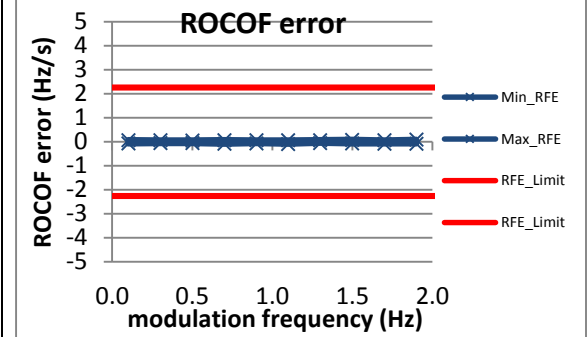


Figure 3499:  $F_s = 20$  FPS

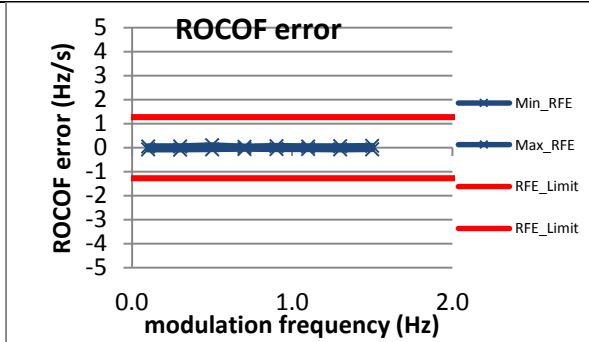


Figure 3500:  $F_s = 15$  FPS

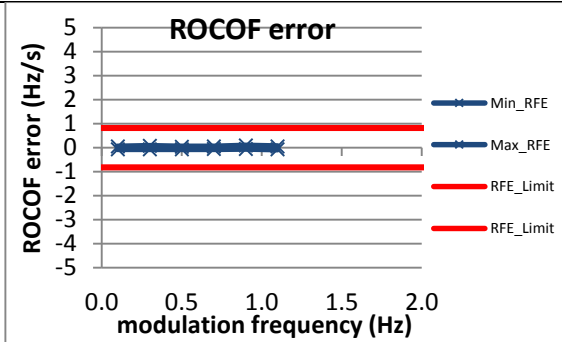


Figure 3501:  $F_s = 12$  FPS

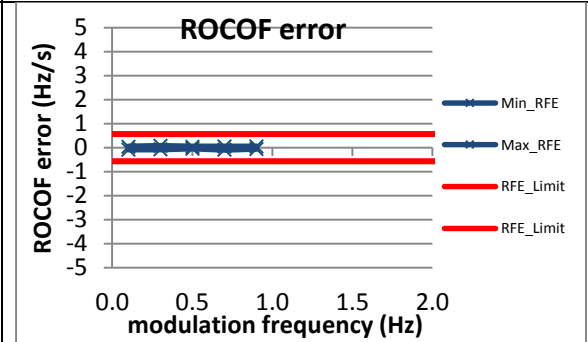


Figure 3502:  $F_s = 10$  FPS



## 8. Dynamic bandwidth measurement: amplitude modulation

8. Dynamic bandwidth measurement: amplitude modulation .....	592
8.1 Amplitude modulation TVE, M class.....	597
8.1.1 C37.118.1 Annex C amplitude modulation voltage TVE: M class .....	597
8.1.2 PMU A amplitude modulation voltage TVE: M class .....	598
8.1.3 PMU B amplitude modulation voltage TVE: M class .....	599
8.1.4 PMU C amplitude modulation voltage TVE: M class .....	600
8.1.5 PMU D amplitude modulation voltage TVE: M class .....	601
8.1.6 PMU E amplitude modulation voltage TVE: M class.....	602
8.1.7 PMU F amplitude modulation voltage TVE: M class.....	603
8.1.8 PMU G amplitude modulation voltage TVE: M class .....	604
8.1.9 PMU H amplitude modulation voltage TVE: M class .....	605
8.1.10 PMU I amplitude modulation voltage TVE: M class .....	606
8.1.11 PMU J amplitude modulation voltage TVE: M class .....	607
8.2 Amplitude modulation current TVE: M class.....	608
8.2.1 C37.118.1 Annex C amplitude modulation current TVE: M class .....	608
8.2.2 PMU A amplitude modulation current TVE: M class .....	609
8.2.3 PMU B amplitude modulation current TVE: M class .....	610
8.2.4 PMU C amplitude modulation current TVE: M class .....	611
8.2.5 PMU D amplitude modulation current TVE: M class .....	612
8.2.6 PMU E amplitude modulation current TVE: M class .....	613
8.2.7 PMU F amplitude modulation current TVE: M class.....	614
8.2.8 PMU G amplitude modulation current TVE: M class .....	615
8.2.9 PMU H amplitude modulation current TVE: M class .....	616
8.2.10 PMU I amplitude modulation current TVE: M class .....	617
8.2.11 PMU J amplitude modulation current TVE: M class .....	618
8.3 Amplitude modulation frequency error: M class .....	619
8.3.1 C37.118.1 Annex C amplitude modulation frequency error: M class.....	619
8.3.2 PMU A amplitude modulation frequency error: M class.....	620
8.3.3 PMU B amplitude modulation frequency error: M class.....	621
8.3.4 PMU C amplitude modulation frequency error: M class.....	622
8.3.5 PMU D amplitude modulation frequency error: M class .....	623
8.3.6 PMU E amplitude modulation frequency error: M class .....	624
8.3.7 PMU F amplitude modulation frequency error: M class .....	625
8.3.8 PMU G amplitude modulation frequency error: M class .....	626
8.3.9 PMU H amplitude modulation frequency error: M class .....	627
8.3.10 PMU I amplitude modulation frequency error: M class .....	628
8.3.11 PMU J amplitude modulation frequency error: M class.....	629
8.4 Amplitude modulation ROCOF error: M class .....	630

8.4.1 C37.118.1 Annex C amplitude modulation ROCOF error: M class.....	630
8.4.2 PMU A amplitude modulation ROCOF error: M class.....	631
8.4.3 PMU B amplitude modulation ROCOF error: M class.....	632
8.4.4 PMU C amplitude modulation ROCOF error: M class.....	633
8.4.5 PMU D amplitude modulation ROCOF error: M class .....	634
8.4.6 PMU E amplitude modulation ROCOF error: M class.....	635
8.4.7 PMU F amplitude modulation ROCOF error: M class.....	636
8.4.8 PMU G * amplitude modulation ROCOF error: M class .....	637
8.4.9 PMU H amplitude modulation ROCOF error: M class .....	638
8.4.10 PMU I amplitude modulation ROCOF error: M class.....	639
8.4.11 PMU J amplitude modulation ROCOF error: M class.....	640
8.5 Dynamic bandwidth measurement: amplitude modulation voltage TVE: P class.....	641
8.5.1 C37.118.1 Annex C dynamic bandwidth measurement: amplitude modulation voltage TVE: P class .....	641
8.5.2 PMU A dynamic bandwidth measurement: amplitude modulation voltage TVE: P class .....	642
8.5.3 PMU B dynamic bandwidth measurement: amplitude modulation voltage TVE: P class .....	643
8.5.4 PMU C dynamic bandwidth measurement: amplitude modulation voltage TVE: P class .....	644
8.5.5 PMU D dynamic bandwidth measurement: amplitude modulation voltage TVE: P class .....	645
8.5.6 PMU E dynamic bandwidth measurement: amplitude modulation voltage TVE: P class .....	645
8.5.7 PMU F dynamic bandwidth measurement: amplitude modulation voltage TVE: P class.....	646
8.5.8 PMU G dynamic bandwidth measurement: amplitude modulation voltage TVE: P class.....	646
8.5.9 PMU H dynamic bandwidth measurement: amplitude modulation voltage TVE: P class.....	647
8.5.10 PMU I dynamic bandwidth measurement: amplitude modulation voltage TVE: P class .....	647
8.5.11 PMU J dynamic bandwidth measurement: amplitude modulation voltage TVE: P class .....	648
8.6 Dynamic bandwidth measurement: amplitude modulation current TVE: P class .....	649
8.6.1 C37.118.1 Annex C dynamic bandwidth measurement: amplitude modulation current TVE: P class .....	649
8.6.2 PMU A dynamic bandwidth measurement: amplitude modulation current TVE: P class .....	650
8.6.3 PMU B dynamic bandwidth measurement: amplitude modulation current TVE: P class .....	651
8.6.4 PMU C dynamic bandwidth measurement: amplitude modulation current TVE: P class .....	652
8.6.5 PMU D dynamic bandwidth measurement: amplitude modulation current TVE: P class .....	653
8.6.6 PMU E dynamic bandwidth measurement: amplitude modulation current TVE: P class .....	653
8.6.7 PMU F dynamic bandwidth measurement: amplitude modulation current TVE: P class.....	654
8.6.8 PMU G dynamic bandwidth measurement: amplitude modulation current TVE: P class.....	654
8.6.9 PMU H dynamic bandwidth measurement: amplitude modulation current TVE: P class.....	655
8.6.10 PMU I dynamic bandwidth measurement: amplitude modulation current TVE: P class .....	655
8.6.11 PMU J dynamic bandwidth measurement: amplitude modulation current TVE: P class .....	655
8.7 Dynamic bandwidth measurement: amplitude modulation frequency error: P class.....	656
8.7.1 C37.118.1 Annex C dynamic bandwidth measurement: amplitude modulation frequency error: P class.....	656
8.7.2 PMU A dynamic bandwidth measurement: amplitude modulation frequency error: P class.....	657
8.7.3 PMU B dynamic bandwidth measurement: amplitude modulation frequency error: P class.....	658
8.7.4 PMU C dynamic bandwidth measurement: amplitude modulation frequency error: P class.....	659
8.7.5 PMU D dynamic bandwidth measurement: amplitude modulation frequency error: P class.....	660

8.7.6 PMU E dynamic bandwidth measurement: amplitude modulation frequency error: P class .....	660
8.7.7 PMU F dynamic bandwidth measurement: amplitude modulation frequency error: P class .....	661
8.7.8 PMU G dynamic bandwidth measurement: amplitude modulation frequency error: P class .....	661
8.7.9 PMU H dynamic bandwidth measurement: amplitude modulation frequency error: P class .....	662
8.7.10 PMU I dynamic bandwidth measurement: amplitude modulation frequency error: P class .....	662
8.7.11 PMU J dynamic bandwidth measurement: amplitude modulation frequency error: P class.....	663
8.8 dynamic bandwidth measurement: amplitude modulation ROCOF error: P class .....	664
8.8.1 C37.118.1 Annex C dynamic bandwidth measurement: amplitude modulation ROCOF error: P class .....	664
8.8.2 PMU A dynamic bandwidth measurement: amplitude modulation ROCOF error: P class.....	665
8.8.3 PMU B dynamic bandwidth measurement: amplitude modulation ROCOF error: P class.....	666
8.8.4 PMU C dynamic bandwidth measurement: amplitude modulation ROCOF error: P class.....	667
8.8.5 PMU D dynamic bandwidth measurement: amplitude modulation ROCOF error: P class .....	668
8.8.6 PMU E dynamic bandwidth measurement: amplitude modulation ROCOF error: P class .....	668
8.8.7 PMU F dynamic bandwidth measurement: amplitude modulation ROCOF error: P class .....	669
8.8.8 PMU G dynamic bandwidth measurement: amplitude modulation ROCOF error: P class .....	669
8.8.9 PMU H dynamic bandwidth measurement: amplitude modulation ROCOF error: P class .....	670
8.8.10 PMU I dynamic bandwidth measurement: amplitude modulation ROCOF error: P class.....	670
8.8.11 PMU J dynamic bandwidth measurement: amplitude modulation ROCOF error: P class.....	671

The measurement bandwidth tests apply modulated input signals to the PMU to ensure that the in-band performance is within limits. The amplitude modulation tests are a series of individual dynamic tests where the input signal amplitude is modulated at a 10% index of modulation. Individual tests are run with 0.2 Hz modulation frequency increments beginning at 0.1 Hz until the modulation frequency has reached the lesser of  $F_s/5$  Hz or 5 Hz for M class and 2 Hz for P class PMUs.

The maximum TVE, Fe and RFe of all tests are compared against the limits for TVE, Fe, and RFe to determine if the unit passes or fails the test.

C37.118.1-2011 amended by C37.118.1a-2014 specifies the limits as:

- max TVE: 3%
- max Fe:
  - M class:  $0.06 \times \min(F_s/5, 5)$
  - P class:  $0.03 \times \min(F_s/10, 2)$
- max RFe:
  - M class:  $0.18 \times \pi \times (\min(F_s/5, 5))^2$
  - P class:  $0.18 \times \pi \times (\min(F_s/10, 2))^2$

The test plan for measurement bandwidth is as follows:

$X_m$  is the peak amplitude of the input signal

$\omega_0$  is the nominal power system frequency in radians/second ( $2\pi F_0$ )

$\omega$  is the modulation frequency in radians/second

$k_x$  is the amplitude modulation index

$k_a$  is the phase angle modulation index

$t$  is time

- a) Begin with phase modulated input at  $\omega/2\pi = 0.1$  Hz,  $k_x = 0.1$ ,  $k_a = 0$ .
- b) Wait for the system to settle.
- c) Capture the PMU output for at least 2 full cycles of modulation or 5 seconds, whichever is greater.
- d) Calculate the errors: TVE, FE, RFE for each report.
- e) Calculate the Max TVE, FE and RFE.
- f) Increase the modulation frequency  $\omega/2\pi$  by 0.2 Hz.
- g) Repeat steps b through f until the upper frequency range limit is reached.

# Results from the dynamic phase modulation tests

Fs (FPS)	10M			10P			12M			12P			15M			15P			20M			20P			30M			30P			60M			60P		
Test	T	FE	RF	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R	T	F	R			
	V			V	E	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	V	E	F	
	E			E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
PMU A	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	P	P	P	P	P	P	
PMU B	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
PMU C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
PMU D	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
PMU E	P	P	P	-	-	-	-	-	-	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-
PMU F	P	P	P	P	P	P	F	P	P	P	P	P	F	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
PMU G*	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	-	-	-	-	-	
PMU H	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
PMU I	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	F	P	P	-	-	-	P	P	P	-	-	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	

P = Pass (measurement is within the limits), F = Fail (measurement is outside the limits), I = Indeterminate (measurement is within the uncertainty of the test instrument of the limits)

\* PMU G ROCOF output is always 0

## 8.1 Amplitude modulation TVE, M class

### 8.1.1 C37.118.1 Annex C amplitude modulation voltage TVE: M class

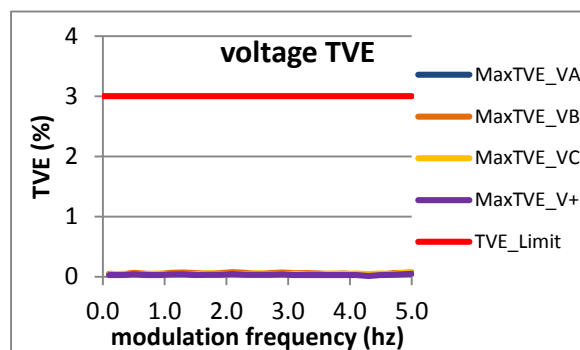


Figure 3503:  $F_s = 60$  FPS

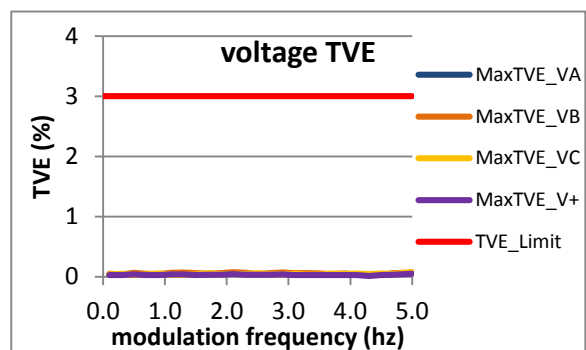


Figure 3504:  $F_s = 30$  FPS

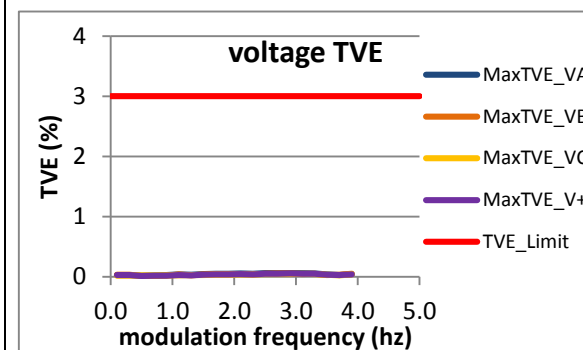


Figure 3505:  $F_s = 20$  FPS

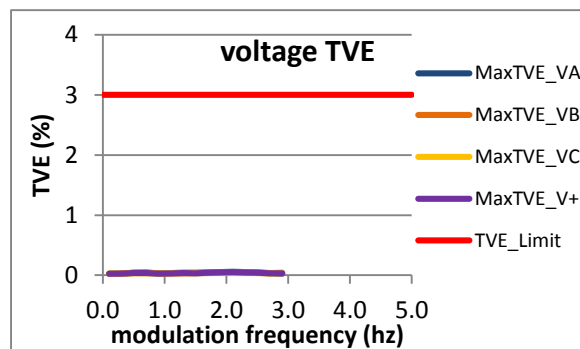


Figure 3506:  $F_s = 15$  FPS

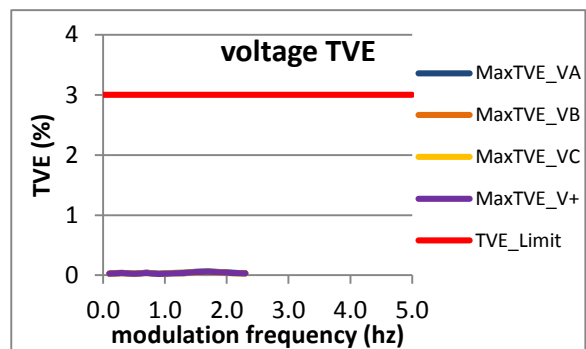


Figure 3507:  $F_s = 12$  FPS

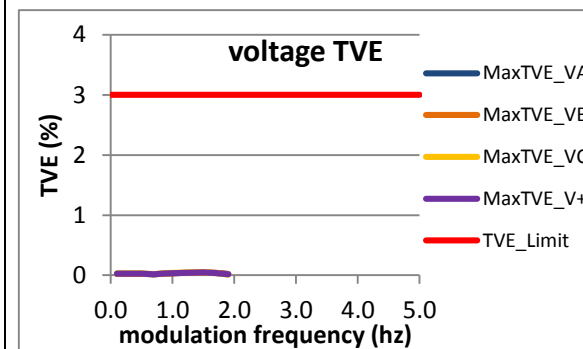


Figure 3508:  $F_s = 10$  FPS

### 8.1.2 PMU A amplitude modulation voltage TVE: M class

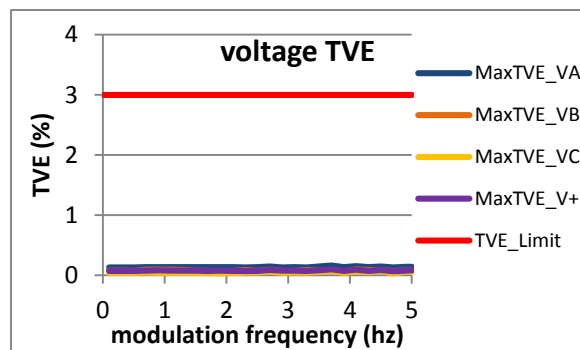


Figure 3509: Fs = 60 FPS

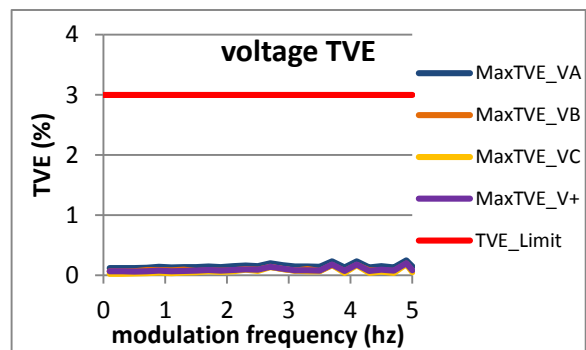


Figure 3510: Fs = 30 FPS

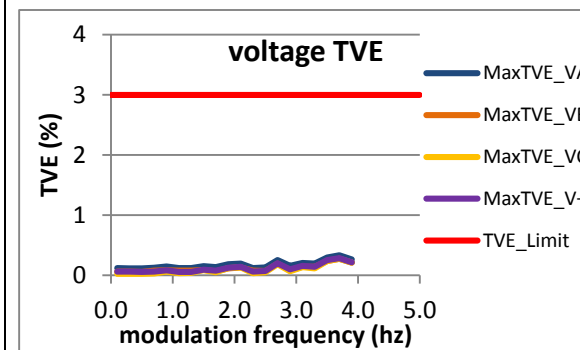


Figure 3511: Fs = 20 FPS

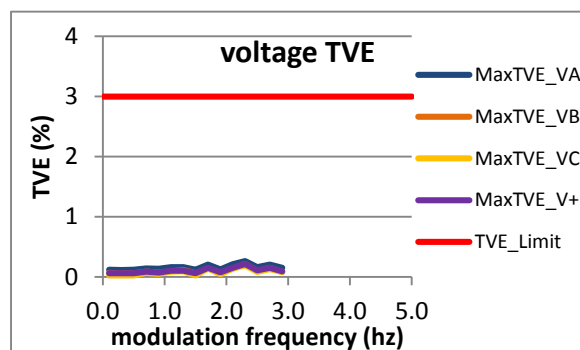


Figure 3512: Fs = 15 FPS

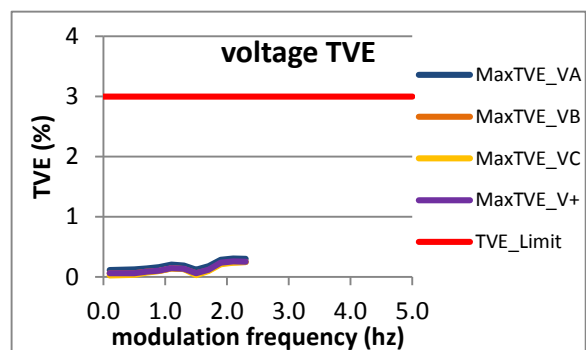


Figure 3513: Fs = 12 FPS

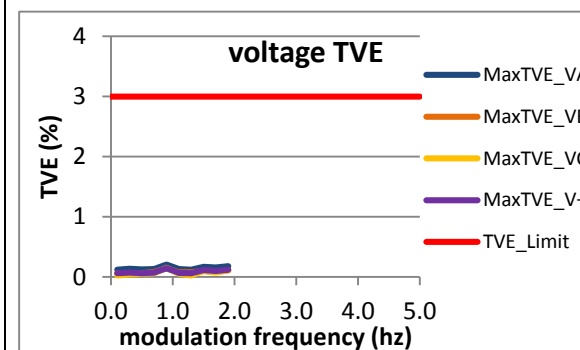


Figure 3514: Fs = 10 FPS

### 8.1.3 PMU B amplitude modulation voltage TVE: M class

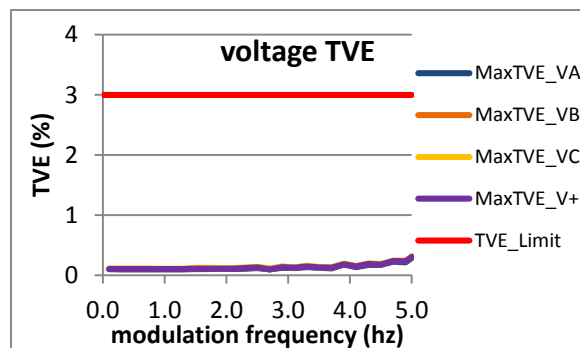


Figure 3515:  $F_s = 60$  FPS

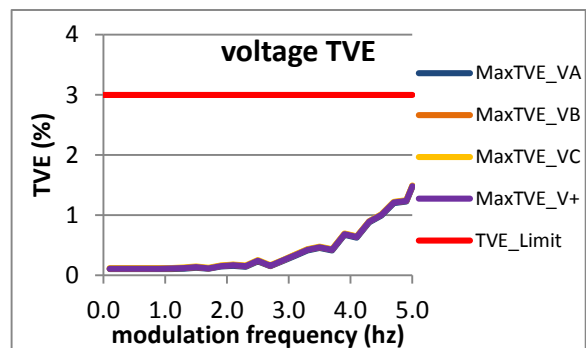


Figure 3516:  $F_s = 30$  FPS

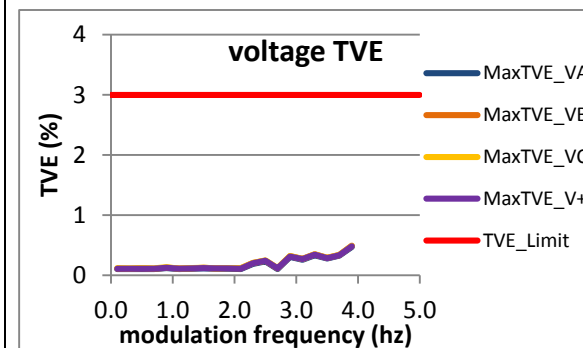


Figure 3517:  $F_s = 20$  FPS

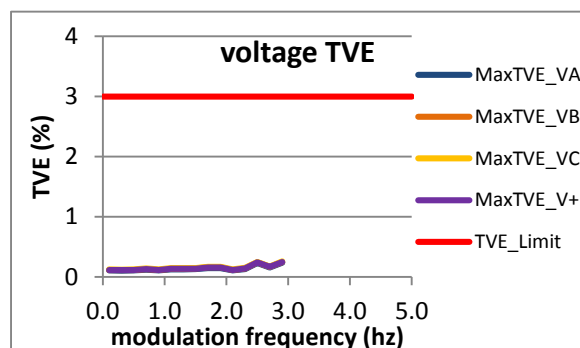


Figure 3518:  $F_s = 15$  FPS

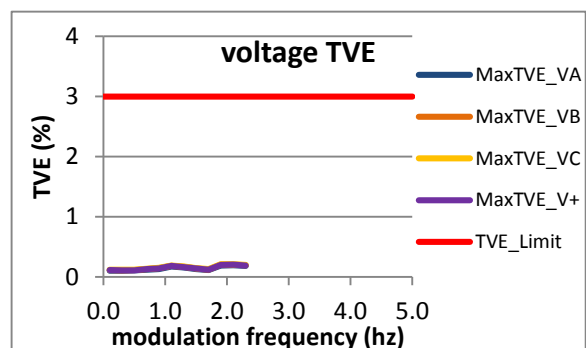


Figure 3519:  $F_s = 12$  FPS

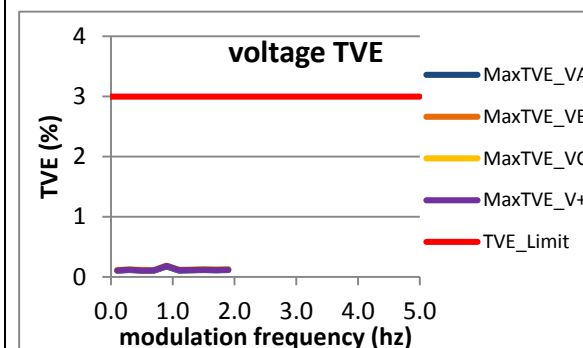


Figure 3520:  $F_s = 10$  FPS



#### 8.1.4 PMU C amplitude modulation voltage TVE: M class

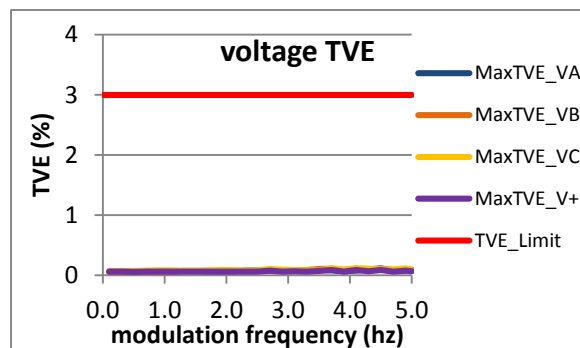


Figure 3521:  $F_s = 60$  FPS

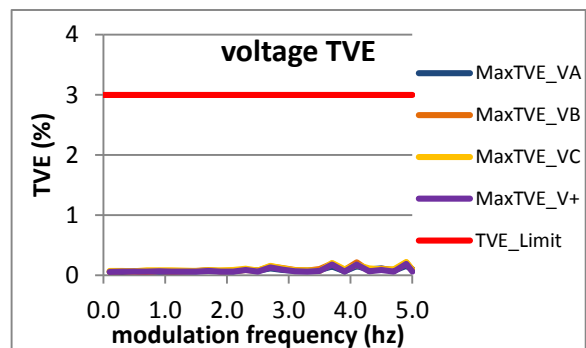


Figure 3522:  $F_s = 30$  FPS

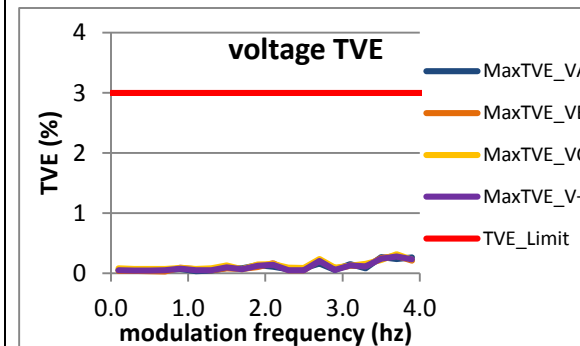


Figure 3523:  $F_s = 20$  FPS

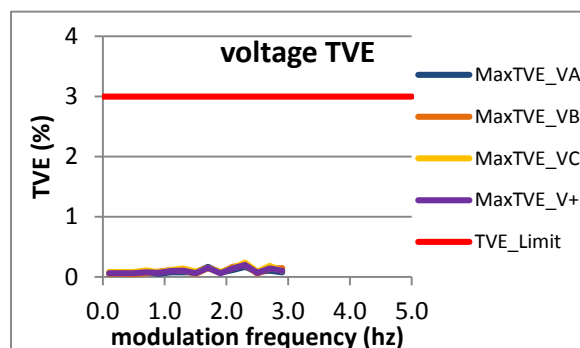


Figure 3524:  $F_s = 15$  FPS

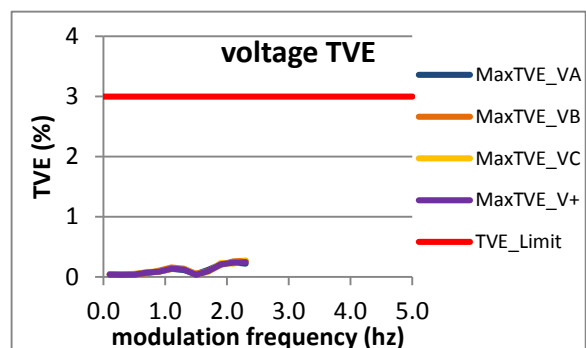


Figure 3525:  $F_s = 12$  FPS

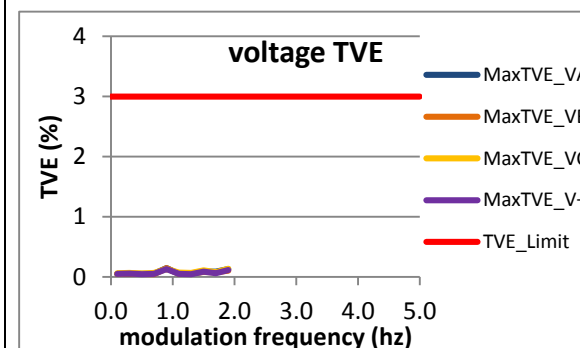


Figure 3526:  $F_s = 10$  FPS

### 8.1.5 PMU D amplitude modulation voltage TVE: M class

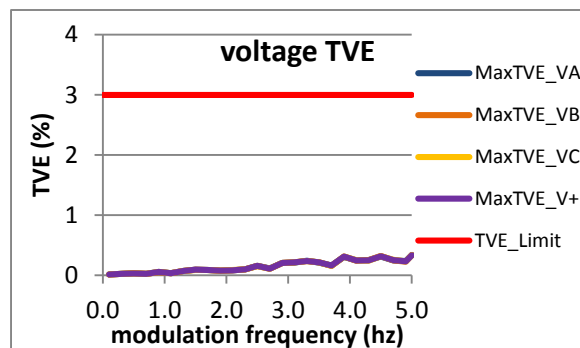


Figure 3527:  $F_s = 60$  FPS

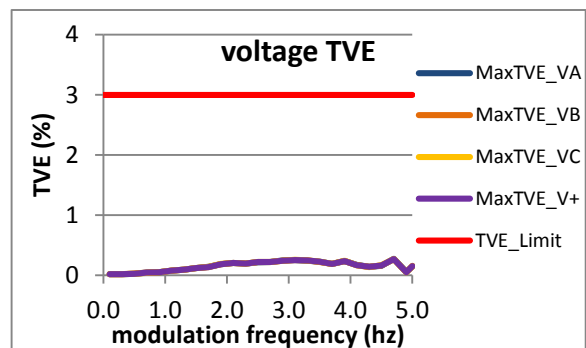


Figure 3528:  $F_s = 30$  FPS

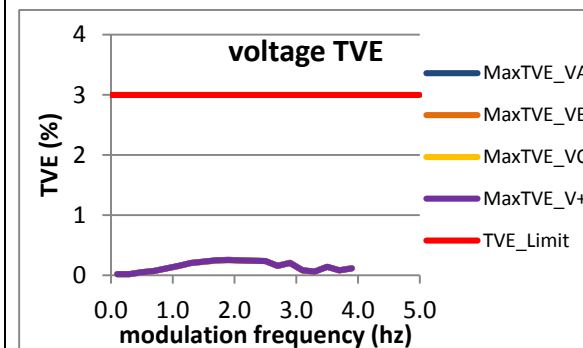


Figure 3529:  $F_s = 20$  FPS

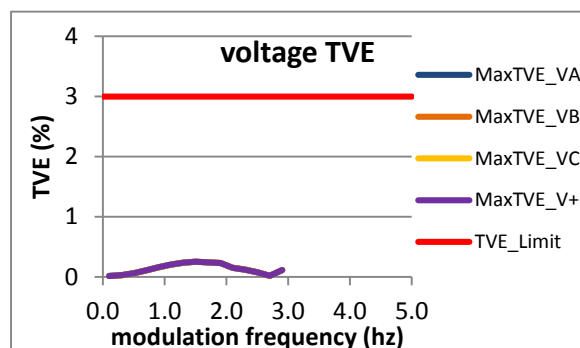


Figure 3530:  $F_s = 15$  FPS

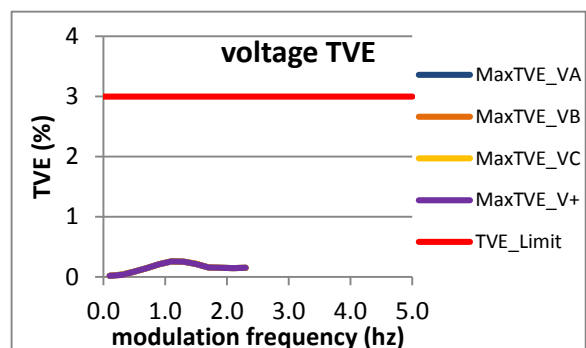


Figure 3531:  $F_s = 12$  FPS

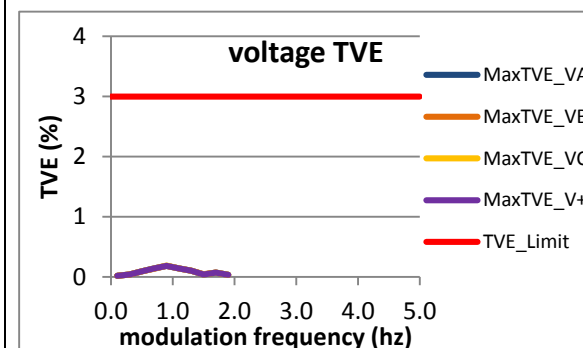


Figure 3532:  $F_s = 10$  FPS

### 8.1.6 PMU E amplitude modulation voltage TVE: M class

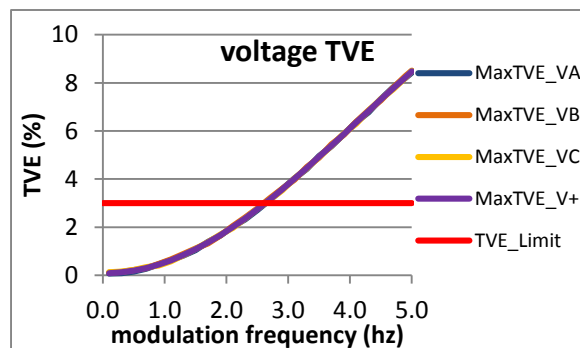


Figure 3533:  $F_s = 60$  FPS

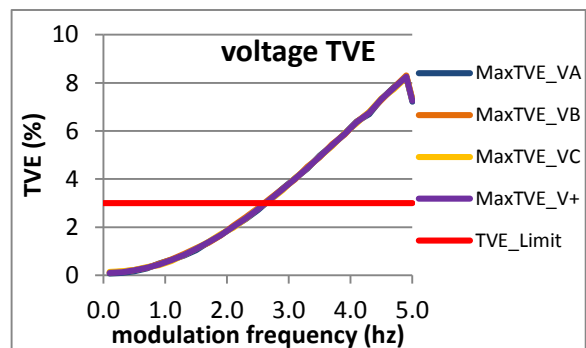


Figure 3534:  $F_s = 30$  FPS

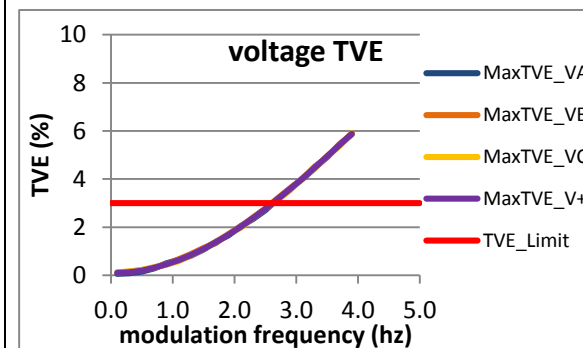


Figure 3535:  $F_s = 20$  FPS

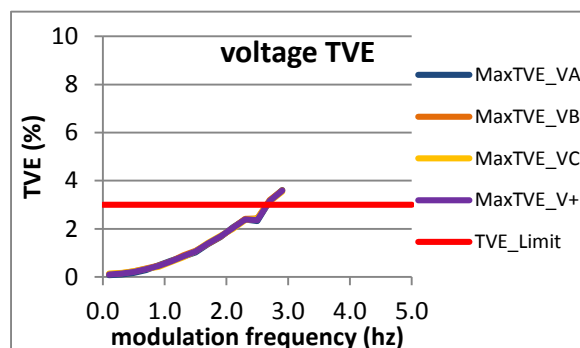


Figure 3536:  $F_s = 15$  FPS

Figure 3537:  $F_s = 12$  FPS data was lost.

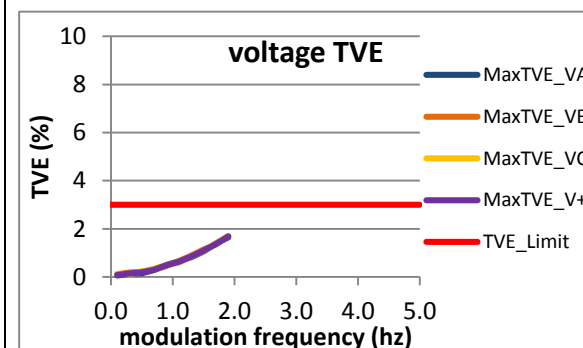
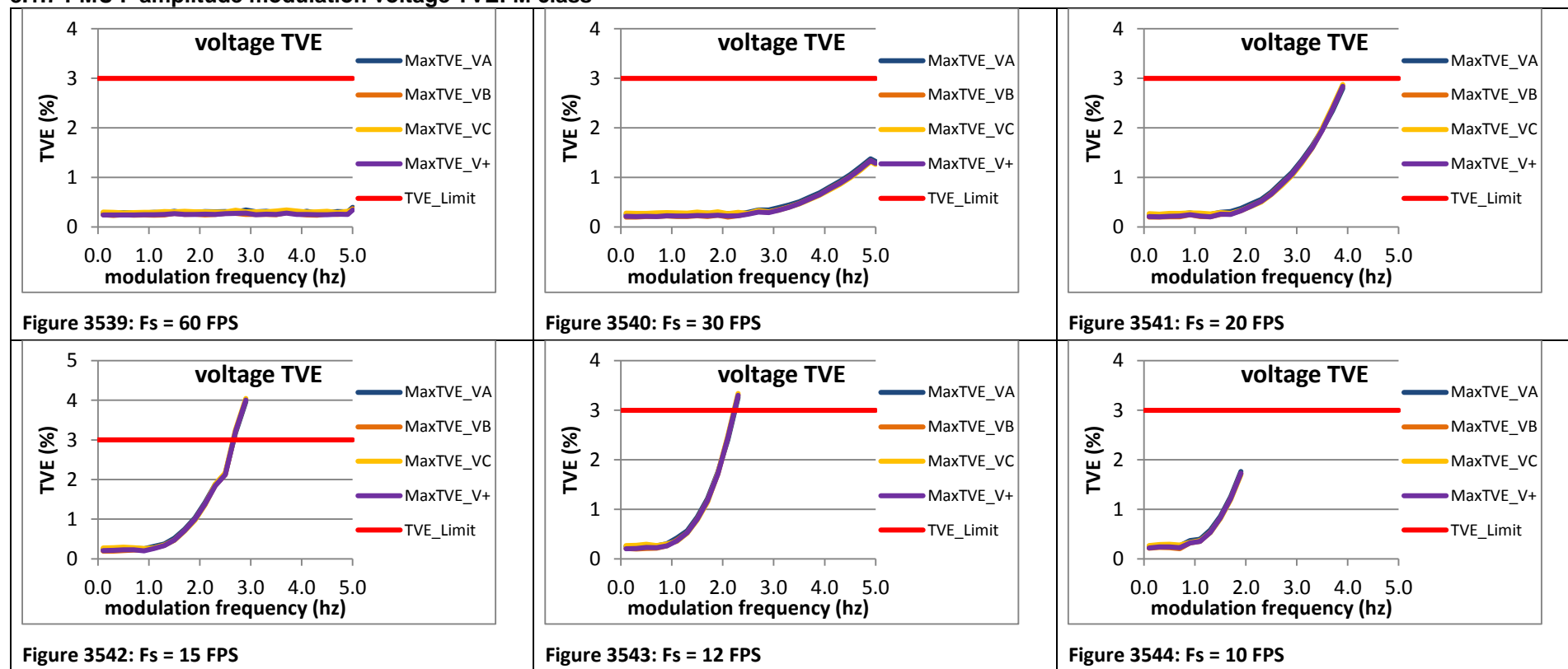


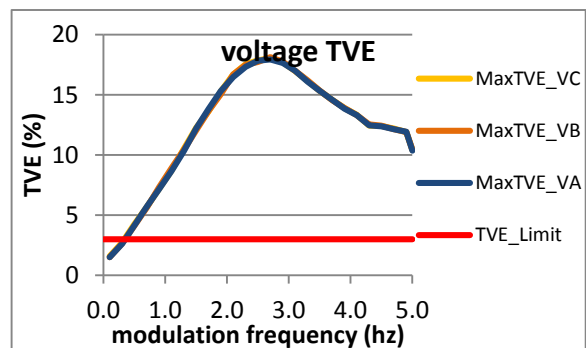
Figure 3538:  $F_s = 10$  FPS

### 8.1.7 PMU F amplitude modulation voltage TVE: M class

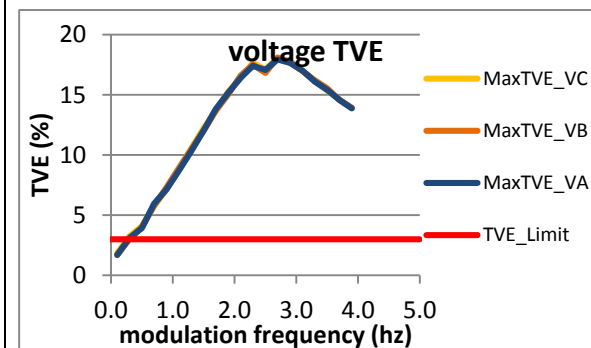


### 8.1.8 PMU G amplitude modulation voltage TVE: M class

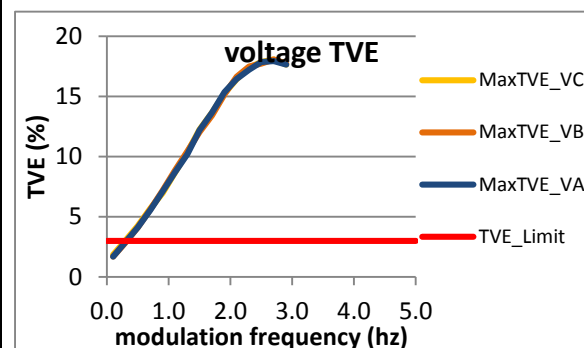
**Figure 3545:  $F_s = 60$  FPS is not supported by this PMU**



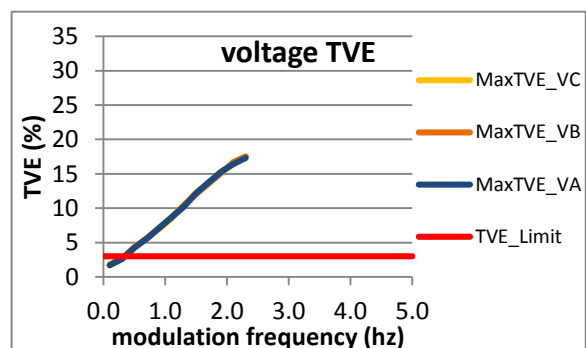
**Figure 3546:  $F_s = 30$  FPS**



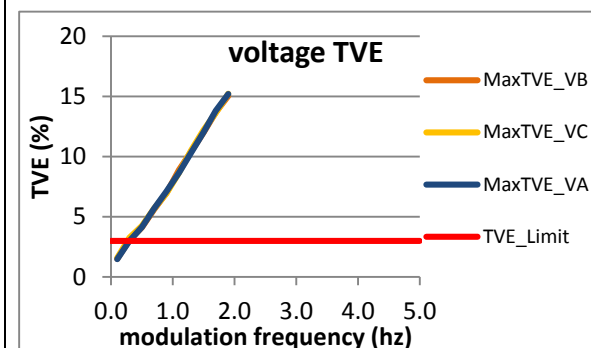
**Figure 3547:  $F_s = 20$  FPS**



**Figure 3548:  $F_s = 15$  FPS**



**Figure 3549:  $F_s = 12$  FPS**



**Figure 3550:  $F_s = 10$  FPS**

### 8.1.9 PMU H amplitude modulation voltage TVE: M class

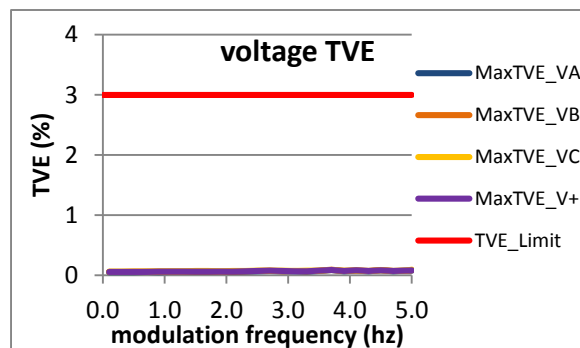


Figure 3551:  $F_s = 60$  FPS

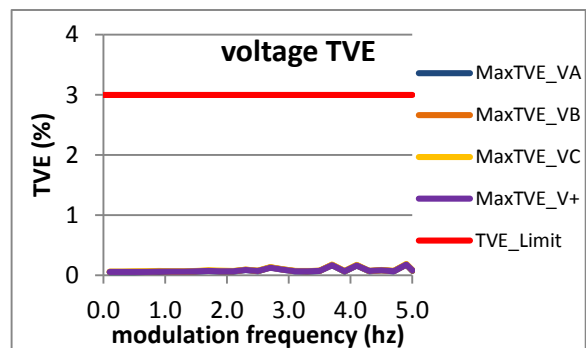


Figure 3552:  $F_s = 30$  FPS

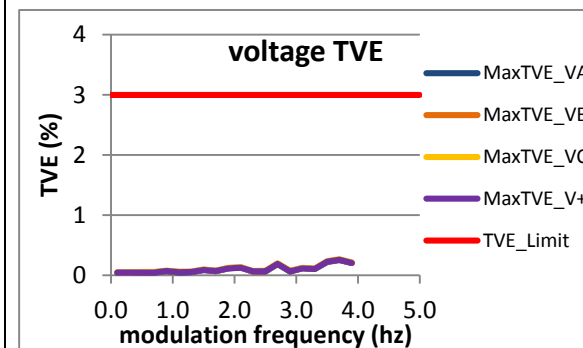


Figure 3553:  $F_s = 20$  FPS

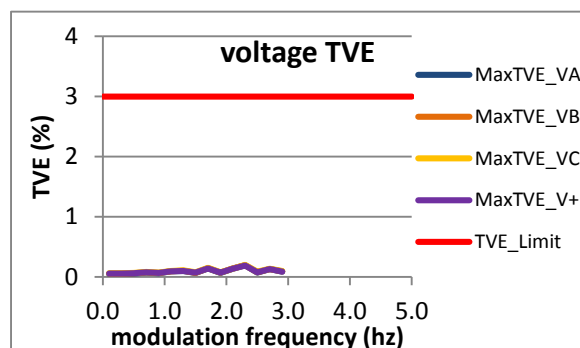


Figure 3554:  $F_s = 15$  FPS

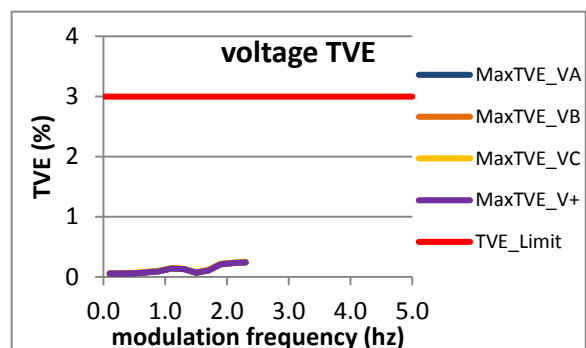


Figure 3555:  $F_s = 12$  FPS

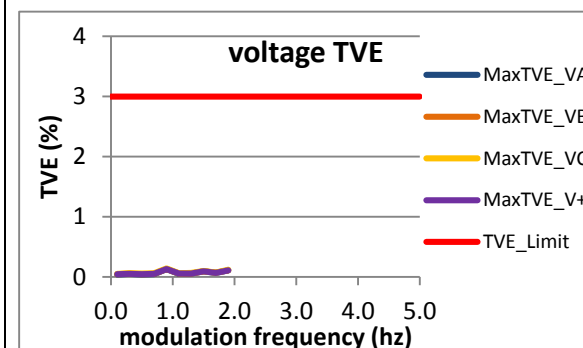


Figure 3556:  $F_s = 10$  FPS

### 8.1.10 PMU I amplitude modulation voltage TVE: M class

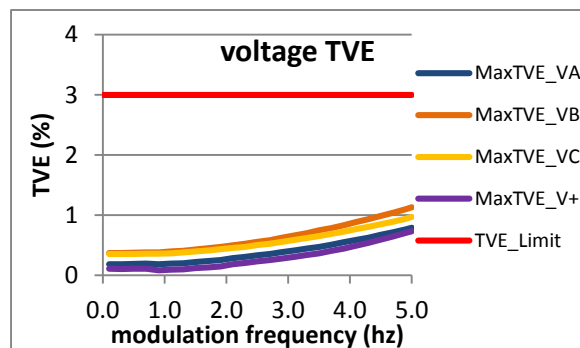


Figure 3557:  $F_s = 60$  FPS

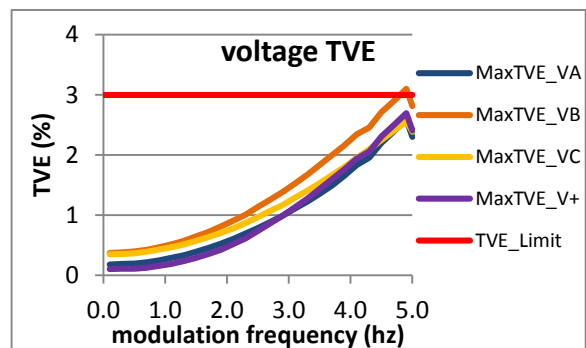


Figure 3558:  $F_s = 30$  FPS

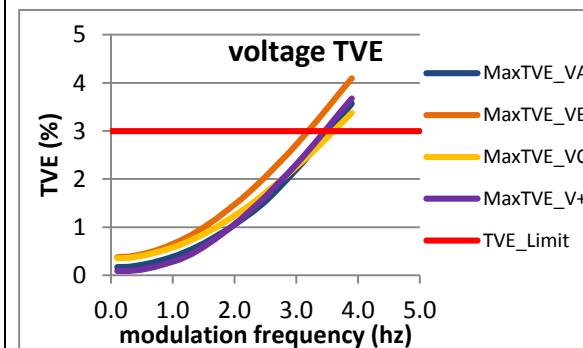


Figure 3559:  $F_s = 20$  FPS

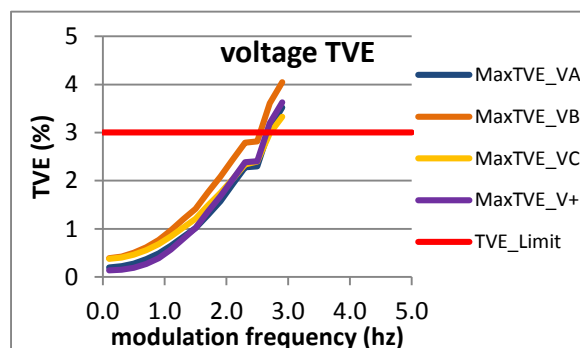


Figure 3560:  $F_s = 15$  FPS

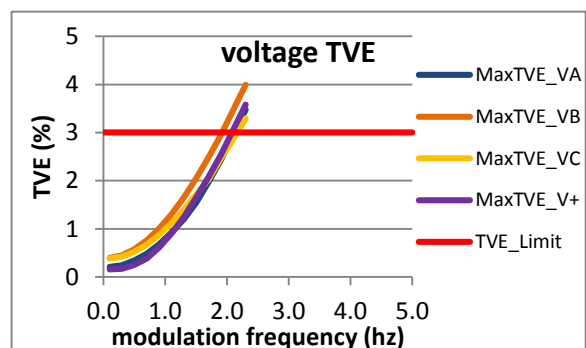


Figure 3561:  $F_s = 12$  FPS

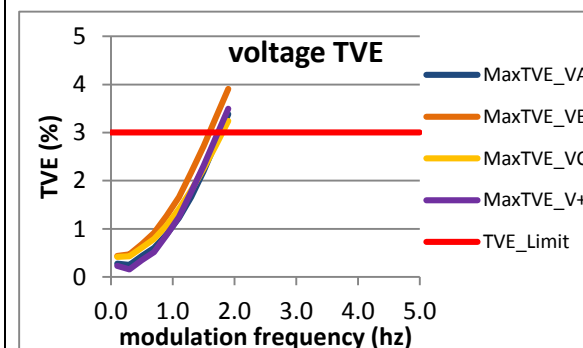
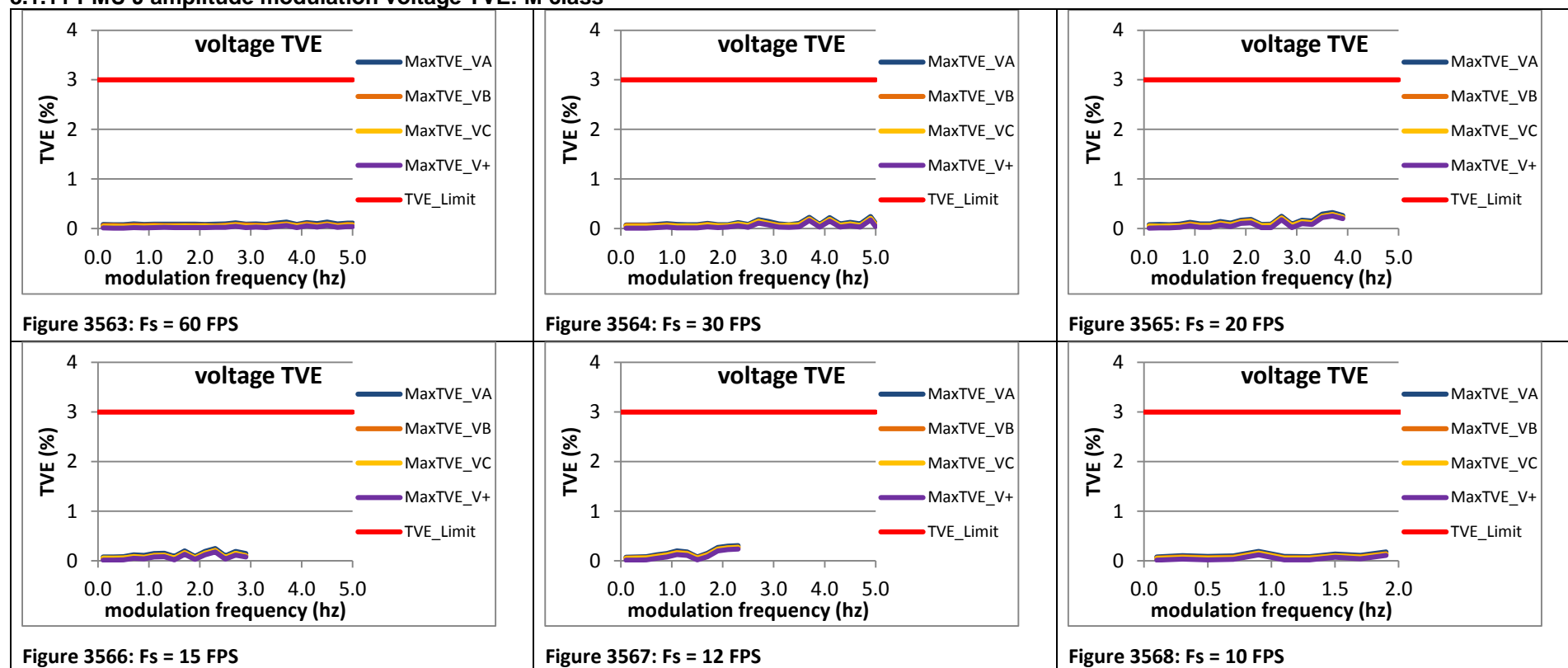


Figure 3562:  $F_s = 10$  FPS

### 8.1.11 PMU J amplitude modulation voltage TVE: M class





## 8.2 Amplitude modulation current TVE: M class

### 8.2.1 C37.118.1 Annex C amplitude modulation current TVE: M class

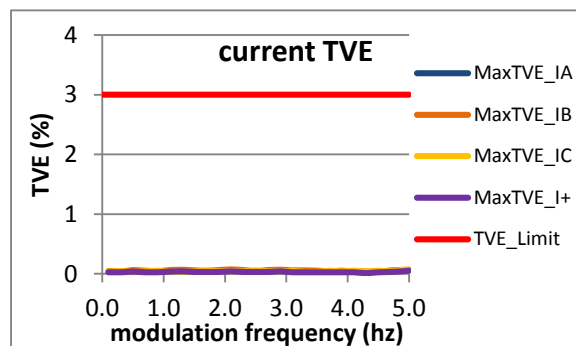


Figure 3569:  $F_s = 60$  FPS

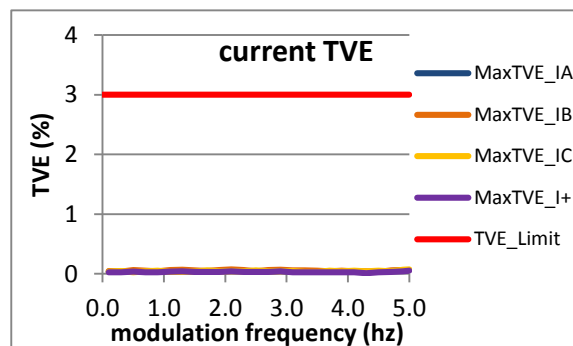


Figure 3570:  $F_s = 30$  FPS

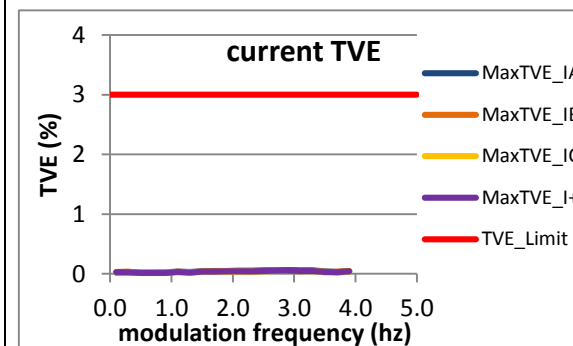


Figure 3571:  $F_s = 20$  FPS

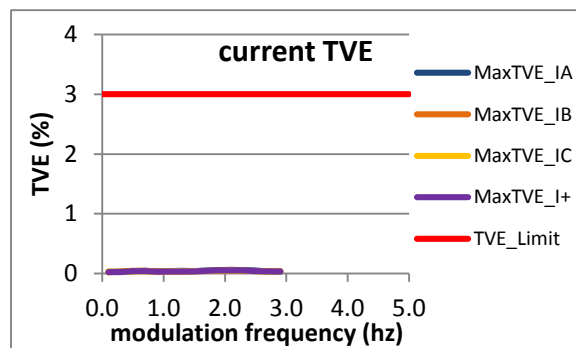


Figure 3572:  $F_s = 15$  FPS

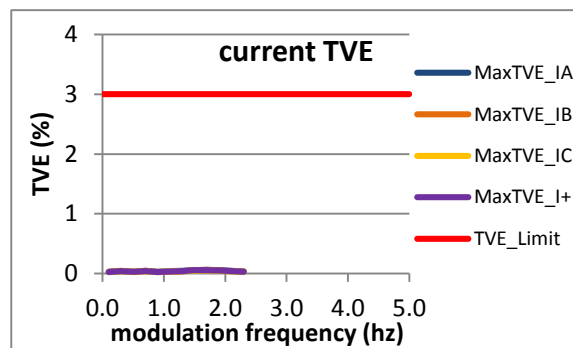


Figure 3573:  $F_s = 12$  FPS

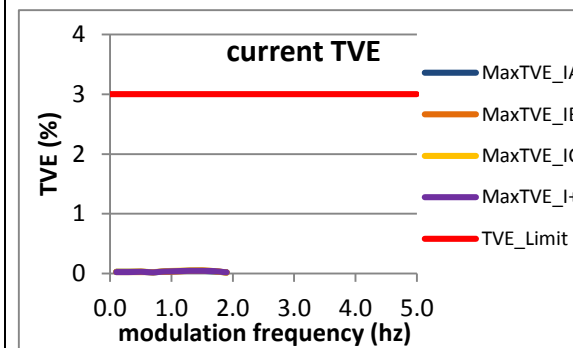


Figure 3574:  $F_s = 10$  FPS

## 8.2.2 PMU A amplitude modulation current TVE: M class

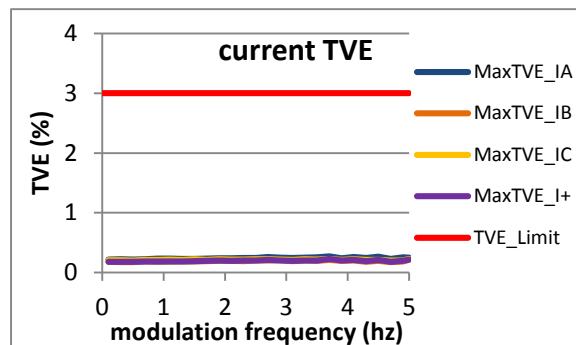


Figure 3575:  $F_s = 60$  FPS

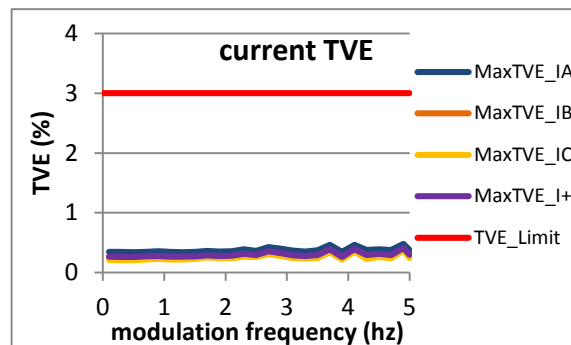


Figure 3576:  $F_s = 30$  FPS

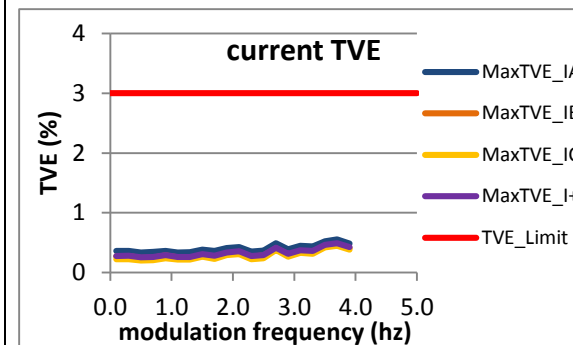


Figure 3577:  $F_s = 20$  FPS

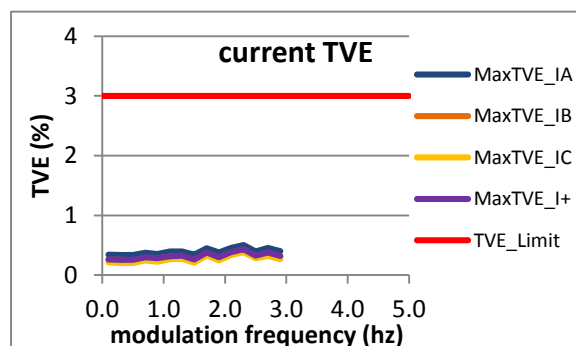


Figure 3578:  $F_s = 15$  FPS

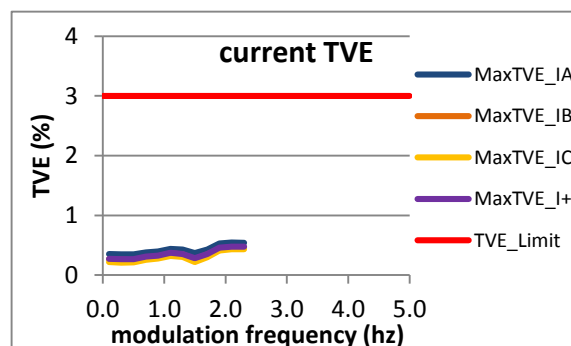


Figure 3579:  $F_s = 12$  FPS

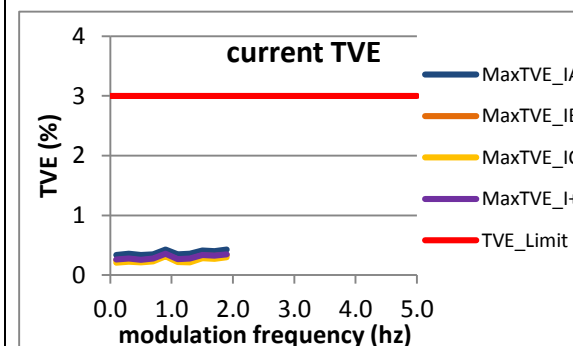


Figure 3580:  $F_s = 10$  FPS

### 8.2.3 PMU B amplitude modulation current TVE: M class

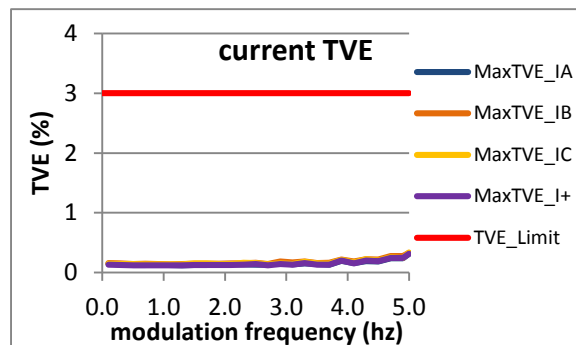


Figure 3581:  $F_s = 60$  FPS

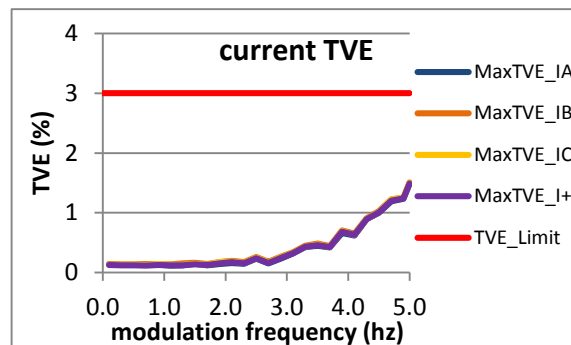


Figure 3582:  $F_s = 30$  FPS

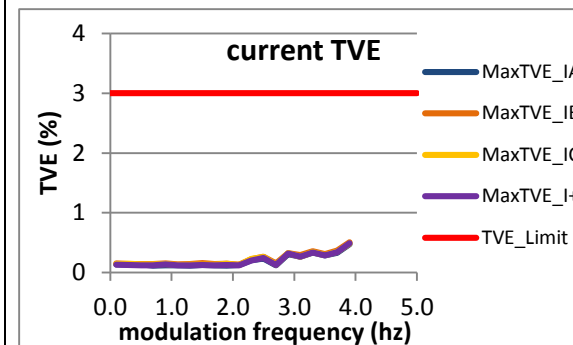


Figure 3583:  $F_s = 20$  FPS

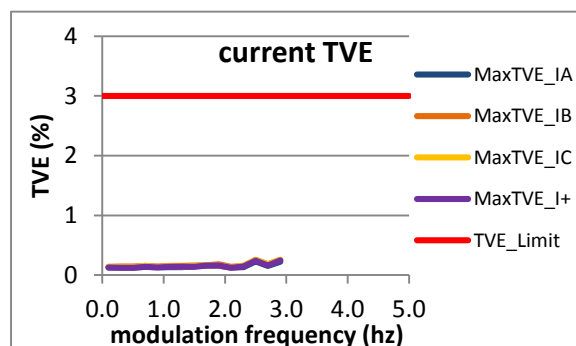


Figure 3584:  $F_s = 15$  FPS

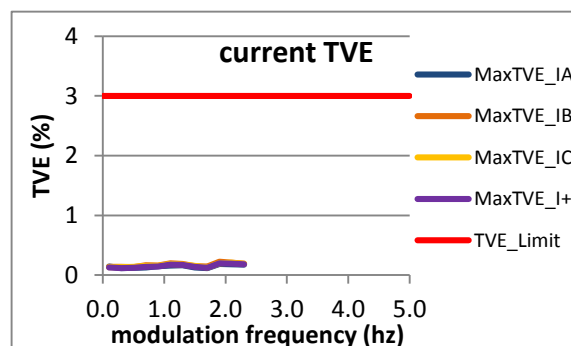


Figure 3585:  $F_s = 12$  FPS

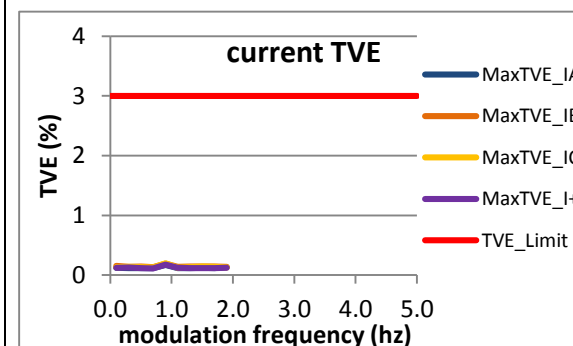


Figure 3586:  $F_s = 10$  FPS

## 8.2.4 PMU C amplitude modulation current TVE: M class

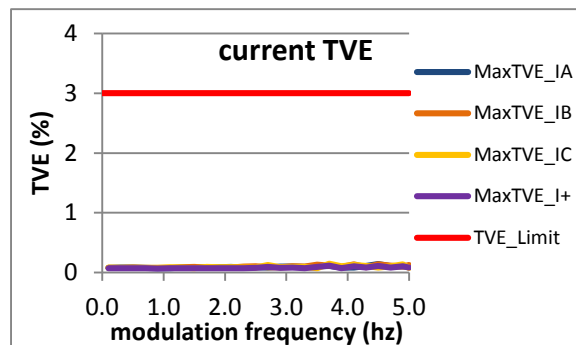


Figure 3587:  $F_s = 60$  FPS

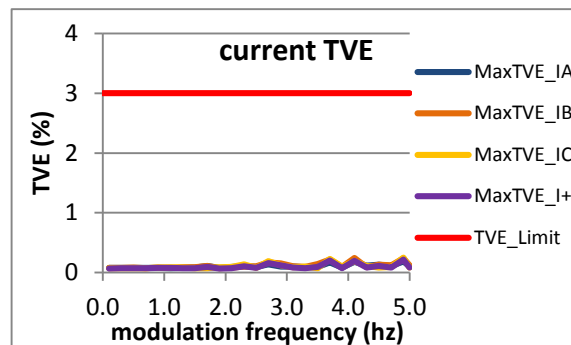


Figure 3588:  $F_s = 30$  FPS

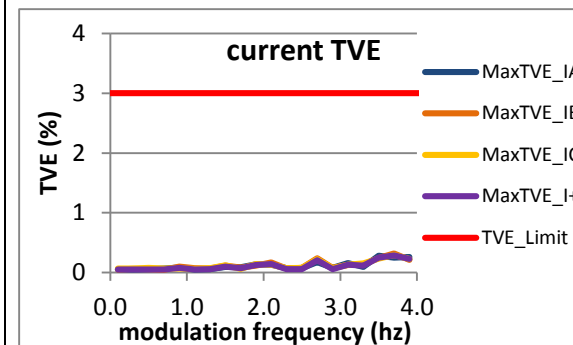


Figure 3589:  $F_s = 20$  FPS

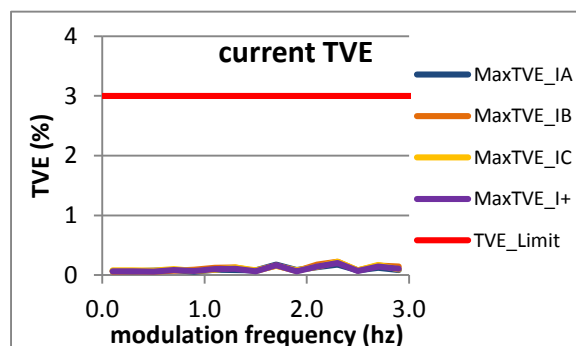


Figure 3590:  $F_s = 15$  FPS

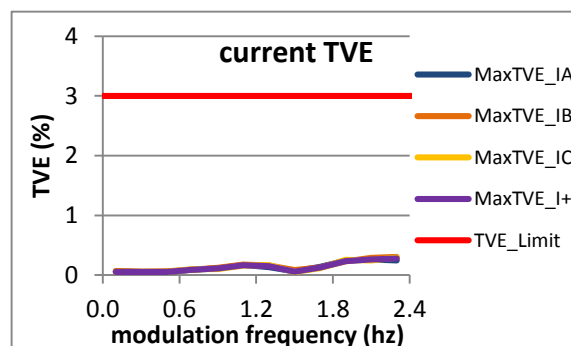


Figure 3591:  $F_s = 12$  FPS

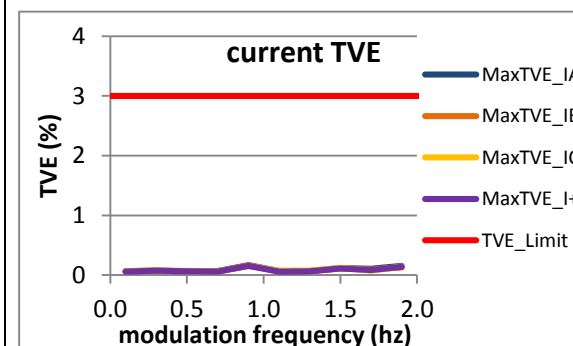


Figure 3592:  $F_s = 10$  FPS

## 8.2.5 PMU D amplitude modulation current TVE: M class

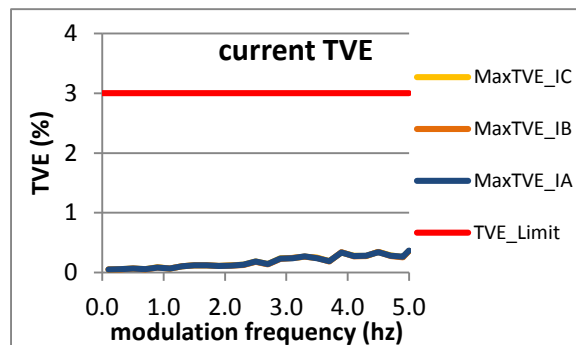


Figure 3593:  $F_s = 60$  FPS

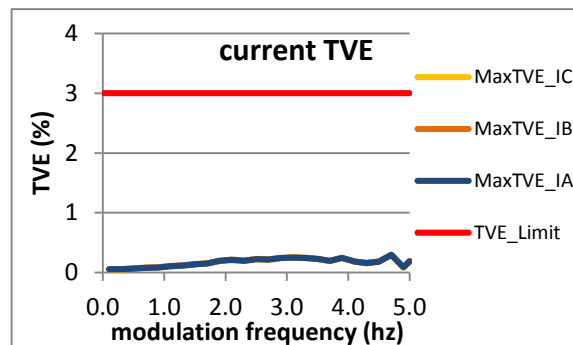


Figure 3594:  $F_s = 30$  FPS

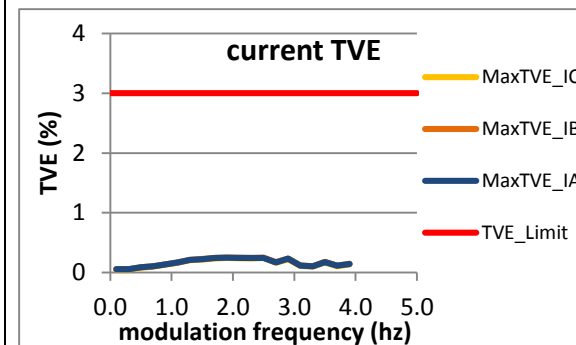


Figure 3595:  $F_s = 20$  FPS

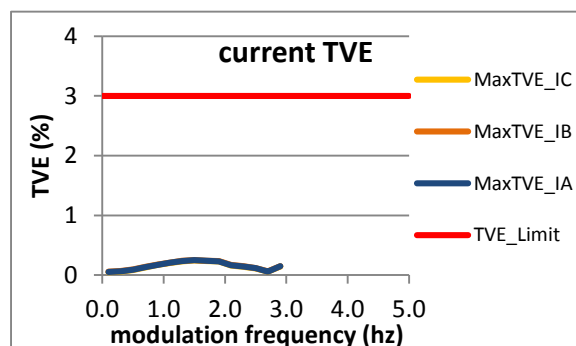


Figure 3596:  $F_s = 15$  FPS

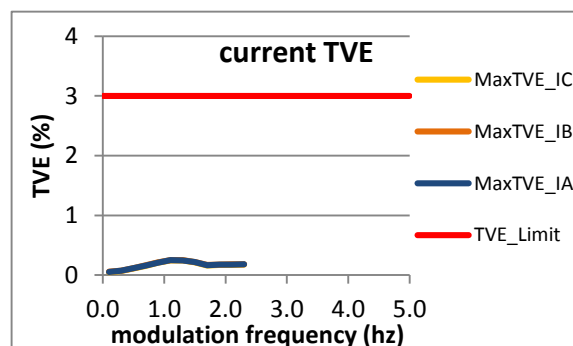


Figure 3597:  $F_s = 12$  FPS

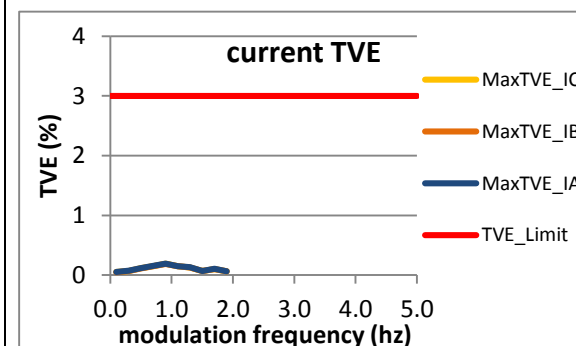


Figure 3598:  $F_s = 10$  FPS

## 8.2.6 PMU E amplitude modulation current TVE: M class

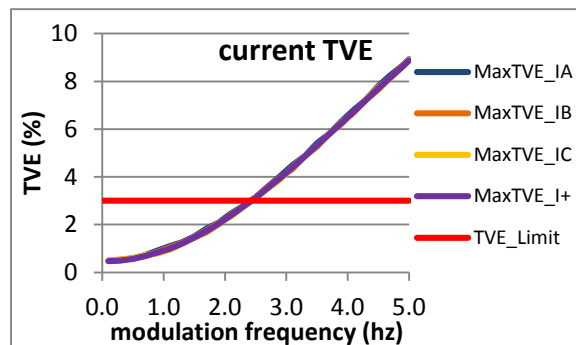


Figure 3599:  $F_s = 60$  FPS

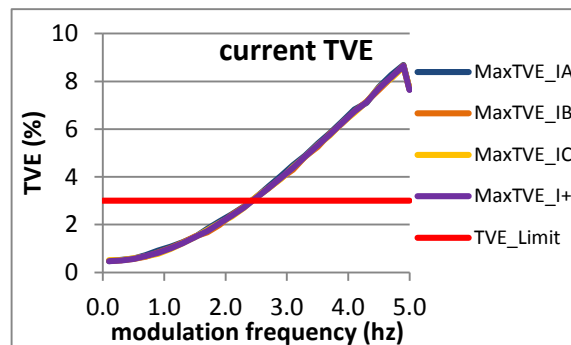


Figure 3600:  $F_s = 30$  FPS

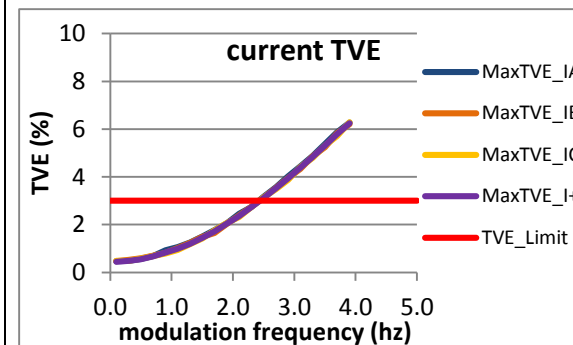


Figure 3601:  $F_s = 20$  FPS

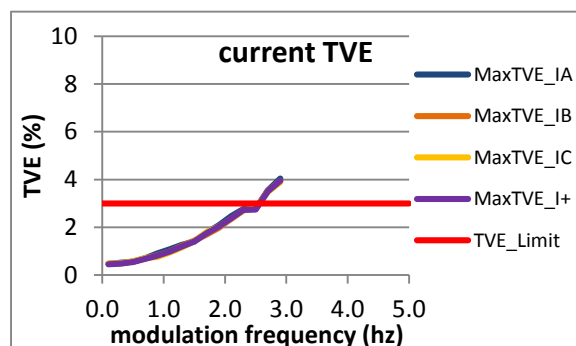


Figure 3602:  $F_s = 15$  FPS

Figure 3603:  $F_s = 12$  FPS data was lost.

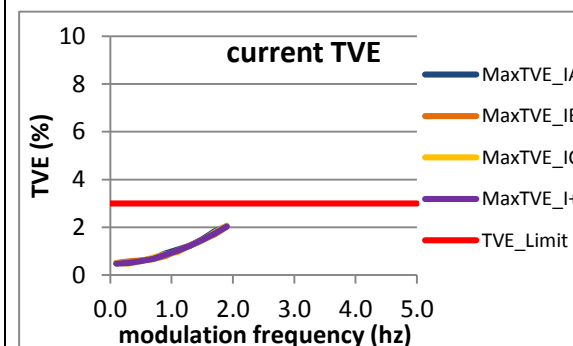
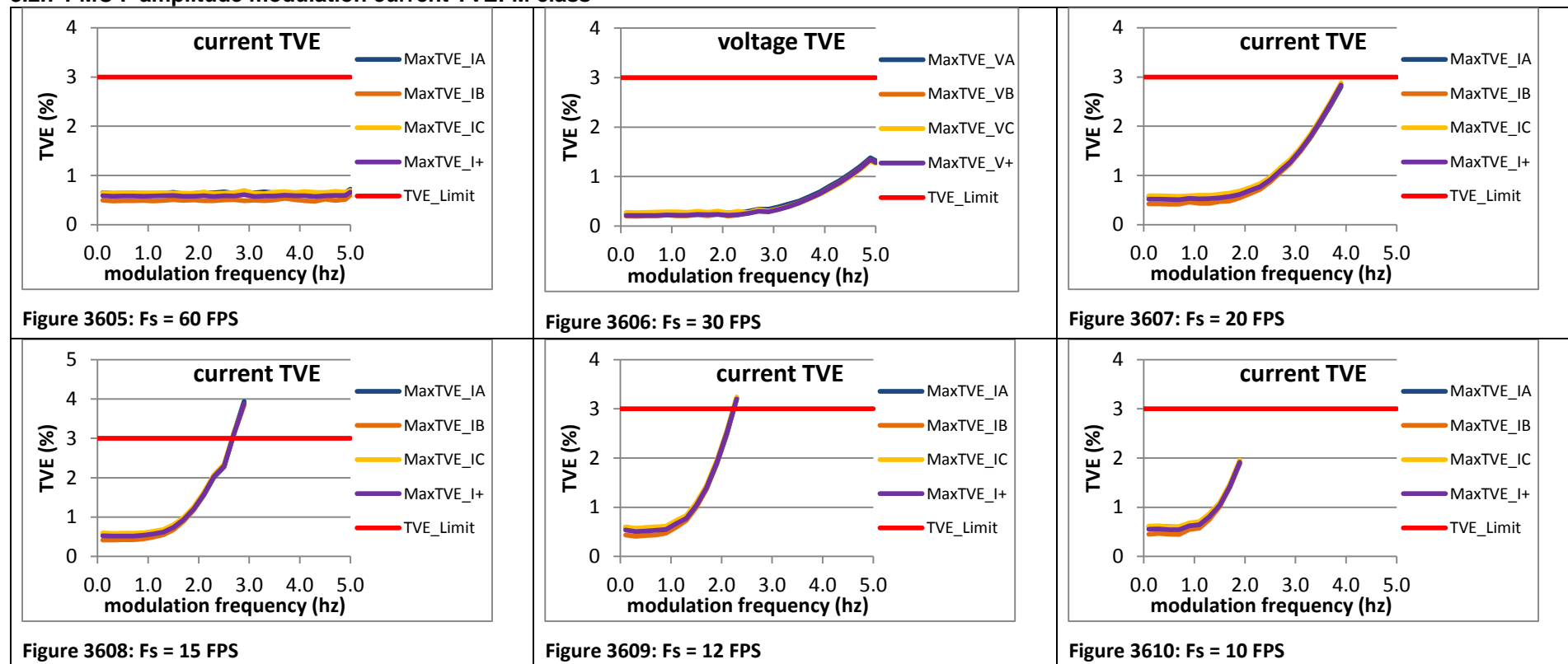


Figure 3604:  $F_s = 10$  FPS

### 8.2.7 PMU F amplitude modulation current TVE: M class



## 8.2.8 PMU G amplitude modulation current TVE: M class

Figure 3611:  $F_s = 60$  FPS is not supported by this PMU

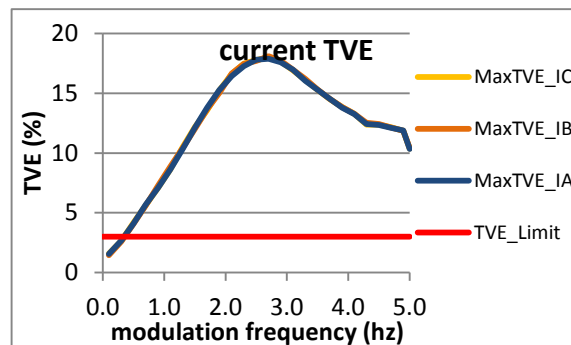


Figure 3612:  $F_s = 30$  FPS

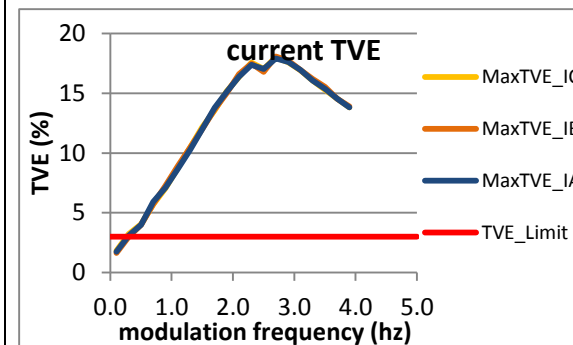


Figure 3613:  $F_s = 20$  FPS

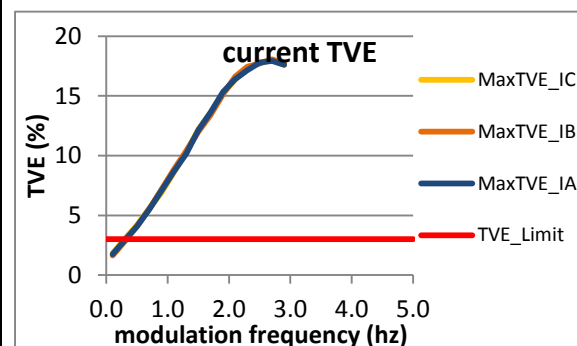


Figure 3614:  $F_s = 15$  FPS

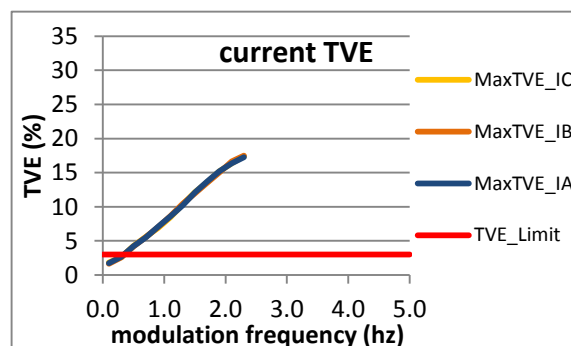


Figure 3615:  $F_s = 12$  FPS

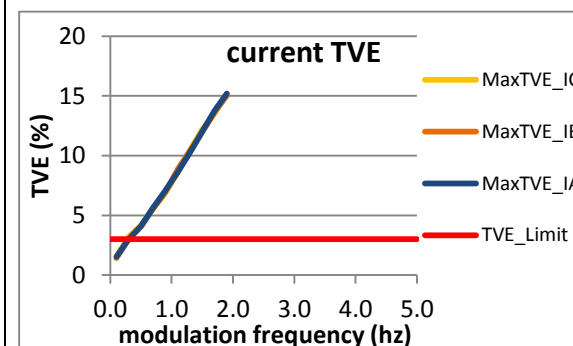


Figure 3616:  $F_s = 10$  FPS



### 8.2.9 PMU H amplitude modulation current TVE: M class

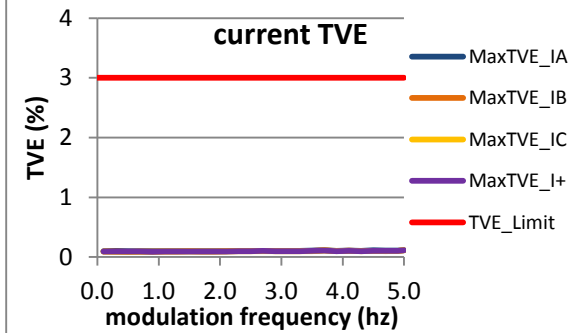


Figure 3617:  $F_s = 60$  FPS

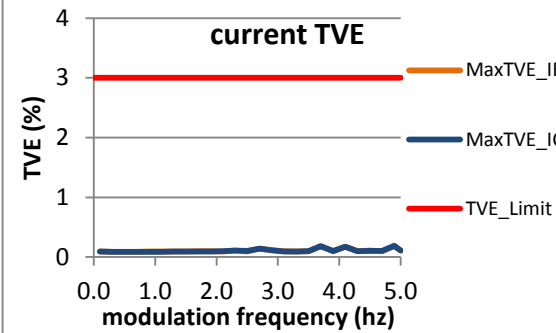


Figure 3618:  $F_s = 30$  FPS

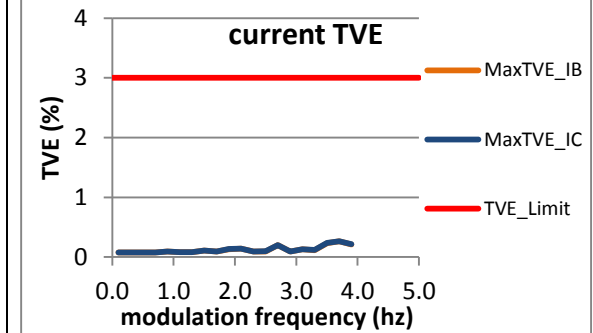


Figure 3619:  $F_s = 20$  FPS

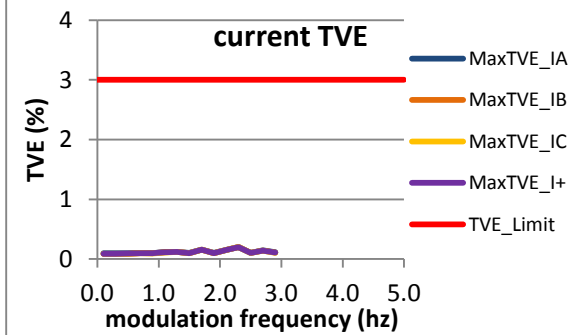


Figure 3620:  $F_s = 15$  FPS

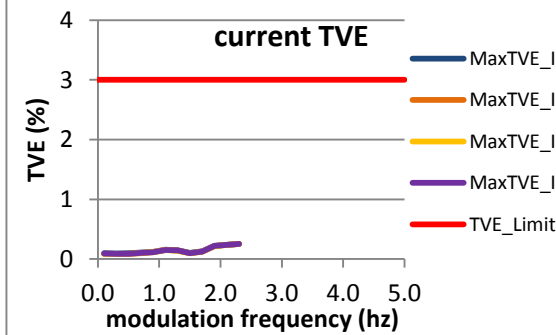


Figure 3621:  $F_s = 12$  FPS

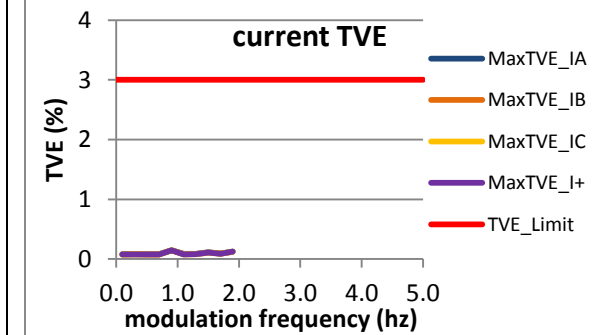


Figure 3622:  $F_s = 10$  FPS

## 8.2.10 PMU I amplitude modulation current TVE: M class

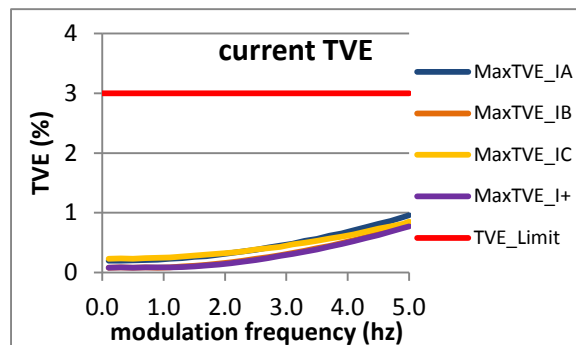


Figure 3623: Fs = 60 FPS

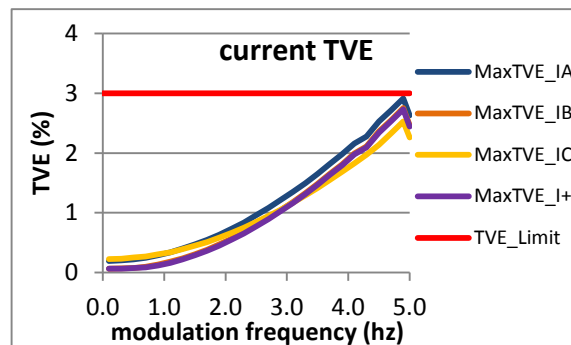


Figure 3624: Fs = 30 FPS

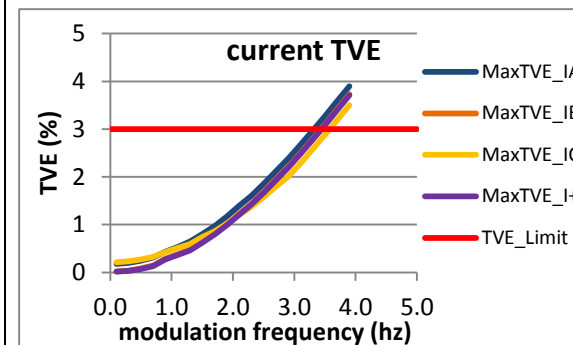


Figure 3625: Fs = 20 FPS

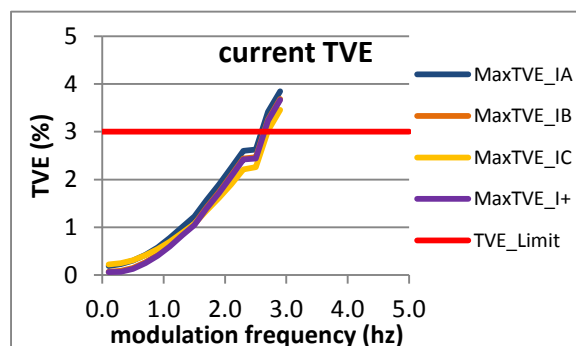


Figure 3626: Fs = 15 FPS

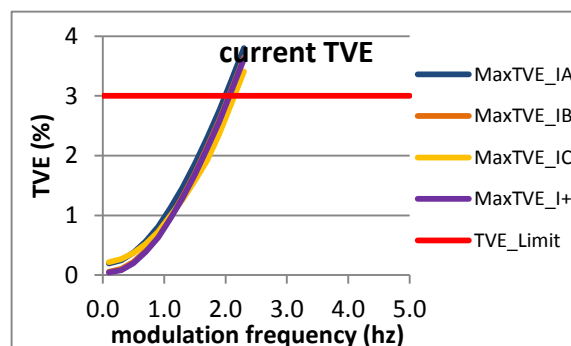


Figure 3627: Fs = 12 FPS

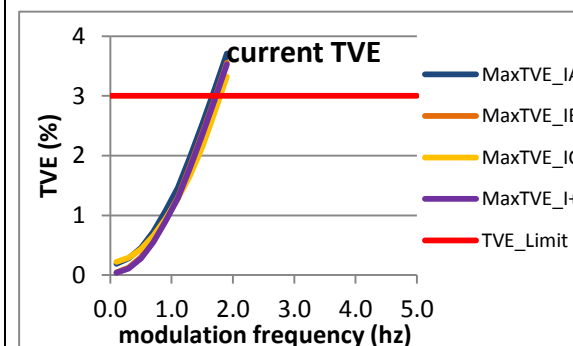


Figure 3628: Fs = 10 FPS

## 8.2.11 PMU J amplitude modulation current TVE: M class

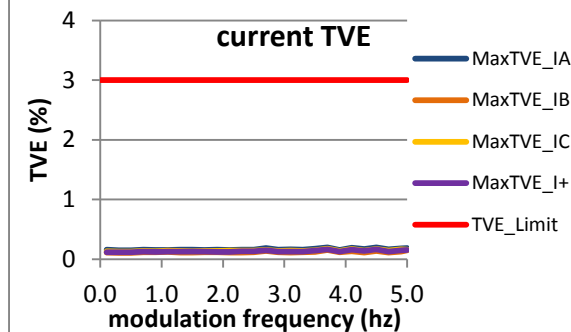


Figure 3629: Fs = 60 FPS

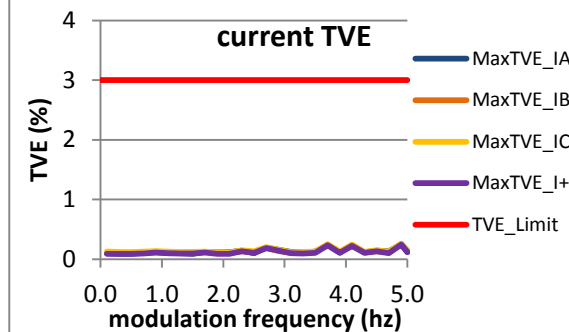


Figure 3630: Fs = 30 FPS

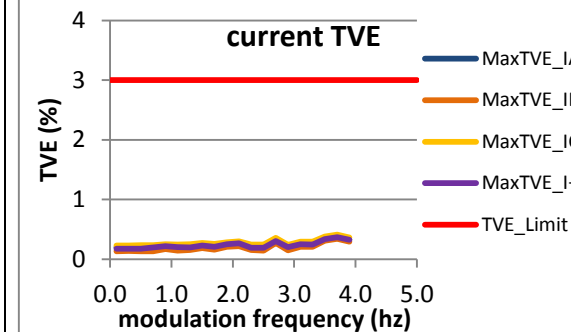


Figure 3631: Fs = 20 FPS

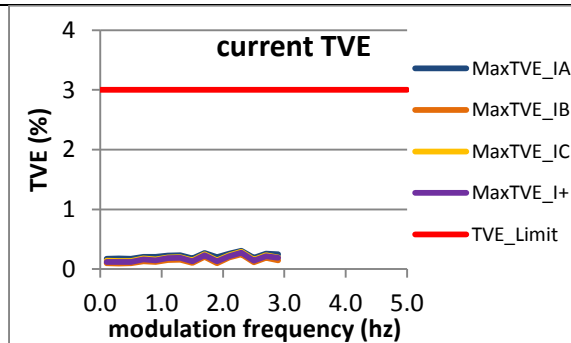


Figure 3632: Fs = 15 FPS

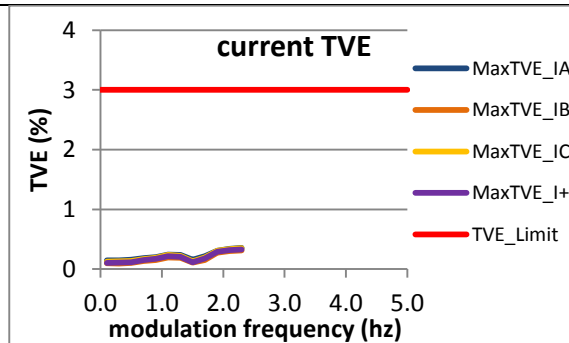


Figure 3633: Fs = 12 FPS

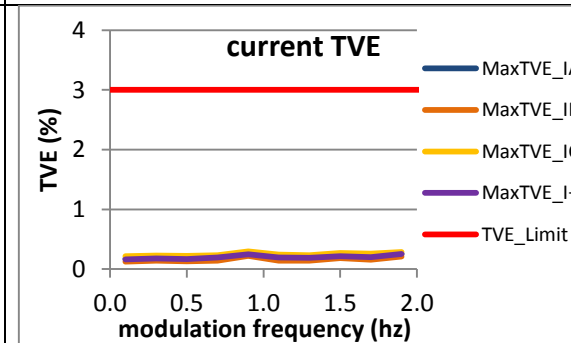


Figure 3634: Fs = 10 FPS

### 8.3 Amplitude modulation frequency error: M class

#### 8.3.1 C37.118.1 Annex C amplitude modulation frequency error: M class

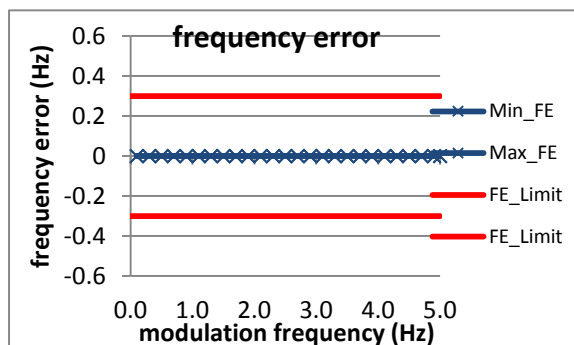


Figure 3635:  $F_s = 60$  FPS

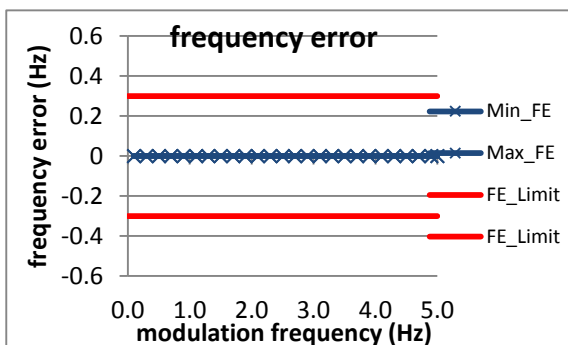


Figure 3636:  $F_s = 30$  FPS

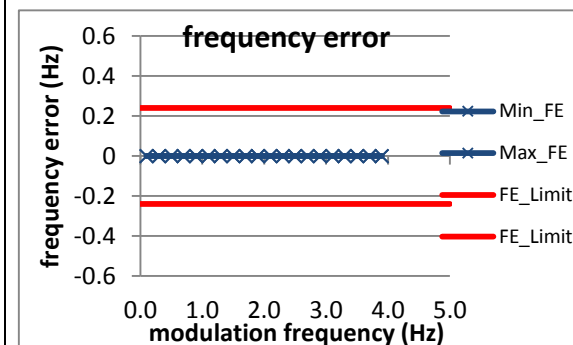


Figure 3637:  $F_s = 20$  FPS

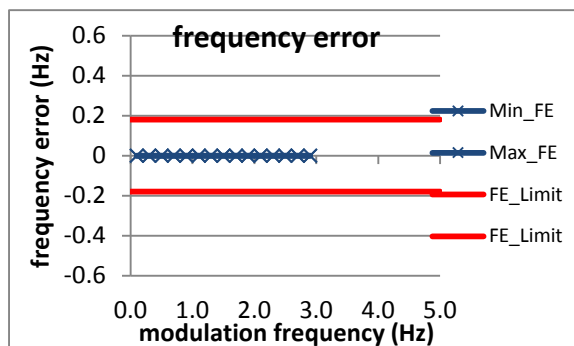


Figure 3638:  $F_s = 15$  FPS

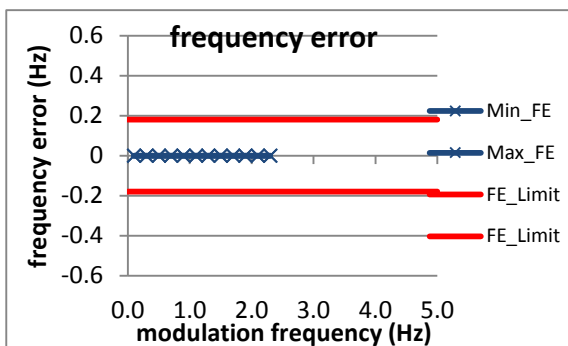


Figure 3639:  $F_s = 12$  FPS

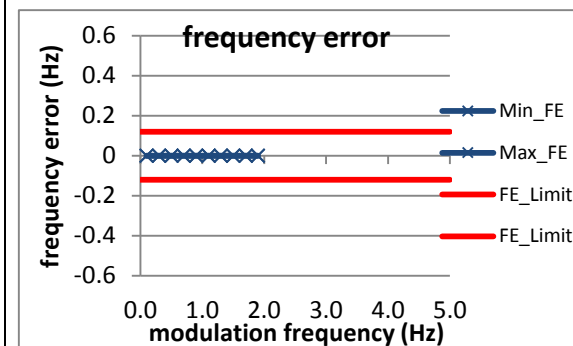


Figure 3640:  $F_s = 10$  FPS

### 8.3.2 PMU A amplitude modulation frequency error: M class

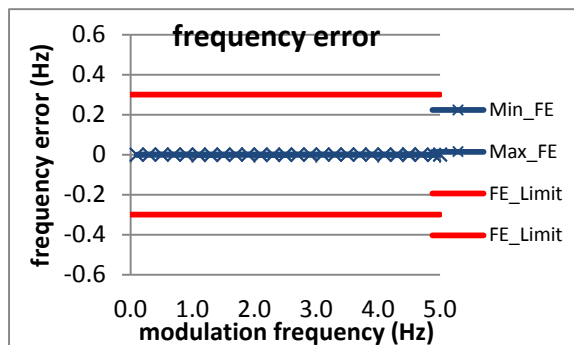


Figure 3641:  $F_s = 60$  FPS

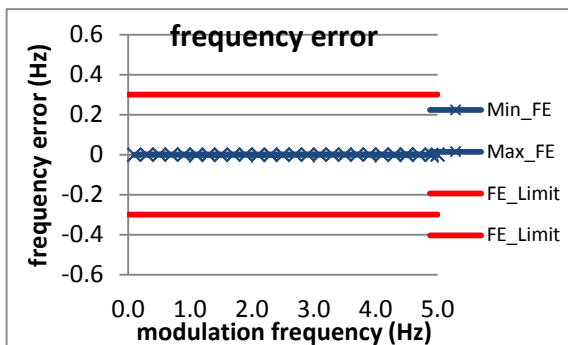


Figure 3642:  $F_s = 30$  FPS

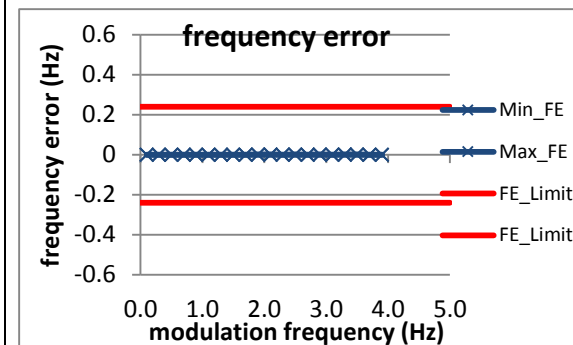


Figure 3643:  $F_s = 20$  FPS

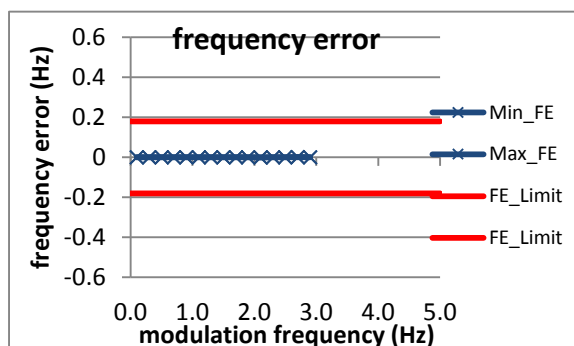


Figure 3644:  $F_s = 15$  FPS

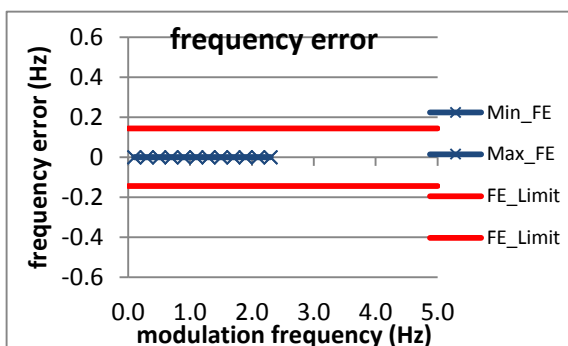


Figure 3645:  $F_s = 12$  FPS

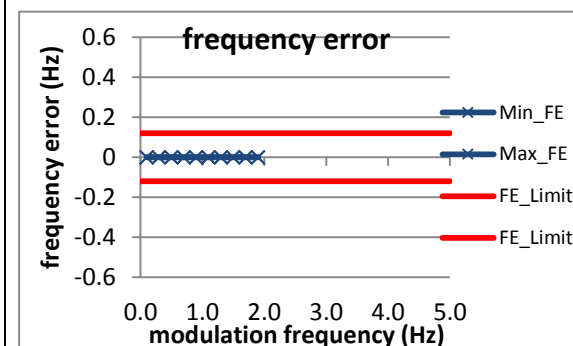


Figure 3646:  $F_s = 10$  FPS

### 8.3.3 PMU B amplitude modulation frequency error: M class

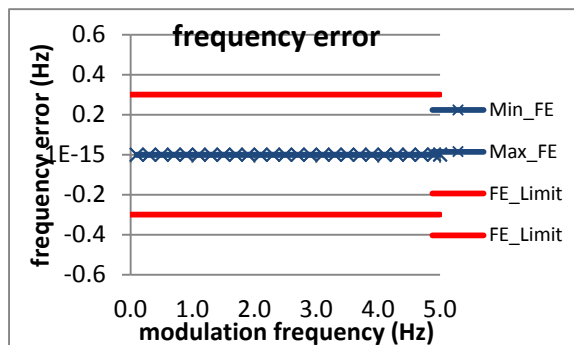


Figure 3647:  $F_s = 60$  FPS

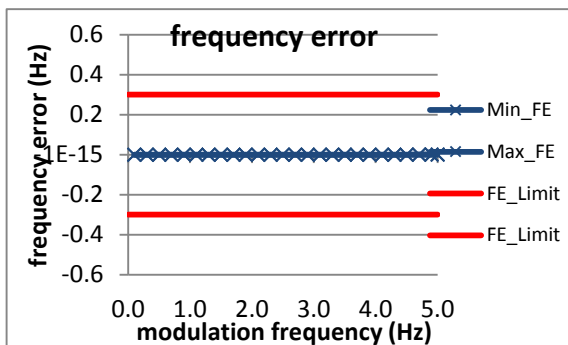


Figure 3648:  $F_s = 30$  FPS

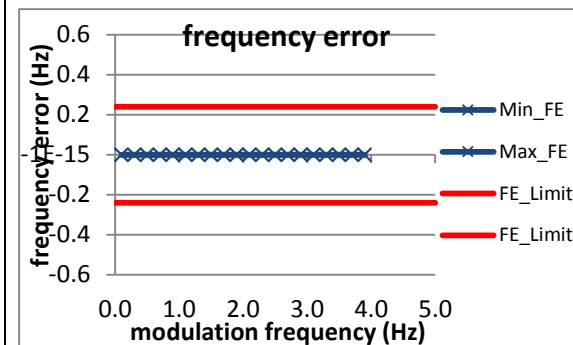


Figure 3649:  $F_s = 20$  FPS

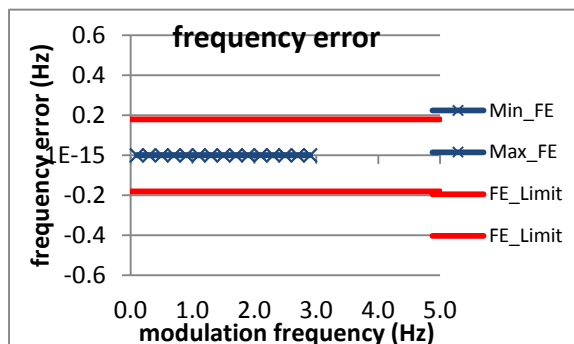


Figure 3650:  $F_s = 15$  FPS

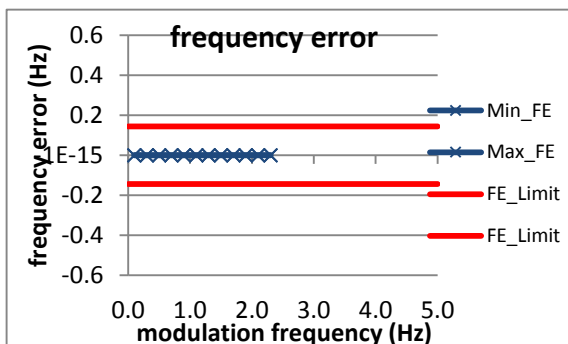


Figure 3651:  $F_s = 12$  FPS

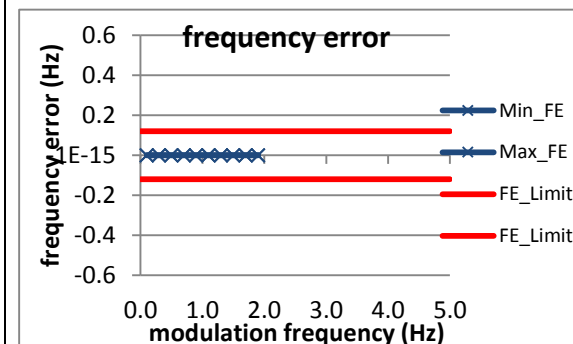


Figure 3652:  $F_s = 10$  FPS

### 8.3.4 PMU C amplitude modulation frequency error: M class

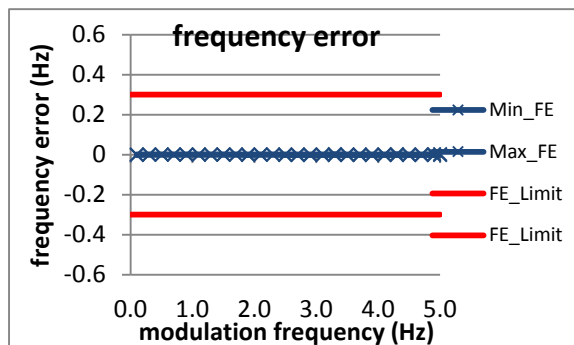


Figure 3653:  $F_s = 60$  FPS

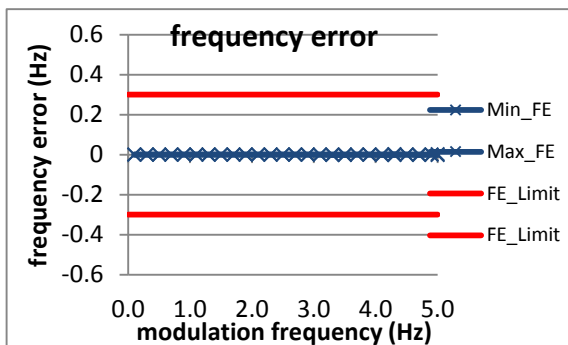


Figure 3654:  $F_s = 30$  FPS

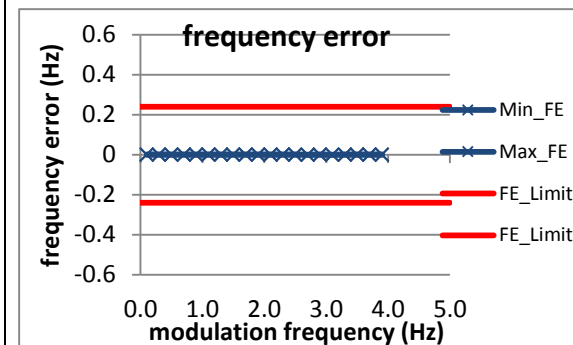


Figure 3655:  $F_s = 20$  FPS

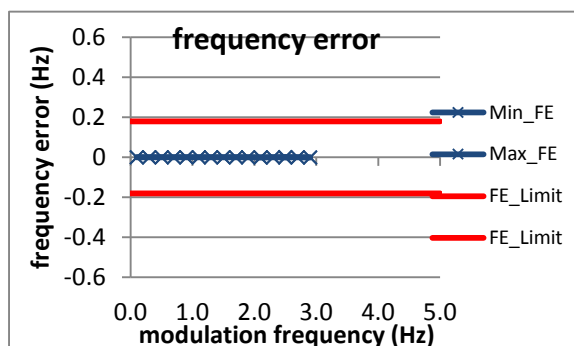


Figure 3656:  $F_s = 15$  FPS

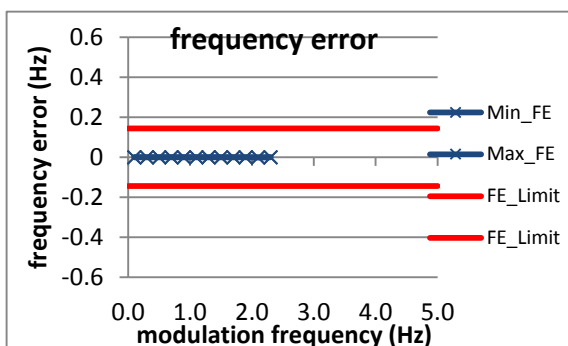


Figure 3657:  $F_s = 12$  FPS

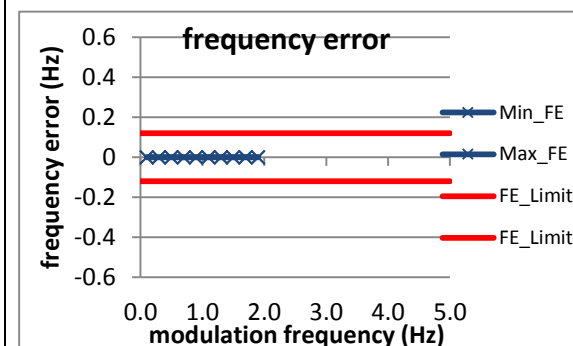


Figure 3658:  $F_s = 10$  FPS

### 8.3.5 PMU D amplitude modulation frequency error: M class

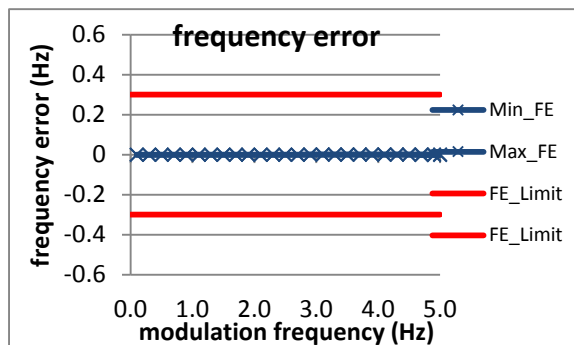


Figure 3659:  $F_s = 60$  FPS

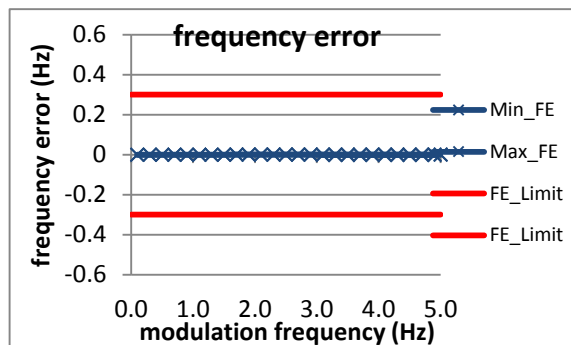


Figure 3660:  $F_s = 30$  FPS

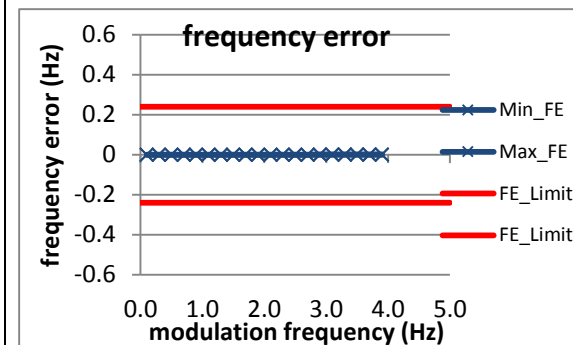


Figure 3661:  $F_s = 20$  FPS

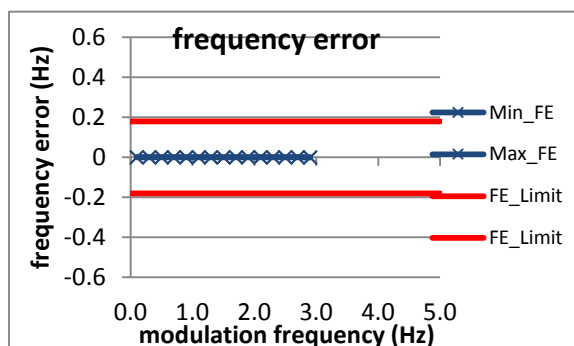


Figure 3662:  $F_s = 15$  FPS

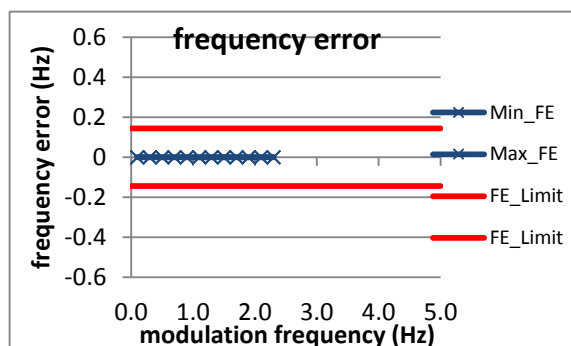


Figure 3663:  $F_s = 12$  FPS

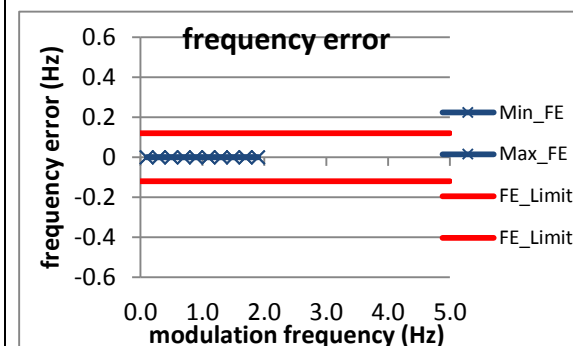


Figure 3664:  $F_s = 10$  FPS



### 8.3.6 PMU E amplitude modulation frequency error: M class

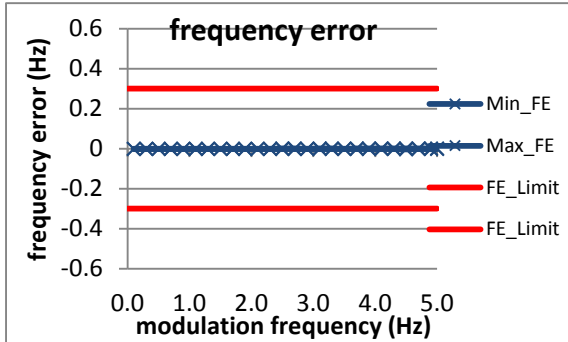


Figure 3665:  $F_s = 60$  FPS

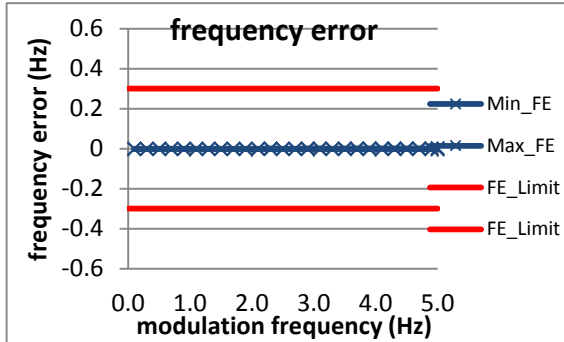


Figure 3666:  $F_s = 30$  FPS

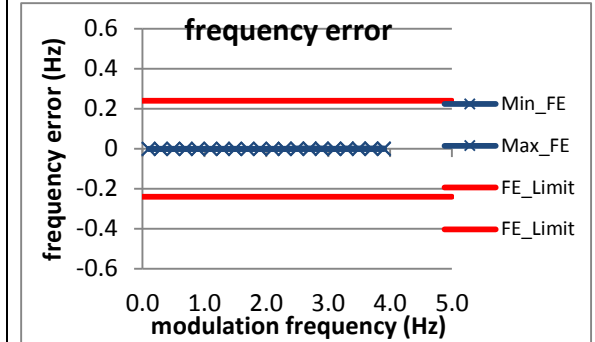


Figure 3667:  $F_s = 20$  FPS

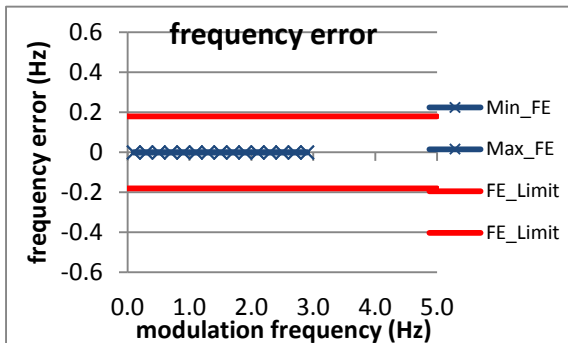


Figure 3668:  $F_s = 15$  FPS

Figure 3669:  $F_s = 12$  FPS data was lost

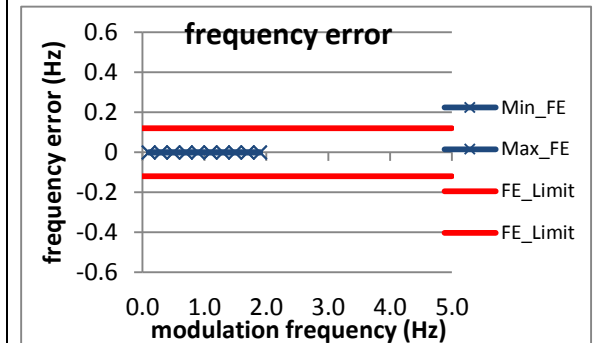
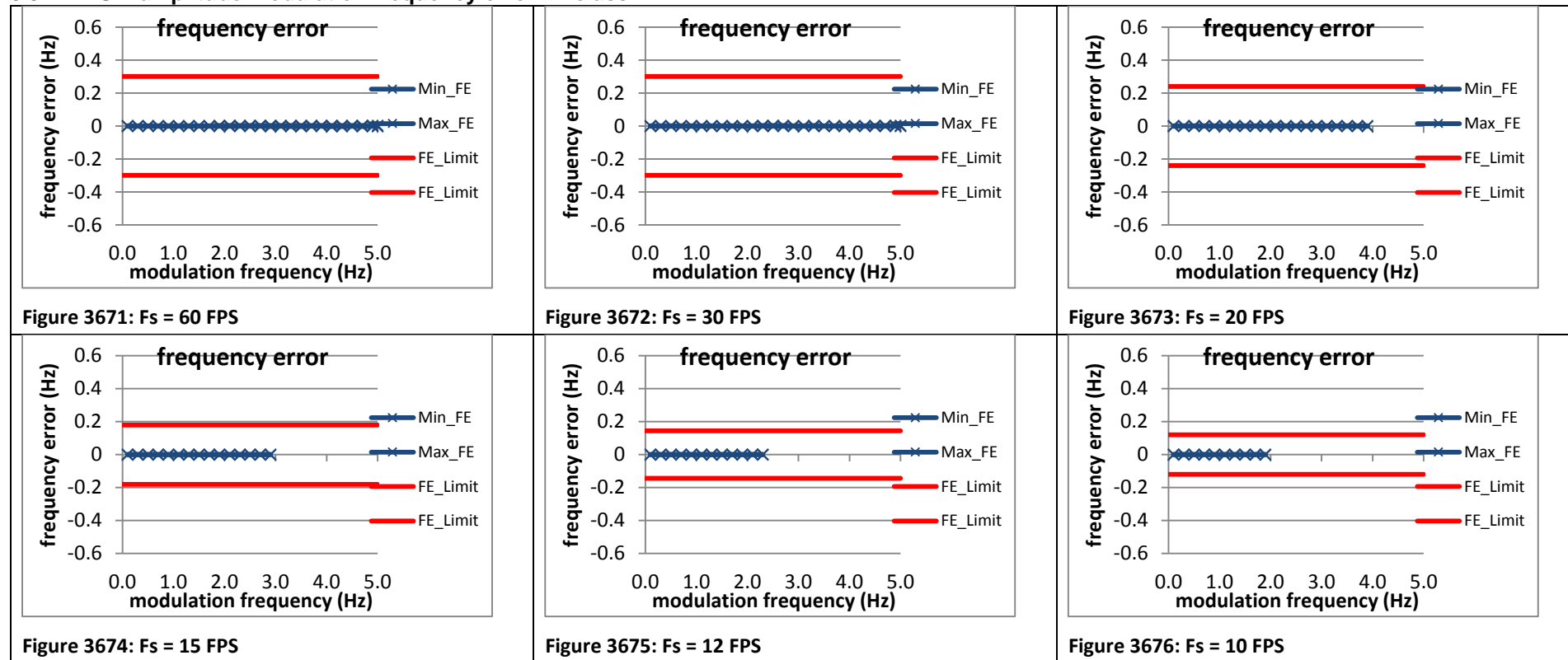


Figure 3670:  $F_s = 10$  FPS

### 8.3.7 PMU F amplitude modulation frequency error: M class



### 8.3.8 PMU G amplitude modulation frequency error: M class

Figure 3677:  $F_s = 60$  FPS is not supported by this PMU

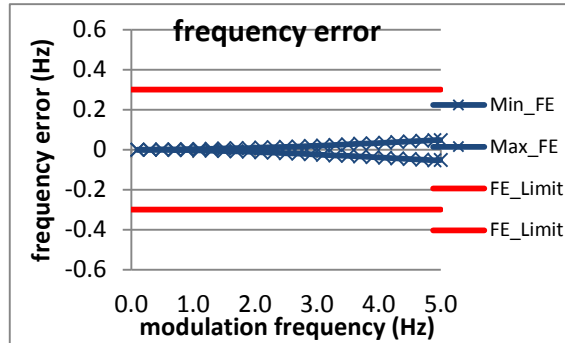


Figure 3678:  $F_s = 30$  FPS

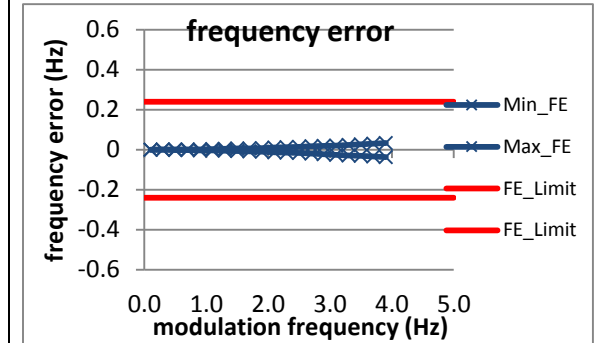


Figure 3679:  $F_s = 20$  FPS

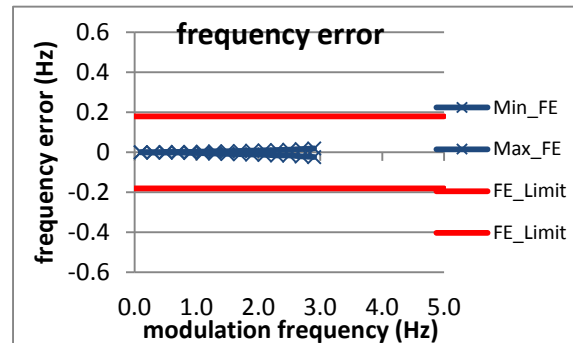


Figure 3680:  $F_s = 15$  FPS

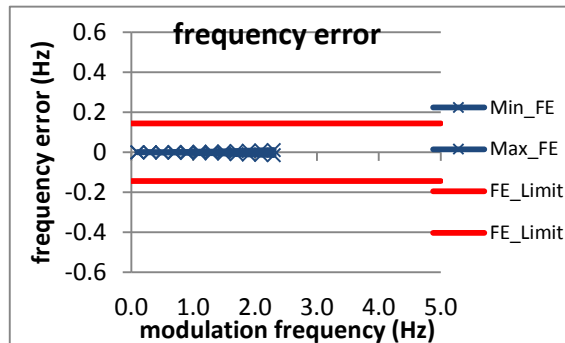


Figure 3681:  $F_s = 12$  FPS

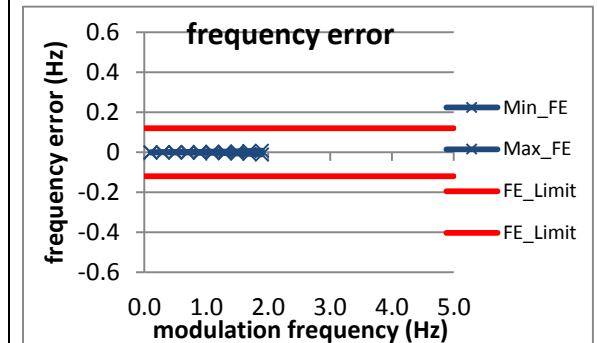


Figure 3682:  $F_s = 10$  FPS

### 8.3.9 PMU H amplitude modulation frequency error: M class

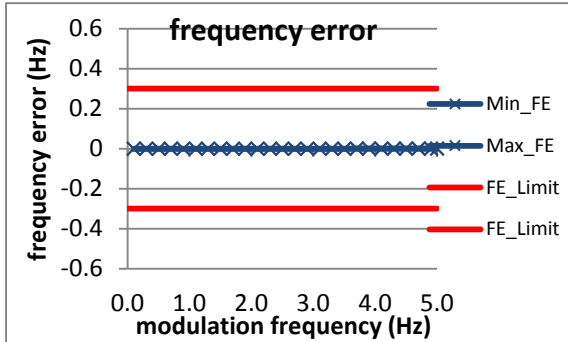


Figure 3683:  $F_s = 60$  FPS

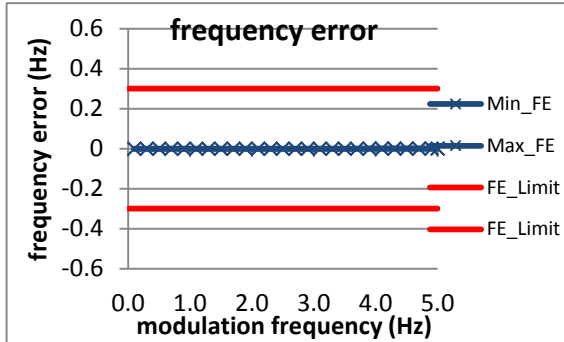


Figure 3684:  $F_s = 30$  FPS

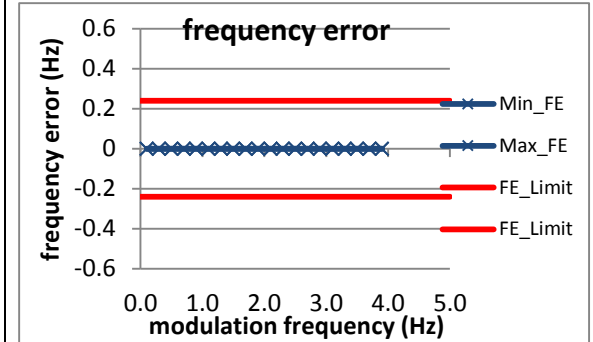


Figure 3685:  $F_s = 20$  FPS

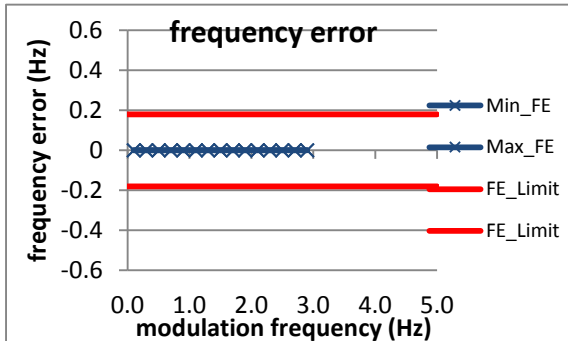


Figure 3686:  $F_s = 15$  FPS

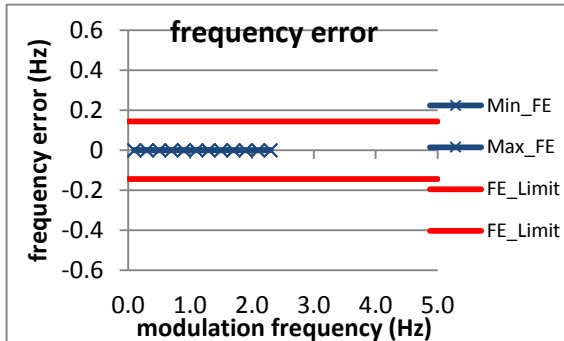


Figure 3687:  $F_s = 12$  FPS

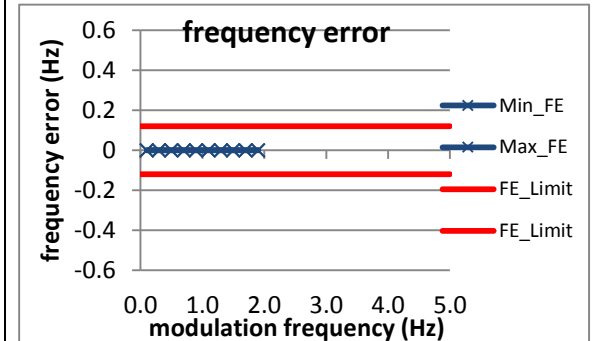


Figure 3688:  $F_s = 10$  FPS

### 8.3.10 PMU I amplitude modulation frequency error: M class

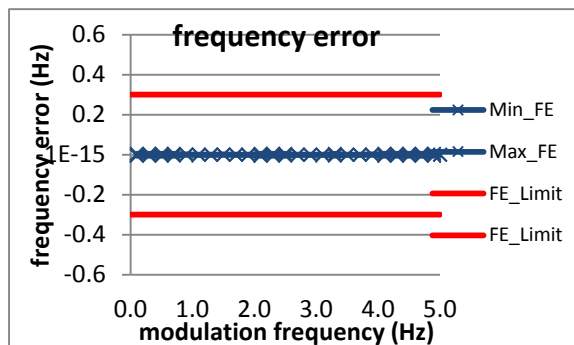


Figure 3689:  $F_s = 60$  FPS

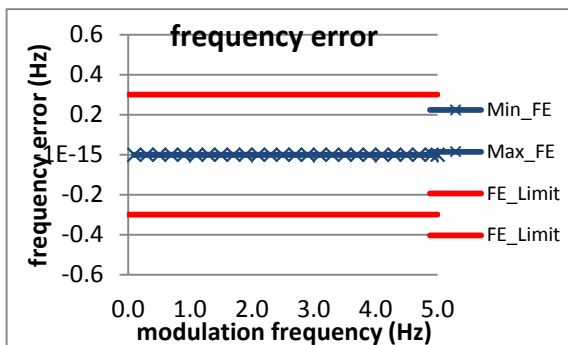


Figure 3690:  $F_s = 30$  FPS

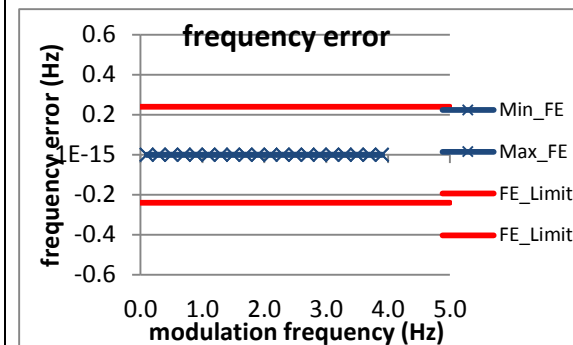


Figure 3691:  $F_s = 20$  FPS

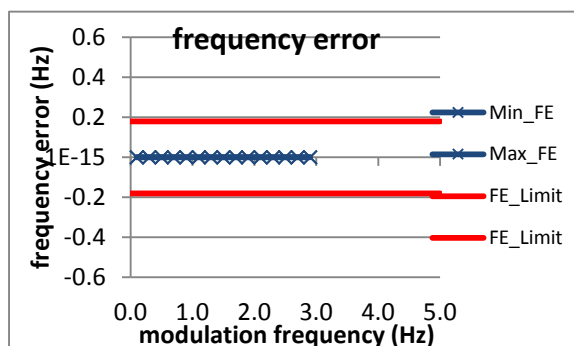


Figure 3692:  $F_s = 15$  FPS

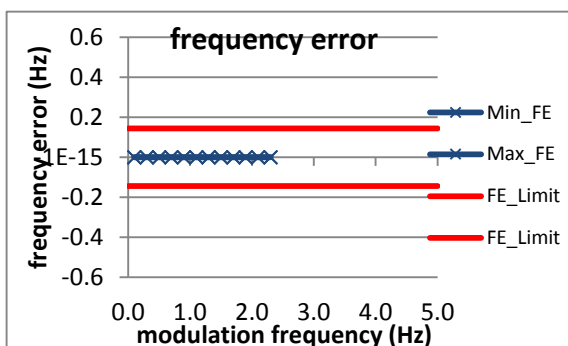


Figure 3693:  $F_s = 12$  FPS

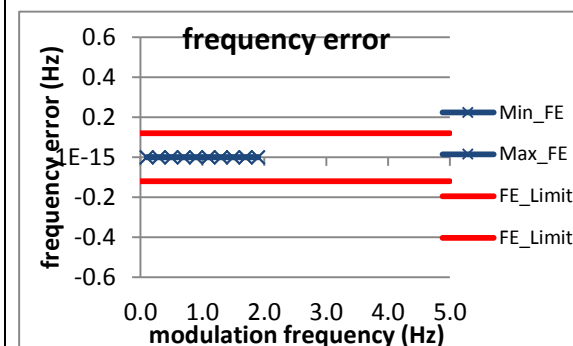
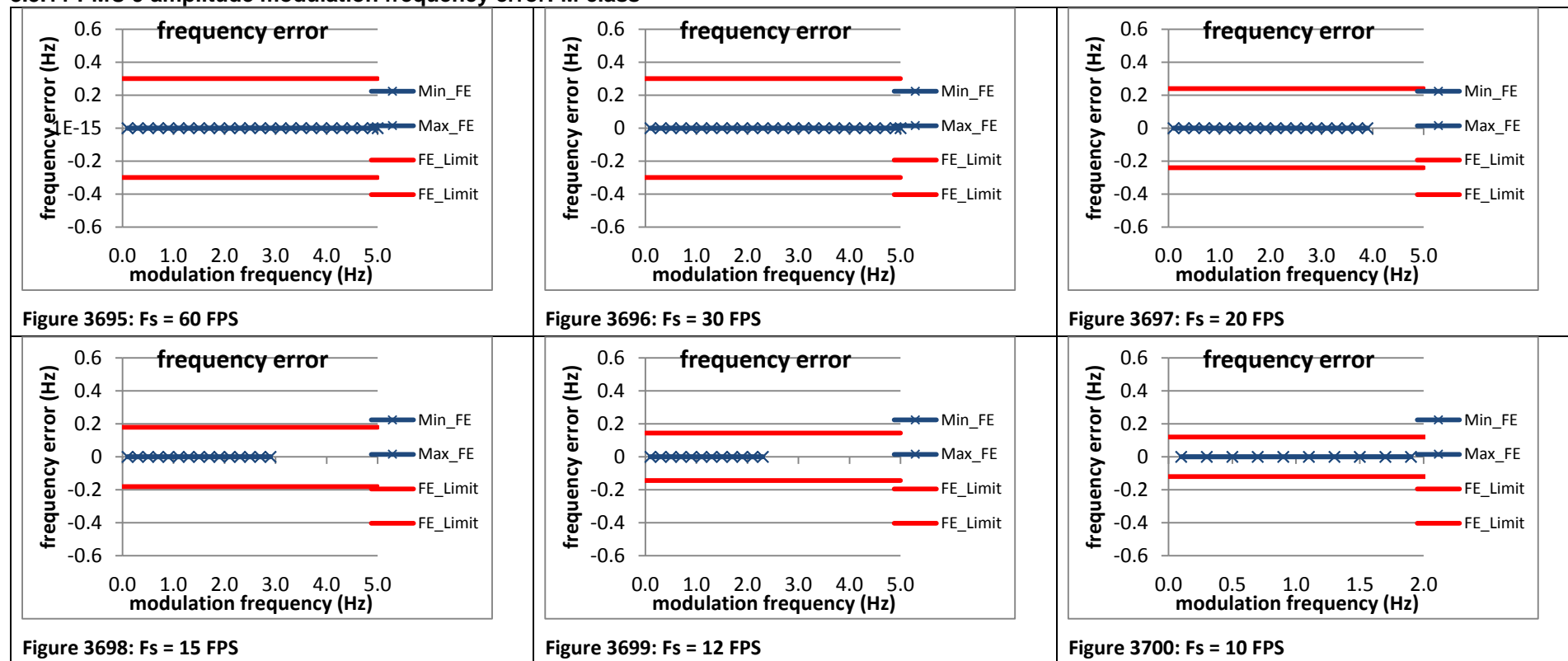


Figure 3694:  $F_s = 10$  FPS

### 8.3.11 PMU J amplitude modulation frequency error: M class



## 8.4 Amplitude modulation ROCOF error: M class

### 8.4.1 C37.118.1 Annex C amplitude modulation ROCOF error: M class

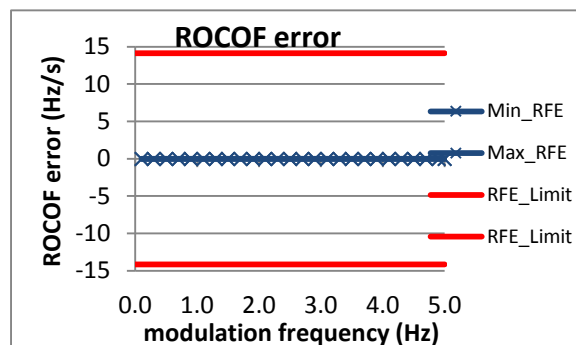


Figure 3701:  $F_s = 60$  FPS

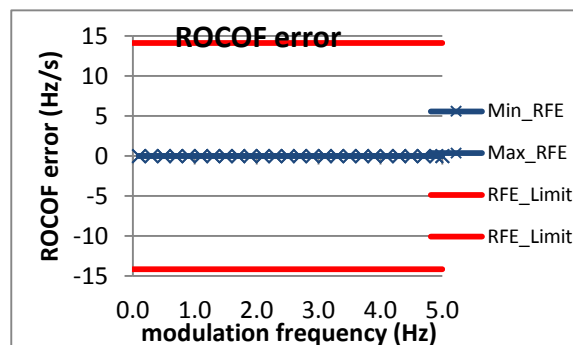


Figure 3702:  $F_s = 30$  FPS

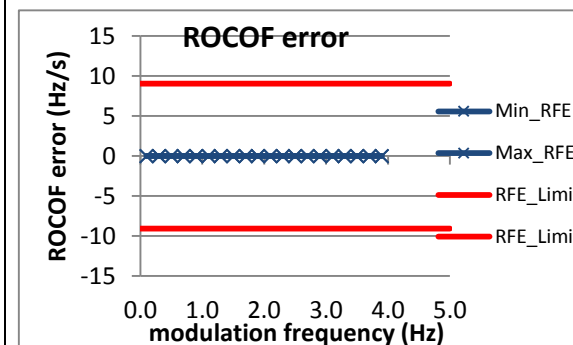


Figure 3703:  $F_s = 20$  FPS

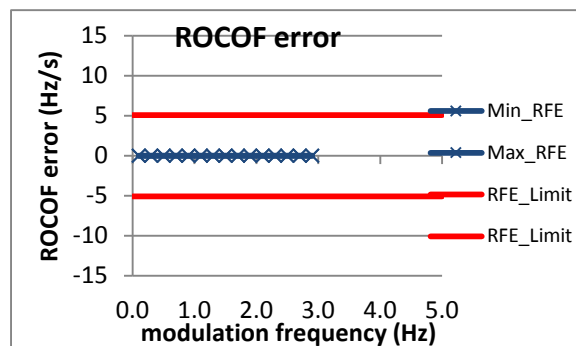


Figure 3704:  $F_s = 15$  FPS

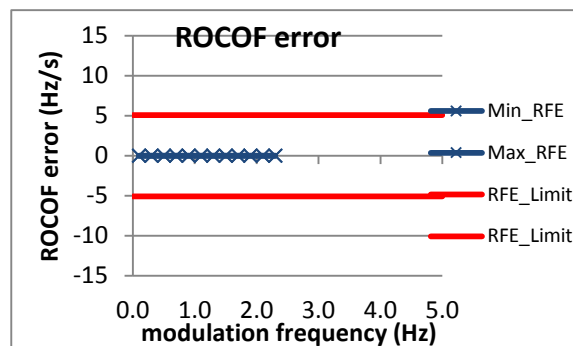


Figure 3705:  $F_s = 12$  FPS

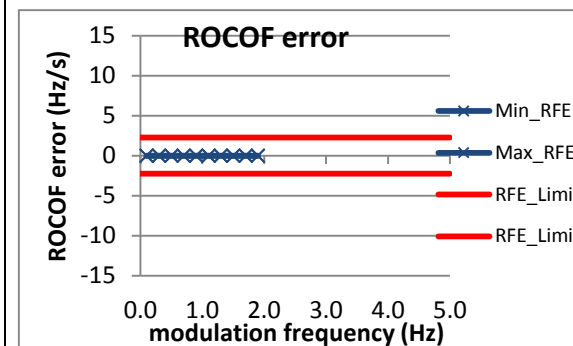


Figure 3706:  $F_s = 10$  FPS

#### 8.4.2 PMU A amplitude modulation ROCOF error: M class

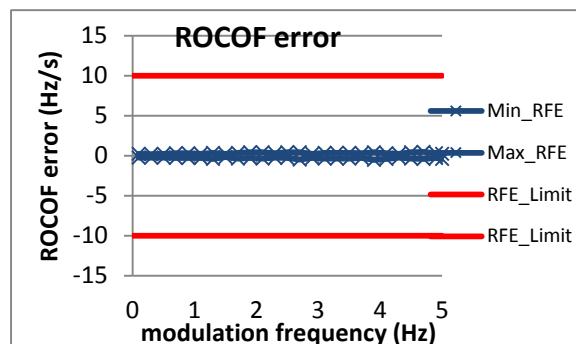


Figure 3707:  $F_s = 60$  FPS

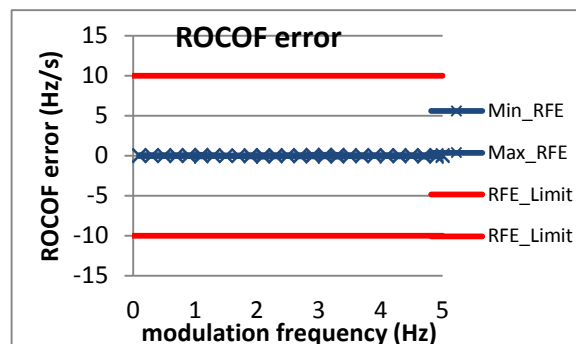


Figure 3708:  $F_s = 30$  FPS

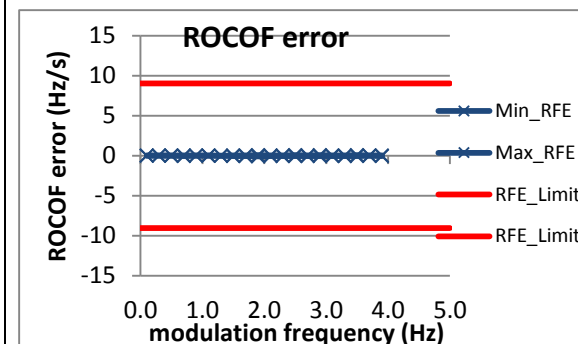


Figure 3709:  $F_s = 20$  FPS

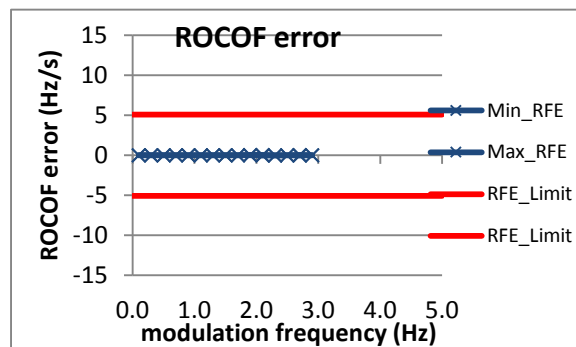


Figure 3710:  $F_s = 15$  FPS

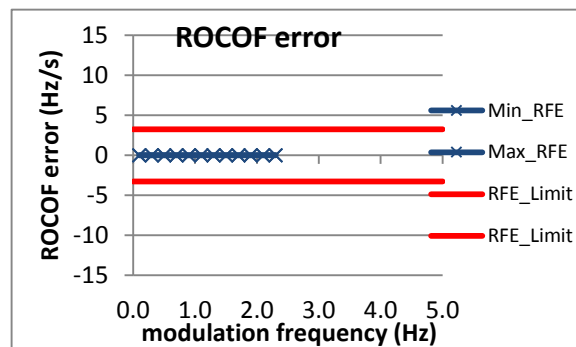


Figure 3711:  $F_s = 12$  FPS

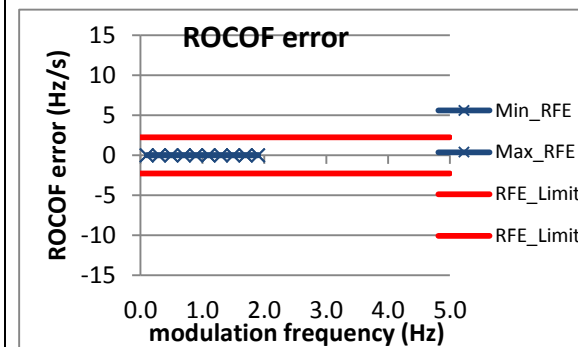


Figure 3712:  $F_s = 10$  FPS



#### 8.4.3 PMU B amplitude modulation ROCOF error: M class

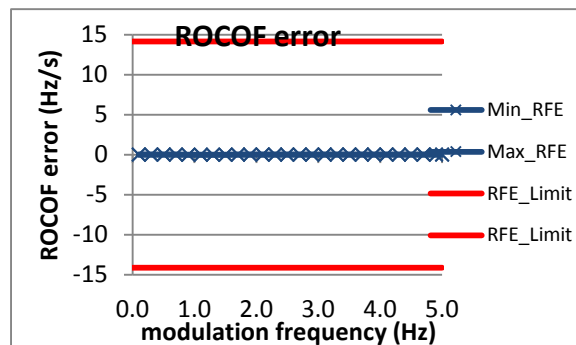


Figure 3713:  $F_s = 60$  FPS

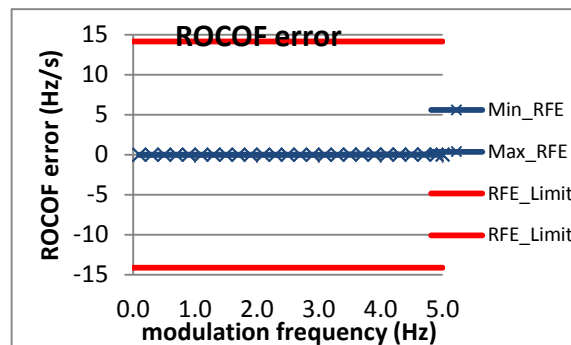


Figure 3714:  $F_s = 30$  FPS

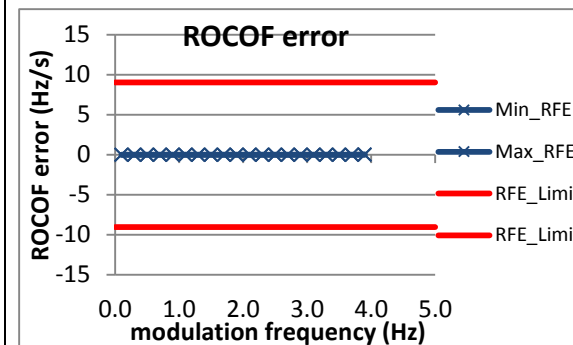


Figure 3715:  $F_s = 20$  FPS

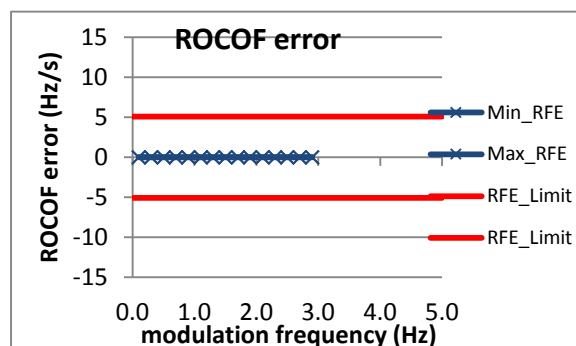


Figure 3716:  $F_s = 15$  FPS

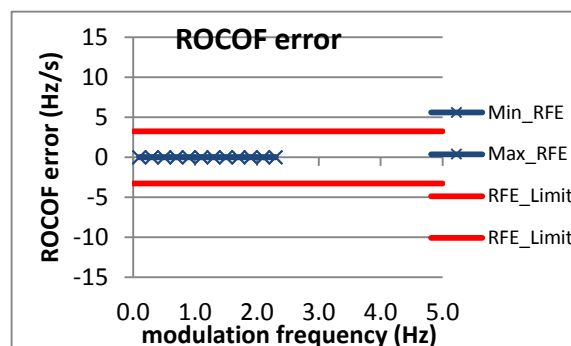


Figure 3717:  $F_s = 12$  FPS

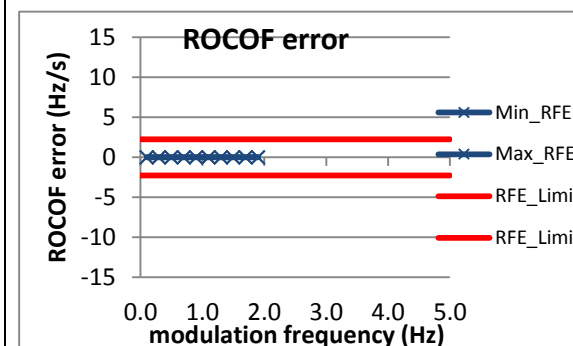


Figure 3718:  $F_s = 10$  FPS

#### 8.4.4 PMU C amplitude modulation ROCOF error: M class

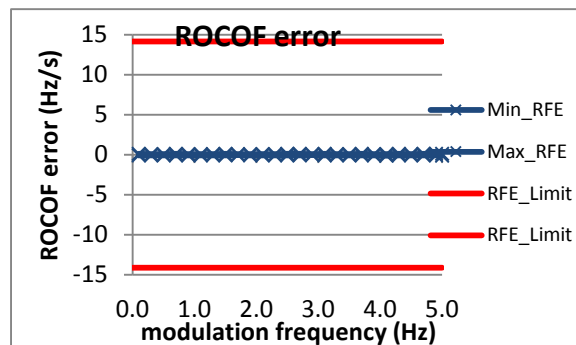


Figure 3719:  $F_s = 60$  FPS

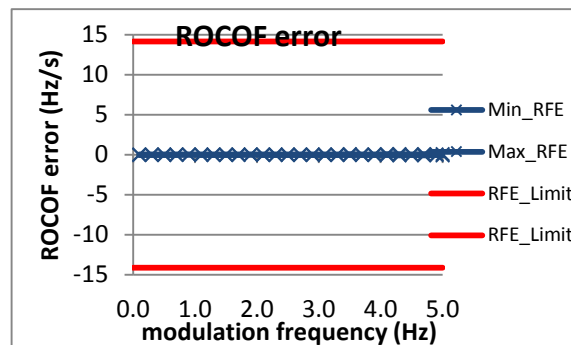


Figure 3720:  $F_s = 30$  FPS

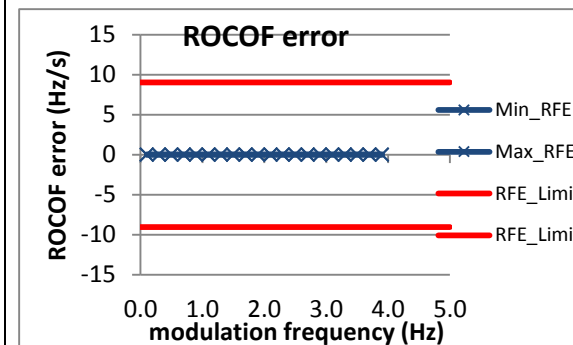


Figure 3721:  $F_s = 20$  FPS

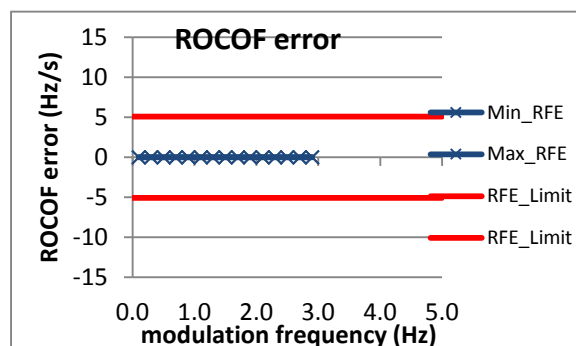


Figure 3722:  $F_s = 15$  FPS

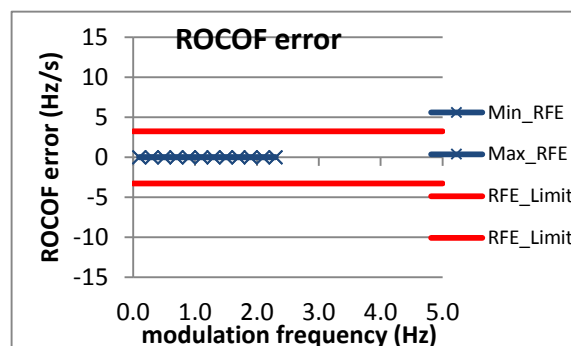


Figure 3723:  $F_s = 12$  FPS

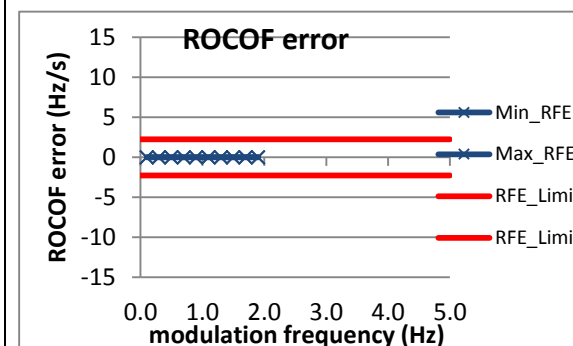


Figure 3724:  $F_s = 10$  FPS

#### 8.4.5 PMU D amplitude modulation ROCOF error: M class

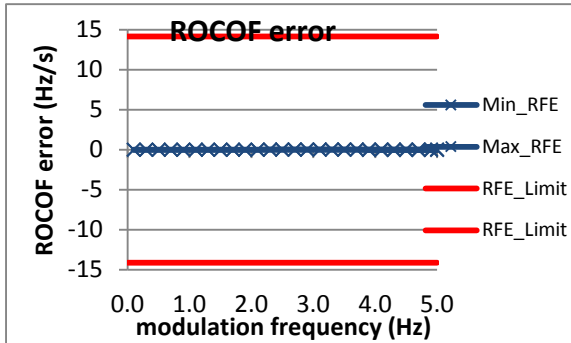


Figure 3725:  $F_s = 60$  FPS

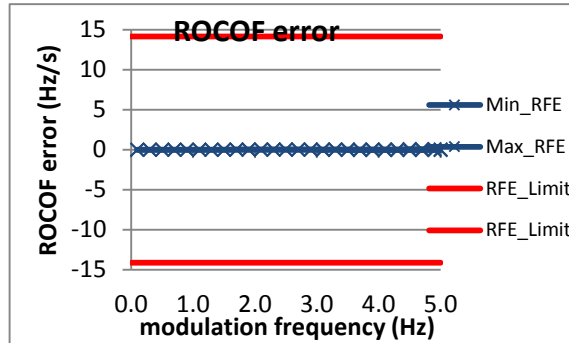


Figure 3726:  $F_s = 30$  FPS

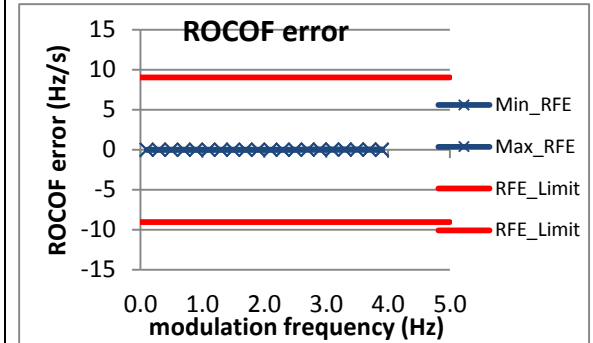


Figure 3727:  $F_s = 20$  FPS

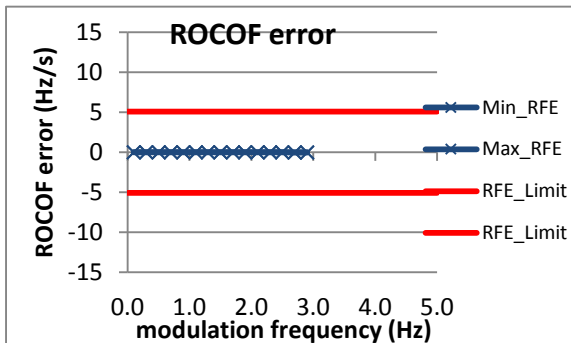


Figure 3728:  $F_s = 15$  FPS

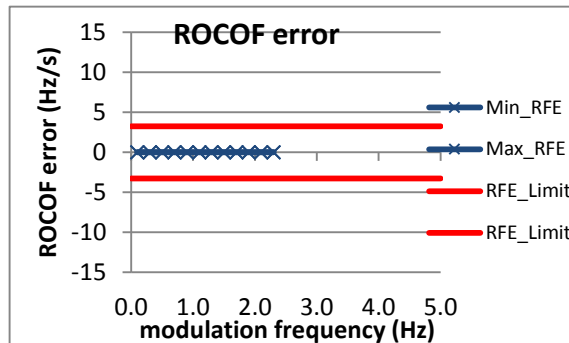


Figure 3729:  $F_s = 12$  FPS

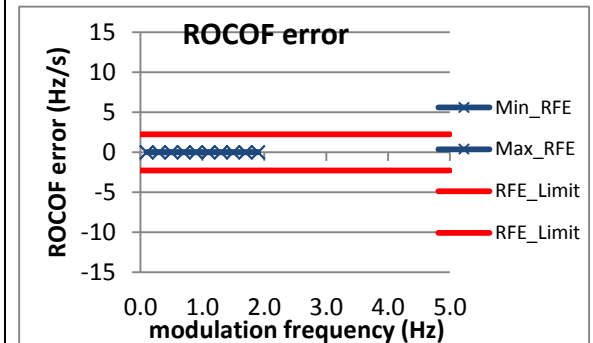


Figure 3730:  $F_s = 10$  FPS

#### 8.4.6 PMU E amplitude modulation ROCOF error: M class

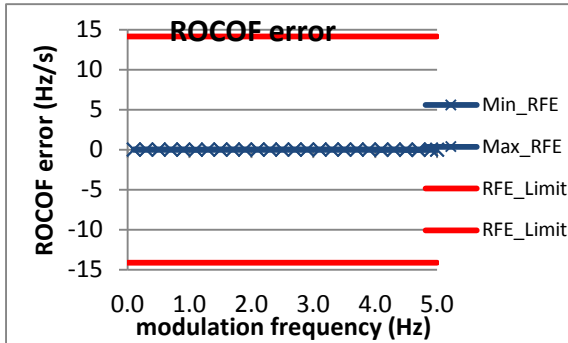


Figure 3731:  $F_s = 60$  FPS

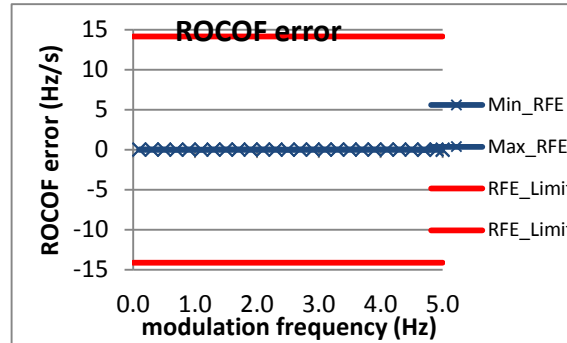


Figure 3732:  $F_s = 30$  FPS

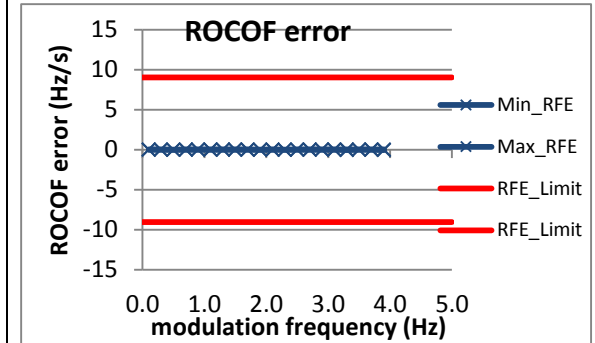


Figure 3733:  $F_s = 20$  FPS

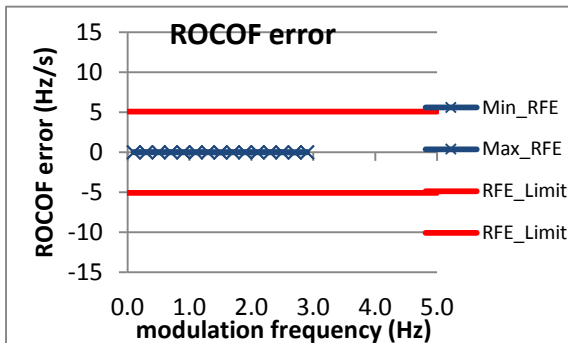


Figure 3734:  $F_s = 15$  FPS

Figure 3735:  $F_s = 12$  FPS data was lost

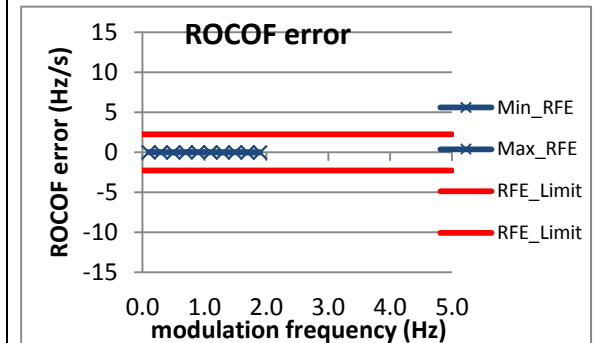
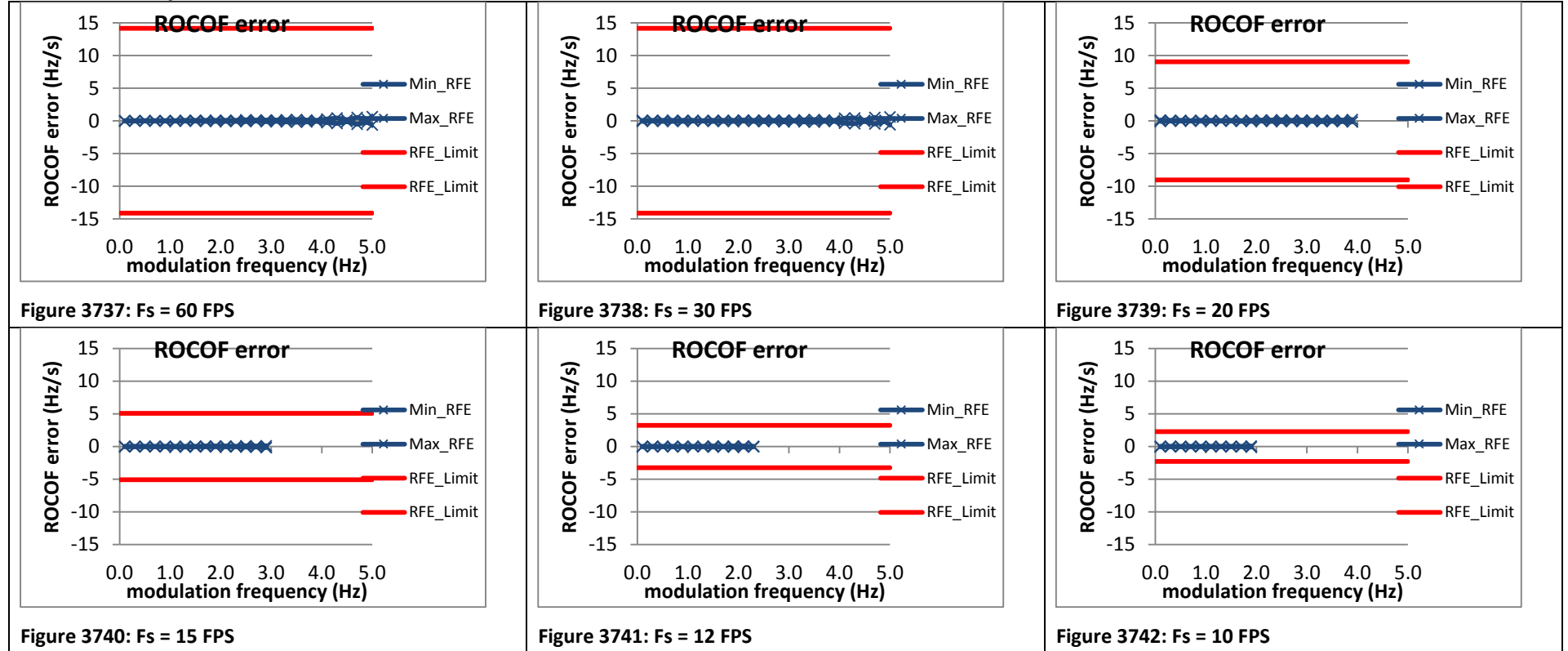


Figure 3736:  $F_s = 10$  FPS

#### 8.4.7 PMU F amplitude modulation ROCOF error: M class



#### 8.4.8 PMU G \* amplitude modulation ROCOF error: M class

Figure 3743:  $F_s = 60$  FPS is not supported by this PMU

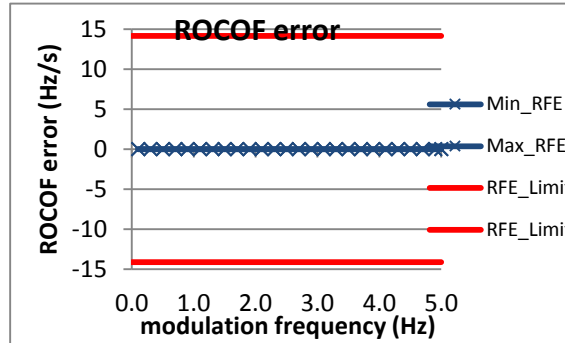


Figure 3744:  $F_s = 30$  FPS

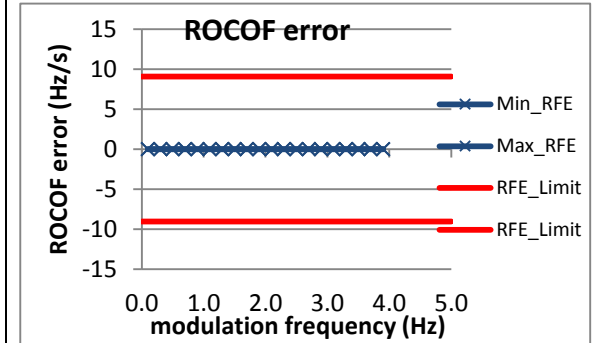


Figure 3745:  $F_s = 20$  FPS

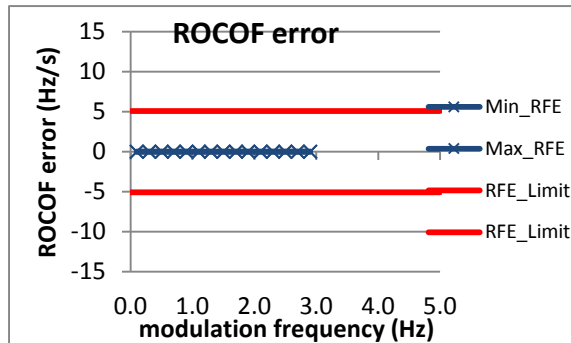


Figure 3746:  $F_s = 15$  FPS

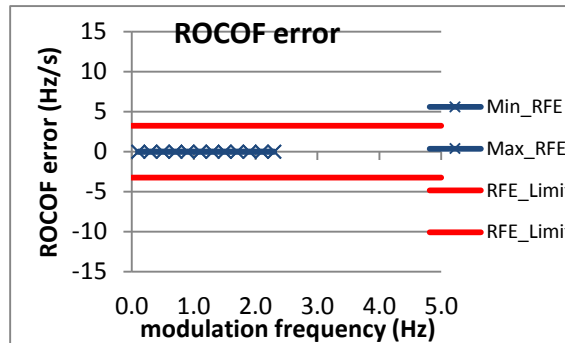


Figure 3747:  $F_s = 12$  FPS

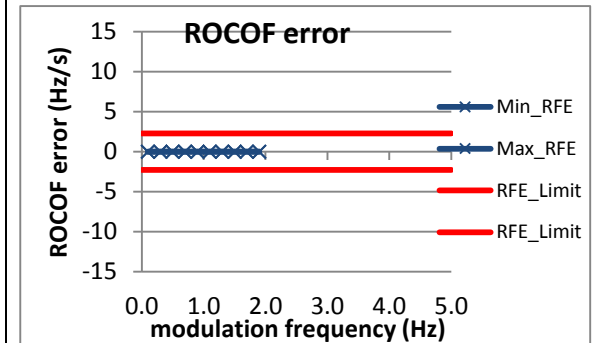


Figure 3748:  $F_s = 10$  FPS

\* PMU G always outputs ROCOF = 0

#### 8.4.9 PMU H amplitude modulation ROCOF error: M class

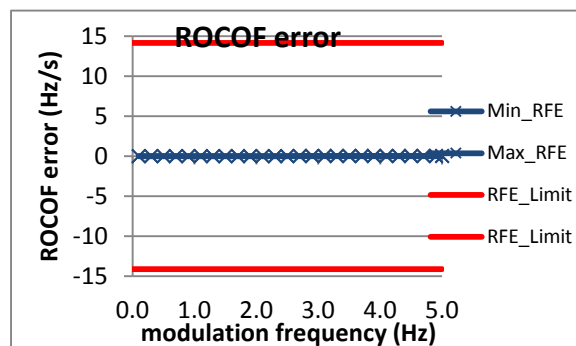


Figure 3749:  $F_s = 60$  FPS

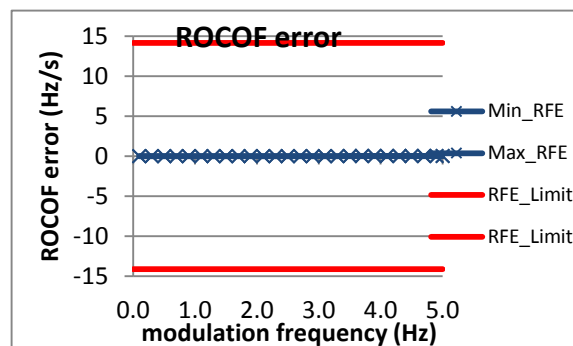


Figure 3750:  $F_s = 30$  FPS

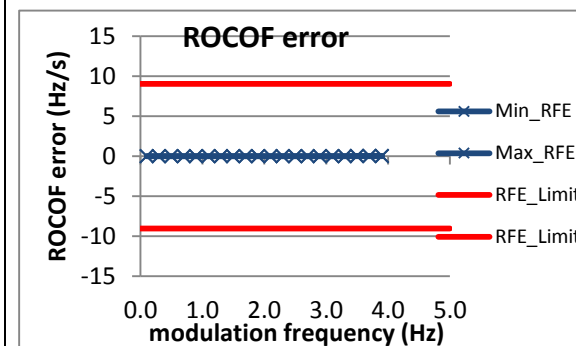


Figure 3751:  $F_s = 20$  FPS

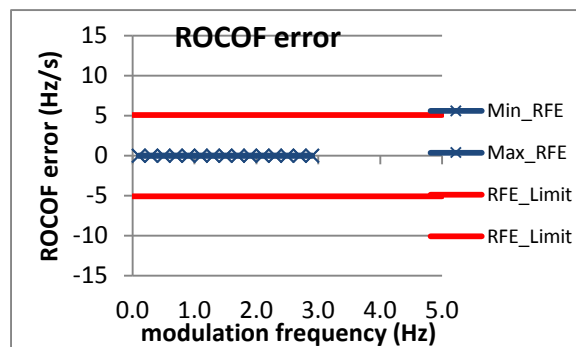


Figure 3752:  $F_s = 15$  FPS

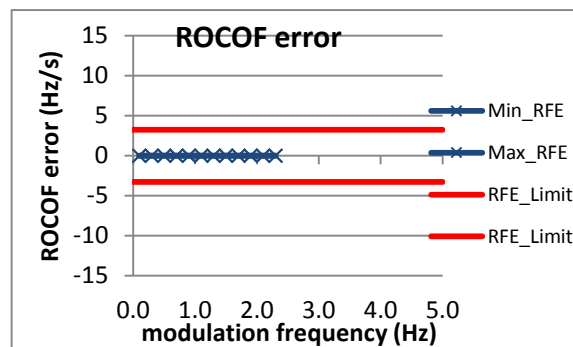


Figure 3753:  $F_s = 12$  FPS

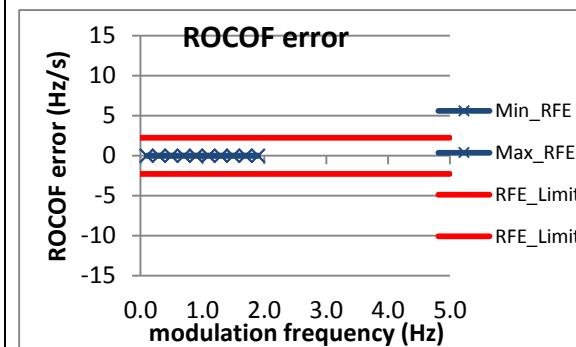


Figure 3754:  $F_s = 10$  FPS

#### 8.4.10 PMU I amplitude modulation ROCOF error: M class

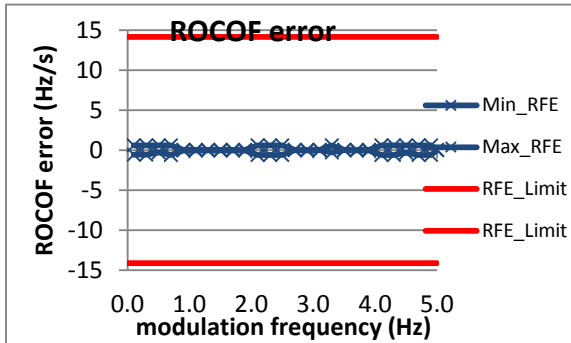


Figure 3755:  $F_s = 60$  FPS

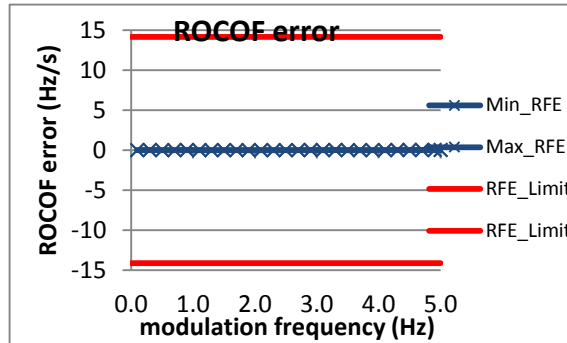


Figure 3756:  $F_s = 30$  FPS

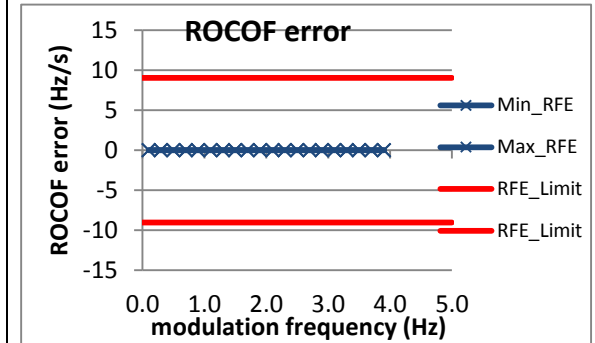


Figure 3757:  $F_s = 20$  FPS

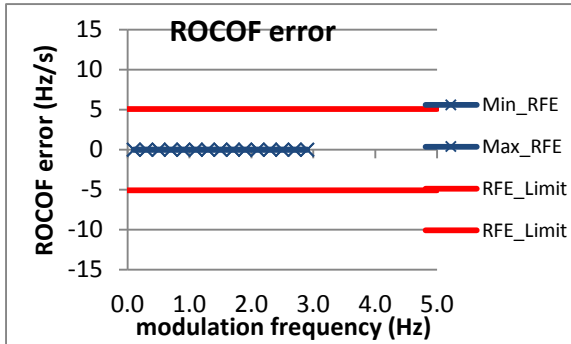


Figure 3758:  $F_s = 15$  FPS

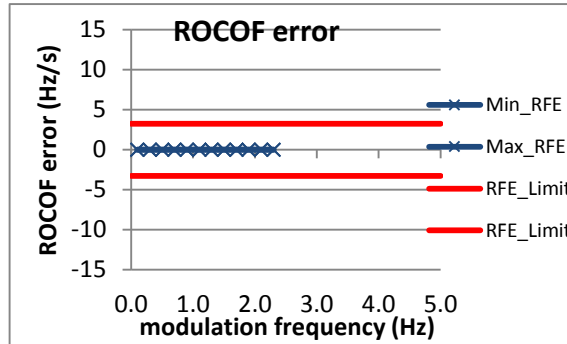


Figure 3759:  $F_s = 12$  FPS

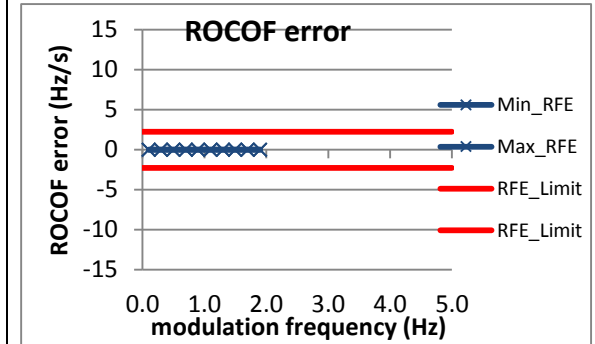
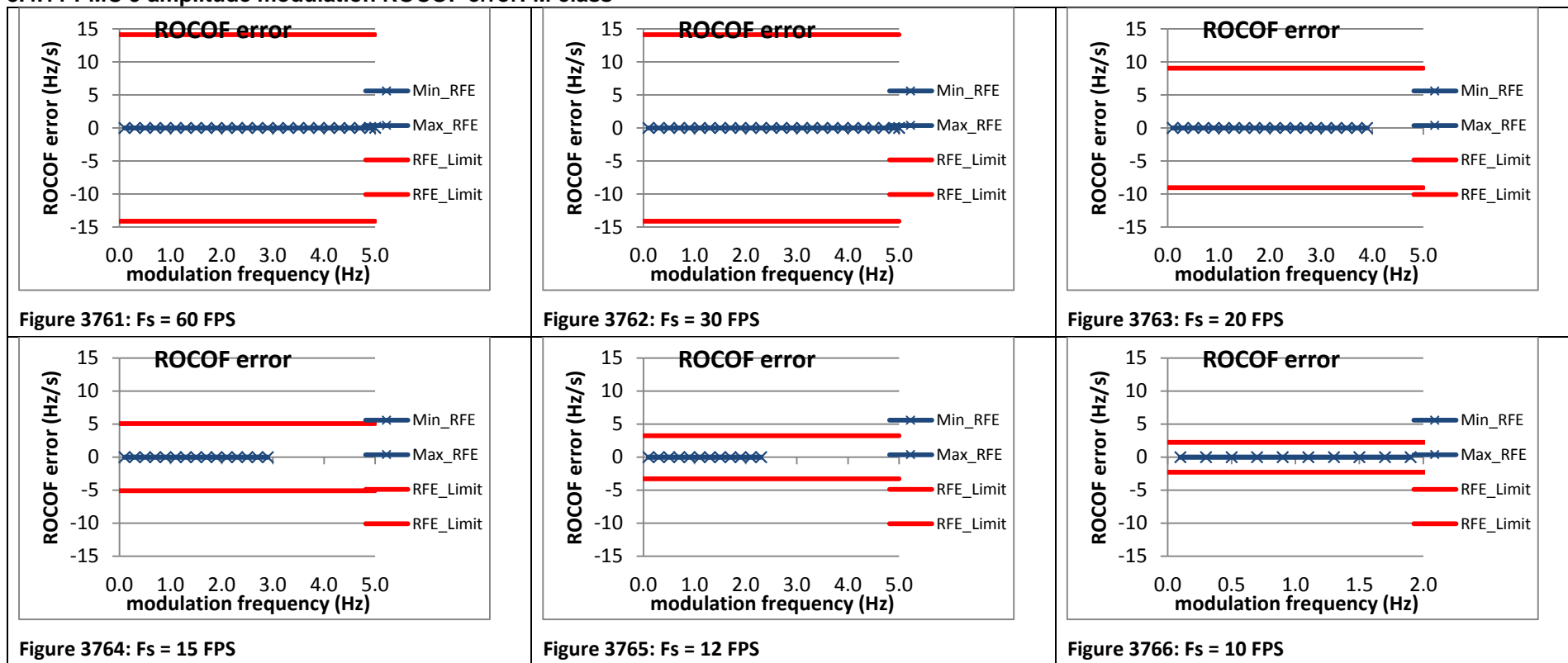


Figure 3760:  $F_s = 10$  FPS



#### 8.4.11 PMU J amplitude modulation ROCOF error: M class



## 8.5 Dynamic bandwidth measurement: amplitude modulation voltage TVE: P class

### 8.5.1 C37.118.1 Annex C dynamic bandwidth measurement: amplitude modulation voltage TVE: P class

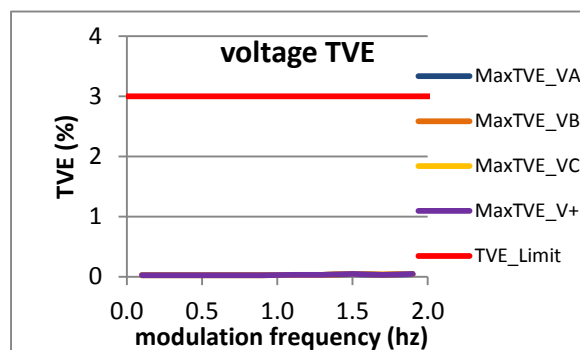


Figure 3767:  $F_s = 60$  FPS

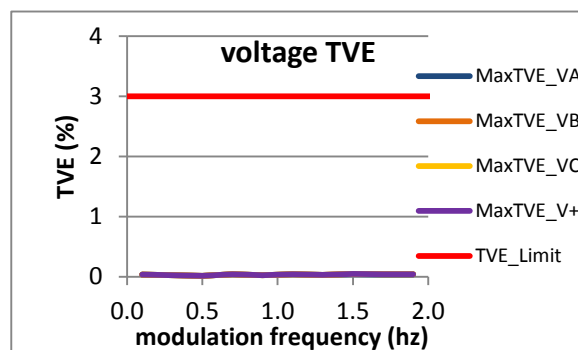


Figure 3768:  $F_s = 30$  FPS

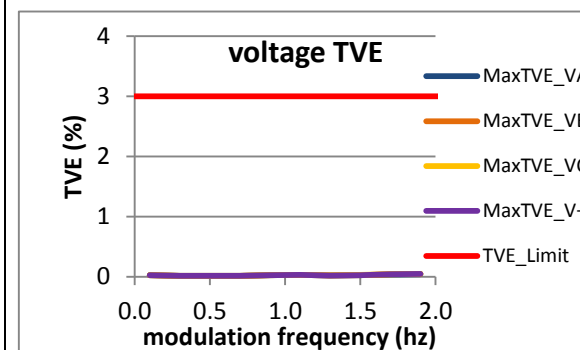


Figure 3769:  $F_s = 20$  FPS

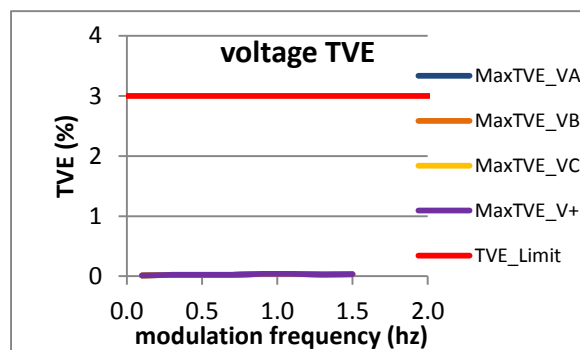


Figure 3770:  $F_s = 15$  FPS

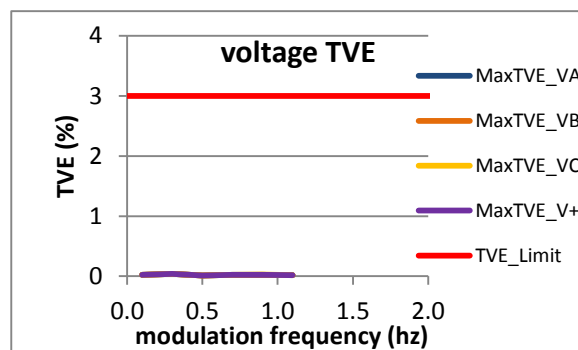


Figure 3771:  $F_s = 12$  FPS

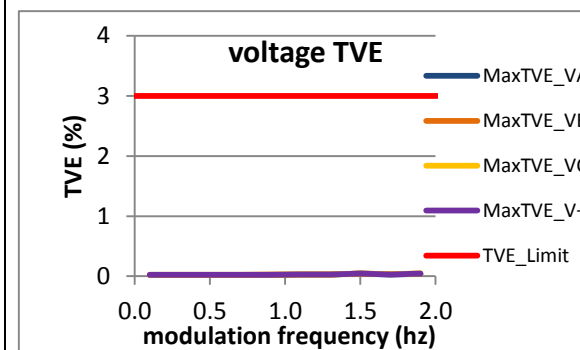


Figure 3772:  $F_s = 10$  FPS

### 8.5.2 PMU A dynamic bandwidth measurement: amplitude modulation voltage TVE: P class

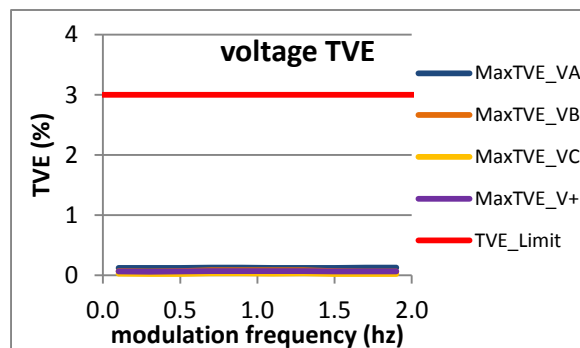


Figure 3773:  $F_s = 60$  FPS

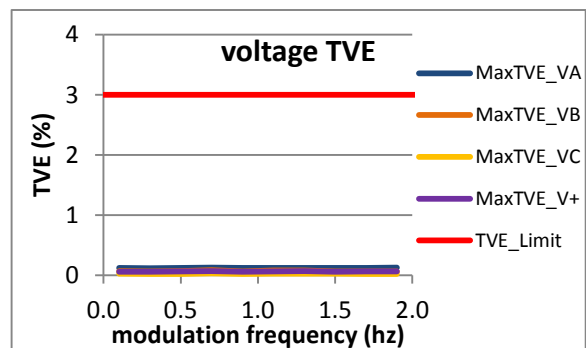


Figure 3774:  $F_s = 30$  FPS

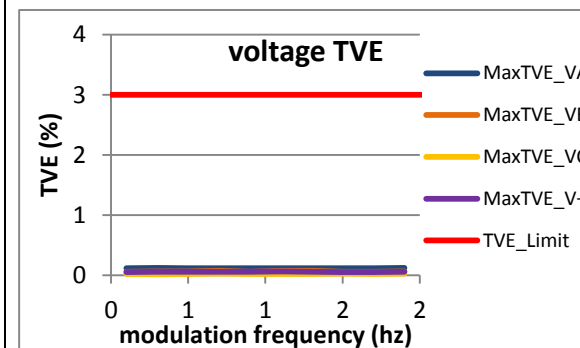


Figure 3775:  $F_s = 20$  FPS

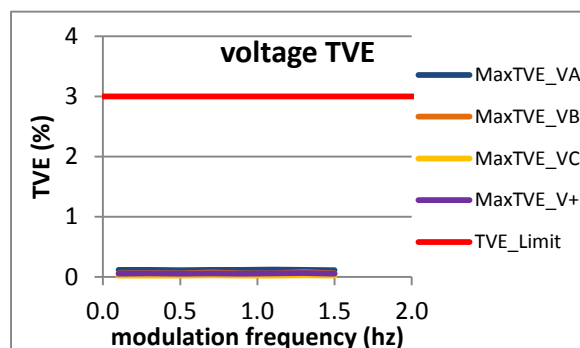


Figure 3776:  $F_s = 15$  FPS

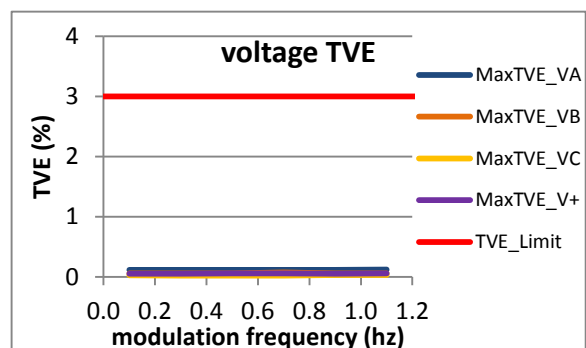


Figure 3777:  $F_s = 12$  FPS

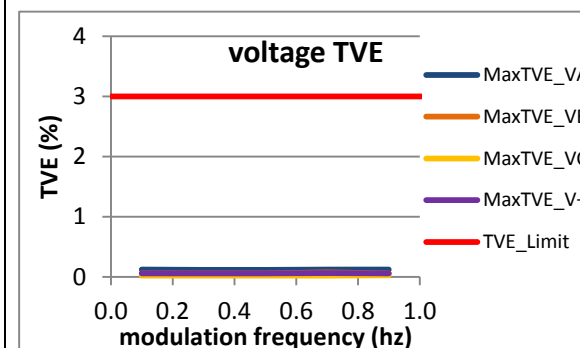


Figure 3778:  $F_s = 10$  FPS

### 8.5.3 PMU B dynamic bandwidth measurement: amplitude modulation voltage TVE: P class

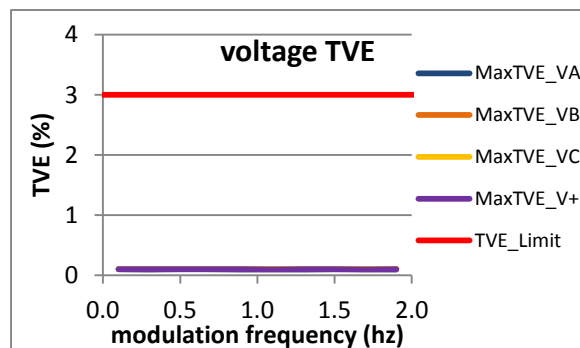


Figure 3779:  $F_s = 60$  FPS

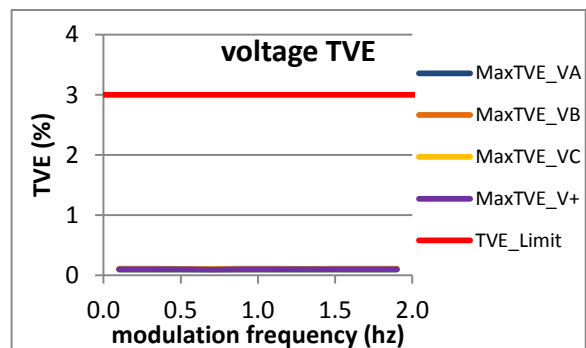


Figure 3780:  $F_s = 30$  FPS

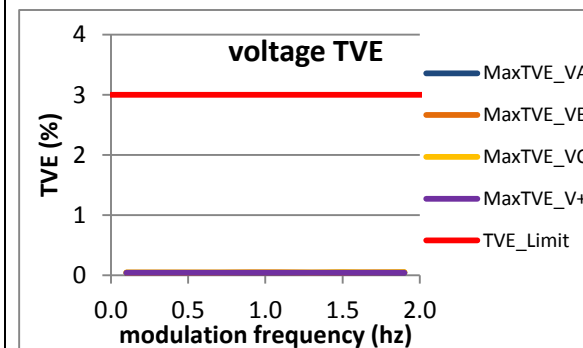


Figure 3781:  $F_s = 20$  FPS

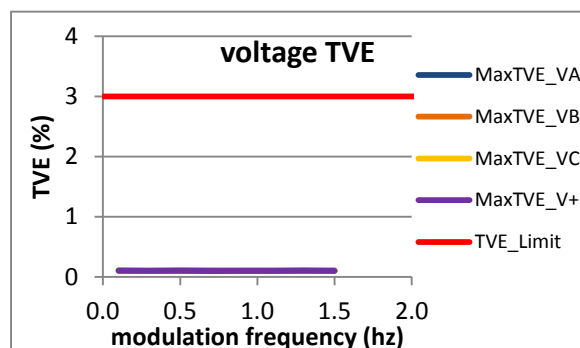


Figure 3782:  $F_s = 15$  FPS

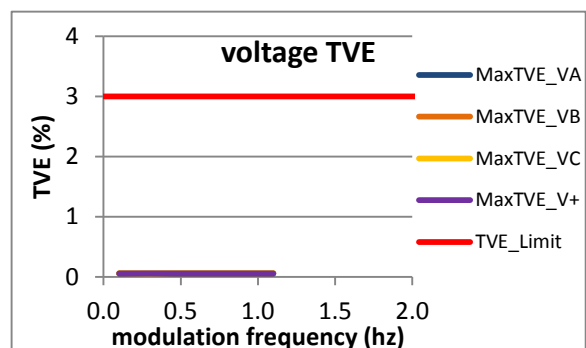


Figure 3783:  $F_s = 12$  FPS

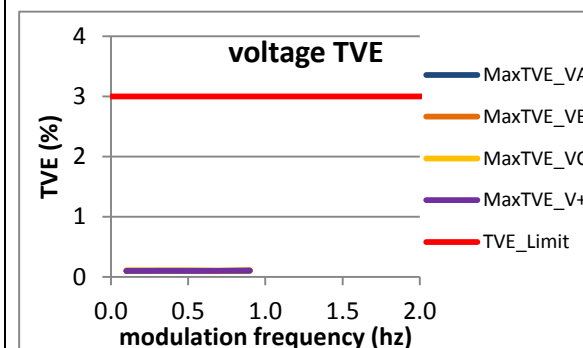


Figure 3784:  $F_s = 10$  FPS

#### 8.5.4 PMU C dynamic bandwidth measurement: amplitude modulation voltage TVE: P class

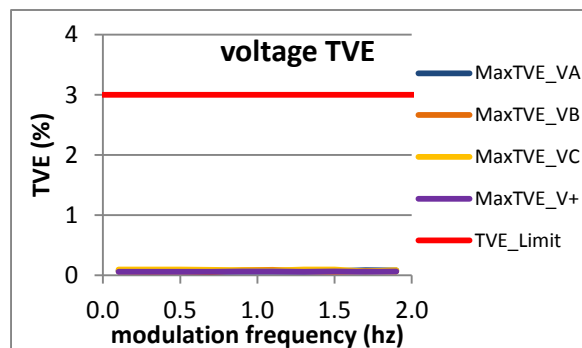


Figure 3785:  $F_s = 60$  FPS

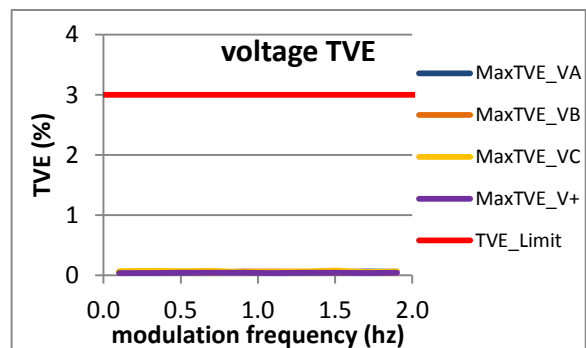


Figure 3786:  $F_s = 30$  FPS

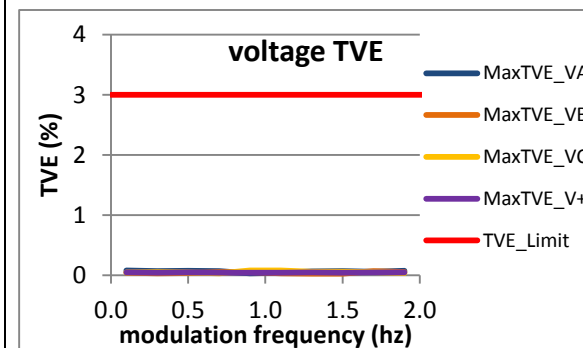


Figure 3787:  $F_s = 20$  FPS

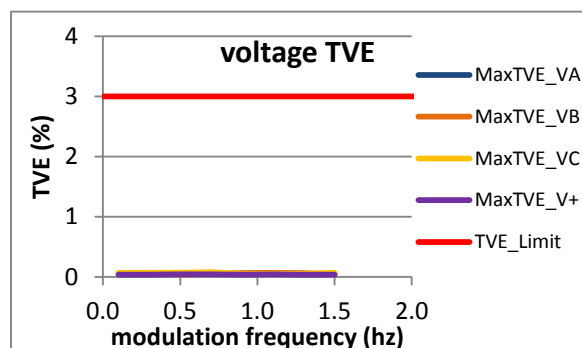


Figure 3788:  $F_s = 15$  FPS

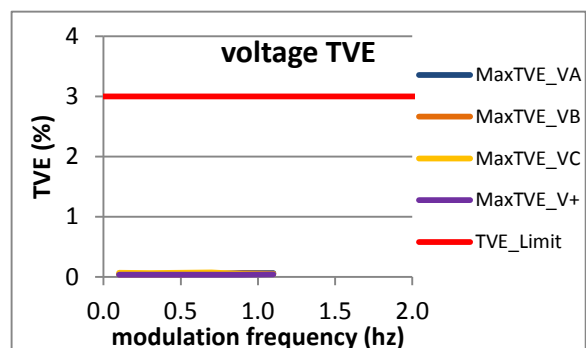


Figure 3789:  $F_s = 12$  FPS

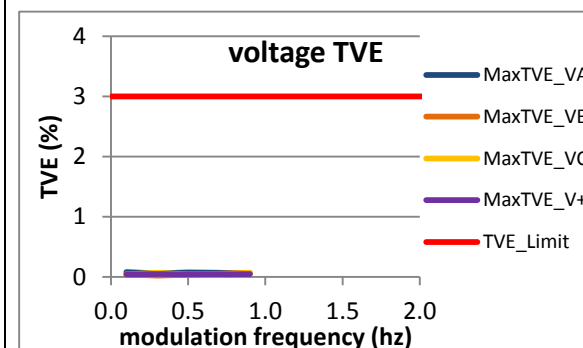


Figure 3790:  $F_s = 10$  FPS

### 8.5.5 PMU D dynamic bandwidth measurement: amplitude modulation voltage TVE: P class

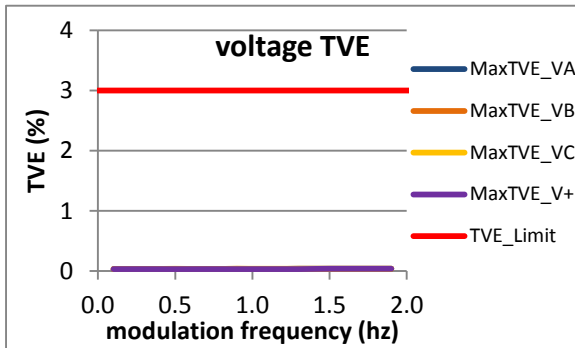


Figure 3791:  $F_s = 60$  FPS

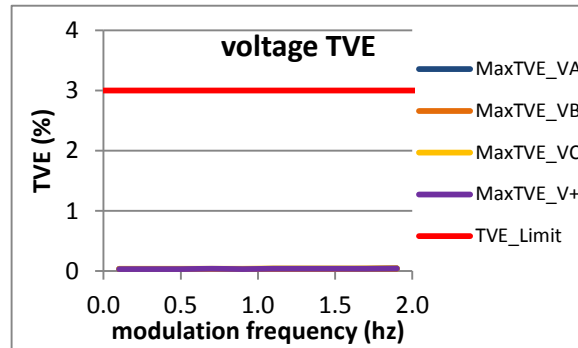


Figure 3792:  $F_s = 30$  FPS

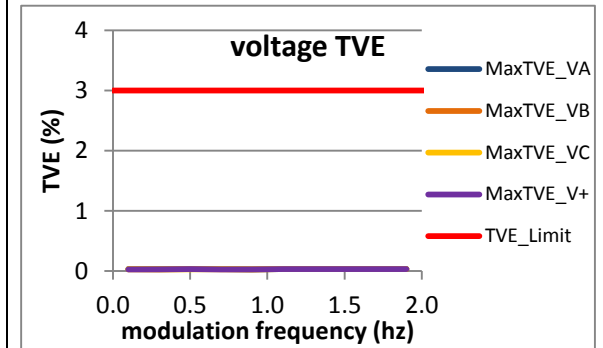


Figure 3793:  $F_s = 20$  FPS

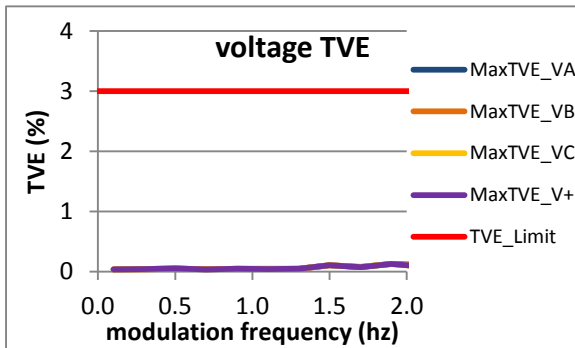


Figure 3794:  $F_s = 15$  FPS

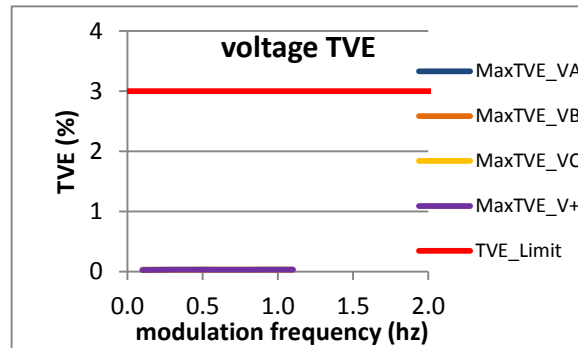


Figure 3795:  $F_s = 12$  FPS

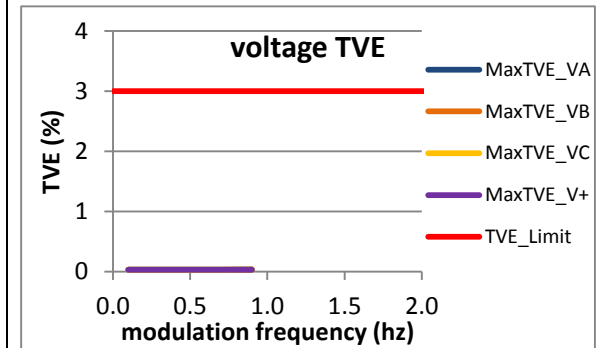
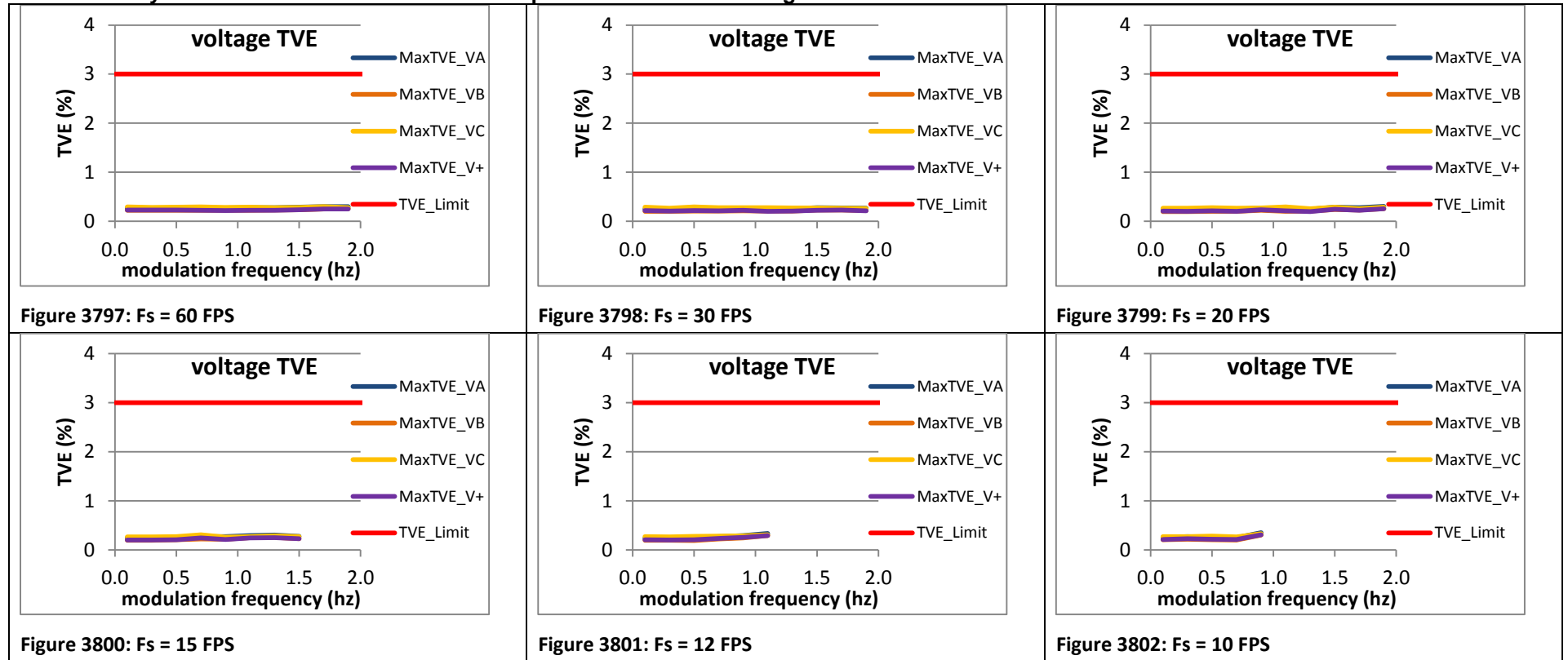


Figure 3796:  $F_s = 10$  FPS

### 8.5.6 PMU E dynamic bandwidth measurement: amplitude modulation voltage TVE: P class

PMU E does not support P class

### 8.5.7 PMU F dynamic bandwidth measurement: amplitude modulation voltage TVE: P class



### 8.5.8 PMU G dynamic bandwidth measurement: amplitude modulation voltage TVE: P class

PMU G does not support P class

### 8.5.9 PMU H dynamic bandwidth measurement: amplitude modulation voltage TVE: P class

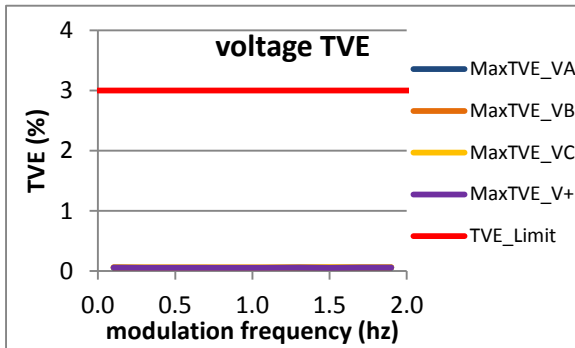


Figure 3803: Fs = 60 FPS

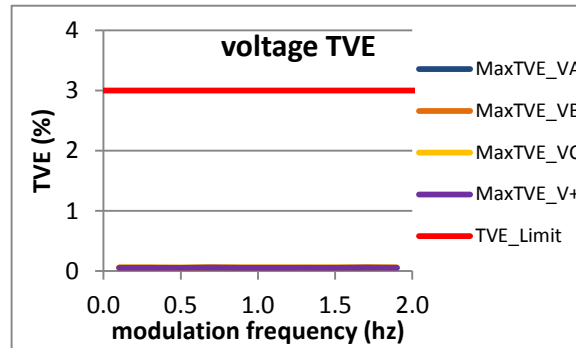


Figure 3804: Fs = 30 FPS

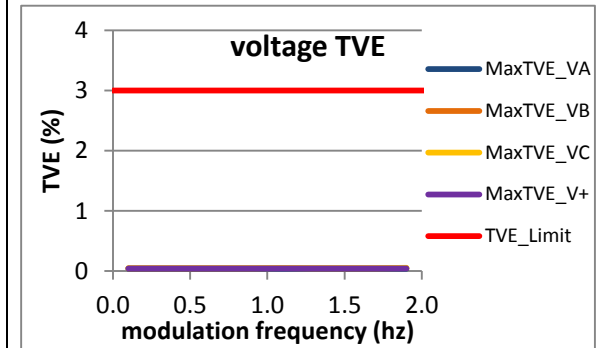


Figure 3805: Fs = 20 FPS

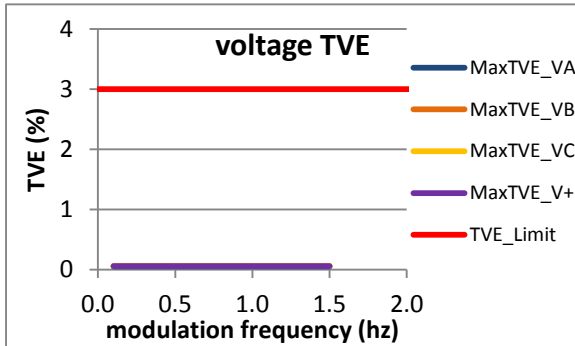


Figure 3806: Fs = 15 FPS

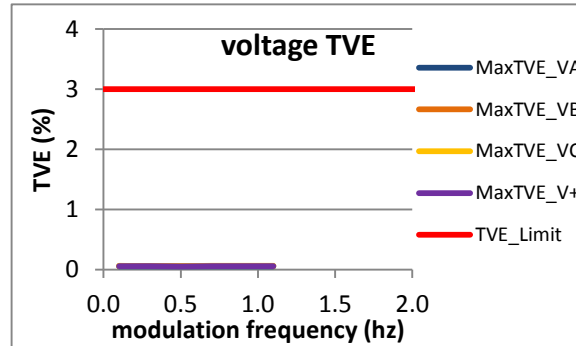


Figure 3807: Fs = 12 FPS

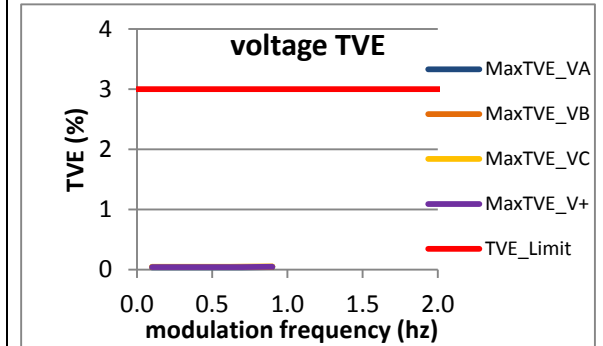


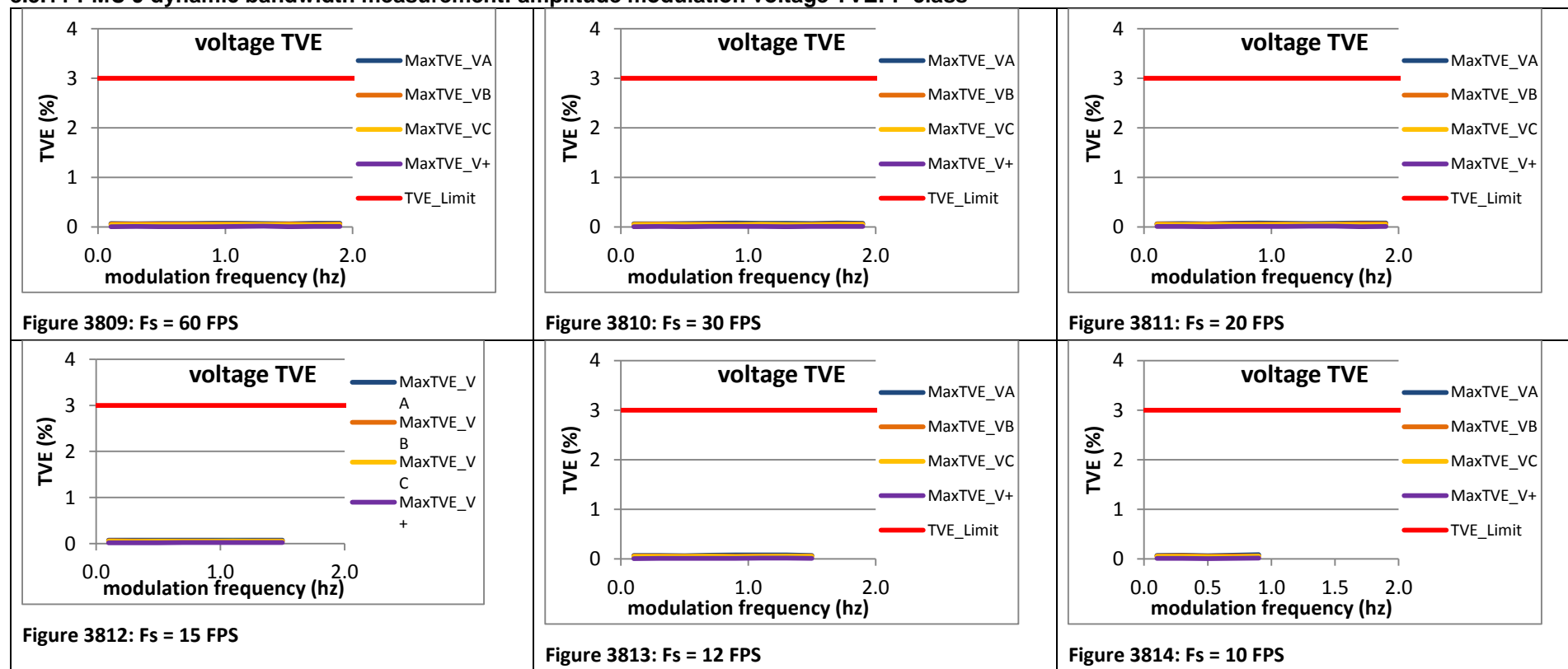
Figure 3808: Fs = 10 FPS

### 8.5.10 PMU I dynamic bandwidth measurement: amplitude modulation voltage TVE: P class

PMU I does not support P class



### 8.5.11 PMU J dynamic bandwidth measurement: amplitude modulation voltage TVE: P class



## 8.6 Dynamic bandwidth measurement: amplitude modulation current TVE: P class

### 8.6.1 C37.118.1 Annex C dynamic bandwidth measurement: amplitude modulation current TVE: P class

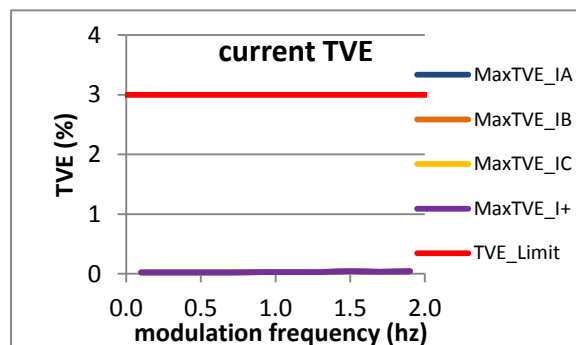


Figure 3815:  $F_s = 60$  FPS

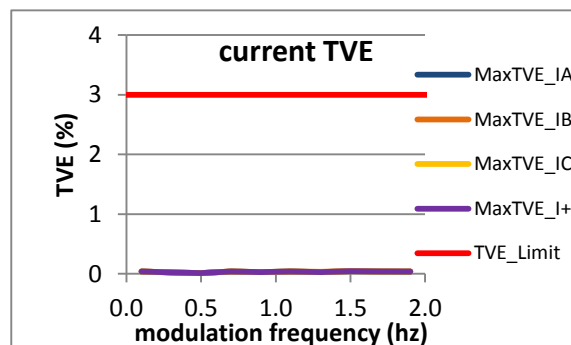


Figure 3816:  $F_s = 30$  FPS

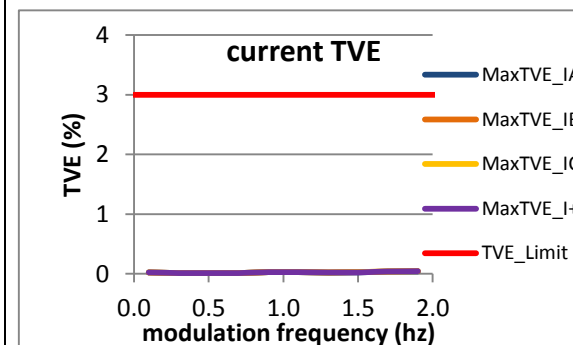


Figure 3817:  $F_s = 20$  FPS

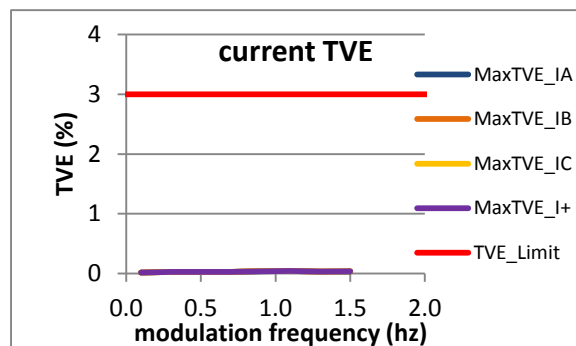


Figure 3818:  $F_s = 15$  FPS

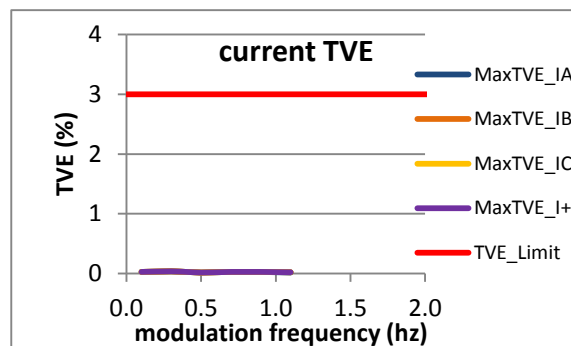


Figure 3819:  $F_s = 12$  FPS

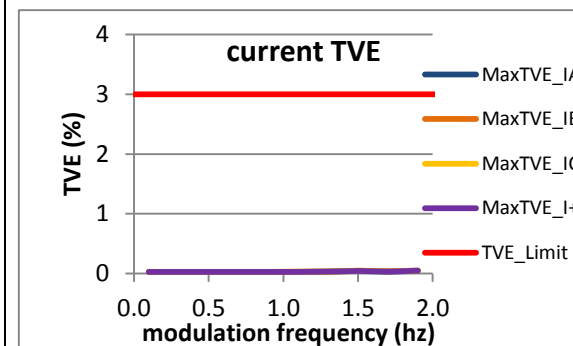


Figure 3820:  $F_s = 10$  FPS

### 8.6.2 PMU A dynamic bandwidth measurement: amplitude modulation current TVE: P class

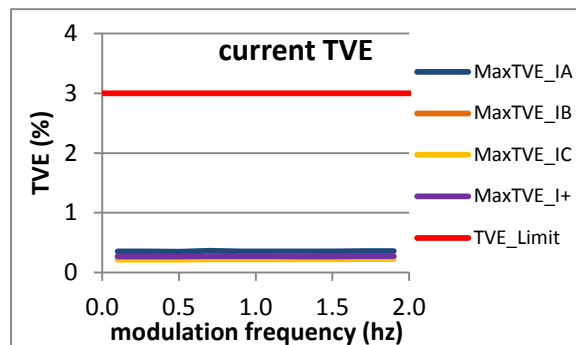


Figure 3821:  $F_s = 60$  FPS

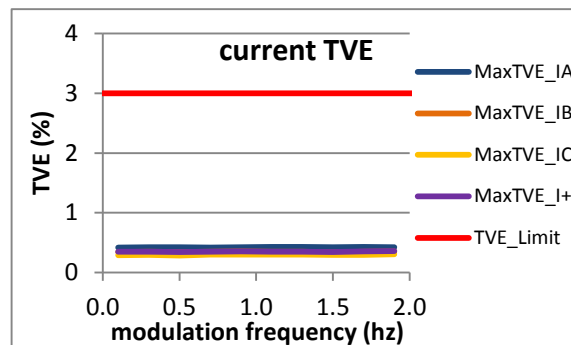


Figure 3822:  $F_s = 30$  FPS

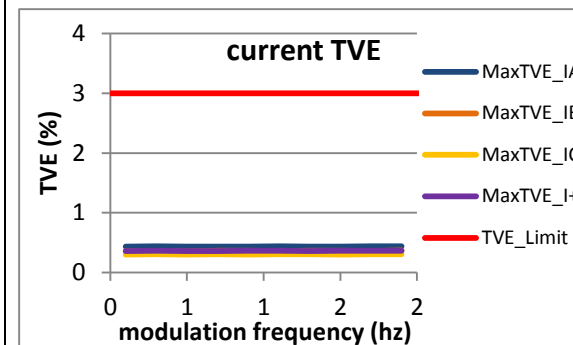


Figure 3823:  $F_s = 20$  FPS

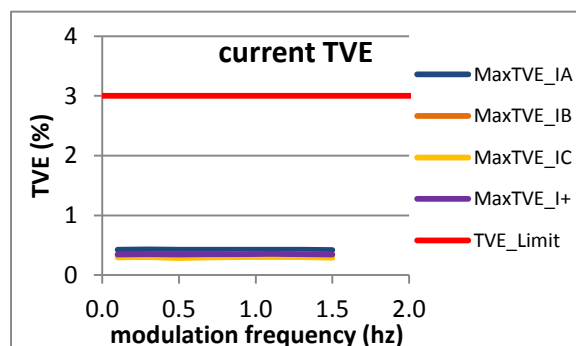


Figure 3824:  $F_s = 15$  FPS

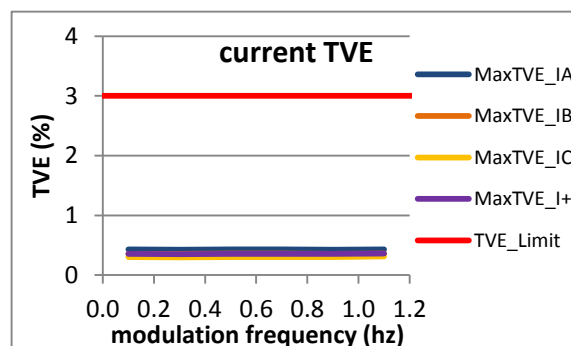


Figure 3825:  $F_s = 12$  FPS

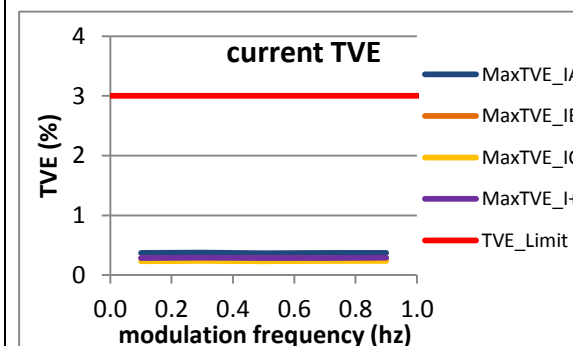


Figure 3826:  $f_s = 10$  FPS

### 8.6.3 PMU B dynamic bandwidth measurement: amplitude modulation current TVE: P class

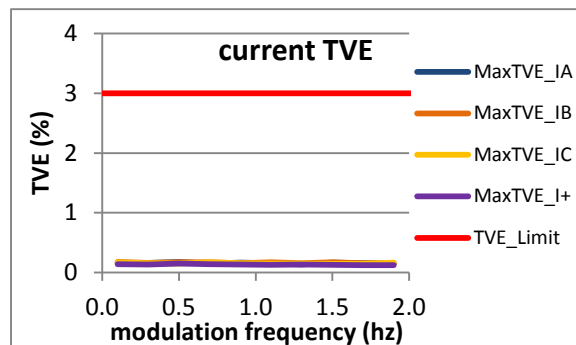


Figure 3827:  $F_s = 60$  FPS

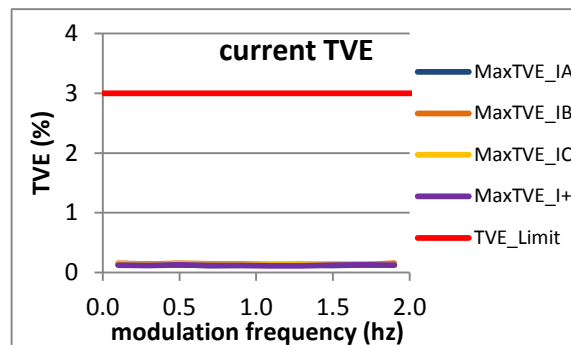


Figure 3828:  $F_s = 30$  FPS

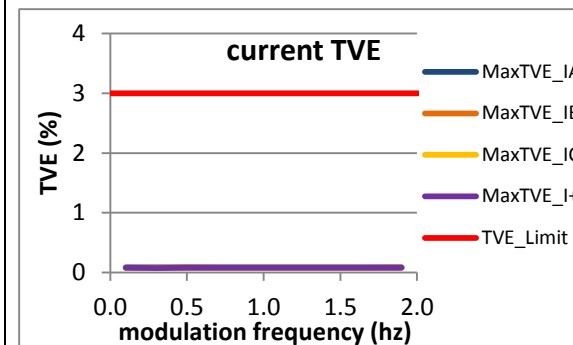


Figure 3829:  $F_s = 20$  FPS

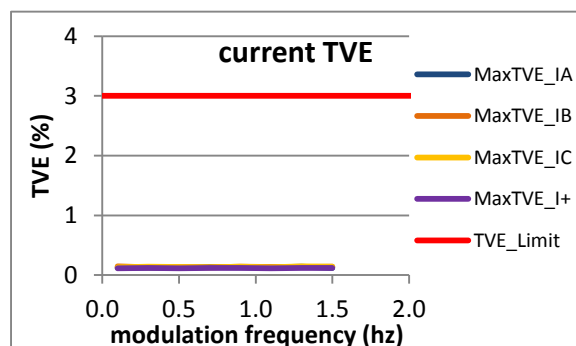


Figure 3830:  $F_s = 15$  FPS

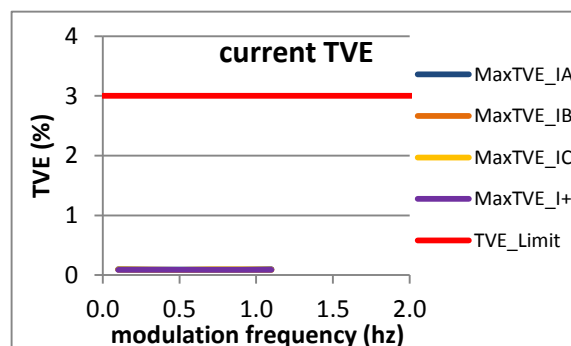


Figure 3831:  $F_s = 12$  FPS

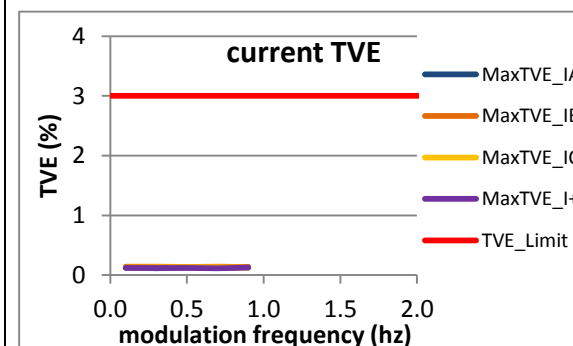


Figure 3832:  $F_s = 10$  FPS

#### 8.6.4 PMU C dynamic bandwidth measurement: amplitude modulation current TVE: P class

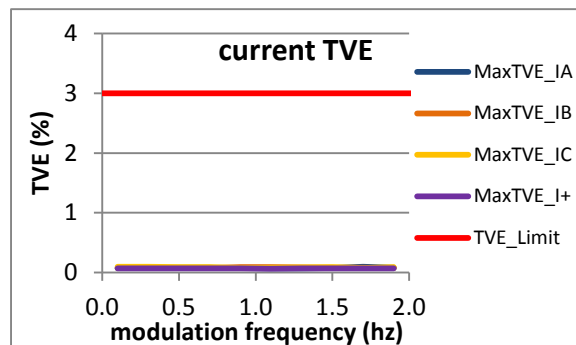


Figure 3833:  $F_s = 60$  FPS

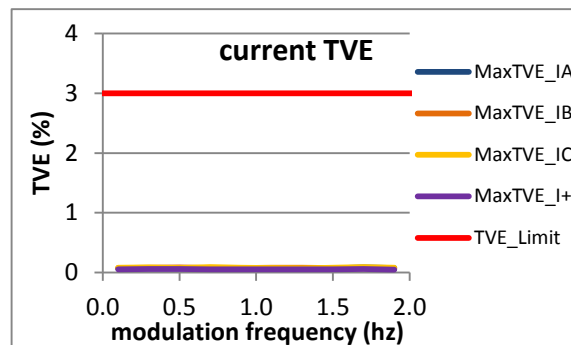


Figure 3834:  $F_s = 30$  FPS

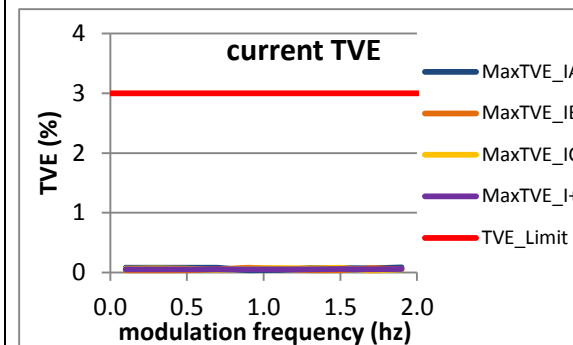


Figure 3835:  $F_s = 20$  FPS

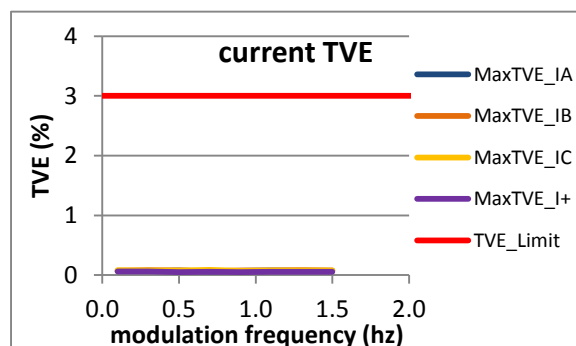


Figure 3836:  $F_s = 15$  FPS

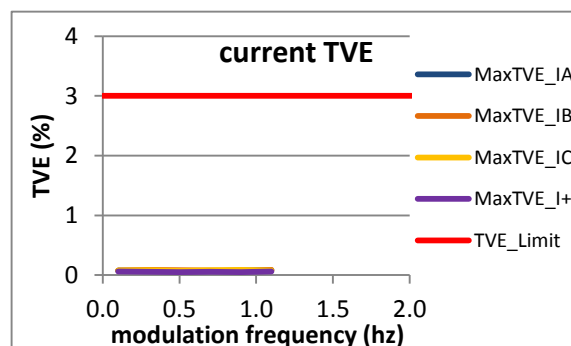


Figure 3837:  $F_s = 12$  FPS

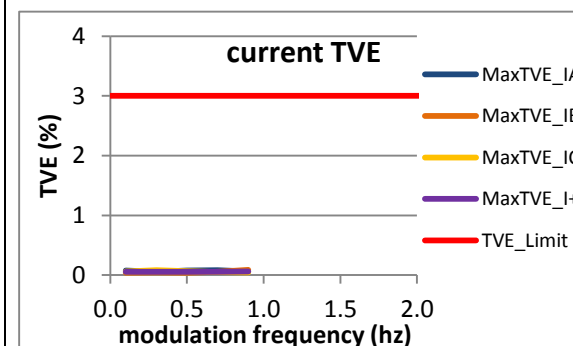


Figure 3838:  $F_s = 10$  FPS

### 8.6.5 PMU D dynamic bandwidth measurement: amplitude modulation current TVE: P class

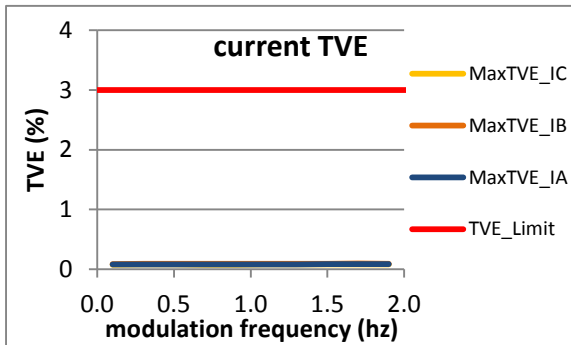


Figure 3839:  $F_s = 60$  FPS

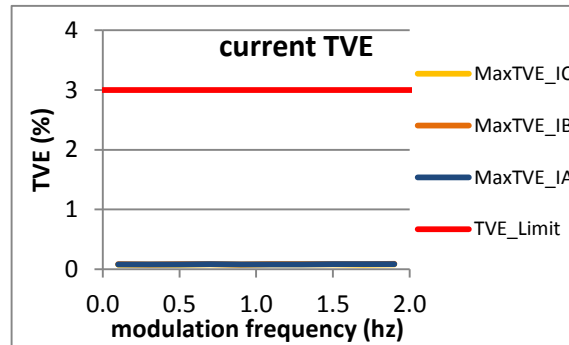


Figure 3840:  $F_s = 30$  FPS

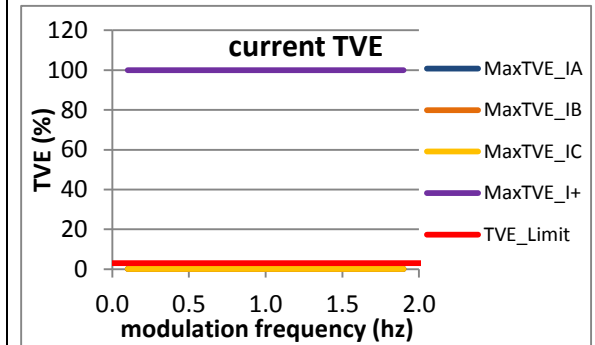


Figure 3841:  $F_s = 20$  FPS

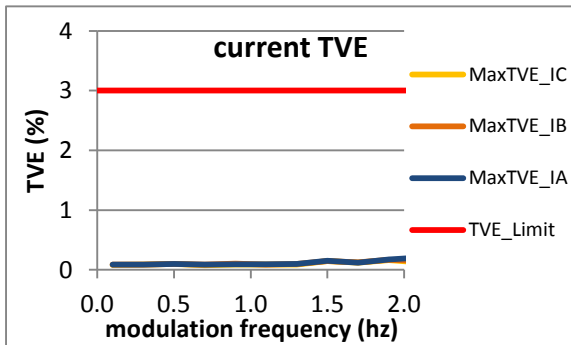


Figure 3842:  $F_s = 15$  FPS

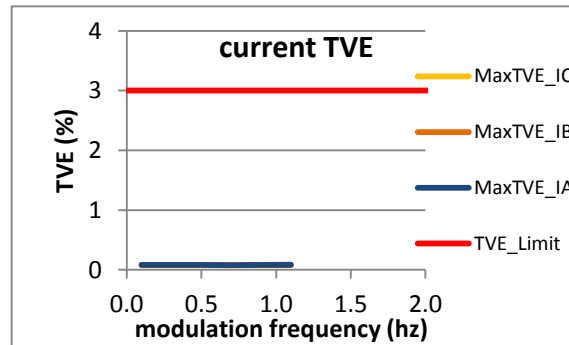


Figure 3843:  $F_s = 12$  FPS

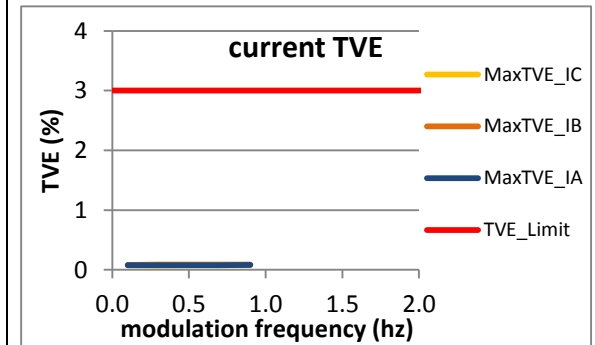
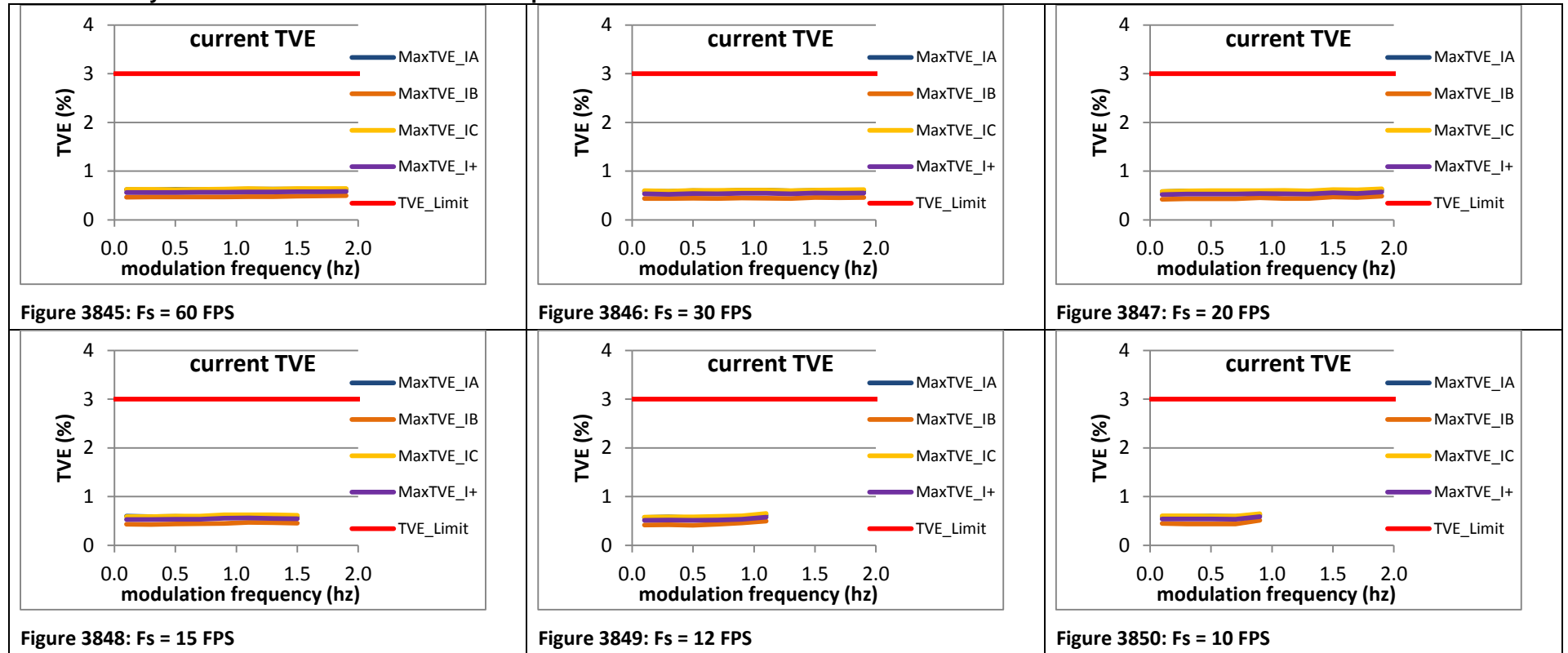


Figure 3844:  $F_s = 10$  FPS

### 8.6.6 PMU E dynamic bandwidth measurement: amplitude modulation current TVE: P class

PMU E does not support P class

### 8.6.7 PMU F dynamic bandwidth measurement: amplitude modulation current TVE: P class



### 8.6.8 PMU G dynamic bandwidth measurement: amplitude modulation current TVE: P class

PMU G does not support P class

### 8.6.9 PMU H dynamic bandwidth measurement: amplitude modulation current TVE: P class

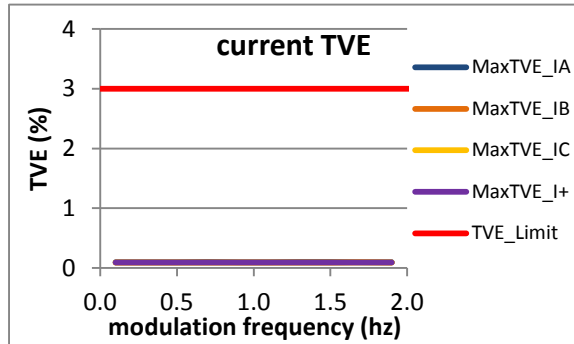


Figure 3851:  $F_s = 60$  FPS

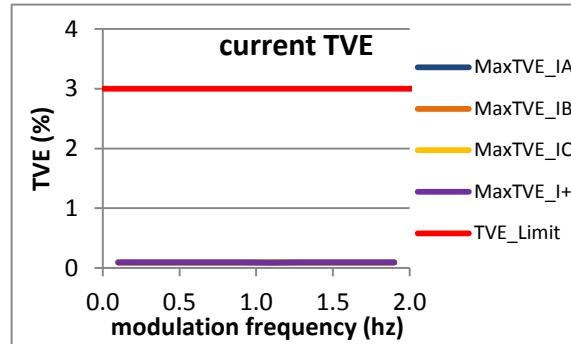


Figure 3852:  $F_s = 30$  FPS

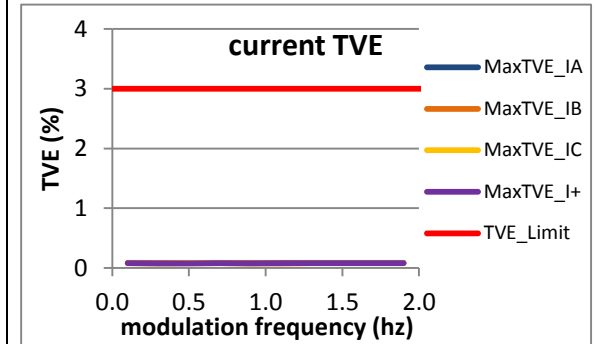


Figure 3853:  $F_s = 20$  FPS

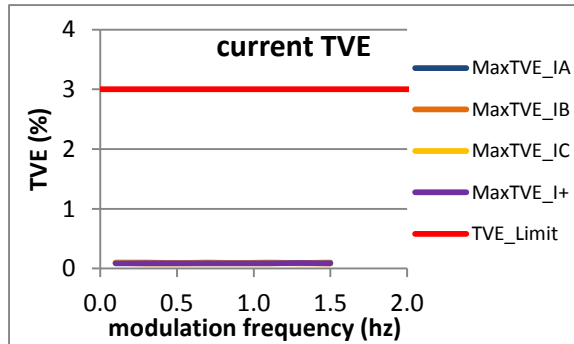


Figure 3854:  $F_s = 15$  FPS

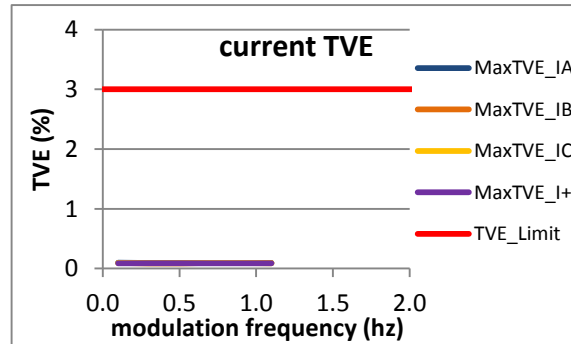


Figure 3855:  $F_s = 12$  FPS

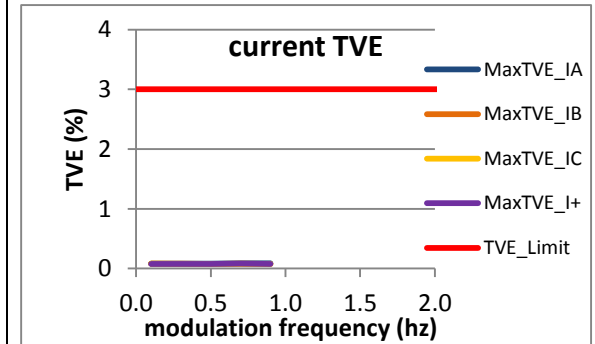


Figure 3856:  $F_s = 10$  FPS

### 8.6.10 PMU I dynamic bandwidth measurement: amplitude modulation current TVE: P class

PMU I does not support P class

### 8.6.11 PMU J dynamic bandwidth measurement: amplitude modulation current TVE: P class



## 8.7 Dynamic bandwidth measurement: amplitude modulation frequency error: P class

### 8.7.1 C37.118.1 Annex C dynamic bandwidth measurement: amplitude modulation frequency error: P class

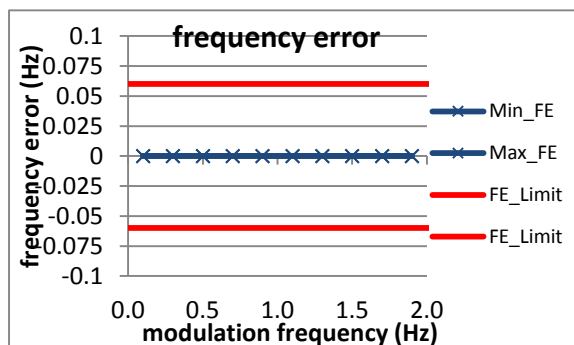


Figure 3857:  $F_s = 60$  FPS

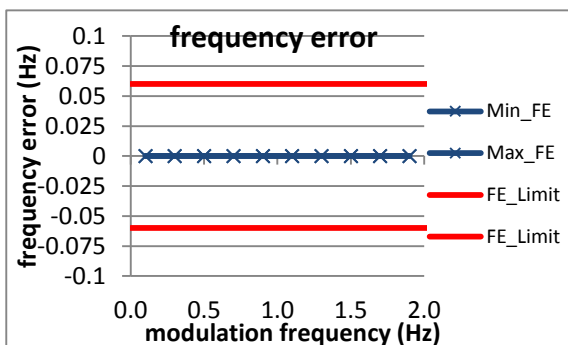


Figure 3858:  $F_s = 30$  FPS

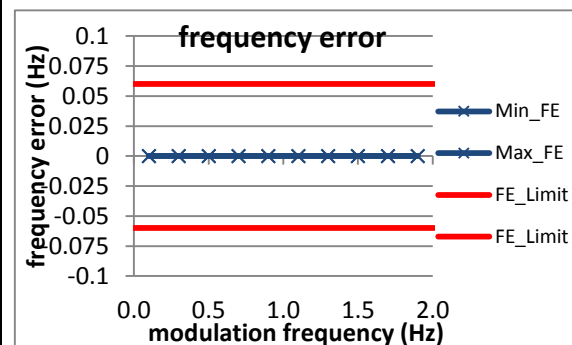


Figure 3859:  $F_s = 20$  FPS

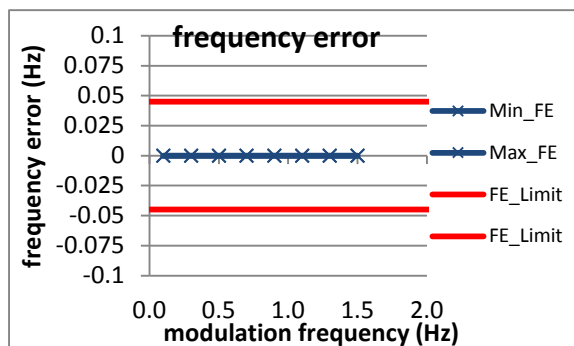


Figure 3860:  $F_s = 15$  FPS

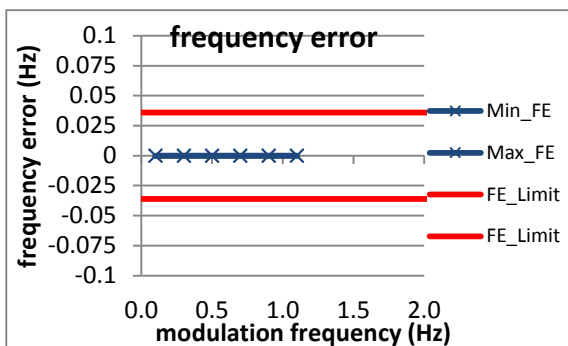


Figure 3861:  $F_s = 12$  FPS

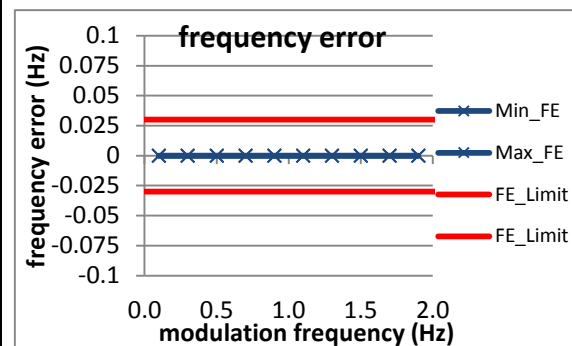


Figure 3862:  $F_s = 10$  FPS

## 8.7.2 PMU A dynamic bandwidth measurement: amplitude modulation frequency error: P class

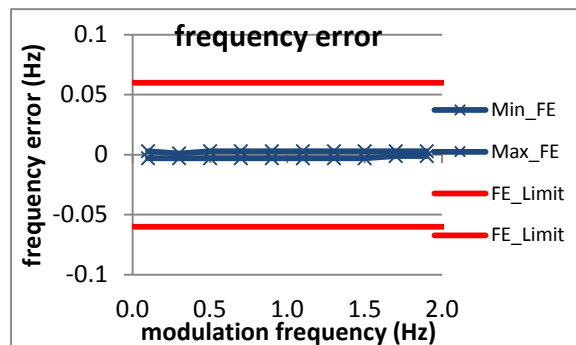


Figure 3863:  $F_s = 60$  FPS

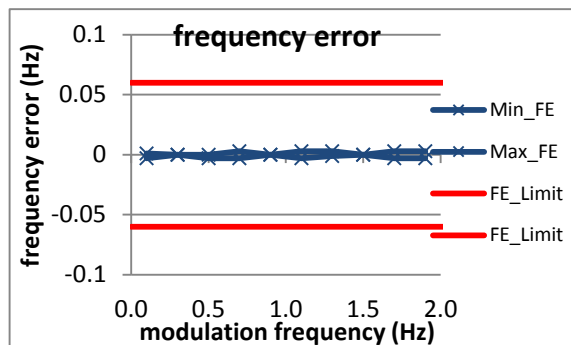


Figure 3864:  $F_s = 30$  FPS

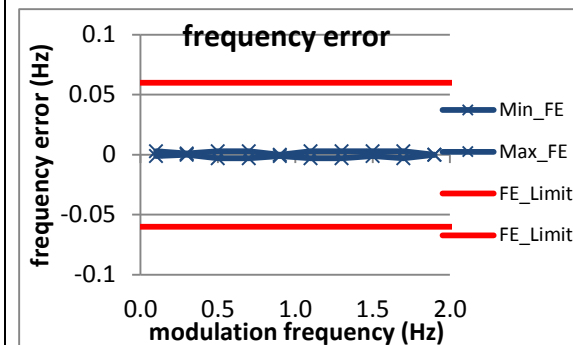


Figure 3865:  $F_s = 20$  FPS

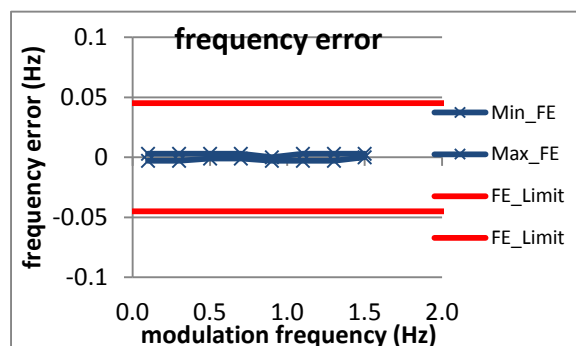


Figure 3866:  $F_s = 15$  FPS

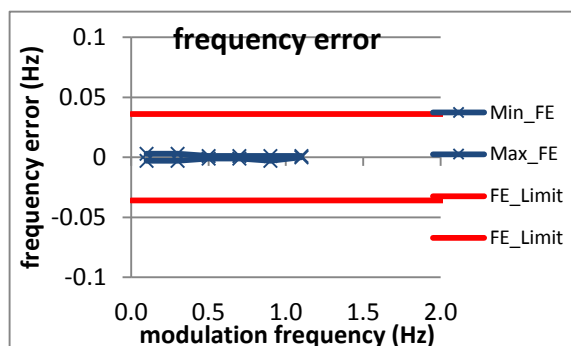


Figure 3867:  $F_s = 12$  FPS

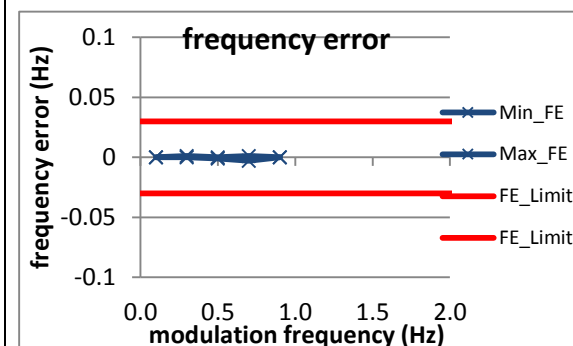


Figure 3868:  $F_s = 10$  FPS

### 8.7.3 PMU B dynamic bandwidth measurement: amplitude modulation frequency error: P class

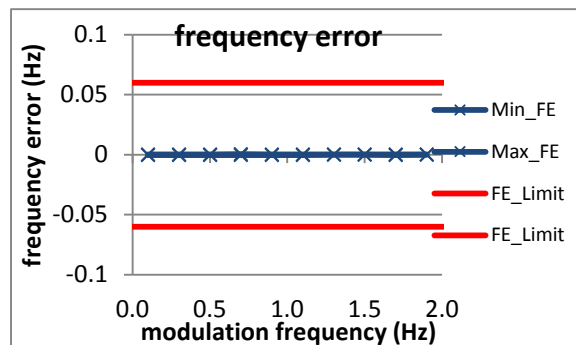


Figure 3869:  $F_s = 60$  FPS

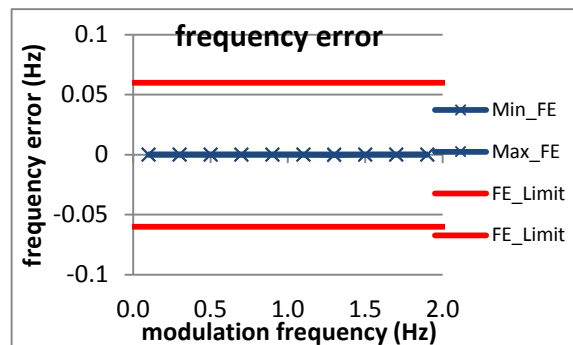


Figure 3870:  $F_s = 30$  FPS

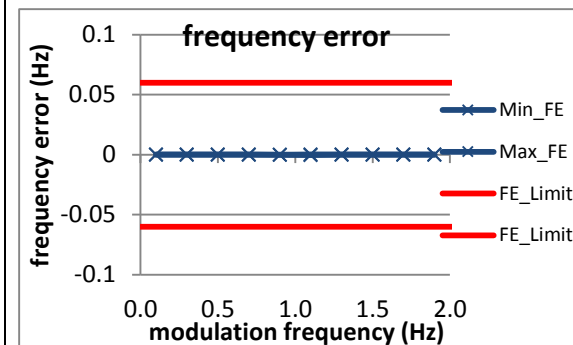


Figure 3871:  $F_s = 20$  FPS

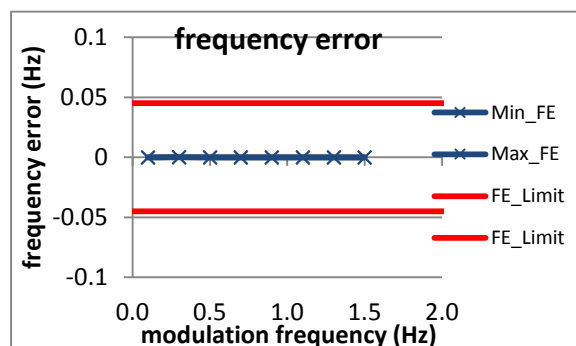


Figure 3872:  $F_s = 15$  FPS

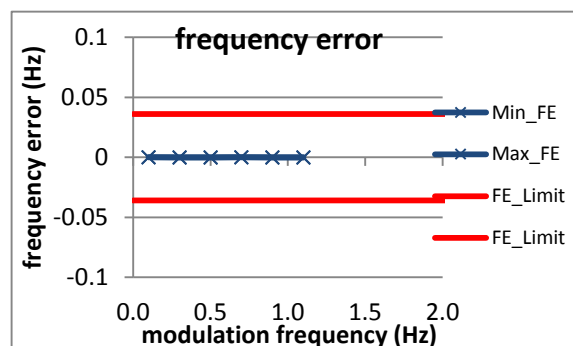


Figure 3873:  $F_s = 12$  FPS

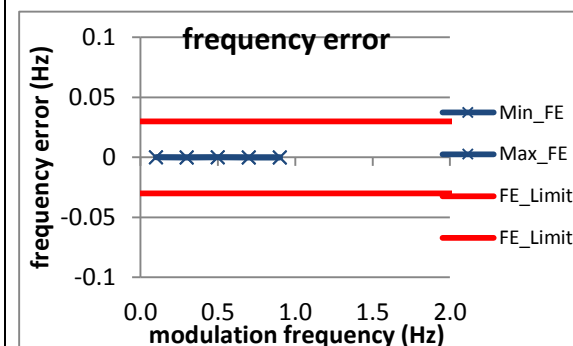


Figure 3874:  $F_s = 10$  FPS

#### 8.7.4 PMU C dynamic bandwidth measurement: amplitude modulation frequency error: P class

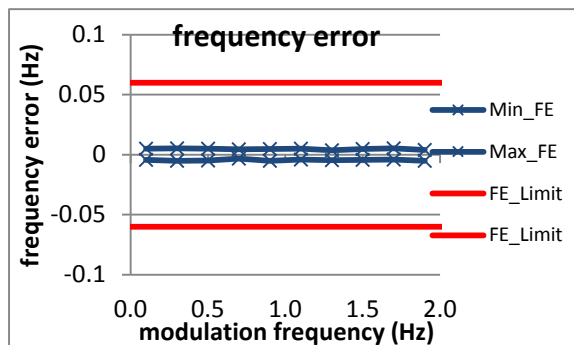


Figure 3875:  $F_s = 60$  FPS

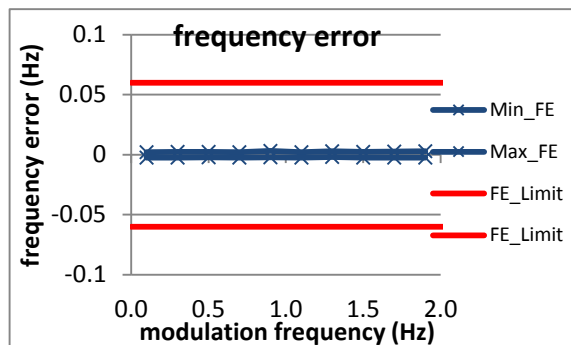


Figure 3876:  $F_s = 30$  FPS

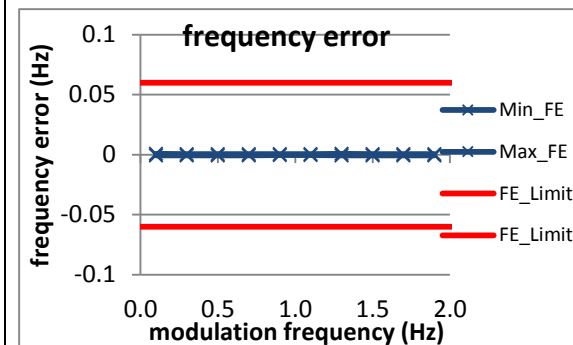


Figure 3877:  $F_s = 20$  FPS

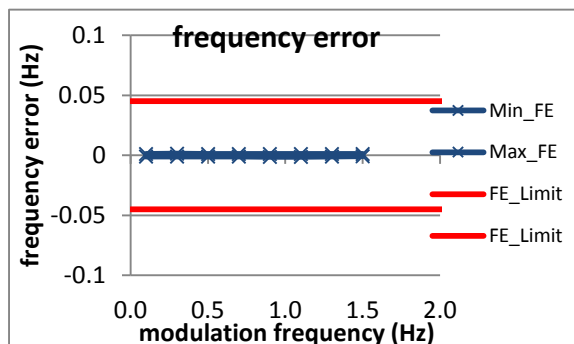


Figure 3878:  $F_s = 15$  FPS

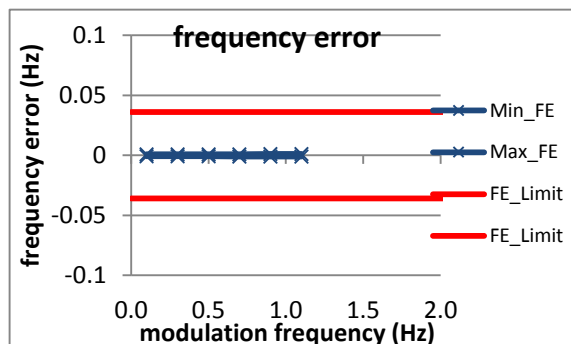


Figure 3879:  $F_s = 12$  FPS

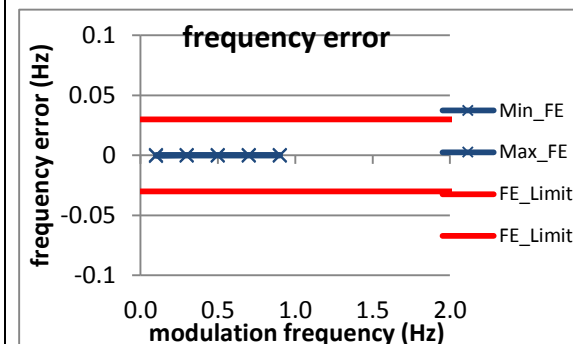


Figure 3880:  $F_s = 10$  FPS

### 8.7.5 PMU D dynamic bandwidth measurement: amplitude modulation frequency error: P class

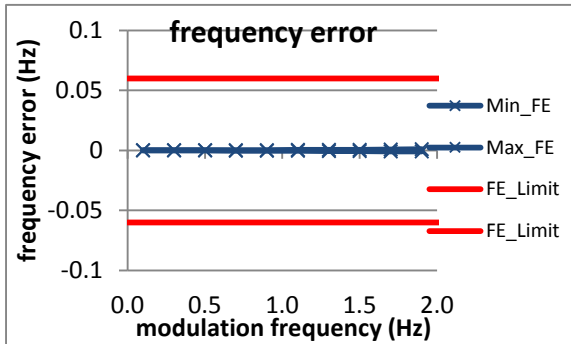


Figure 3881:  $F_s = 60$  FPS

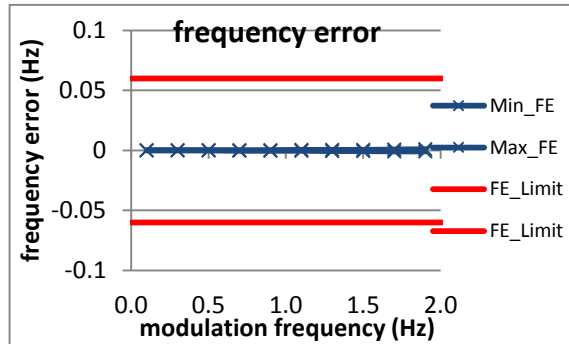


Figure 3882:  $F_s = 30$  FPS

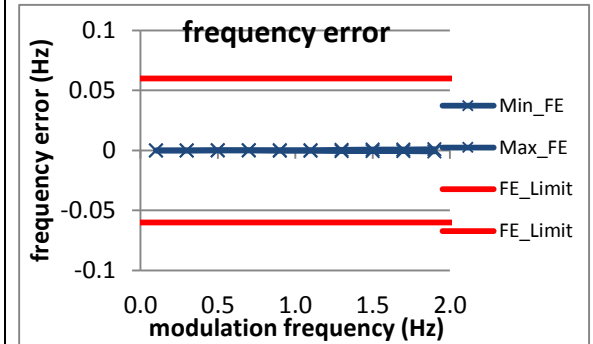


Figure 3883:  $F_s = 20$  FPS

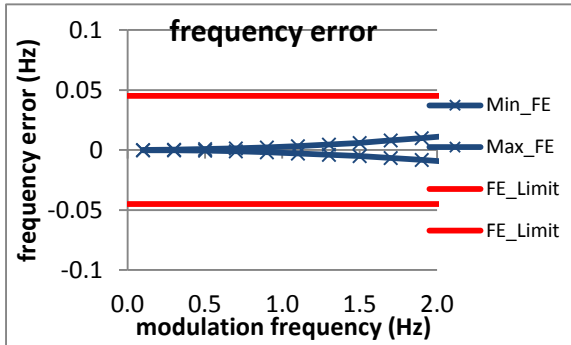


Figure 3884:  $F_s = 15$  FPS

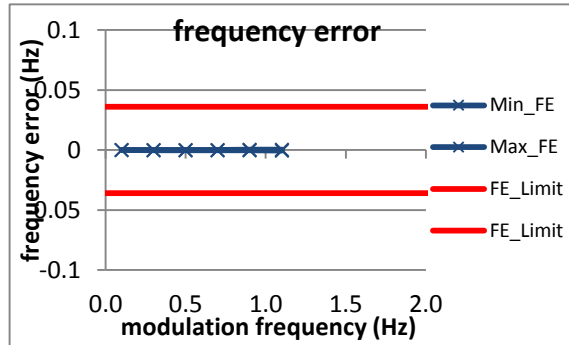


Figure 3885:  $F_s = 12$  FPS

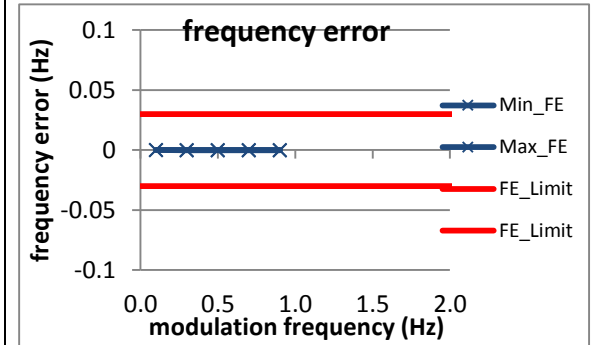
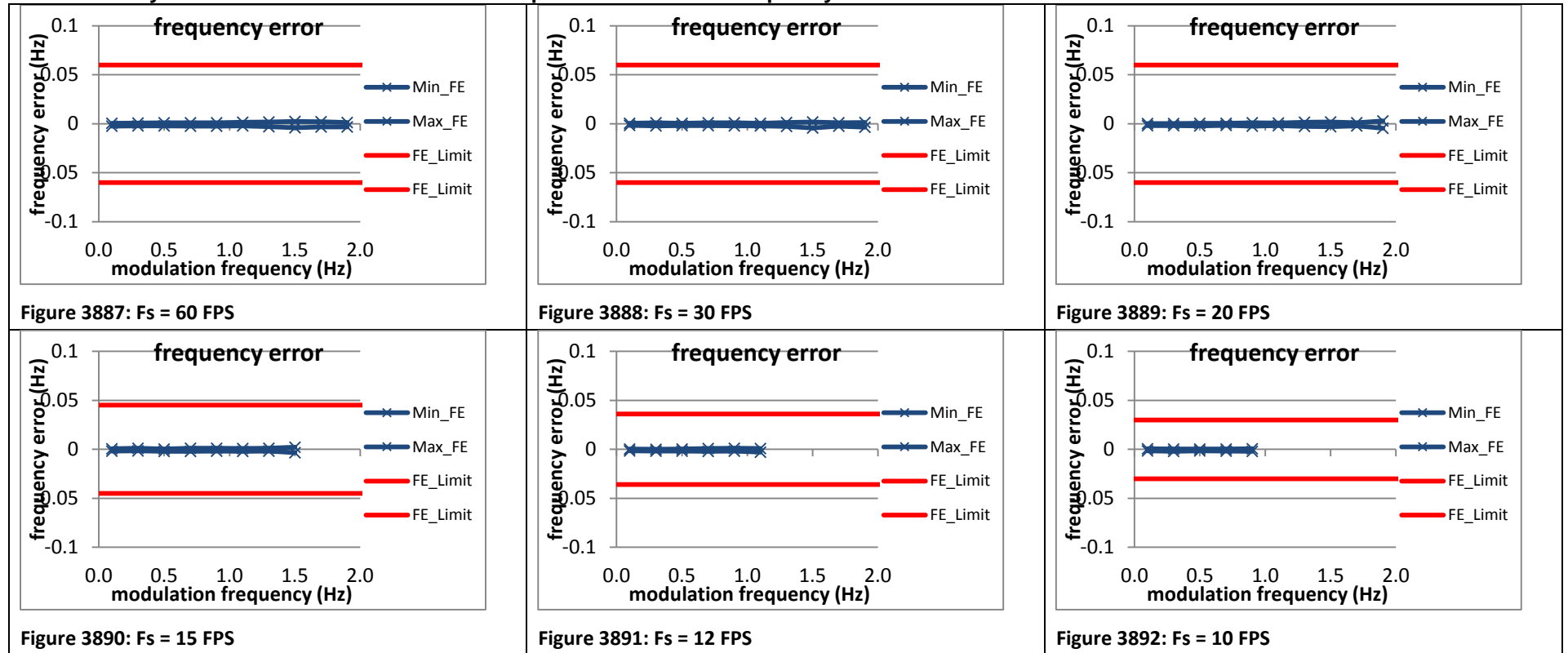


Figure 3886:  $F_s = 10$  FPS

### 8.7.6 PMU E dynamic bandwidth measurement: amplitude modulation frequency error: P class

PMU E does not support P class

### 8.7.7 PMU F dynamic bandwidth measurement: amplitude modulation frequency error: P class



### 8.7.8 PMU G dynamic bandwidth measurement: amplitude modulation frequency error: P class

PMU G does not support P class

### 8.7.9 PMU H dynamic bandwidth measurement: amplitude modulation frequency error: P class

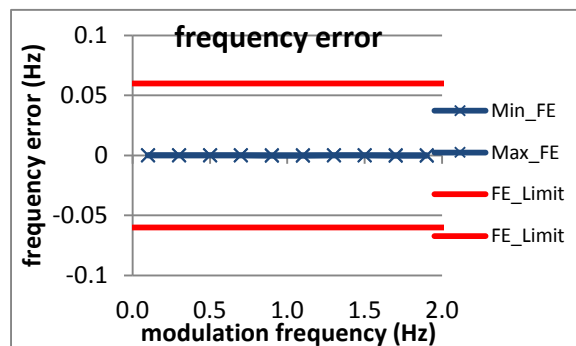


Figure 3893:  $F_s = 60$  FPS

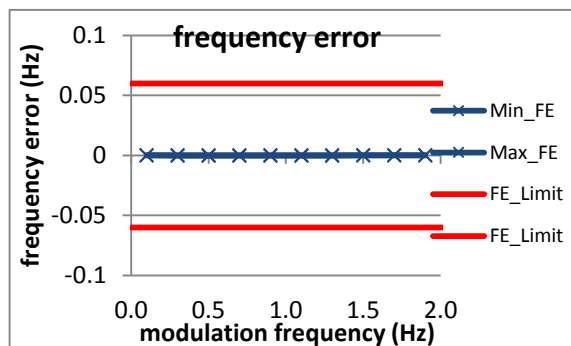


Figure 3894:  $F_s = 30$  FPS

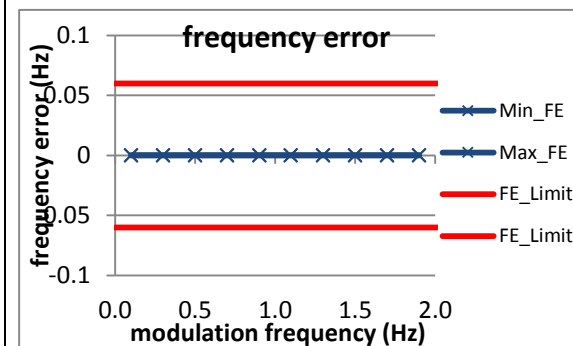


Figure 3895:  $F_s = 20$  FPS

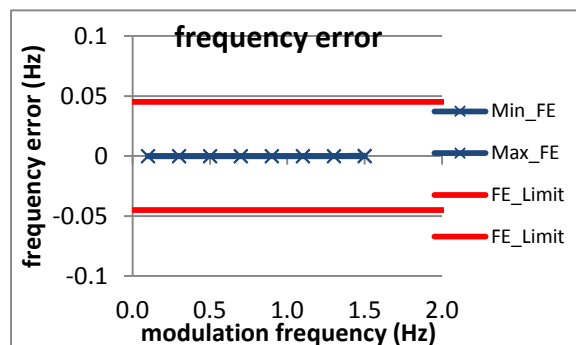


Figure 3896:  $F_s = 15$  FPS

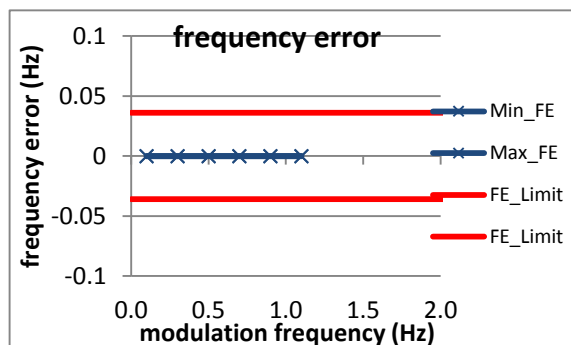


Figure 3897:  $F_s = 12$  FPS

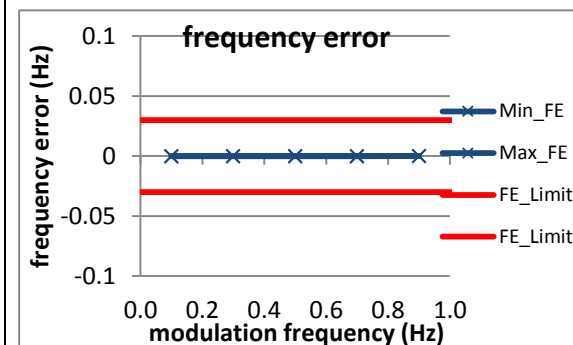


Figure 3898:  $F_s = 10$  FPS

### 8.7.10 PMU I dynamic bandwidth measurement: amplitude modulation frequency error: P class

PMU I does not support P class

### 8.7.11 PMU J dynamic bandwidth measurement: amplitude modulation frequency error: P class

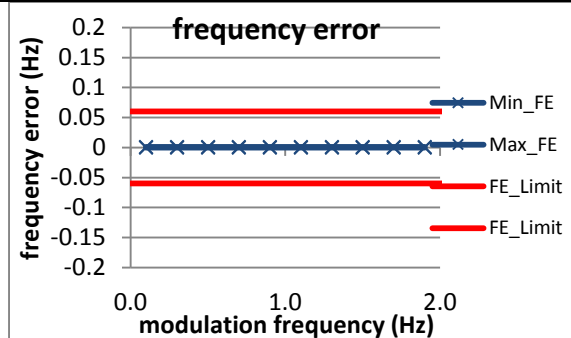


Figure 3899:  $F_s = 60$  FPS

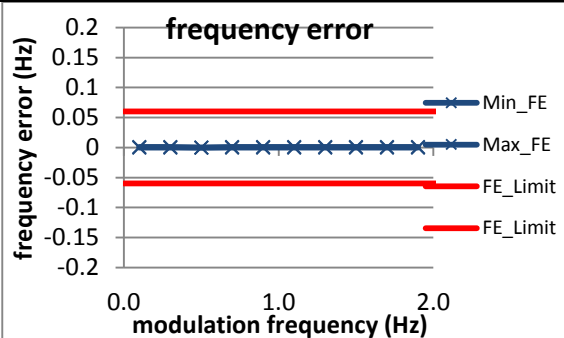


Figure 3900:  $F_s = 30$  FPS

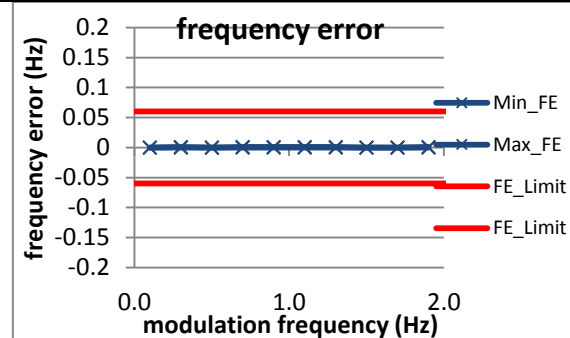


Figure 3901:  $F_s = 20$  FPS

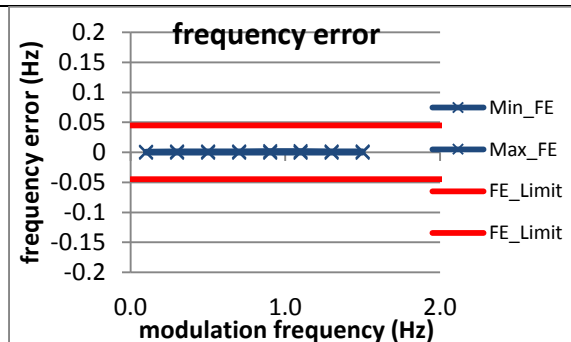


Figure 3902:  $F_s = 15$  FPS

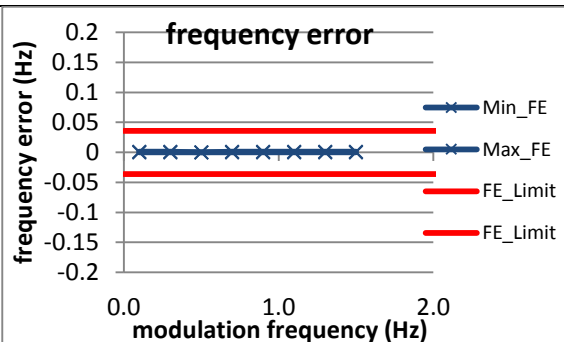


Figure 3903:  $F_s = 12$  FPS

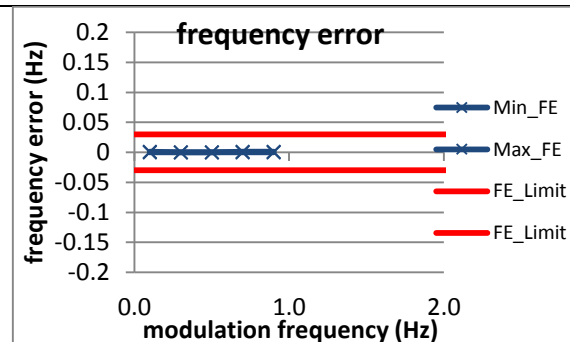


Figure 3904:  $F_s = 10$  FPS



## 8.8 dynamic bandwidth measurement: amplitude modulation ROCOF error: P class

### 8.8.1 C37.118.1 Annex C dynamic bandwidth measurement: amplitude modulation ROCOF error: P class

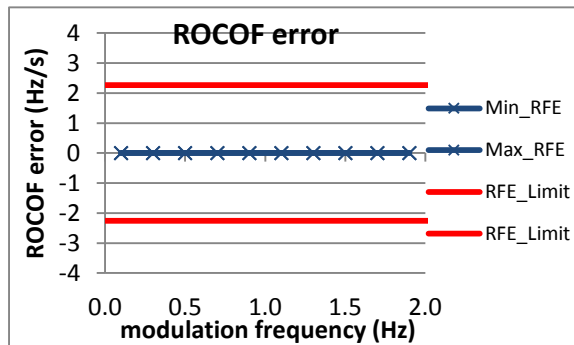


Figure 3905:  $F_s = 60$  FPS

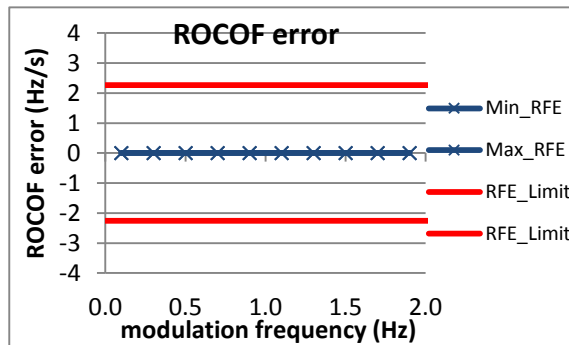


Figure 3906:  $F_s = 30$  FPS

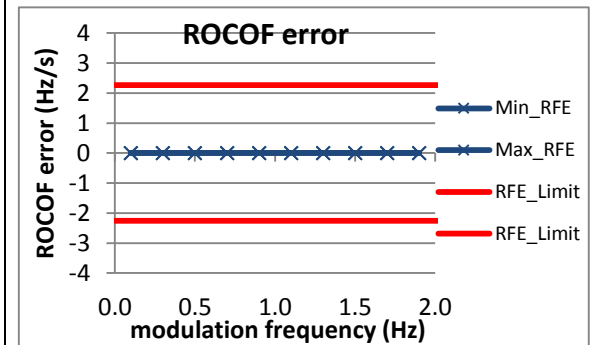


Figure 3907:  $F_s = 20$  FPS

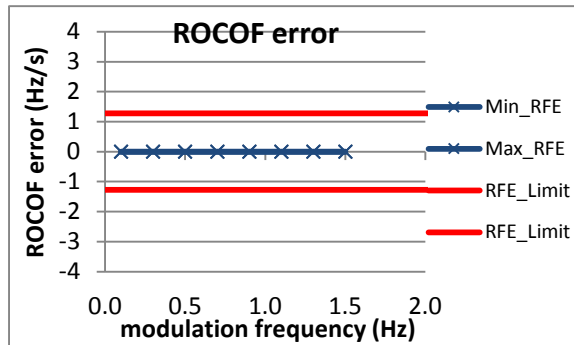


Figure 3908:  $F_s = 15$  FPS

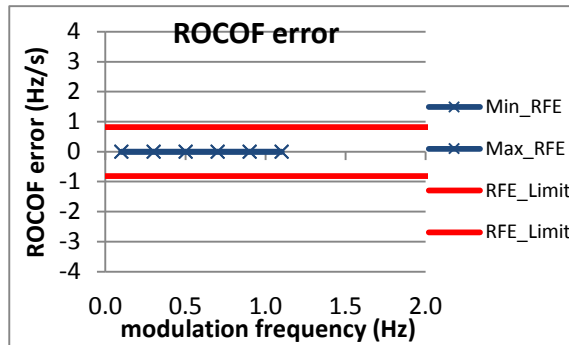


Figure 3909:  $F_s = 12$  FPS

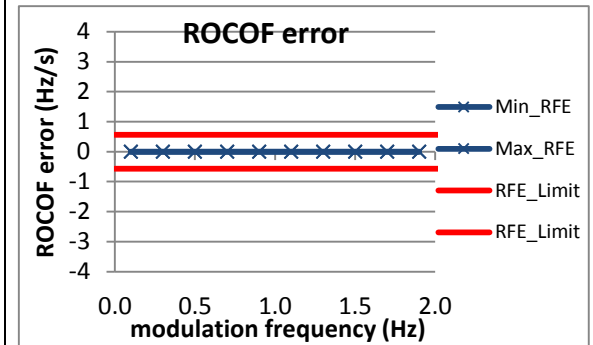


Figure 3910:  $F_s = 10$  FPS

### 8.8.2 PMU A dynamic bandwidth measurement: amplitude modulation ROCOF error: P class

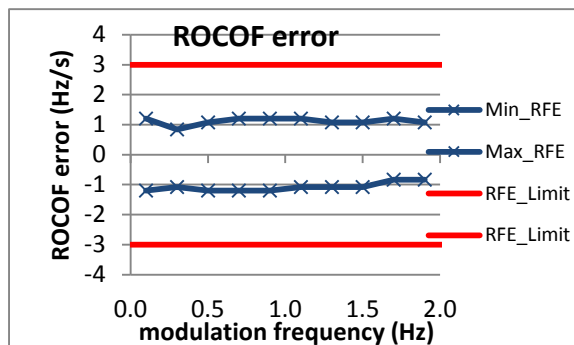


Figure 3911:  $F_s = 60$  FPS

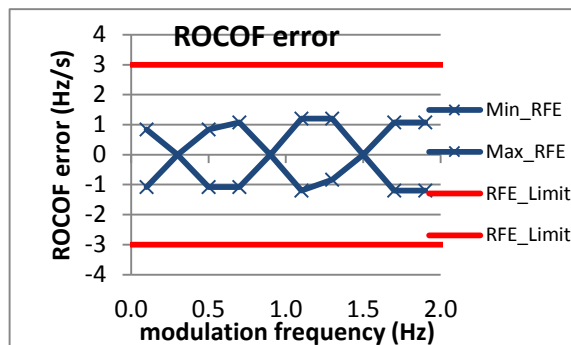


Figure 3912:  $F_s = 30$  FPS

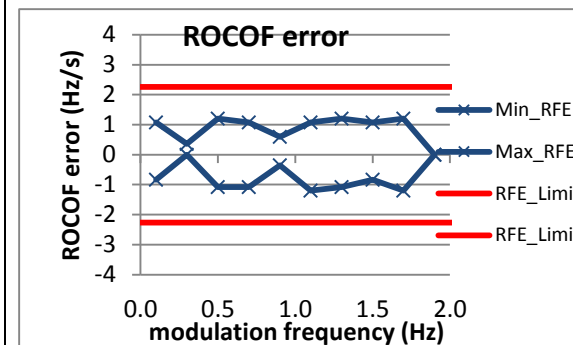


Figure 3913:  $F_s = 20$  FPS

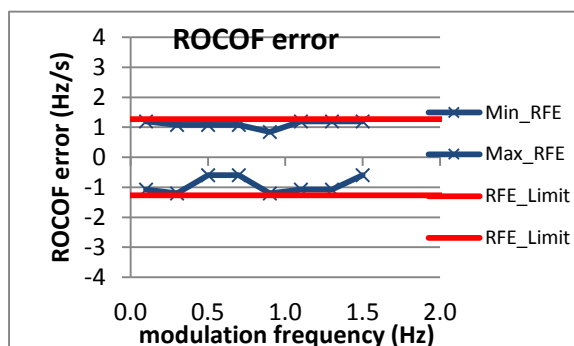


Figure 3914:  $F_s = 15$  FPS

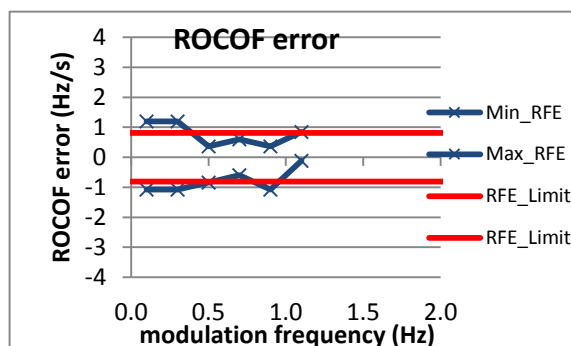


Figure 3915:  $F_s = 12$  FPS

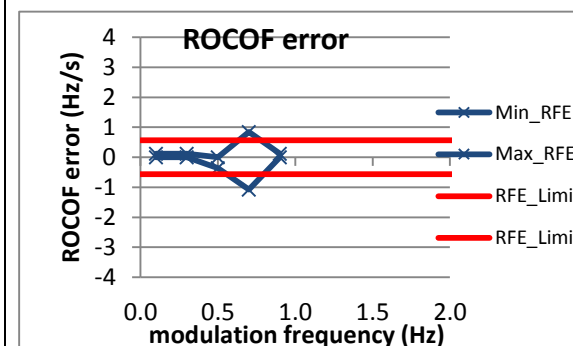


Figure 3916:  $F_s = 10$  FPS

### 8.8.3 PMU B dynamic bandwidth measurement: amplitude modulation ROCOF error: P class

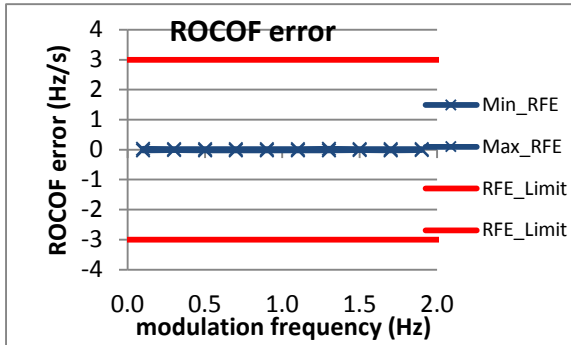


Figure 3917:  $F_s = 60$  FPS

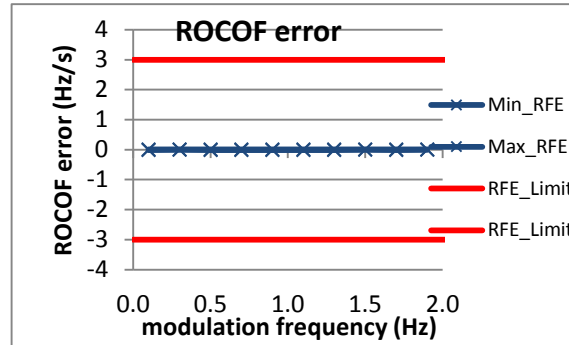


Figure 3918:  $F_s = 30$  FPS

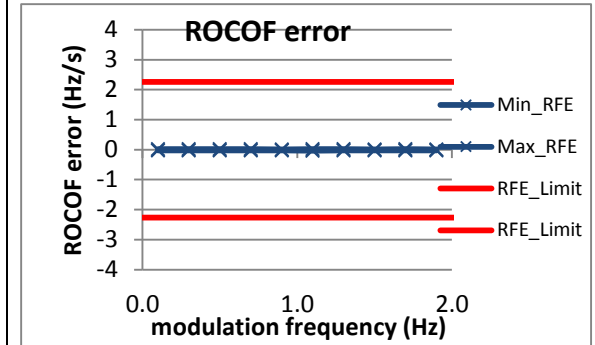


Figure 3919:  $F_s = 20$  FPS

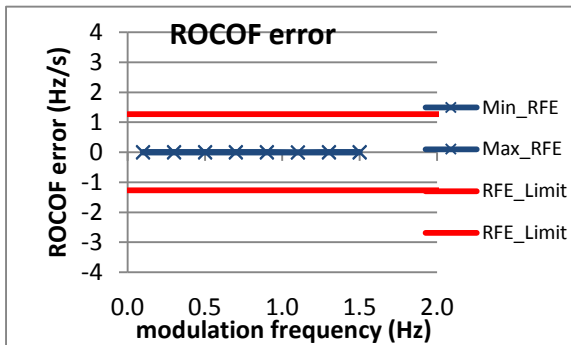


Figure 3920:  $F_s = 15$  FPS

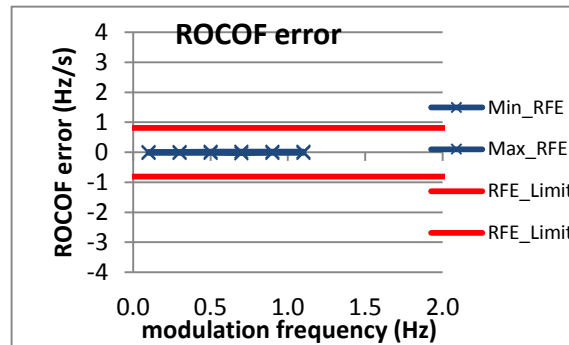


Figure 3921:  $F_s = 12$  FPS

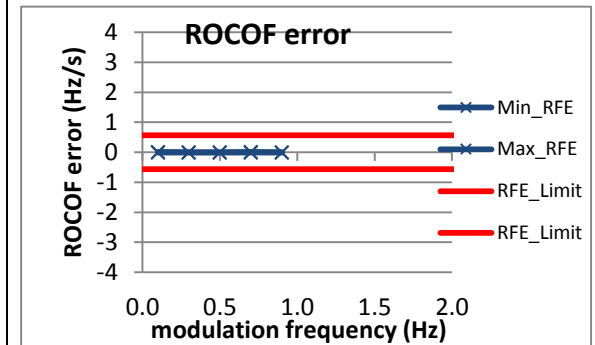


Figure 3922:  $F_s = 10$  FPS

#### 8.8.4 PMU C dynamic bandwidth measurement: amplitude modulation ROCOF error: P class

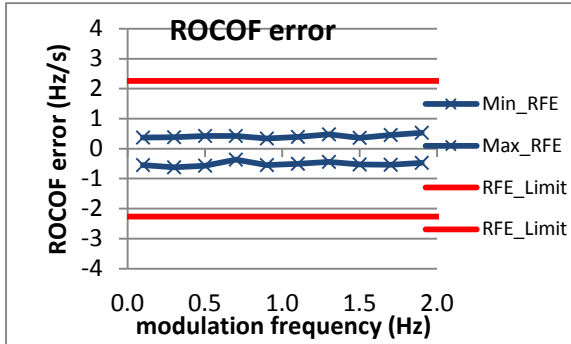


Figure 3923:  $F_s = 60$  FPS

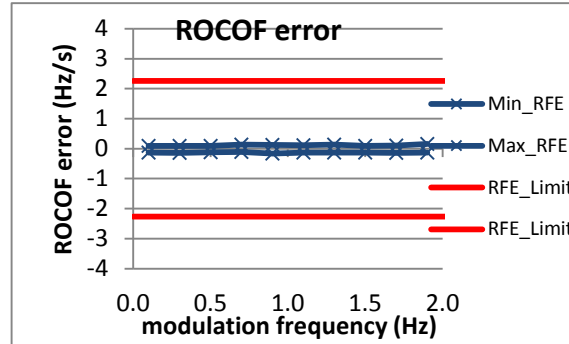


Figure 3924:  $F_s = 30$  FPS

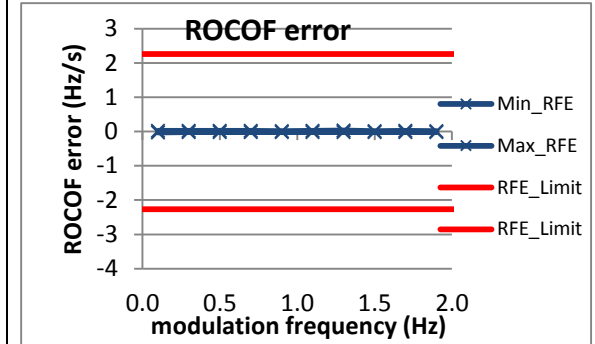


Figure 3925:  $F_s = 20$  FPS

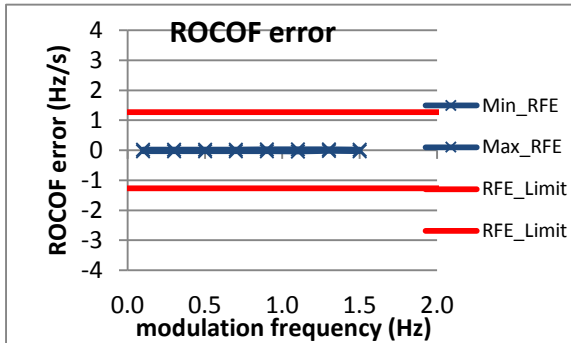


Figure 3926:  $F_s = 15$  FPS

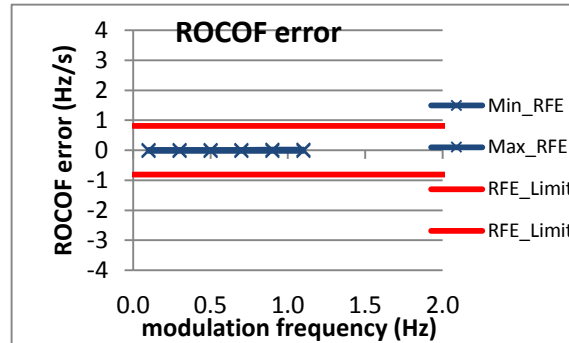


Figure 3927:  $F_s = 12$  FPS

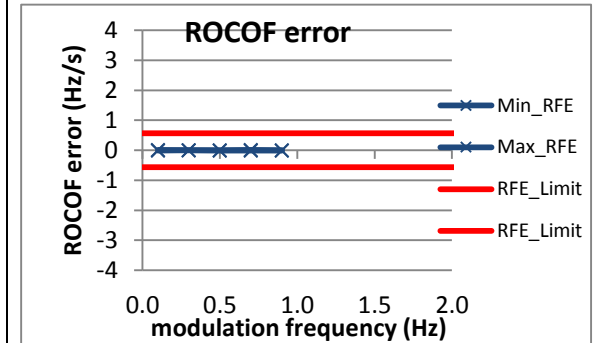


Figure 3928:  $F_s = 10$  FPS

### 8.8.5 PMU D dynamic bandwidth measurement: amplitude modulation ROCOF error: P class

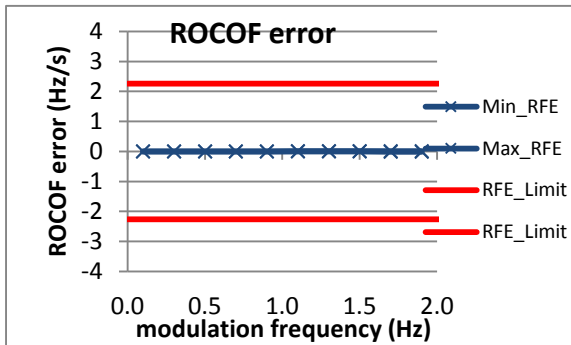


Figure 3929:  $F_s = 60$  FPS

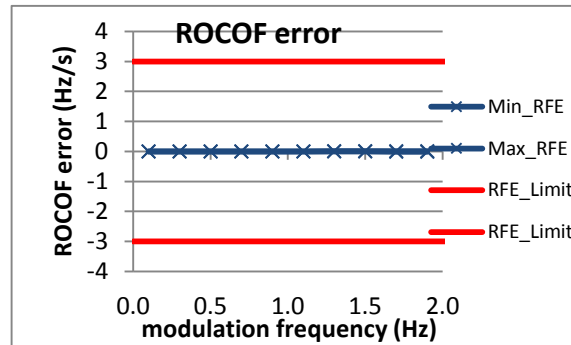


Figure 3930:  $F_s = 30$  FPS

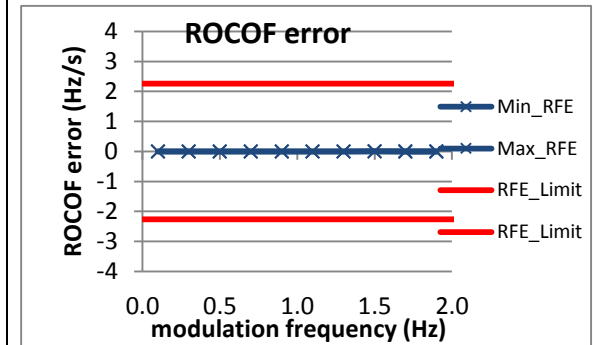


Figure 3931:  $F_s = 20$  FPS

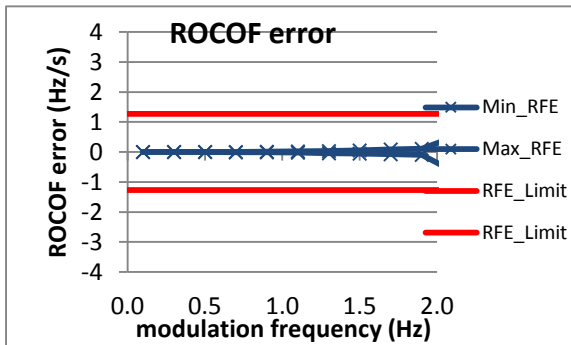


Figure 3932:  $F_s = 15$  FPS

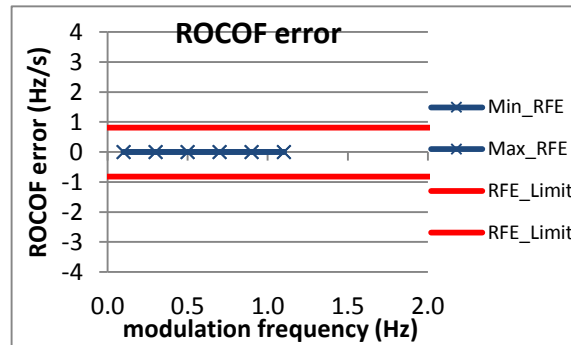


Figure 3933:  $F_s = 12$  FPS

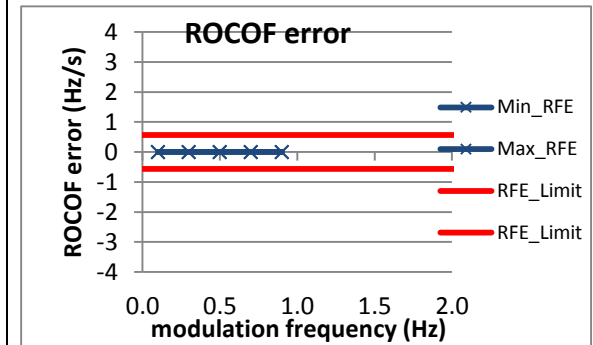
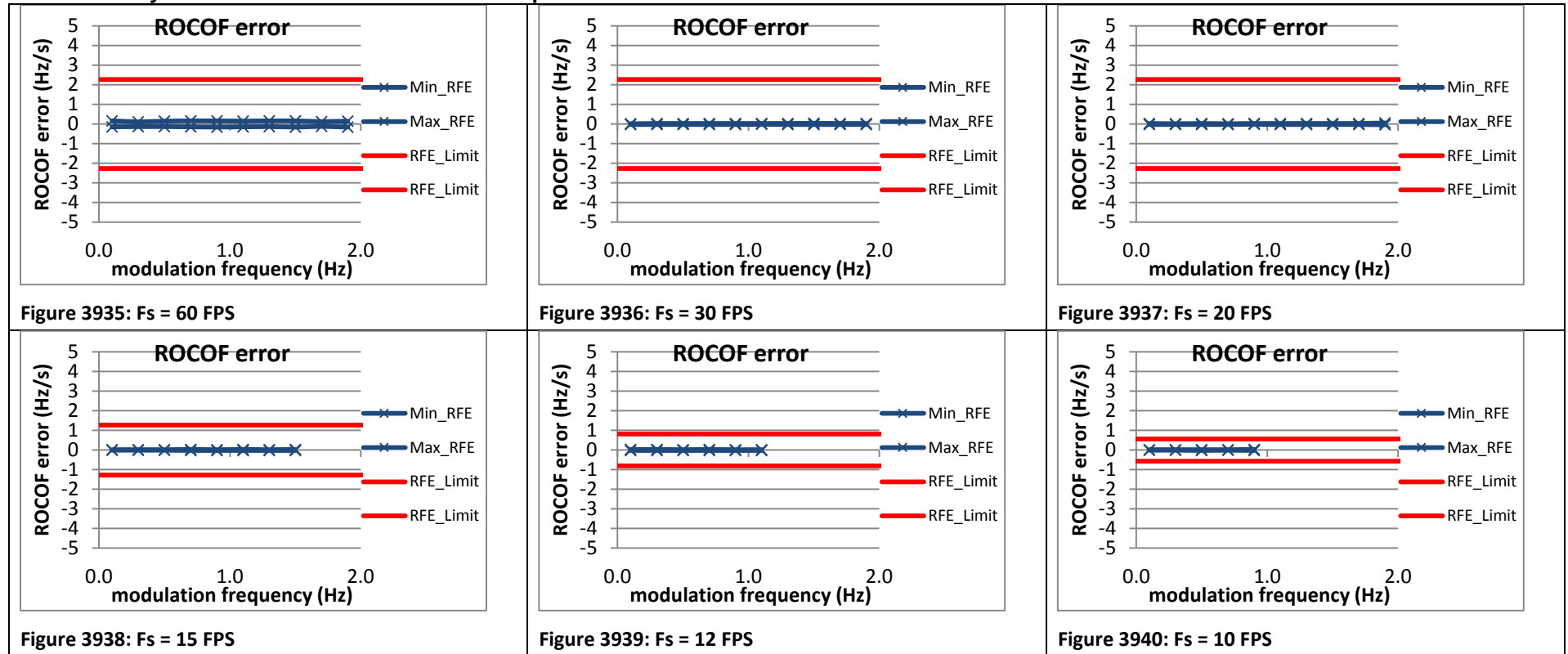


Figure 3934:  $F_s = 10$  FPS

### 8.8.6 PMU E dynamic bandwidth measurement: amplitude modulation ROCOF error: P class

PMU E does not support P class

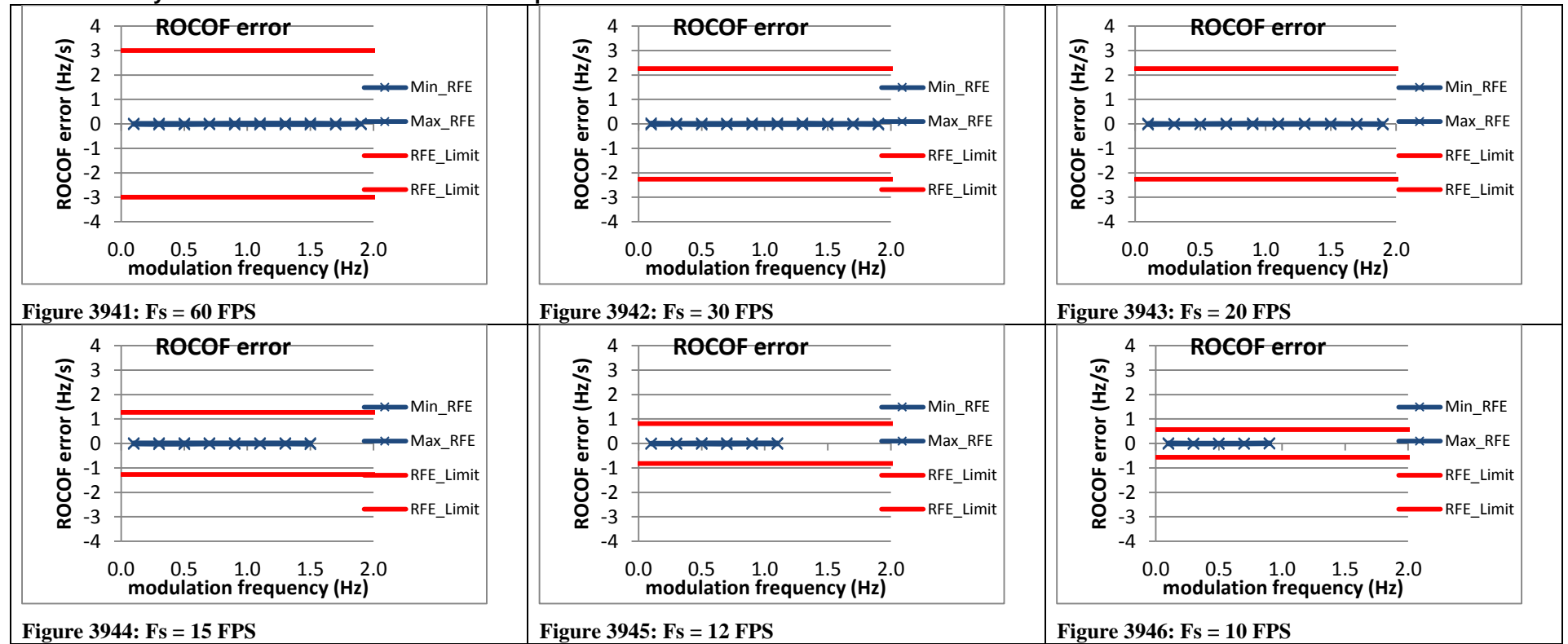
### 8.8.7 PMU F dynamic bandwidth measurement: amplitude modulation ROCOF error: P class



### 8.8.8 PMU G dynamic bandwidth measurement: amplitude modulation ROCOF error: P class

PMU G does not support P class

### 8.8.9 PMU H dynamic bandwidth measurement: amplitude modulation ROCOF error: P class



### 8.8.10 PMU I dynamic bandwidth measurement: amplitude modulation ROCOF error: P class

PMU I does not support P class

# 8.8.11 PMU J dynamic bandwidth measurement: amplitude modulation ROCOF error: P class

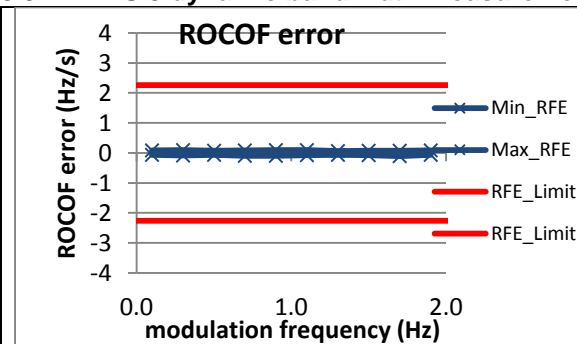


Figure 3947:  $F_s = 60$  FPS

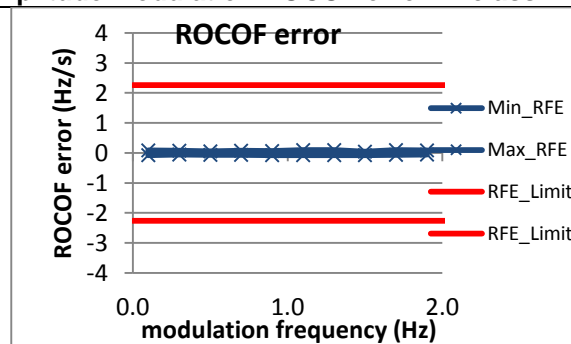


Figure 3948:  $F_s = 30$  FPS

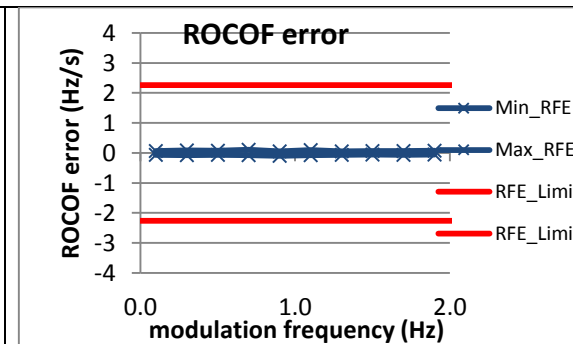


Figure 3949:  $F_s = 20$  FPS

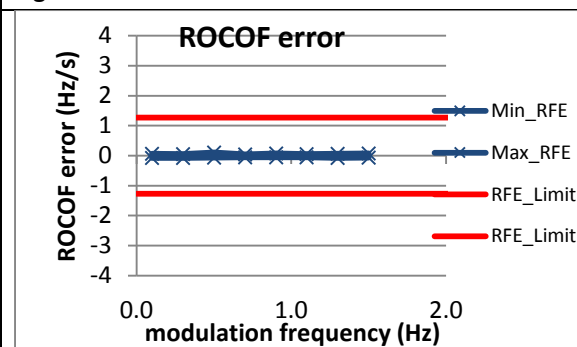


Figure 3950:  $F_s = 15$  FPS

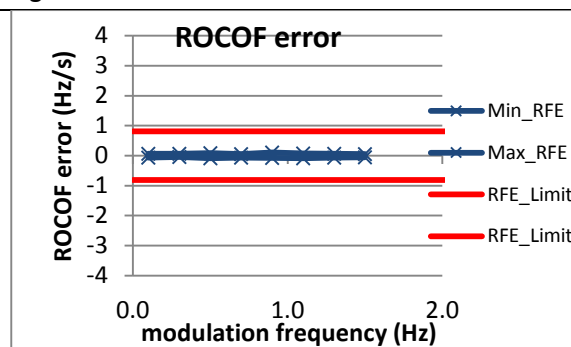


Figure 3951:  $F_s = 12$  FPS

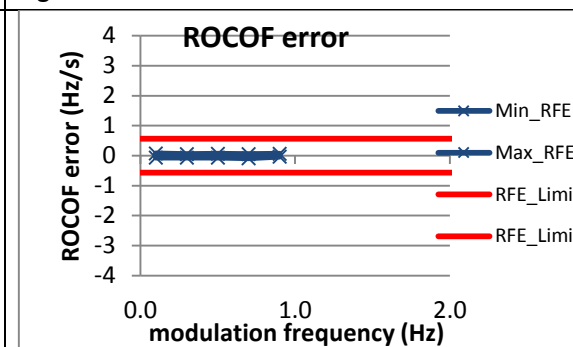


Figure 3952:  $F_s = 10$  FPS



## 9. Dynamic step change in phase

9. Dynamic step change in phase .....	672
9.1 Dynamic step change in phase: voltage response time: .....	677
9.1.1 C37.118.1a Annex C dynamic step change in phase voltage response time: F0 = 60 Hz, M class.....	678
9.1.2 PMU A dynamic step change in phase voltage response time: F0 = 60 Hz, M class .....	681
9.1.3 PMU B dynamic step change in phase voltage response time: F0 = 60 Hz, M class.....	683
9.1.4 PMU C dynamic step change in phase voltage response time: F0 = 60 Hz, M class.....	685
9.1.5 PMU D dynamic step change in phase voltage response time: F0 = 60 Hz, M class .....	687
9.1.6 PMU E dynamic step change in phase voltage response time: F0 = 60 Hz, M class .....	689
9.1.7 PMU F dynamic step change in phase voltage response time: F0 = 60 Hz, M class .....	691
9.1.8 PMU G dynamic step change in phase voltage response time: F0 = 60 Hz, M class .....	693
9.1.9 PMU H dynamic step change in phase voltage response time: F0 = 60 Hz, M class .....	695
9.1.10 PMU I dynamic step change in phase voltage response time: F0 = 60 Hz, M class.....	697
9.1.11 PMU J dynamic step change in phase voltage response time: F0 = 60 Hz, M class .....	699
9.2 Dynamic step change in phase: current response time .....	701
9.2.1 C37.118.1-2011 Annex C dynamic step change in phase current response time: F0 = 60 Hz, M class .....	701
9.2.2 PMU A dynamic step change in phase current response time: F0 = 60 Hz, M class .....	703
9.2.3 PMU B dynamic step change in phase current response time: F0 = 60 Hz, M class.....	705
9.2.4 PMU C dynamic step change in phase current response time: F0 = 60 Hz, M class.....	707
9.2.5 PMU D dynamic step change in phase current response time: F0 = 60 Hz, M class .....	709
9.2.6 PMU E dynamic step change in phase current response time: F0 = 60 Hz, M class .....	711
9.2.7 PMU F dynamic step change in phase current response time: F0 = 60 Hz, M class .....	713
9.2.8 PMU G dynamic step change in phase current response time: F0 = 60 Hz, M class .....	715
9.2.9 PMU H dynamic step change in phase current response time: F0 = 60 Hz, M class .....	717
9.2.10 PMU I dynamic step change in phase current response time: F0 = 60 Hz, M class.....	719
9.2.11 PMU J dynamic step change in phase current response time: F0 = 60 Hz, M class .....	721
9.3 Dynamic step change in phase voltage response time: F0 = 60 Hz, P Class.....	723
9.3.1 C37.118.1a Annex C dynamic step change in phase voltage response time: F0 = 60 Hz, P class.....	723
9.3.2 PMU A dynamic step change in phase voltage response time: F0 = 60 Hz, P class.....	725
9.3.3 PMU B dynamic step change in phase voltage response time: F0 = 60 Hz, P class .....	727
9.3.4 PMU C dynamic step change in phase voltage response time: F0 = 60 Hz, P class .....	729
9.3.5 PMU D dynamic step change in phase voltage response time: F0 = 60 Hz, P class.....	731
9.3.6 PMU E dynamic step change in phase voltage response time: F0 = 60 Hz, P class .....	733
9.3.7 PMU F dynamic step change in phase voltage response time: F0 = 60 Hz, P class .....	733
9.3.8 PMU G dynamic step change in phase voltage response time: F0 = 60 Hz, P class.....	735
9.3.9 PMU H dynamic step change in phase voltage response time: F0 = 60 Hz, P class.....	735
9.3.10 PMU I dynamic step change in phase voltage response time: F0 = 60 Hz, P class .....	737

9.3.11 PMU J dynamic step change in phase voltage response time: F0 = 60 Hz, P class .....	737
9.4 Dynamic step change in phase current response time: F0 = 60 Hz, P Class .....	739
9.4.1 C37.118.1-2011 Annex C dynamic step change in phase current response time: F0 = 60 Hz, P class .....	739
9.4.2 PMU A dynamic step change in phase current response time: F0 = 60 Hz, P class .....	741
9.4.3 PMU B dynamic step change in phase current response time: F0 = 60 Hz, P class .....	743
9.4.4 PMU C dynamic step change in phase current response time: F0 = 60 Hz, P class .....	745
9.4.5 PMU D dynamic step change in phase current response time: F0 = 60 Hz, P class .....	747
9.4.6 PMU E dynamic step change in phase current response time: F0 = 60 Hz, P class .....	749
9.4.7 PMU F dynamic step change in phase current response time: F0 = 60 Hz, P class .....	749
9.4.8 PMU G dynamic step change in phase current response time: F0 = 60 Hz, P class .....	751
9.4.9 PMU H dynamic step change in phase current response time: F0 = 60 Hz, P class .....	751
9.4.10 PMU I dynamic step change in phase current response time: F0 = 60 Hz, P class .....	752
9.4.11 PMU J dynamic step change in phase current response time: F0 = 60 Hz, P class .....	753
9.5 Dynamic step change in phase: frequency response time .....	755
9.5.1 C37.118.1-2011 Annex C dynamic step change in phase frequency response time: F0 = 60 Hz, M class .....	755
9.5.2 PMU A dynamic step change in phase frequency response time: F0 = 60 Hz, M class .....	758
9.5.3 PMU B dynamic step change in phase frequency response time: F0 = 60 Hz, M class .....	760
9.5.4 PMU C dynamic step change in phase frequency response time: F0 = 60 Hz, M class .....	762
9.5.5 PMU D dynamic step change in phase frequency response time: F0 = 60 Hz, M class .....	764
9.5.6 PMU E dynamic step change in phase frequency response time: F0 = 60 Hz, M class .....	766
9.5.7 PMU F dynamic step change in phase frequency response time: F0 = 60 Hz, M class .....	768
9.5.8 PMU G dynamic step change in phase frequency response time: F0 = 60 Hz, M class .....	770
9.5.9 PMU H dynamic step change in phase frequency response time: F0 = 60 Hz, M class .....	772
9.5.10 PMU I dynamic step change in phase frequency response time: F0 = 60 Hz, M class .....	774
9.5.11 PMU J dynamic step change in phase frequency response time: F0 = 60 Hz, M class .....	776
9.6 Dynamic step change in phase frequency response time: F0 = 60 Hz, P Class .....	778
9.6.1 C37.118.1-2011 Annex C dynamic step change in phase frequency response time: F0 = 60 Hz, P class .....	778
9.6.2 PMU A dynamic step change in phase frequency response time: F0 = 60 Hz, P class .....	780
9.6.3 PMU B dynamic step change in phase frequency response time: F0 = 60 Hz, P class .....	782
9.6.4 PMU C dynamic step change in phase frequency response time: F0 = 60 Hz, P class .....	784
9.6.5 PMU D dynamic step change in phase frequency response time: F0 = 60 Hz, P class .....	786
9.6.6 PMU E dynamic step change in phase frequency response time: F0 = 60 Hz, P class .....	788
9.6.7 PMU F dynamic step change in phase frequency response time: F0 = 60 Hz, P class .....	788
9.6.8 PMU G dynamic step change in phase frequency response time: F0 = 60 Hz, P class .....	790
9.6.9 PMU H dynamic step change in phase frequency response time: F0 = 60 Hz, P class .....	790
9.6.10 PMU I dynamic step change in phase frequency response time: F0 = 60 Hz, P class .....	792
9.6.11 PMU J dynamic step change in phase frequency response time: F0 = 60 Hz, P class .....	792
9.7 Dynamic step change in phase: ROCOF response time .....	794
9.7.1 C37.118.1-2011 Annex C dynamic step change in phase ROCOF error: F0 = 60 Hz, M class .....	794
9.7.2 PMU A dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class .....	797

9.7.3 PMU B dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class .....	799
9.7.4 PMU C dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class .....	801
9.7.5 PMU D dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class .....	803
9.7.6 PMU E dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class .....	805
9.7.7 PMU F dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class .....	807
9.7.8 PMU G * dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class .....	809
9.7.9 PMU H dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class .....	811
9.7.10 PMU I dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class .....	813
9.7.11 PMU J dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class .....	815
9.8 Dynamic step change in phase: ROCOF response time: P class .....	817
9.8.1 C37.118.1-2011 Annex C dynamic step change in phase ROCOF error: F0 = 60 Hz, P class .....	817
9.8.2 PMU A dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class .....	819
9.8.3 PMU B dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class .....	821
9.8.4 PMU C dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class .....	823
9.8.5 PMU D dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class .....	825
9.8.6 PMU E dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class .....	827
9.8.7 PMU F dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class .....	827
9.8.8 PMU G dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class .....	829
9.8.9 PMU H dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class .....	829
9.8.10 PMU I dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class .....	830
9.8.11 PMU J dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class .....	831
9.9 Dynamic step change in phase: phasor overshoot: M class .....	833
Dynamic step change in phase: phasor delay time M class .....	833
9.9.1 C37.118.1-2011 Annex C dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class .....	834
9.9.2 PMU A dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class .....	836
9.9.3 PMU B dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class .....	838
9.9.4 PMU C dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class .....	840
9.9.5 PMU D dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class .....	842
9.9.6 PMU E dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class .....	844
9.9.7 PMU F dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class .....	846
9.9.8 PMU G dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class .....	848
9.9.9 PMU H dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class .....	850
9.9.10 PMU I dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class .....	852
9.9.11 PMU J dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class .....	854
9.10 Dynamic step change in phase: phasor overshoot: P class .....	856
Dynamic step change in phase: phasor delay time P class .....	856
9.10.1 C37.118.1-2011 Annex C dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class .....	856
9.10.2 PMU A dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class .....	858
9.10.3 PMU B dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class .....	860

9.10.4 PMU C dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class .....	862
9.10.5 PMU D dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class .....	864
9.10.6 PMU E dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class.....	866
9.10.7 PMU F dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class.....	866
9.10.8 PMU G * dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class .....	869
9.10.9 PMU H dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class .....	869
9.10.10 PMU I dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class .....	872
9.10.11 PMU J dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class .....	872

Performance during step changes in phase is determined by applying  $\pm 10\%$  step changes of phase. Response time and delay time of the phasors, frequency, and ROCOF measurements are compared to the limits. Overshoot of the phasors are compared to the limits.

A recommended practice for measuring a PMU's response to step changes in input is to run a series of  $n$  step sub-tests where the occurrence of the step is displaced in time relative to the PMU report-time. During each ( $n^{\text{th}}$ ) iteration of 10 sub-tests, the step occurs  $1/10^{\text{th}}$  of a reporting period further from the time of the report than the previous iteration of the subtest. The results are combined to trace an equivalent time sampled response curve. During each sub-test, the phase is stepped, the response data are gathered, and the phase is returned to its previous value in preparation for the next sub-test in the series. At the end of the series of sub-tests, the TVE, FE, RFE results and the PMU reported phase data from all sub-tests are indexed and overlaid to create smooth curves approximating the step response of the PMU. From the curves, delay time, response time, and overshoot/undershoot shall be calculated

The test plan for step change in phase and magnitude is as follows:

- a) For the first test, let  $n = 0$ .
- b) Begin with three-phase balanced input at nominal amplitude and frequency. Hold steady state for at least 1 second plus one response time period.
- c) At the beginning of a reporting cycle plus  $n / (10 \times F_s)$  (i.e.,  $n \times$  reporting period/10) step the magnitude by  $+10\%$  of the nominal magnitude and hold steady state for at least 1 second plus one response time period.
- d) Gather the PMU data, return the influence quantity to nominal and wait for the PMU to settle.
- e) Increment  $n$  by one ( $n = n + 1$ ), then repeat step c) through step d) until  $n = 10 - 1$ .
- f) Index and overlay the PMU data to obtain a smooth response curve.
- g) Repeat the tests for negative magnitude step.

IEEE Std. C37.118.1a-2014 sets the M class response time limit for M class phasors at  $7/F_s$  and for frequency and ROCOF at the greater of  $14/F_s$  or  $14/F_0$ .

IEEE Std. C37.118.1a-2014 sets the P class response time limit for phasors at  $2/F_0$  the delay time limit at  $1/(4F_s)$  and the overshoot at 5% of the step magnitude.

IEEE Std. C37.118.1a-2014 sets the P class response time limit for frequency at  $4.5/F_0$  and for ROCOF at  $6/F_0$ .

IEEE Std C37.118.1-2011 sets the M class phasor delay time at  $1/(4F_s)$  and the max overshoot at 10% of the step magnitude.

IEEE Std C37.118.1-2011 sets the P class phasor delay time at  $1/(4F_s)$  and the max overshoot at 5% of the step magnitude.

The response time plots in this section show the limit of TVE, Fe, or RFe as a green horizontal line. A red vertical line appears at the response time limits. note that the limits are not interpolated, the first vertical red line appears at the first report which is above the TVE, FE or RFE limit and the second red line is at the response time limit away from the first. The PMU response must return and remain below the green line before the second vertical red line is crossed in order to comply with the response time limit.

The overshoot plots in this section show red horizontal lines at the overshoot/undershoot limits around the magnitude before and after the step.

### 9.1 Dynamic step change in phase: voltage response time:

Fs (FPS)	10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P
PMU A	P	P	P	P	P	P	P	P	P	P	P	P
PMU B	P	F	P	F	P	F	P	F	P	F	P	F
PMU C	P	P	P	P	P	P	P	P	P	P	P	P
PMU D	P	I	P	I	P	I	P	I	P	I	P	I
PMU E	P	-	P	-	P	-	P	-	P	-	F	-
PMU F	P	P	P	P	P	P	P	P	P	P	P	P
PMU G	P	-	P	-	P	-	P	-	F	-	-	-
PMU H	P	P	P	P	P	P	P	P	P	P	P	P
PMU I	P	-	P	-	P	-	P	-	P	-	P	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P

P = pass, F = fail, I = indeterminate

### 9.1.1 C37.118.1a Annex C dynamic step change in phase voltage response time: F0 = 60 Hz, M class

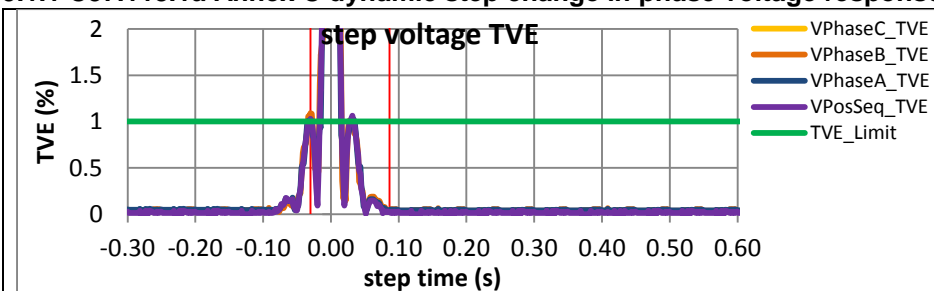


Figure 3953: Fs = 60 FPS, +10 degree phase step

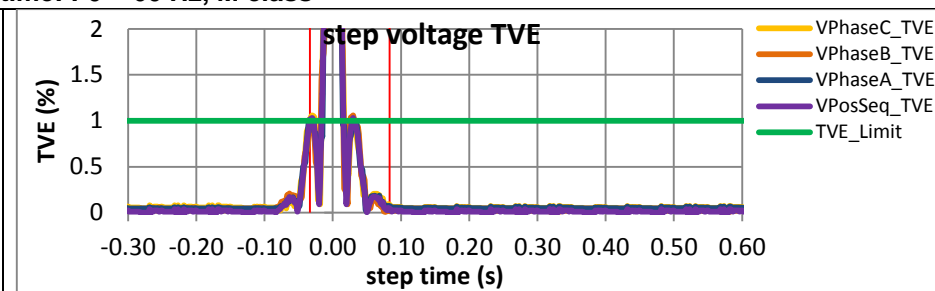


Figure 3954: Fs = 60 FPS, -10 degree phase step

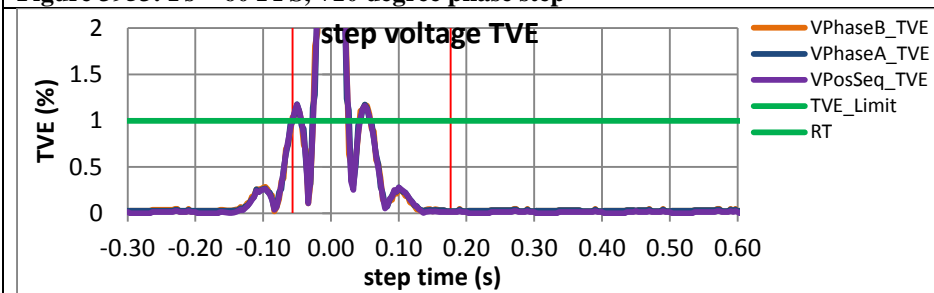


Figure 3955: Fs = 30 FPS, +10 degree phase step

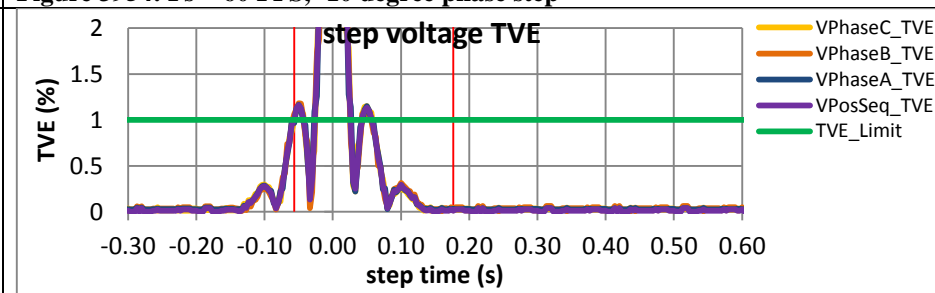


Figure 3956: Fs = 30 FPS, -10 degree phase step

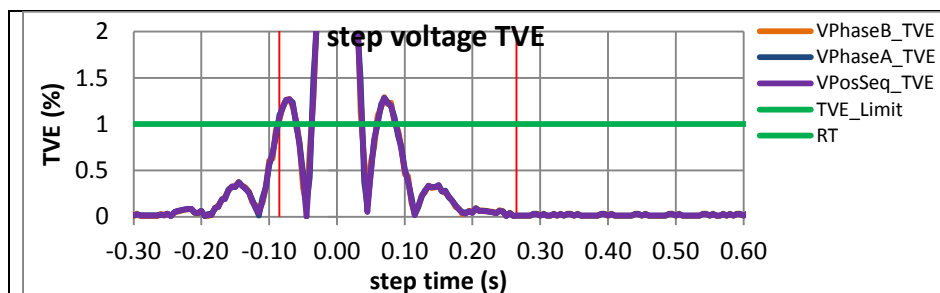


Figure 3957:  $F_s = 20$  FPS, +10 degree phase step

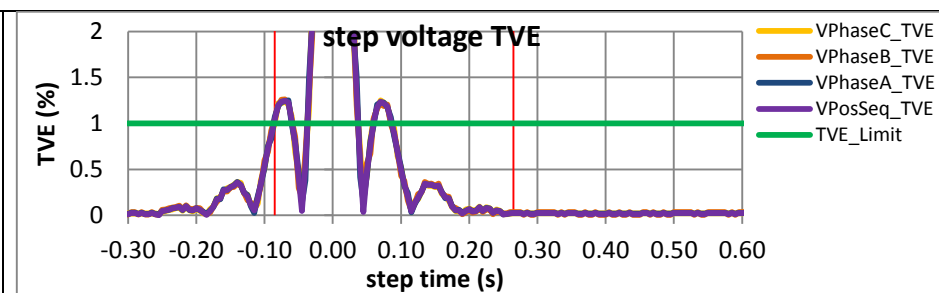


Figure 3958:  $F_s = 20$  FPS, -10 degree phase step

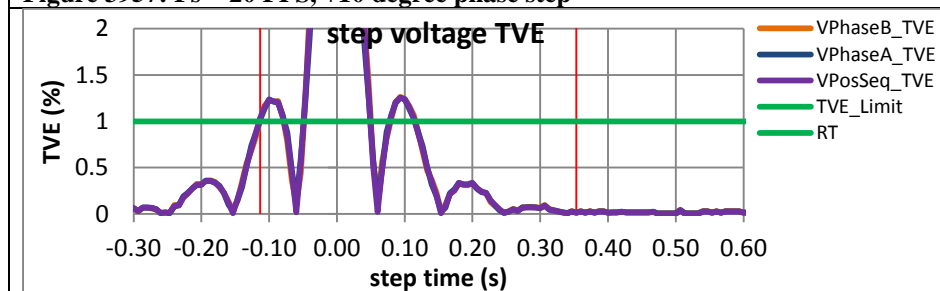


Figure 3959:  $F_s = 15$  FPS, +10 degree phase step

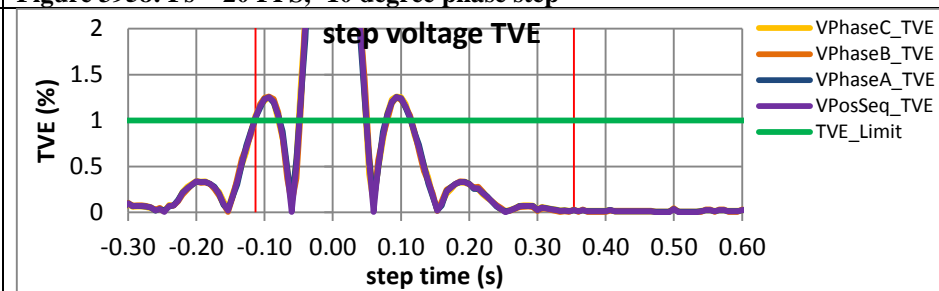


Figure 3960:  $F_s = 15$  FPS, -10 degree phase step

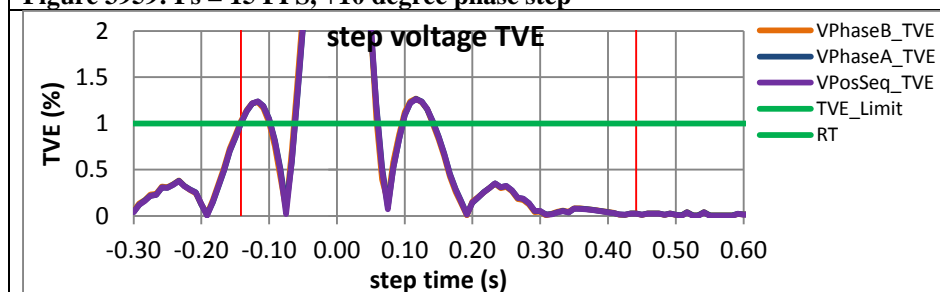


Figure 3961:  $F_s = 12$  FPS, +10 degree phase step

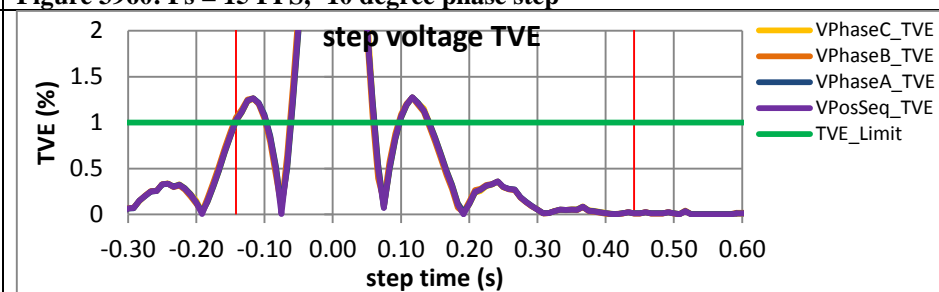


Figure 3962:  $F_s = 12$  FPS, -10 degree phase step



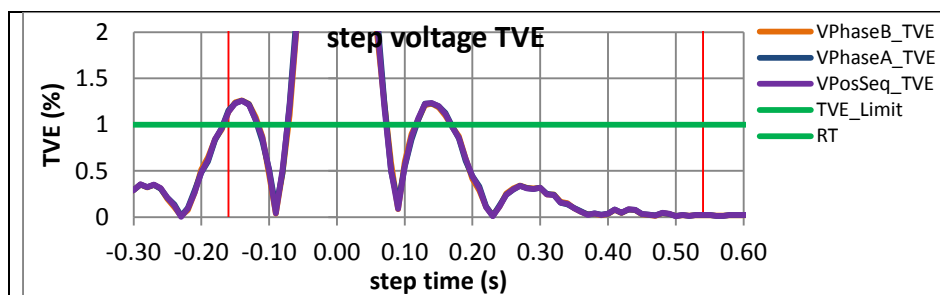


Figure 3963: Fs = 10 FPS, +10 degree phase step

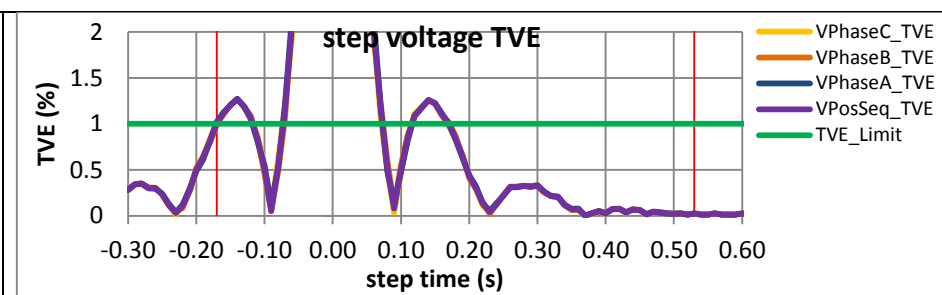
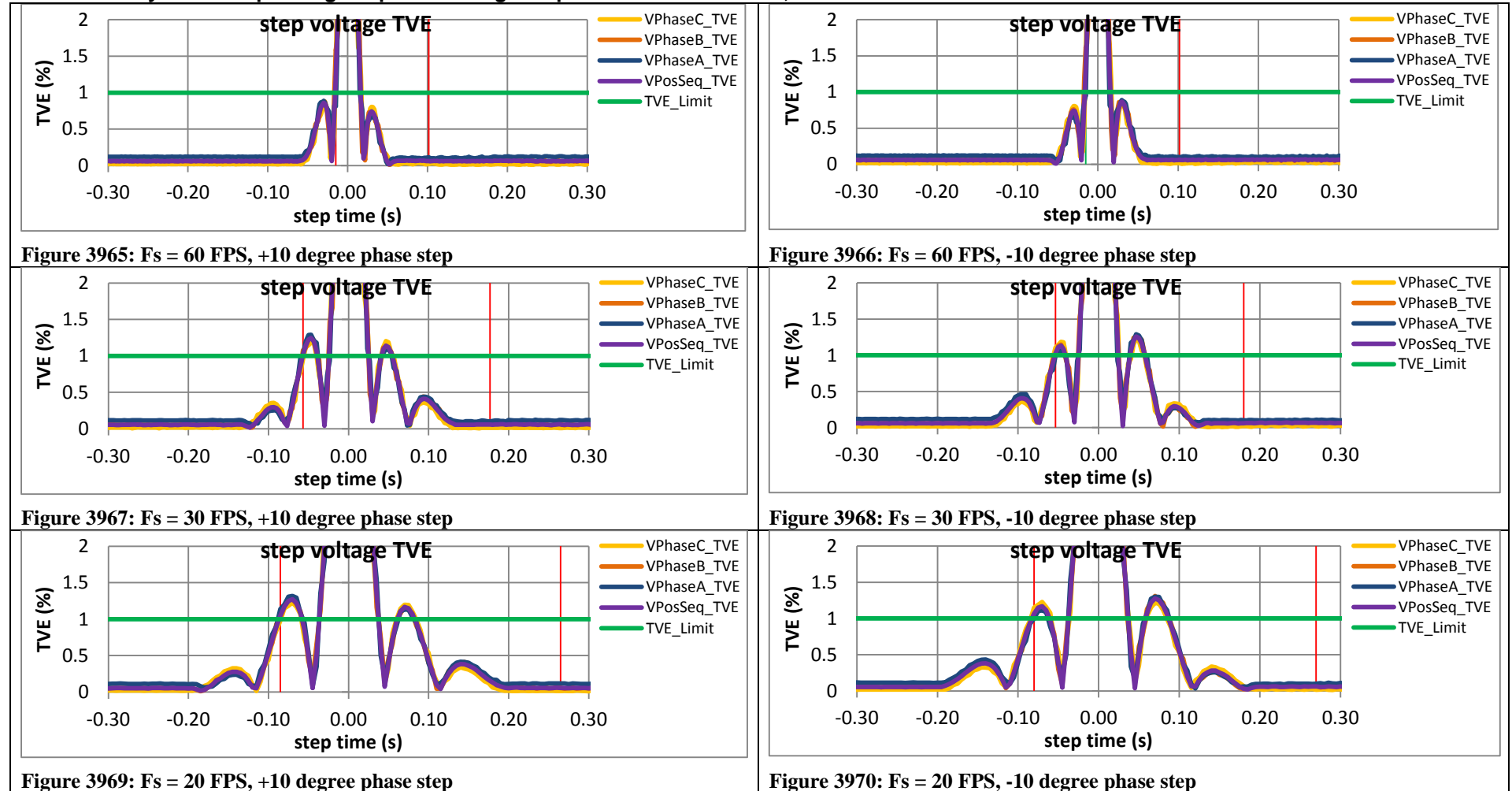


Figure 3964: Fs = 10 FPS, -10 degree phase step

### 9.1.2 PMU A dynamic step change in phase voltage response time: F0 = 60 Hz, M class



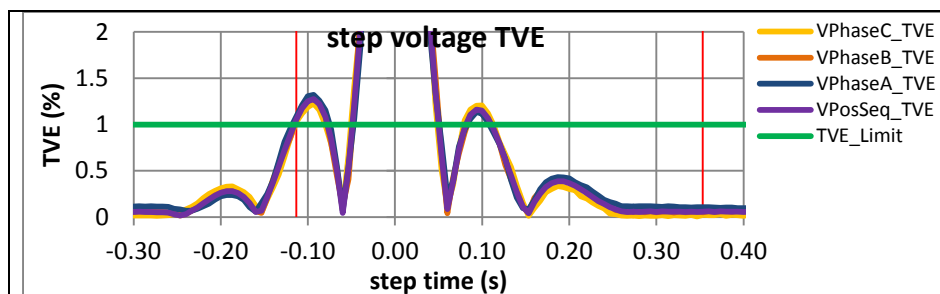


Figure 3971:  $F_s = 15$  FPS, +10 degree phase step

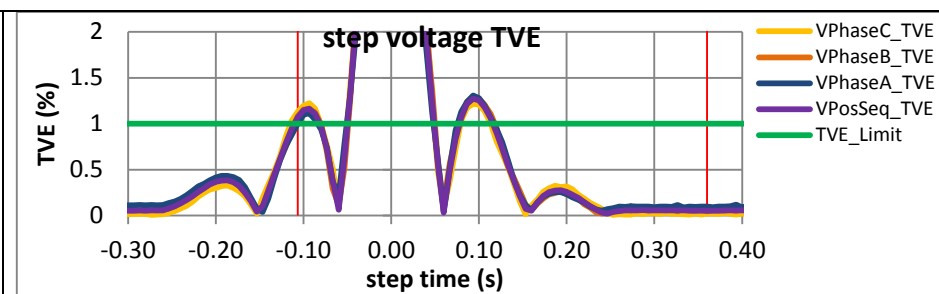


Figure 3972:  $F_s = 15$  FPS, -10 degree phase step

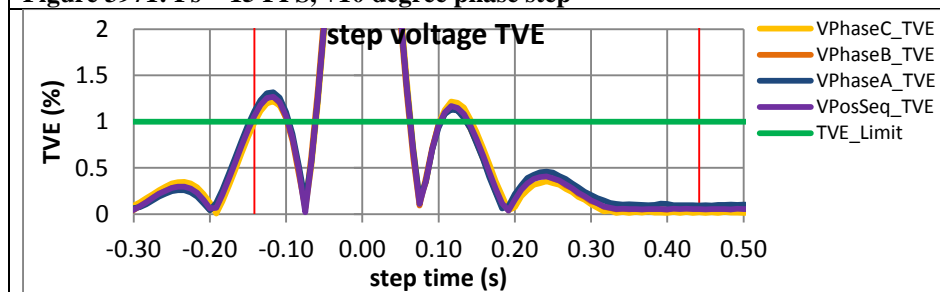


Figure 3973:  $F_s = 12$  FPS, +10 degree phase step

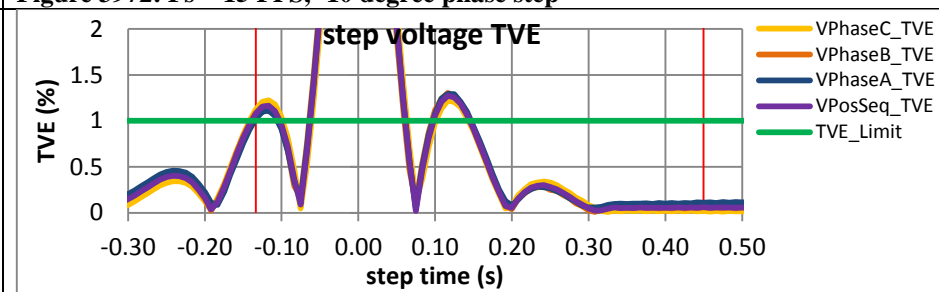


Figure 3974:  $F_s = 12$  FPS, -10 degree phase step

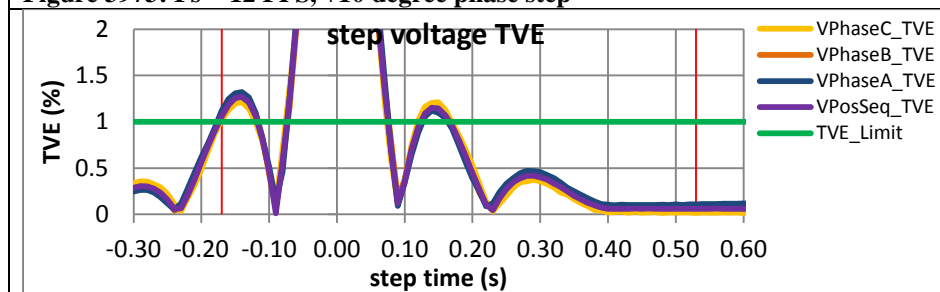


Figure 3975:  $F_s = 10$  FPS, +10 degree phase step

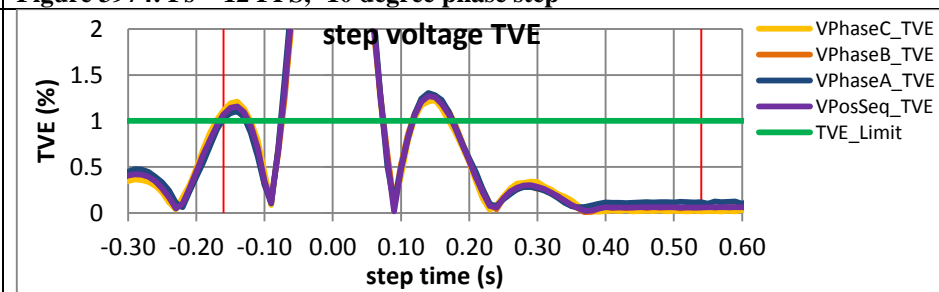
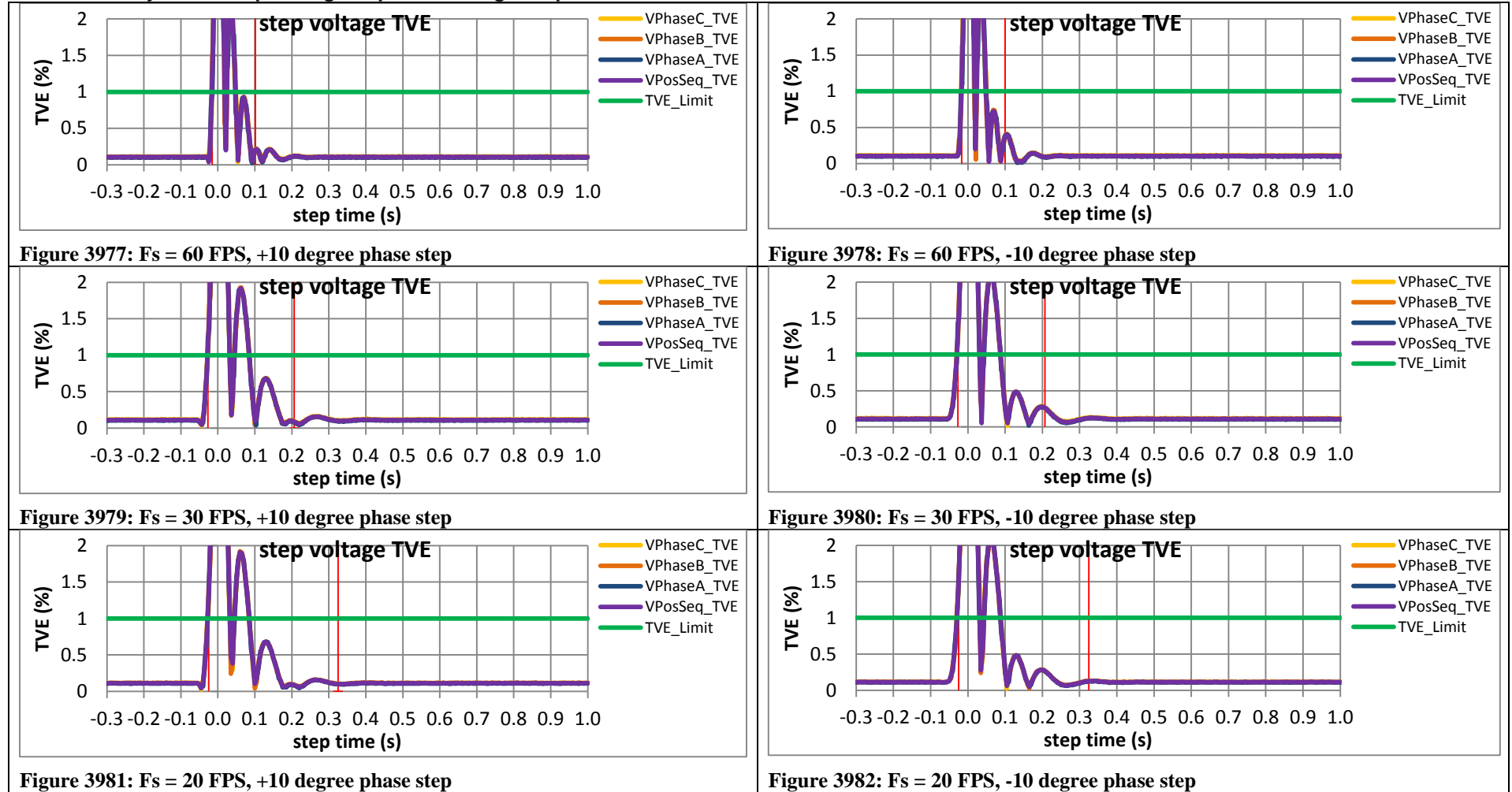


Figure 3976:  $F_s = 10$  FPS, -10 degree phase step

### 9.1.3 PMU B dynamic step change in phase voltage response time: F0 = 60 Hz, M class



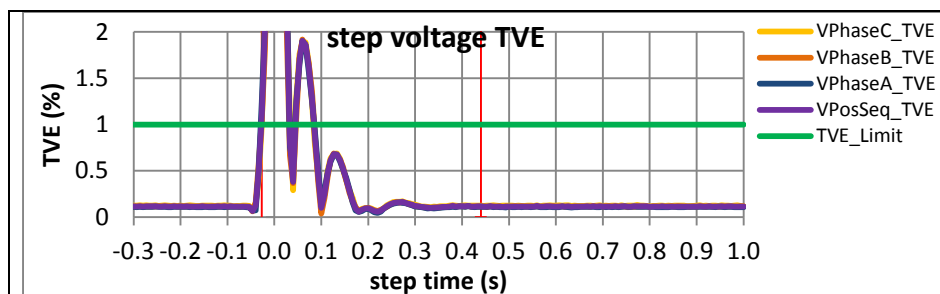


Figure 3983:  $F_s = 15$  FPS, +10 degree phase step

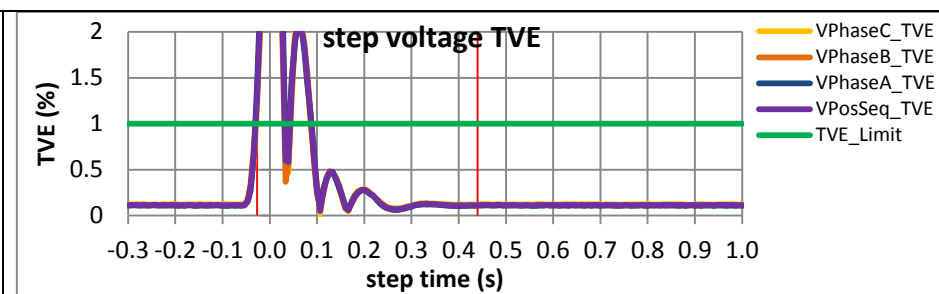


Figure 3984:  $F_s = 15$  FPS, -10 degree phase step

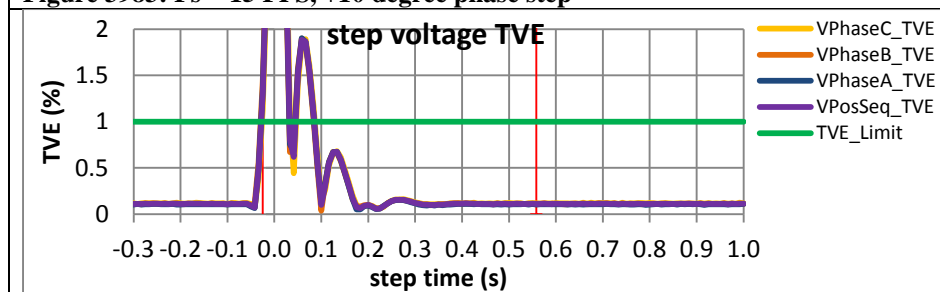


Figure 3985:  $F_s = 12$  FPS, +10 degree phase step

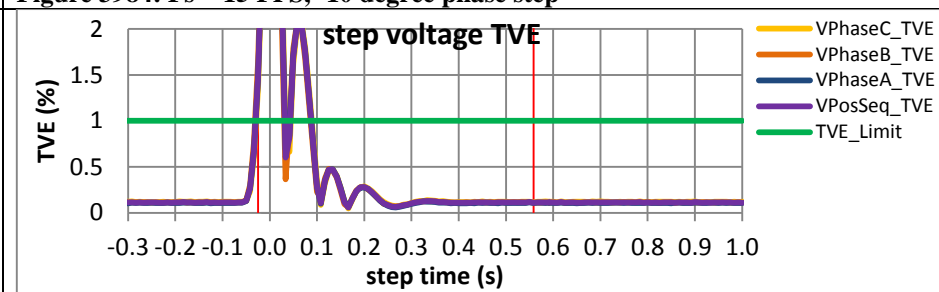


Figure 3986:  $F_s = 12$  FPS, -10 degree phase step

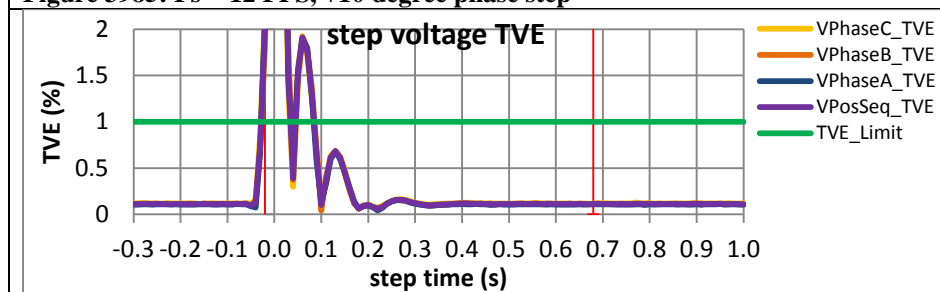


Figure 3987:  $F_s = 10$  FPS, +10 degree phase step

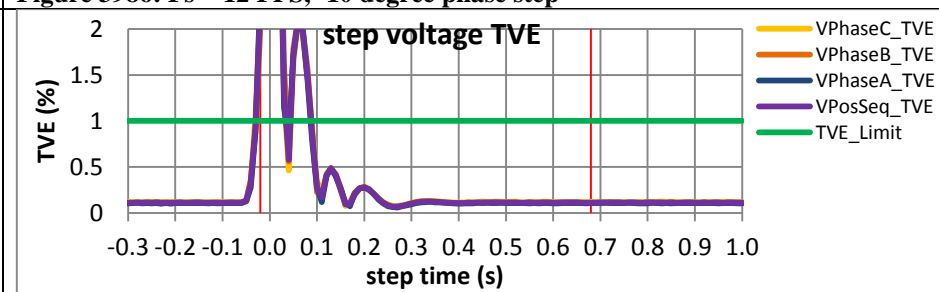


Figure 3988:  $F_s = 10$  FPS, -10 degree phase step

#### 9.1.4 PMU C dynamic step change in phase voltage response time: F0 = 60 Hz, M class

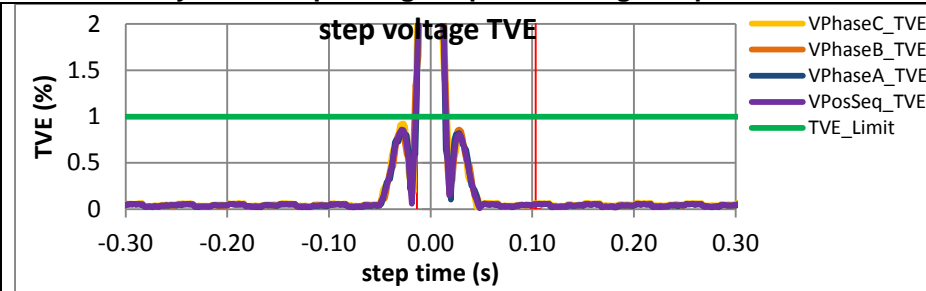


Figure 3989: Fs = 60 FPS, +10 degree phase step

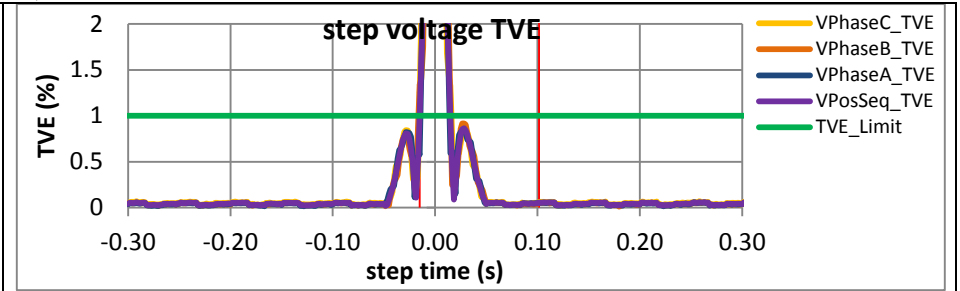


Figure 3990: Fs = 60 FPS, -10 degree phase step

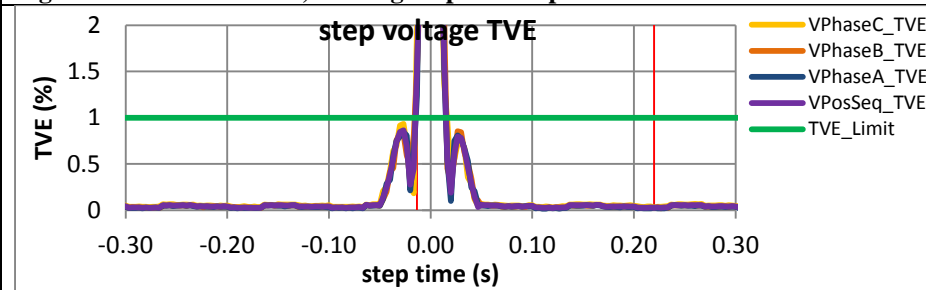


Figure 3991: Fs = 30 FPS, +10 degree phase step

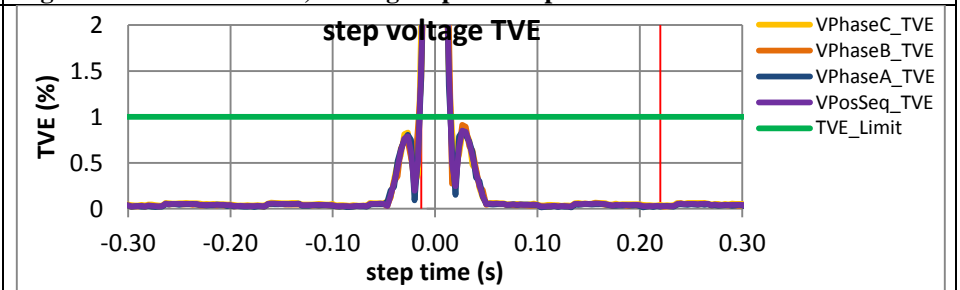


Figure 3992: Fs = 30 FPS, -10 degree phase step

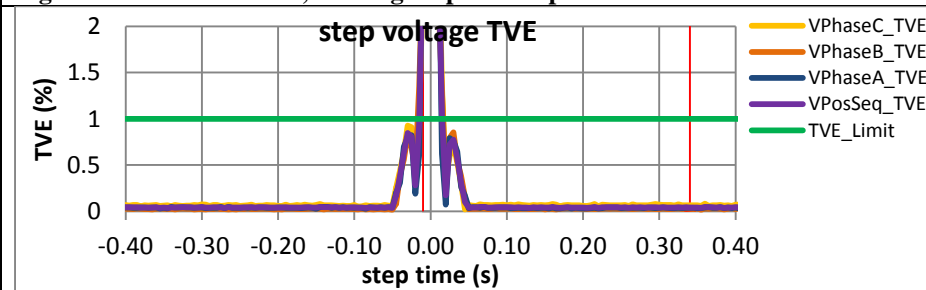


Figure 3993: Fs = 20 FPS, +10 degree phase step

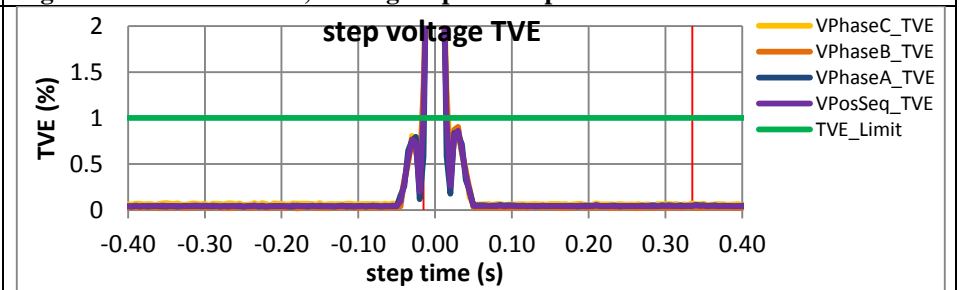


Figure 3994: Fs = 20 FPS, -10 degree phase step

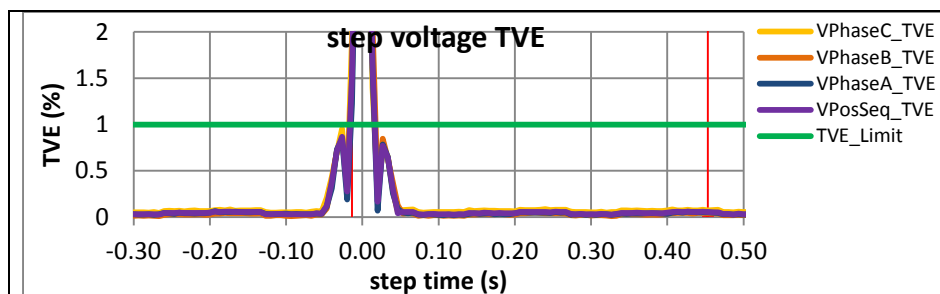


Figure 3995: Fs = 15 FPS, +10 degree phase step

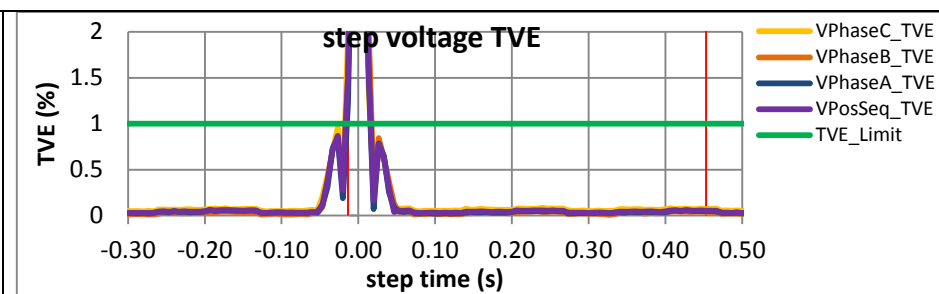


Figure 3996: Fs = 15 FPS, -10 degree phase step

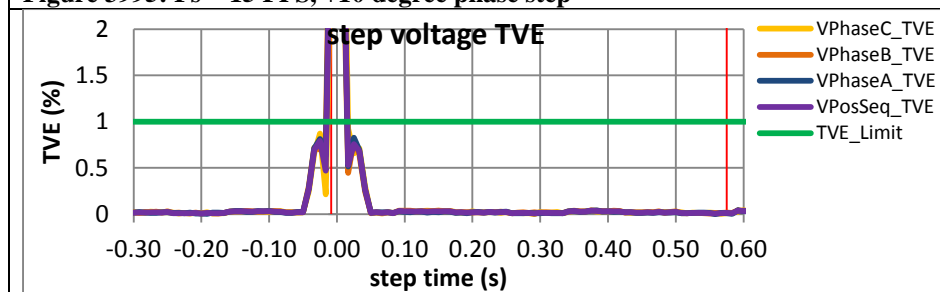


Figure 3997: Fs = 12 FPS, +10 degree phase step

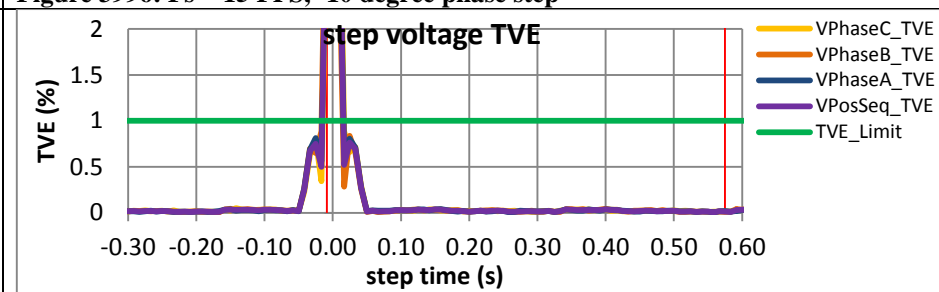


Figure 3998: Fs = 12 FPS, -10 degree phase step

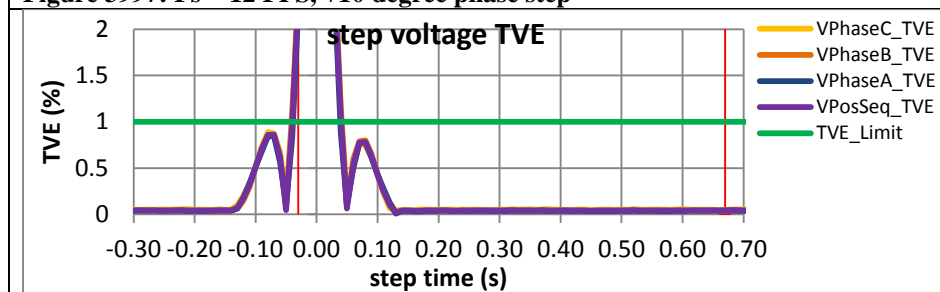


Figure 3999: Fs = 10 FPS, +10 degree phase step

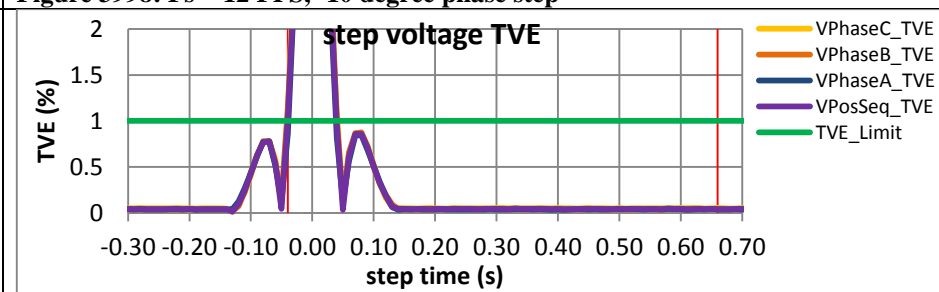


Figure 4000: Fs = 10 FPS, -10 degree phase step

### 9.1.5 PMU D dynamic step change in phase voltage response time: F0 = 60 Hz, M class

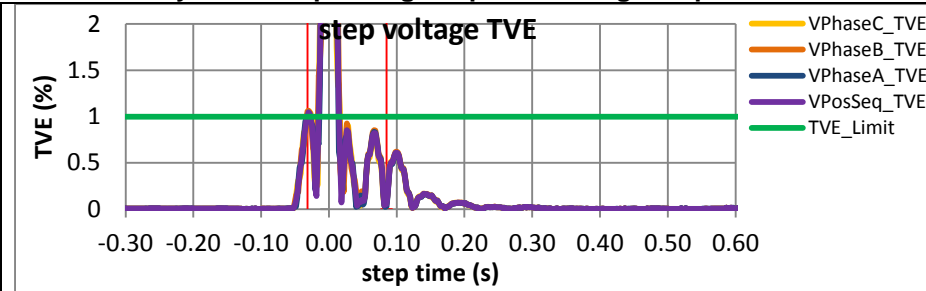


Figure 4001: Fs = 60 FPS, +10 degree phase step

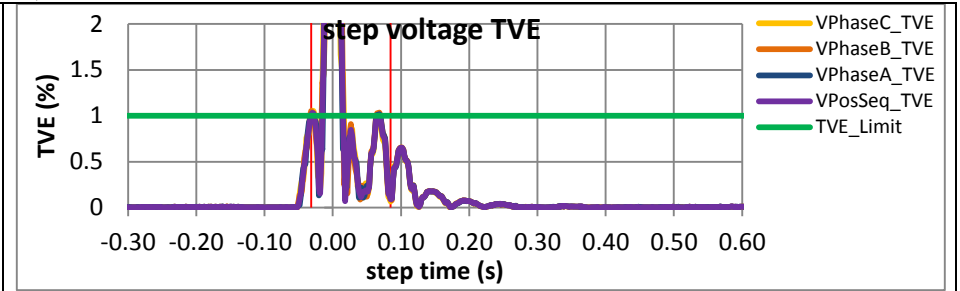


Figure 4002: Fs = 60 FPS, -10 degree phase step

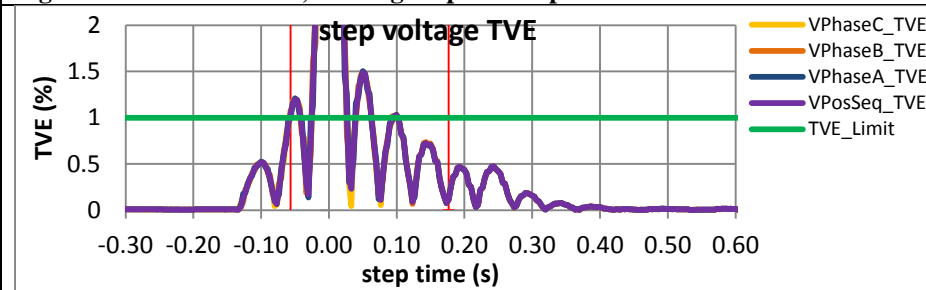


Figure 4003: Fs = 30 FPS, +10 degree phase step

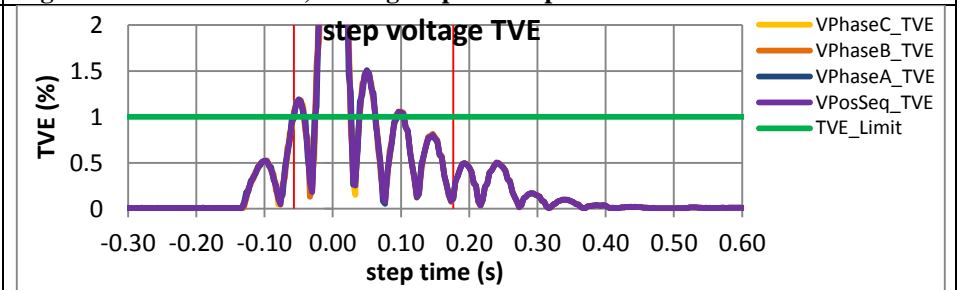


Figure 4004: Fs = 30 FPS, -10 degree phase step

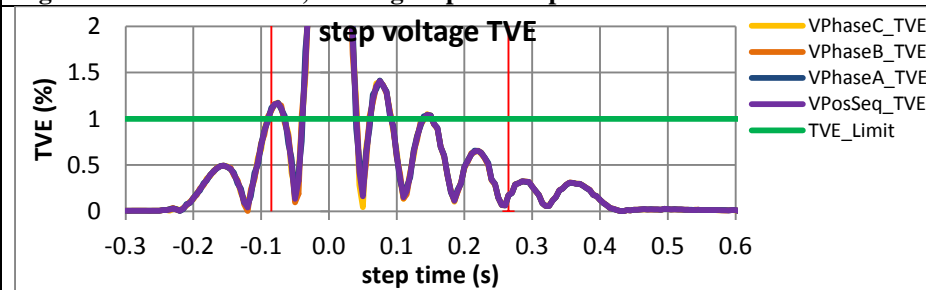


Figure 4005: Fs = 20 FPS, +10 degree phase step

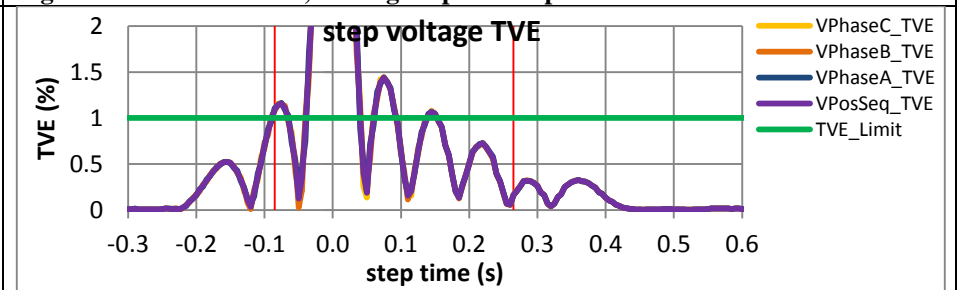


Figure 4006: Fs = 20 FPS, -10 degree phase step



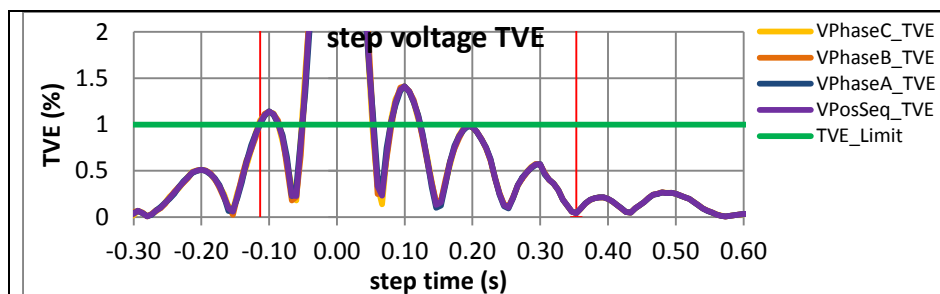


Figure 4007:  $F_s = 15$  FPS, +10 degree phase step

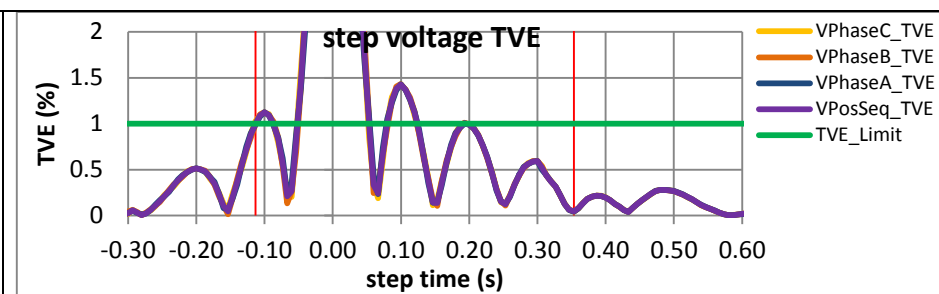


Figure 4008:  $F_s = 15$  FPS, -10 degree phase step

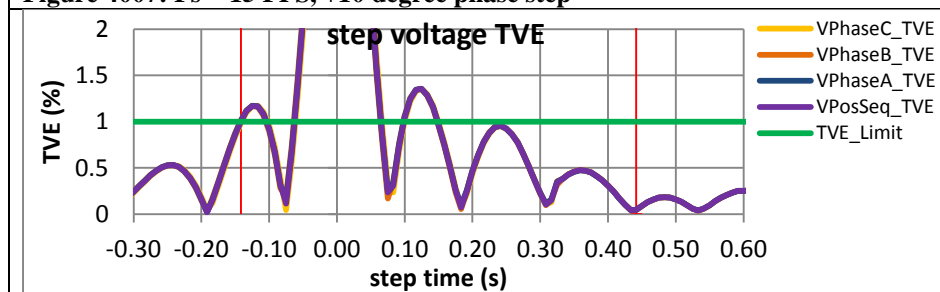


Figure 4009:  $F_s = 12$  FPS, +10 degree phase step

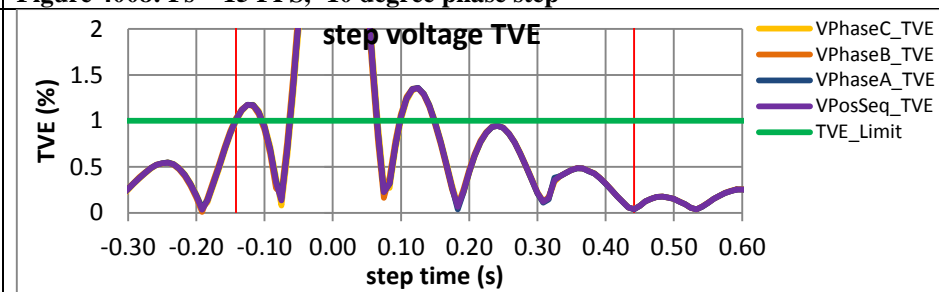


Figure 4010:  $F_s = 12$  FPS, -10 degree phase step

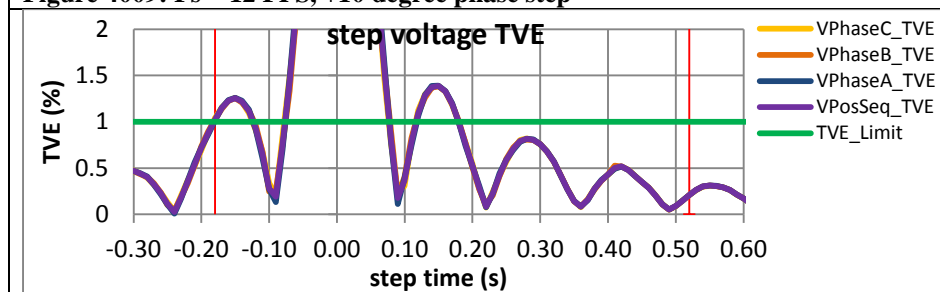


Figure 4011:  $F_s = 10$  FPS, +10 degree phase step

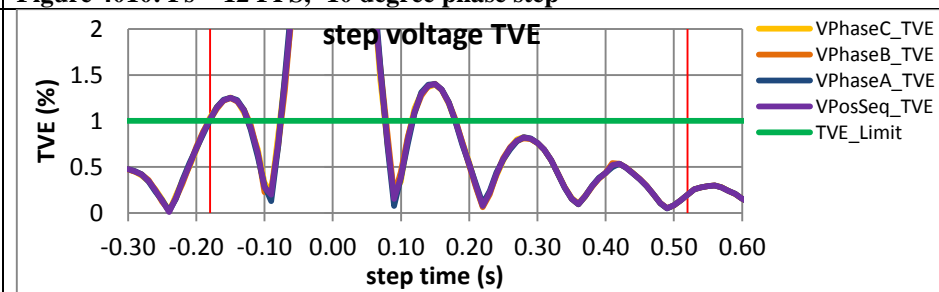


Figure 4012:  $F_s = 10$  FPS, -10 degree phase step

### 9.1.6 PMU E dynamic step change in phase voltage response time: F0 = 60 Hz, M class

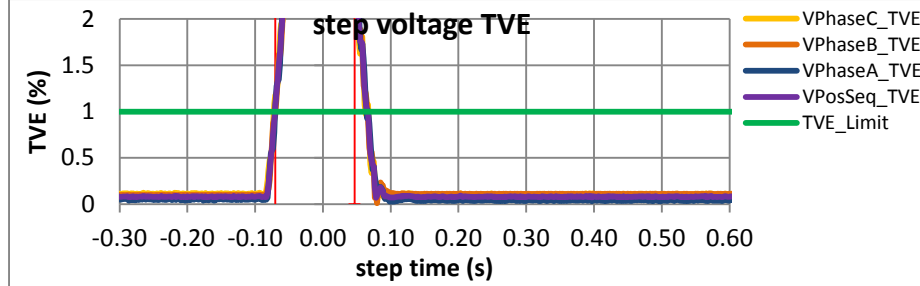


Figure 4013: Fs = 60 FPS, +10 degree phase step

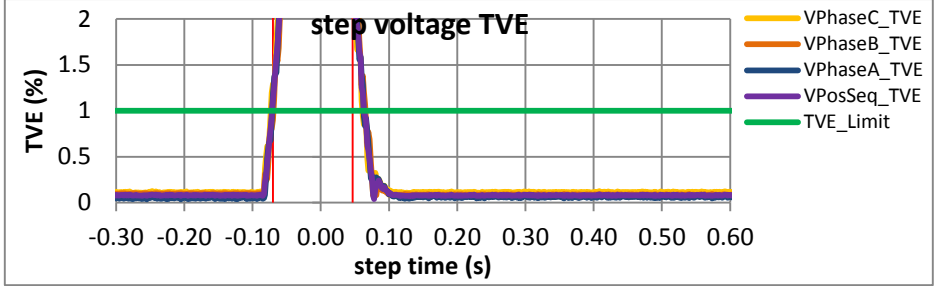


Figure 4014: Fs = 60 FPS, -10 degree phase step

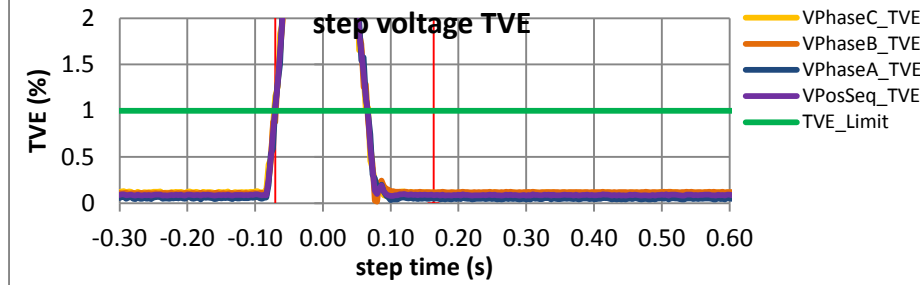


Figure 4015: Fs = 30 FPS, +10 degree phase step

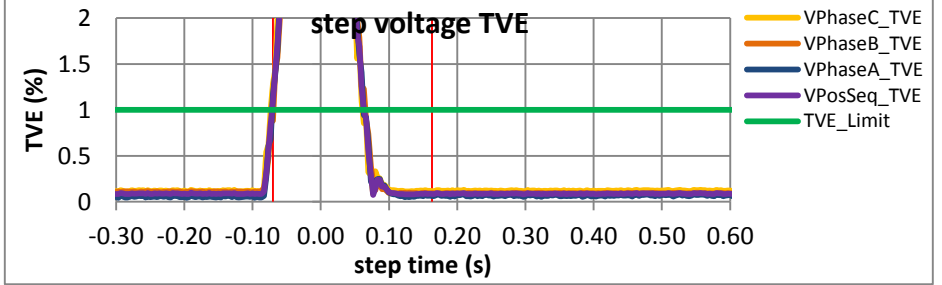


Figure 4016: Fs = 30 FPS, -10 degree phase step

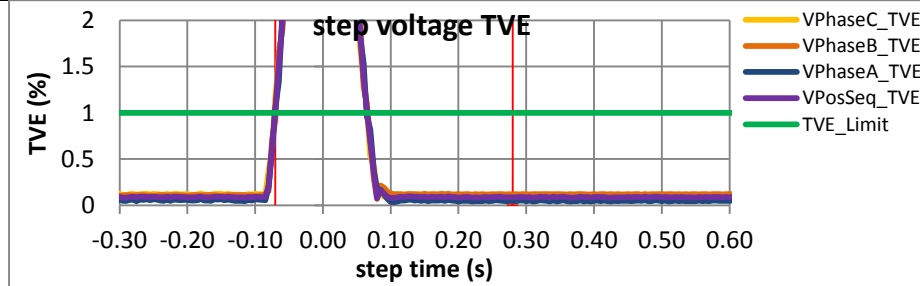


Figure 4017: Fs = 20 FPS, +10 degree phase step

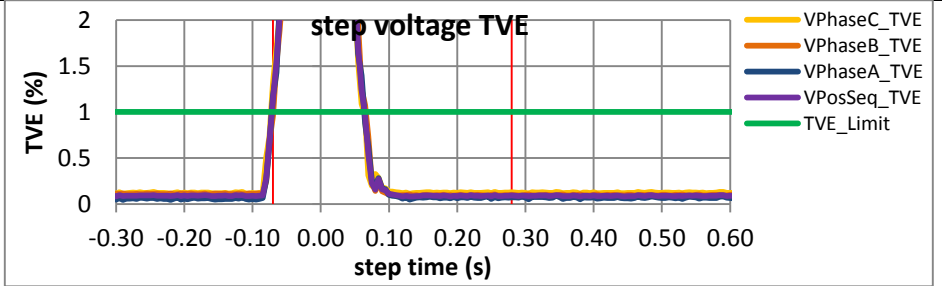


Figure 4018: Fs = 20 FPS, -10 degree phase step

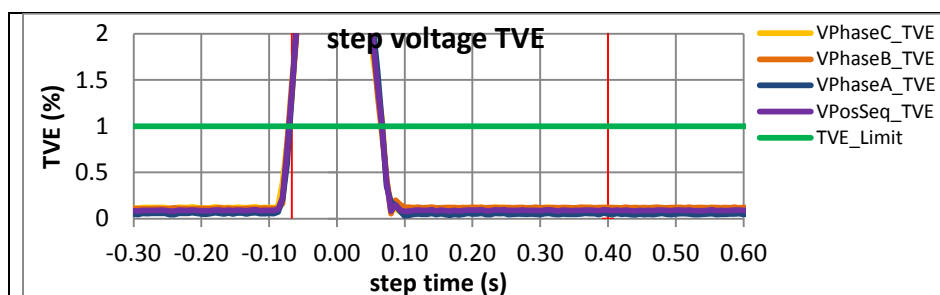


Figure 4019: Fs = 15 FPS, +10 degree phase step

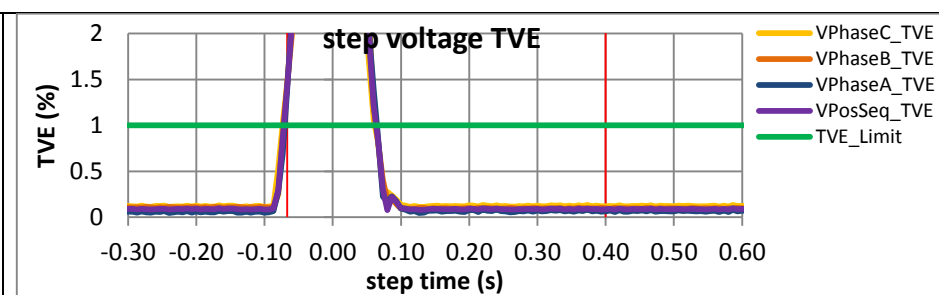


Figure 4020: Fs = 15 FPS, -10 degree phase step

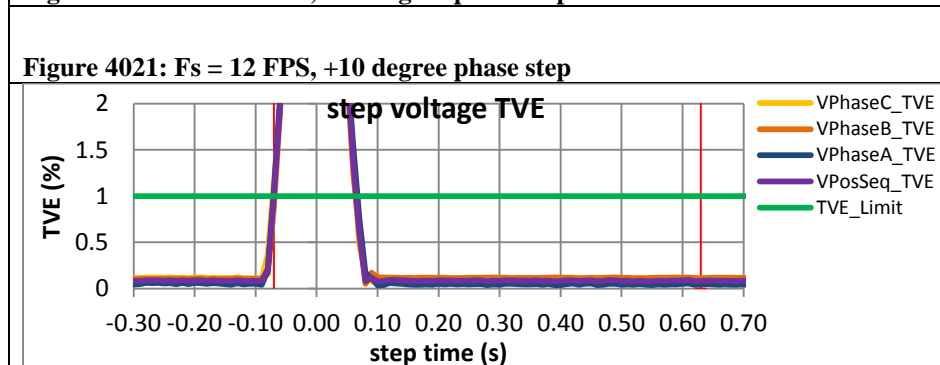


Figure 4021: Fs = 12 FPS, +10 degree phase step

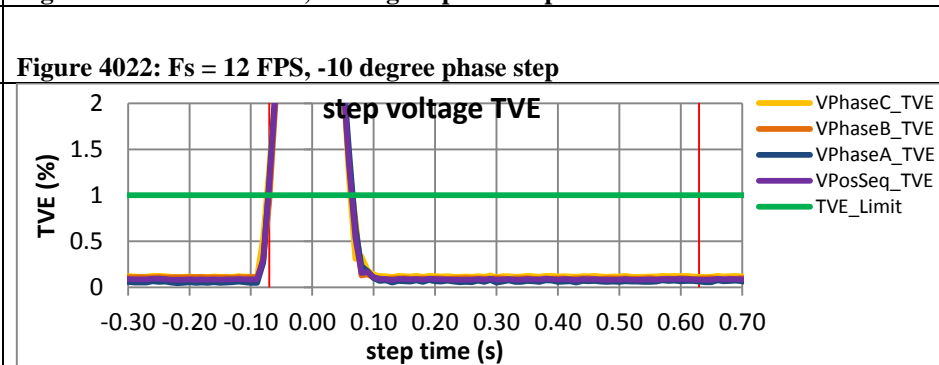


Figure 4022: Fs = 12 FPS, -10 degree phase step

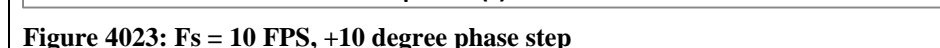


Figure 4023: Fs = 10 FPS, +10 degree phase step

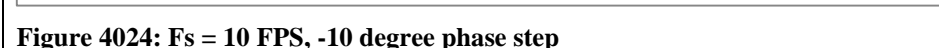


Figure 4024: Fs = 10 FPS, -10 degree phase step

### 9.1.7 PMU F dynamic step change in phase voltage response time: F0 = 60 Hz, M class

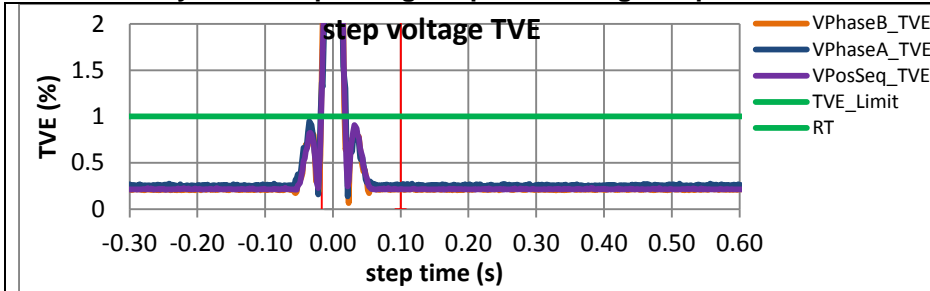


Figure 4025: Fs = 60 FPS, +10 degree phase step

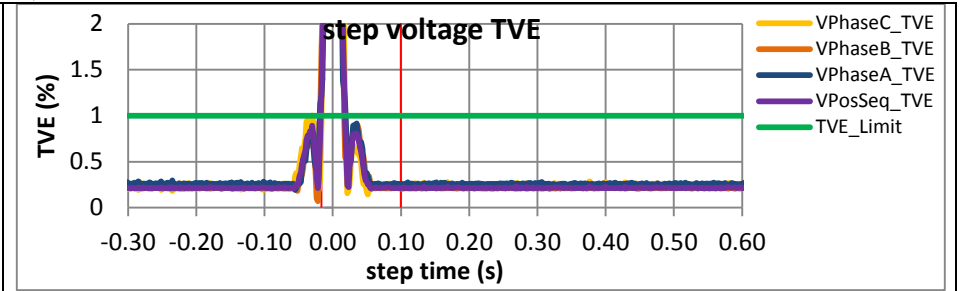


Figure 4026: Fs = 60 FPS, -10 degree phase step

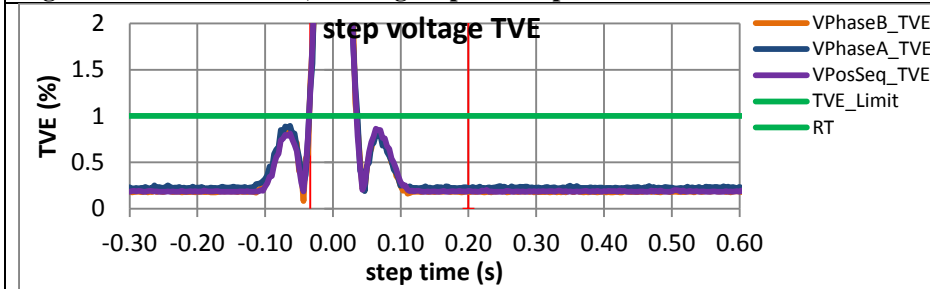


Figure 4027: Fs = 30 FPS, +10 degree phase step

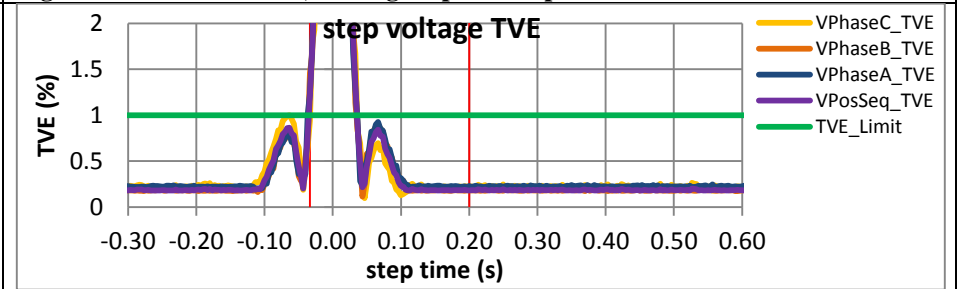


Figure 4028: Fs = 30 FPS, -10 degree phase step

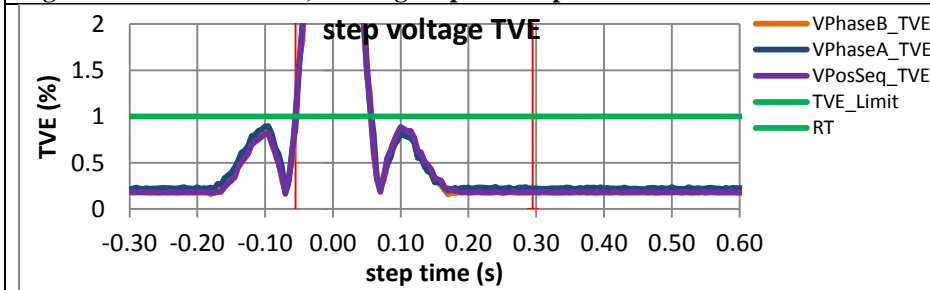


Figure 4029: Fs = 20 FPS, +10 degree phase step

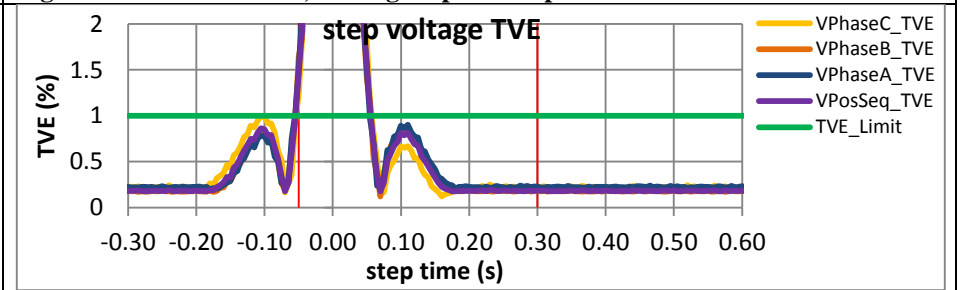


Figure 4030: Fs = 20 FPS, -10 degree phase step

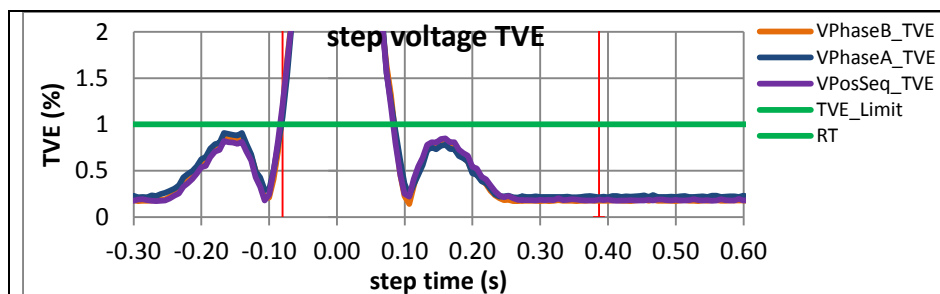


Figure 4031:  $F_s = 15$  FPS, +10 degree phase step

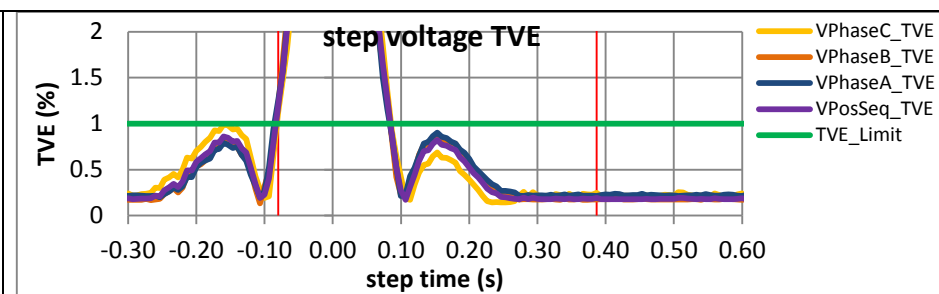


Figure 4032:  $F_s = 15$  FPS, -10 degree phase step

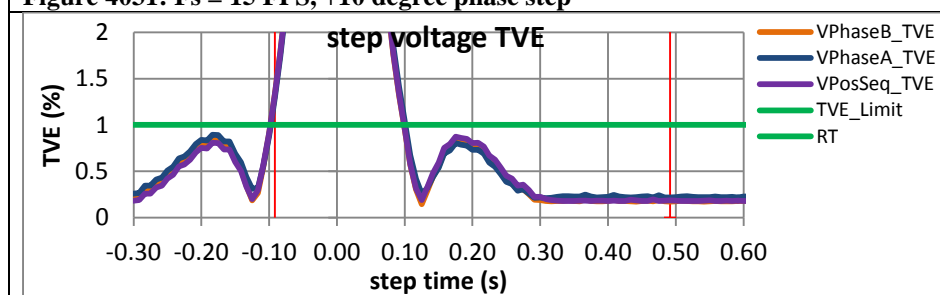


Figure 4033:  $F_s = 12$  FPS, +10 degree phase step

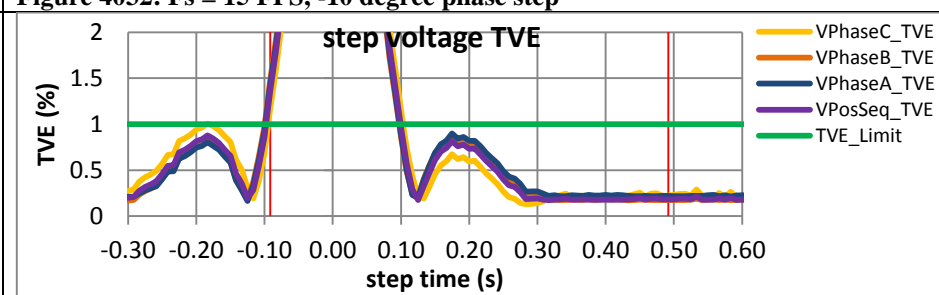


Figure 4034:  $F_s = 12$  FPS, -10 degree phase step

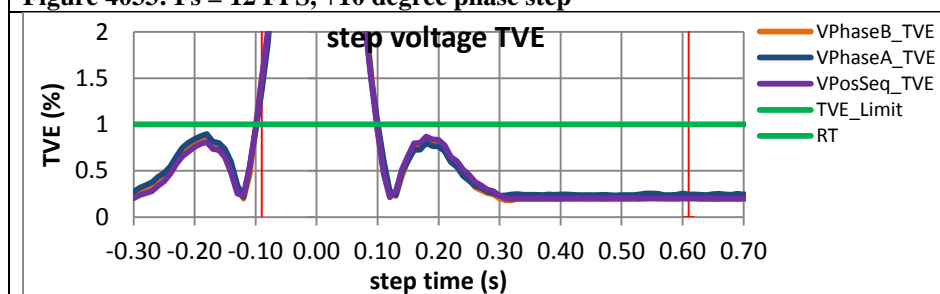


Figure 4035:  $F_s = 10$  FPS, +10 degree phase step

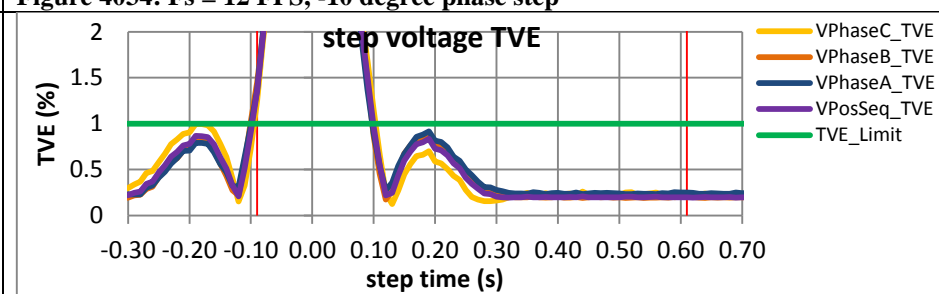


Figure 4036:  $F_s = 10$  FPS, -10 degree phase step

### 9.1.8 PMU G dynamic step change in phase voltage response time: F0 = 60 Hz, M class

Figure 4037:  $F_s = 60$  FPS is not supported by this PMU

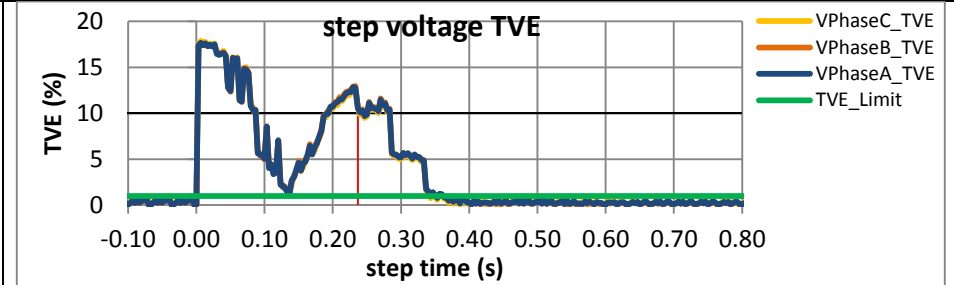
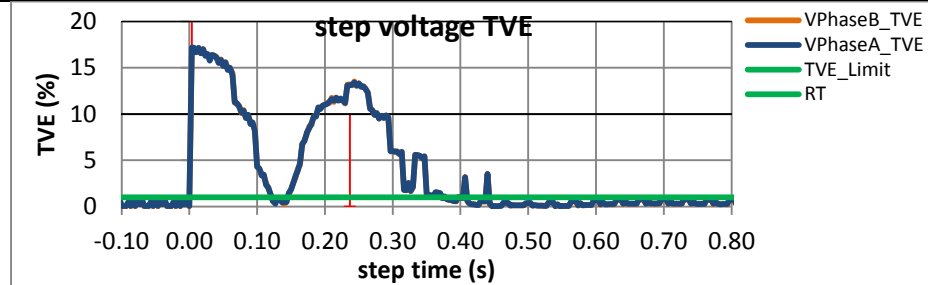


Figure 4038:  $F_s = 30$  FPS, +10 degree phase step

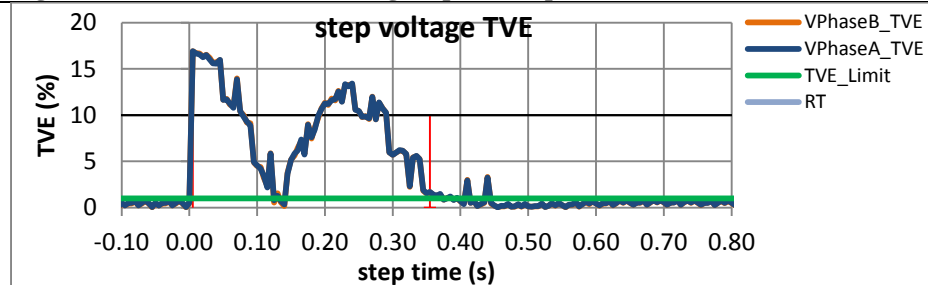


Figure 4039:  $F_s = 30$  FPS, -10 degree phase step

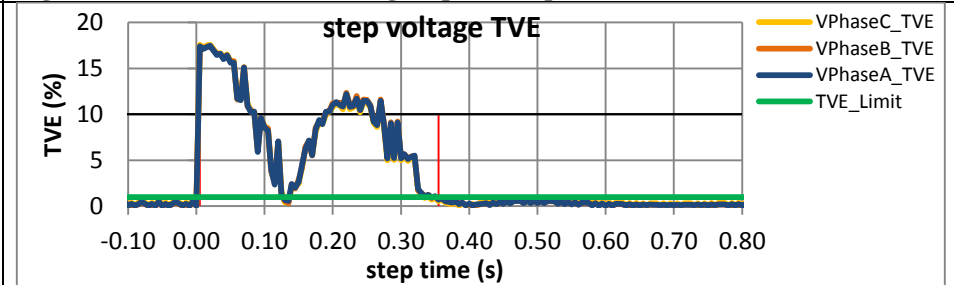


Figure 4040:  $F_s = 20$  FPS, +10 degree phase step

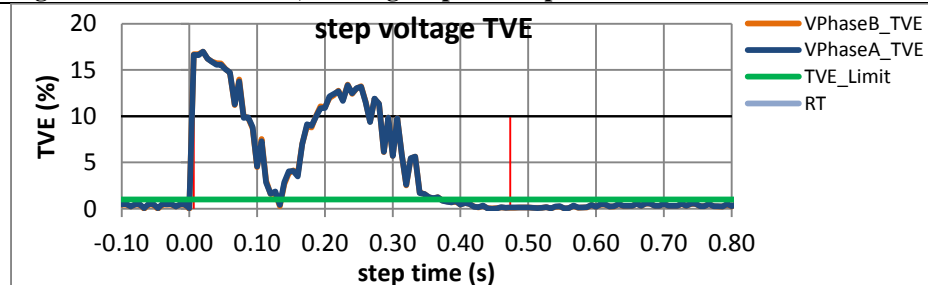


Figure 4041:  $F_s = 20$  FPS, -10 degree phase step

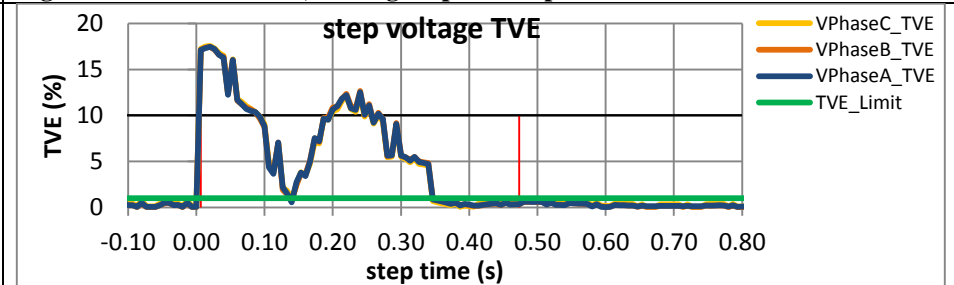


Figure 4042:  $F_s = 15$  FPS, +10 degree phase step

Figure 4043:  $F_s = 15$  FPS, -10 degree phase step

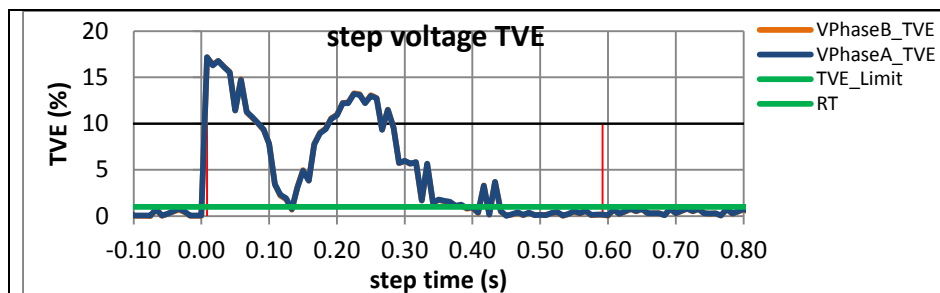


Figure 4044: Fs = 12 FPS, +10 degree phase step

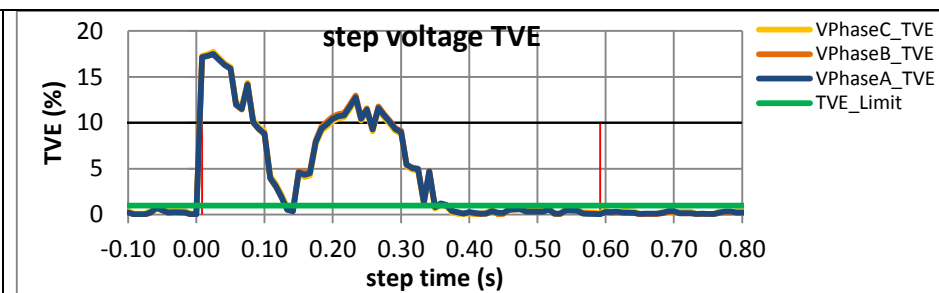


Figure 4045: Fs = 12 FPS, -10 degree phase step

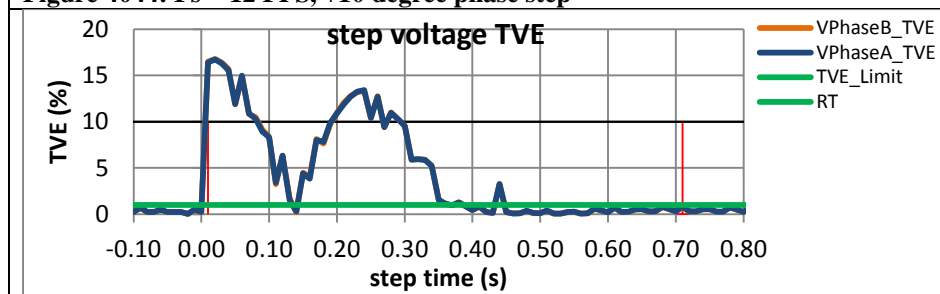


Figure 4046: Fs = 10 FPS, +10 degree phase step

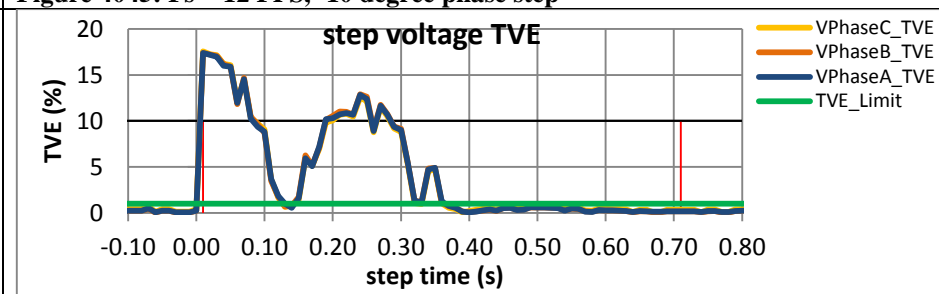


Figure 4047: Fs = 10 FPS, -10 degree phase step

### 9.1.9 PMU H dynamic step change in phase voltage response time: F0 = 60 Hz, M class

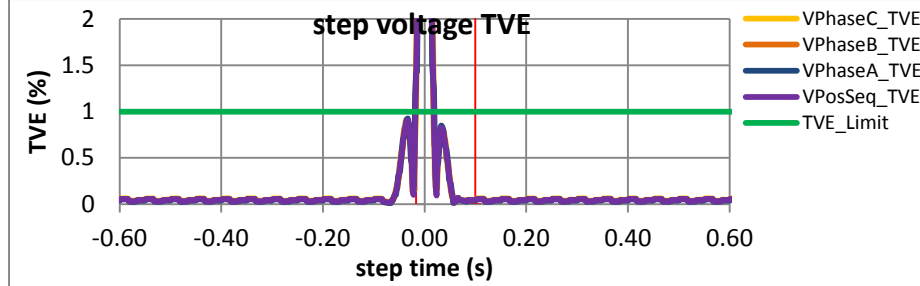


Figure 4048: Fs = 60 FPS, +10 degree phase step

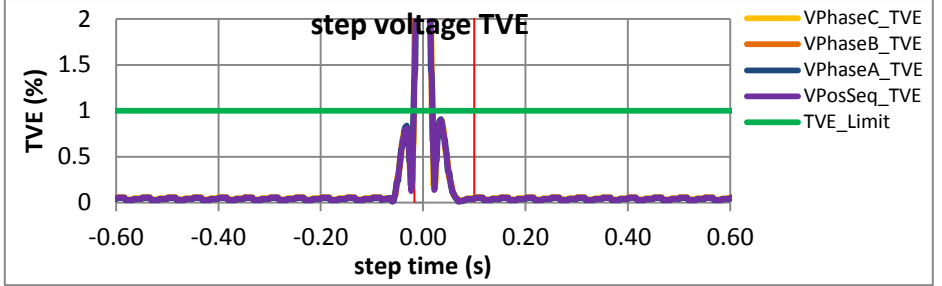


Figure 4049: Fs = 60 FPS, -10 degree phase step

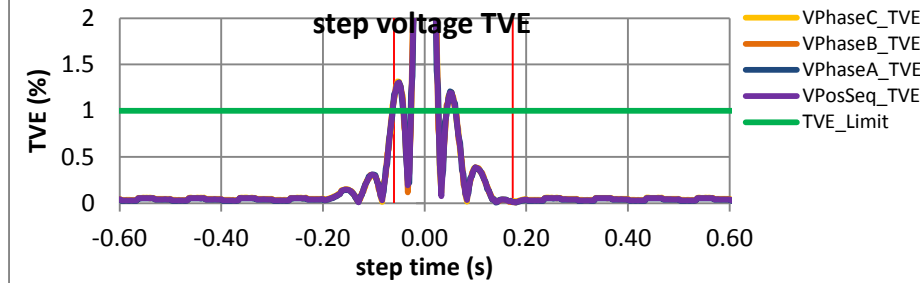


Figure 4050: Fs = 30 FPS, +10 degree phase step

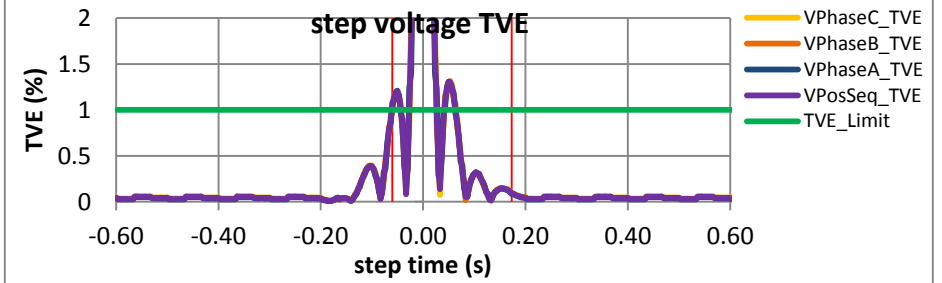


Figure 4051: Fs = 30 FPS, -10 degree phase step

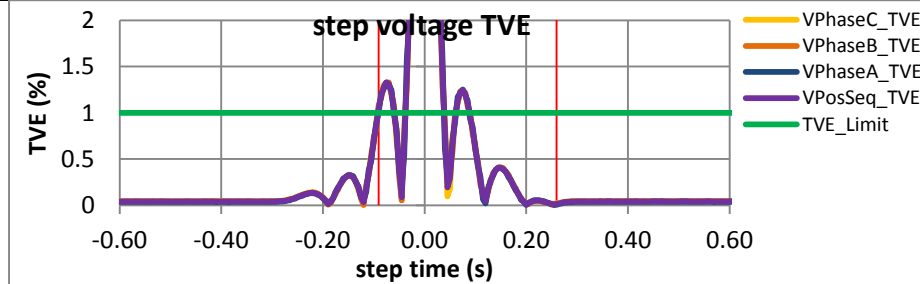


Figure 4052: Fs = 20 FPS, +10 degree phase step

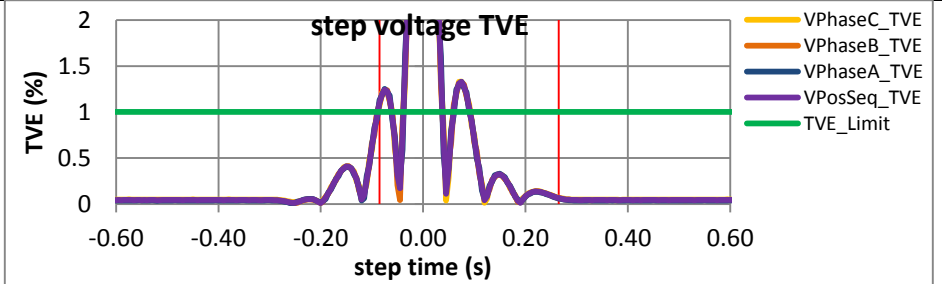


Figure 4053: Fs = 20 FPS, -10 degree phase step



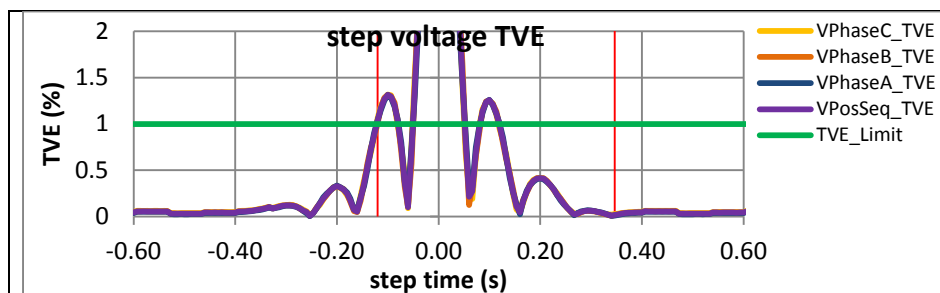


Figure 4054:  $F_s = 15$  FPS, +10 degree phase step

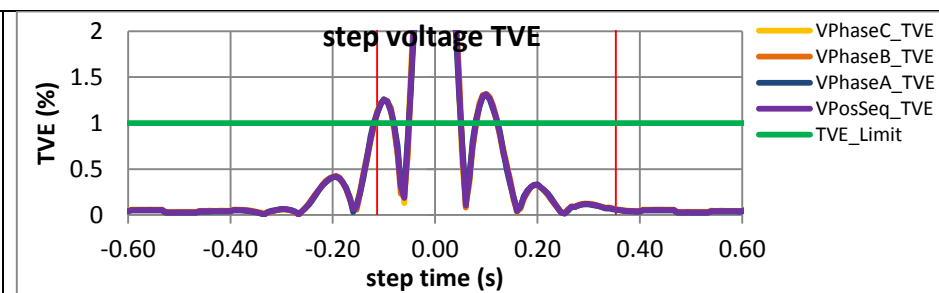


Figure 4055:  $F_s = 15$  FPS, -10 degree phase step

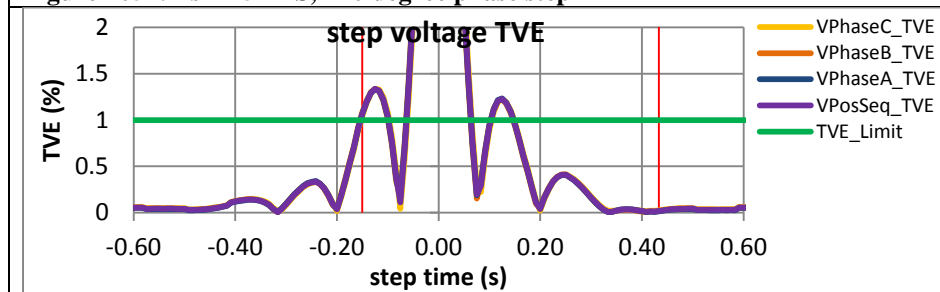


Figure 4056:  $F_s = 12$  FPS, +10 degree phase step

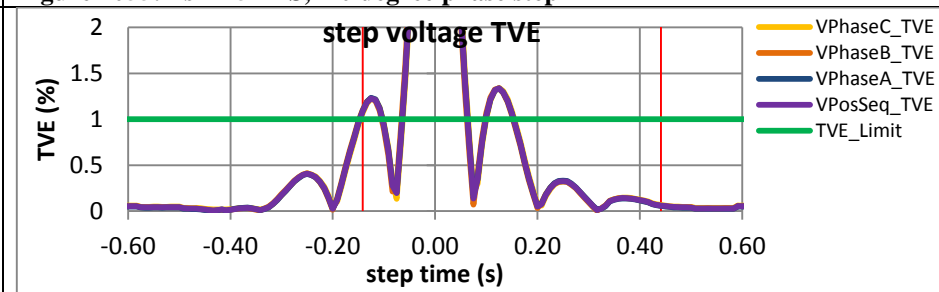


Figure 4057:  $F_s = 12$  FPS, -10 degree phase step

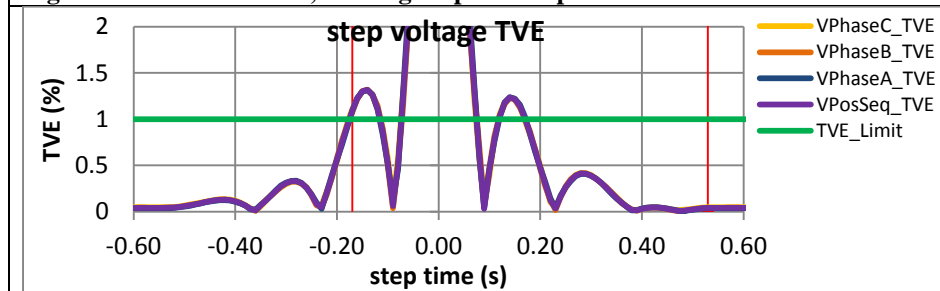


Figure 4058:  $F_s = 10$  FPS, +10 degree phase step

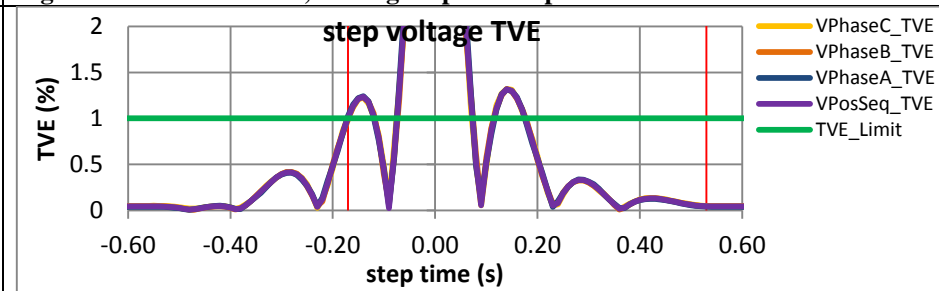


Figure 4059:  $F_s = 10$  FPS, -10 degree phase step

### 9.1.10 PMU I dynamic step change in phase voltage response time: F0 = 60 Hz, M class

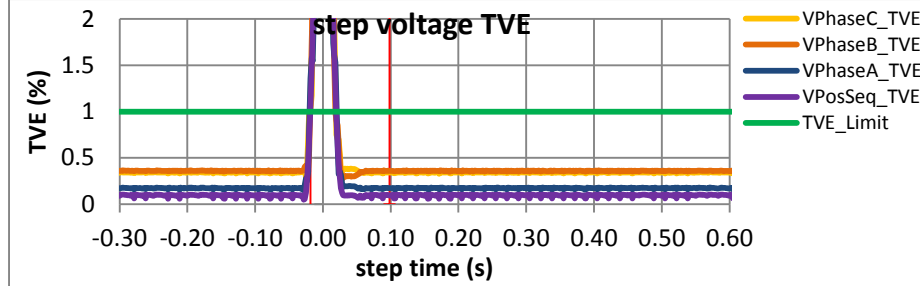


Figure 4060: Fs = 60 FPS, +10 degree phase step

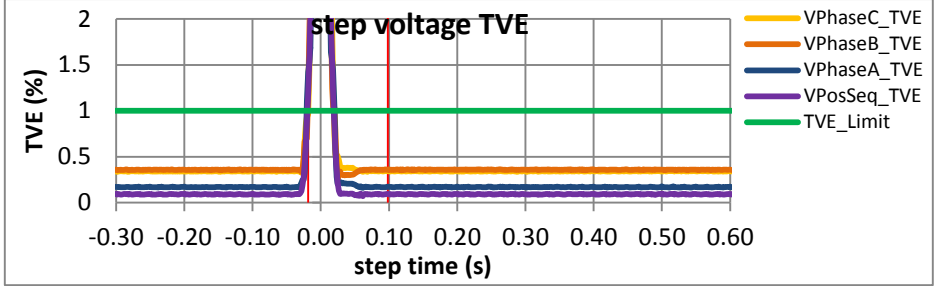


Figure 4061: Fs = 60 FPS, -10 degree phase step

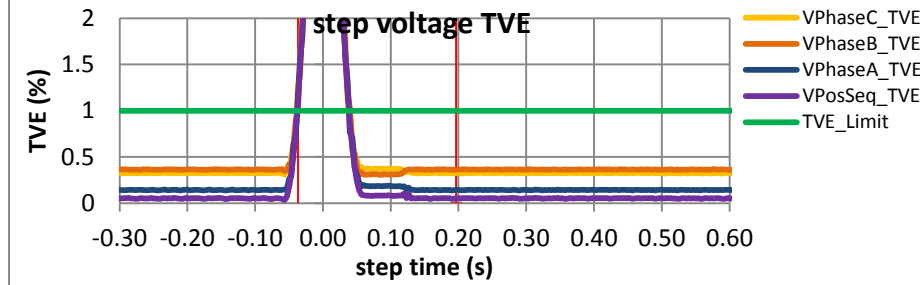


Figure 4062: Fs = 30 FPS, +10 degree phase step

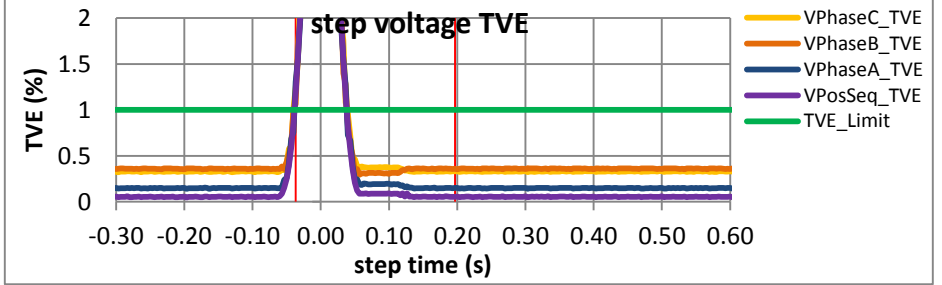


Figure 4063: Fs = 30 FPS, -10 degree phase step

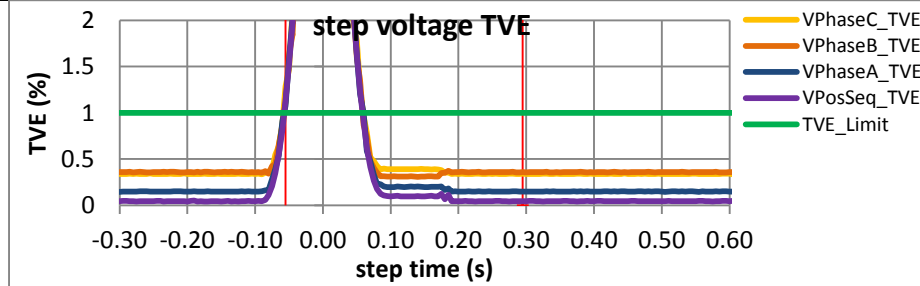


Figure 4064: Fs = 20 FPS, +10 degree phase step

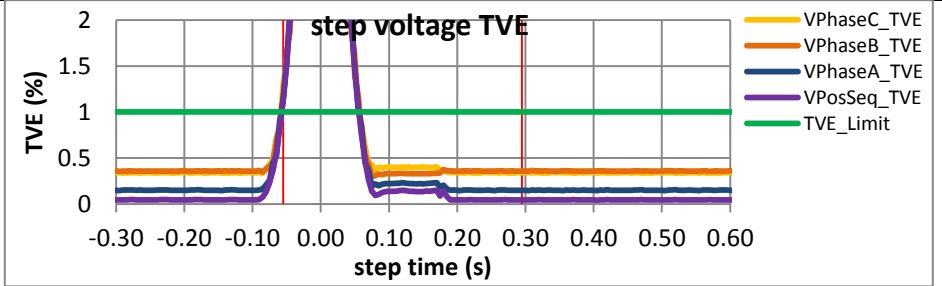


Figure 4065: Fs = 20 FPS, -10 degree phase step

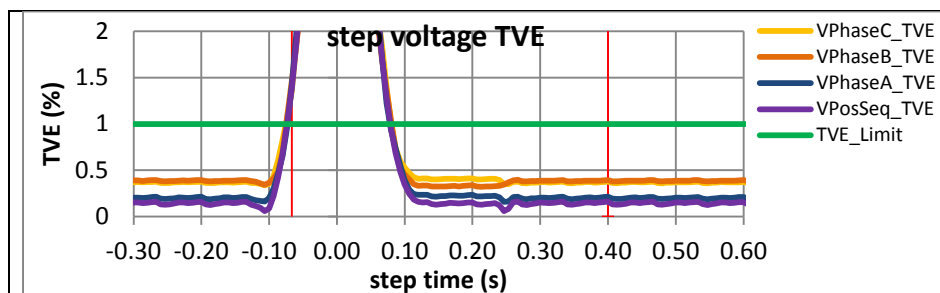


Figure 4066:  $F_s = 15$  FPS, +10 degree phase step

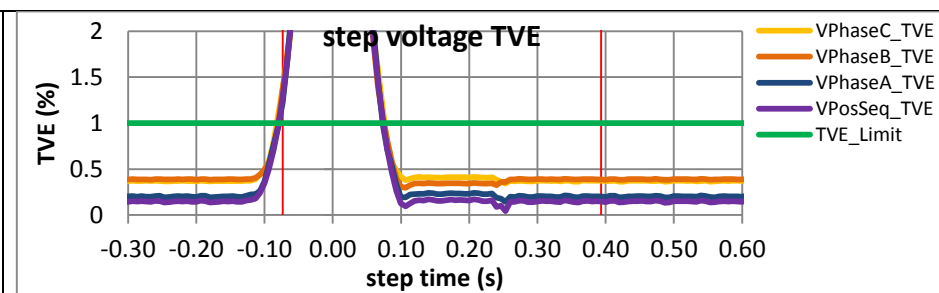


Figure 4067:  $F_s = 15$  FPS, -10 degree phase step

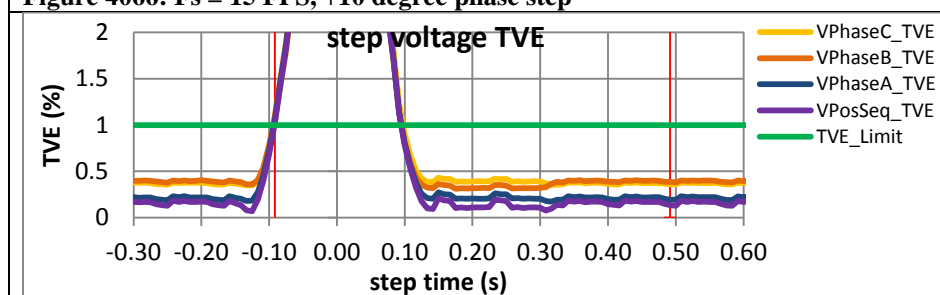


Figure 4068:  $F_s = 12$  FPS, +10 degree phase step

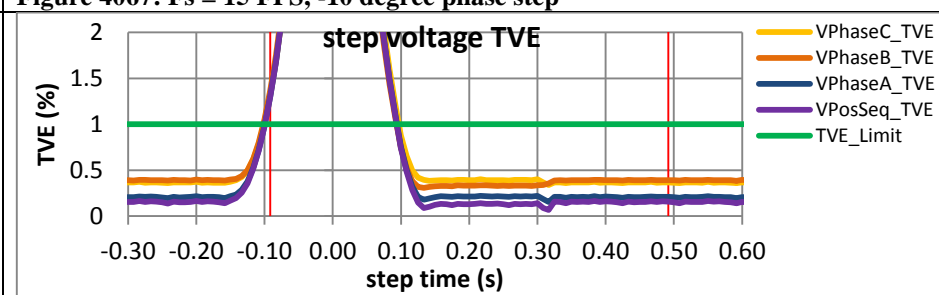


Figure 4069:  $F_s = 12$  FPS, -10 degree phase step

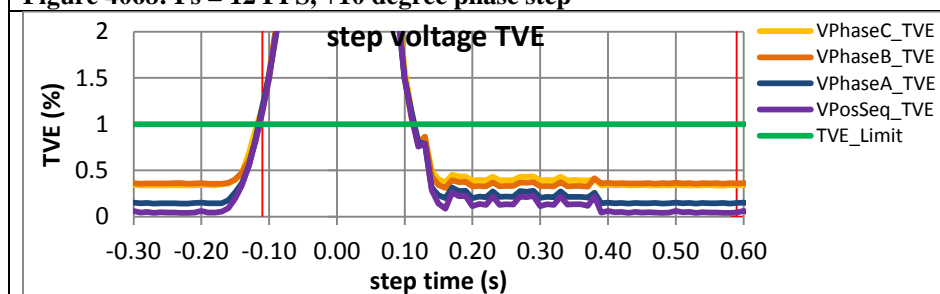


Figure 4070:  $F_s = 10$  FPS, +10 degree phase step

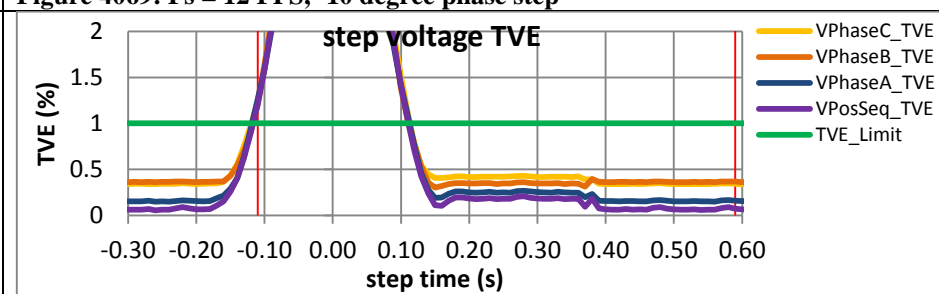


Figure 4071:  $F_s = 10$  FPS, -10 degree phase step

### 9.1.11 PMU J dynamic step change in phase voltage response time: F0 = 60 Hz, M class

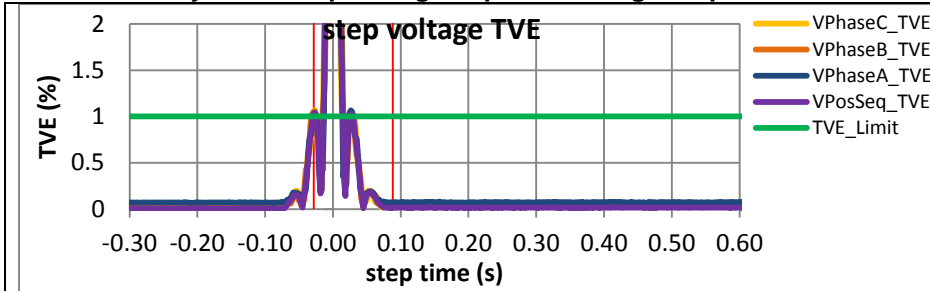


Figure 4072: Fs = 60 FPS, +10 degree phase step

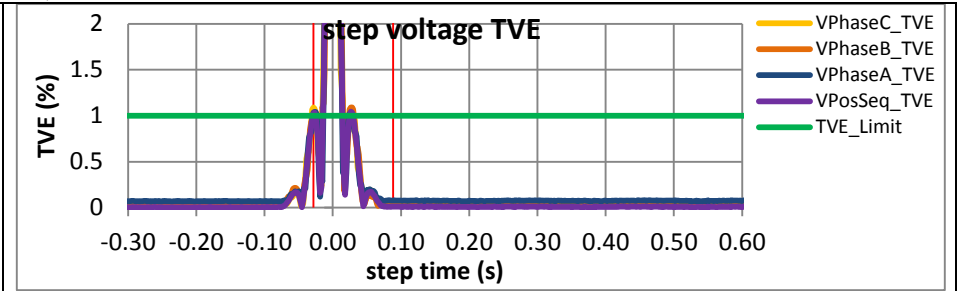


Figure 4073: Fs = 60 FPS, -10 degree phase step

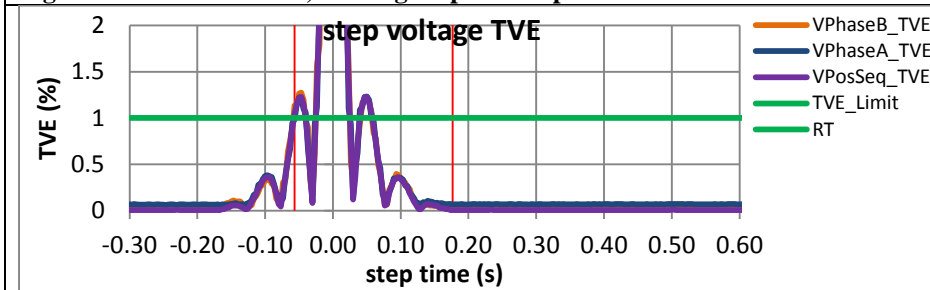


Figure 4074: Fs = 30 FPS, +10 degree phase step

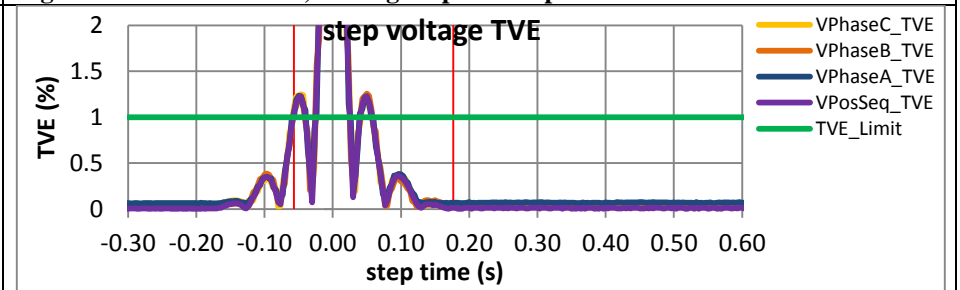


Figure 4075: Fs = 30 FPS, -10 degree phase step

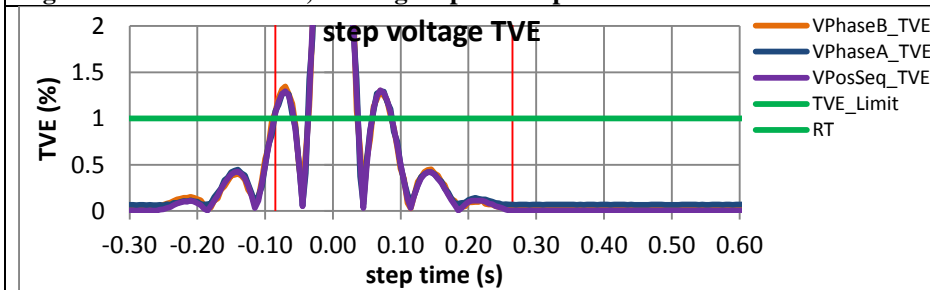


Figure 4076: Fs = 20 FPS, +10 degree phase step

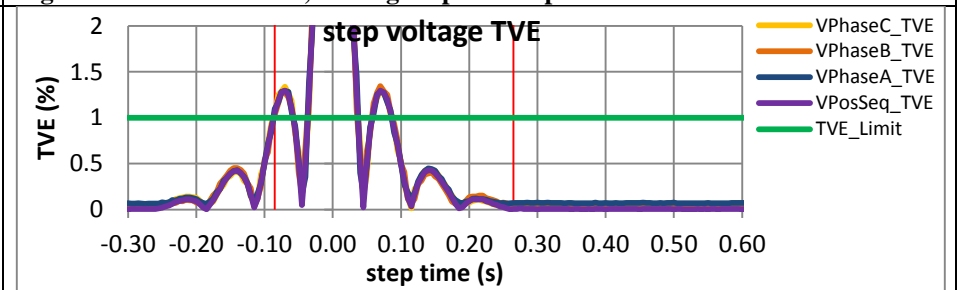


Figure 4077: Fs = 20 FPS, -10 degree phase step

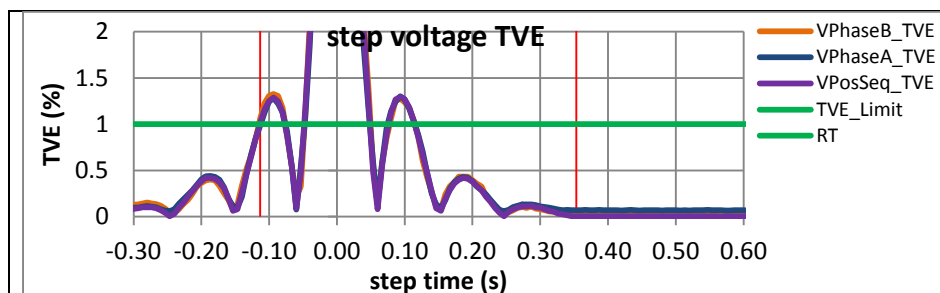


Figure 4078:  $F_s = 15$  FPS, +10 degree phase step

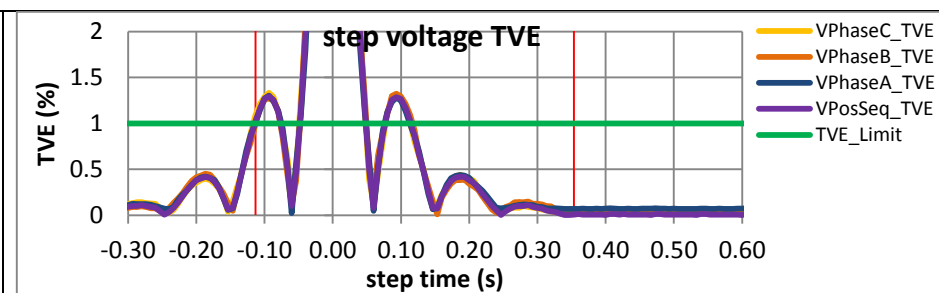


Figure 4079:  $F_s = 15$  FPS, -10 degree phase step

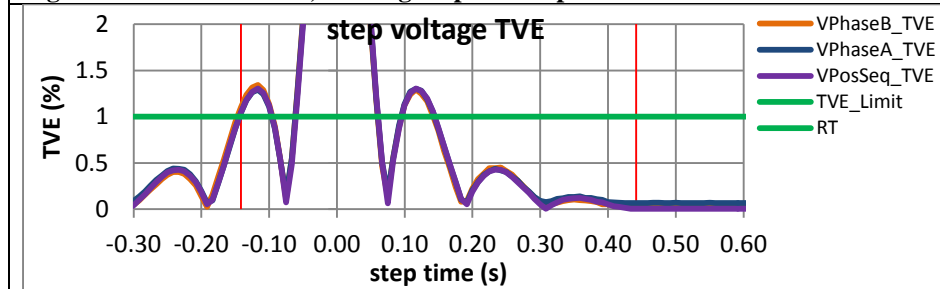


Figure 4080:  $F_s = 12$  FPS, +10 degree phase step

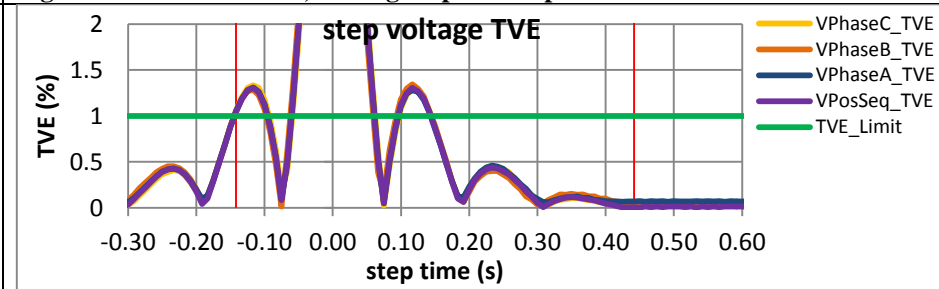


Figure 4081:  $F_s = 12$  FPS, -10 degree phase step

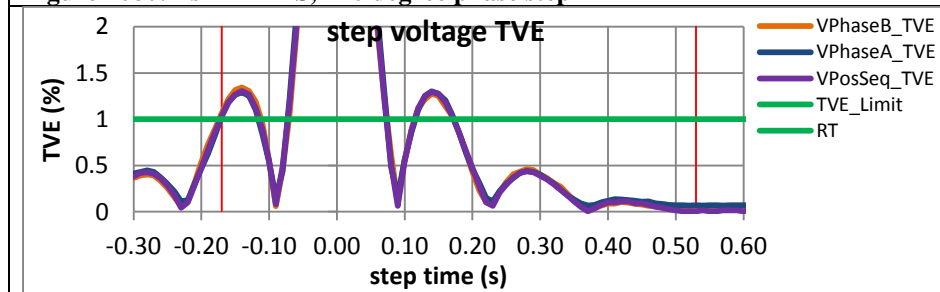


Figure 4082:  $F_s = 10$  FPS, +10 degree phase step

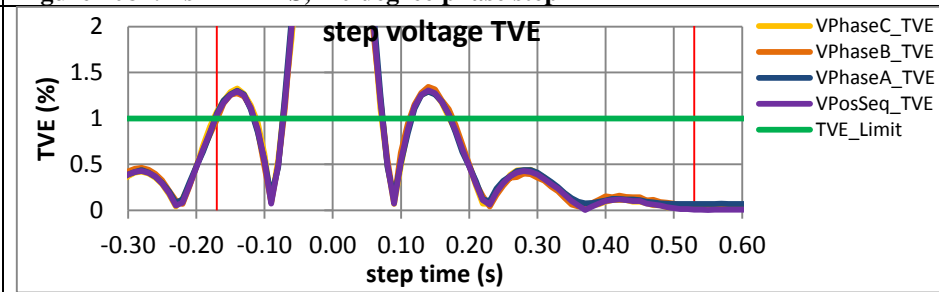


Figure 4083:  $F_s = 10$  FPS, -10 degree phase step

## 9.2 Dynamic step change in phase: current response time

### 9.2.1 C37.118.1-2011 Annex C dynamic step change in phase current response time: F0 = 60 Hz, M class

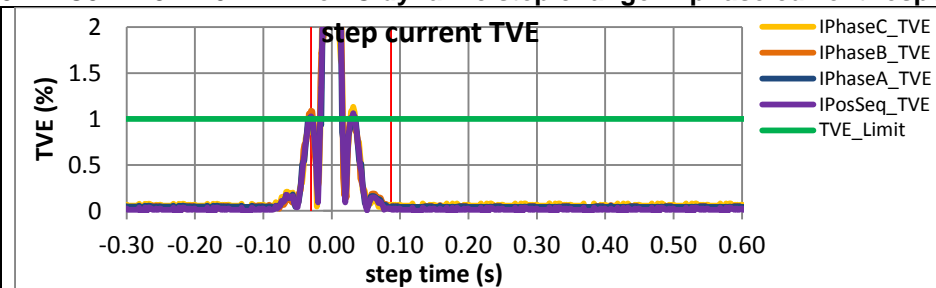


Figure 4084: Fs = 60 FPS, +10 degree phase step

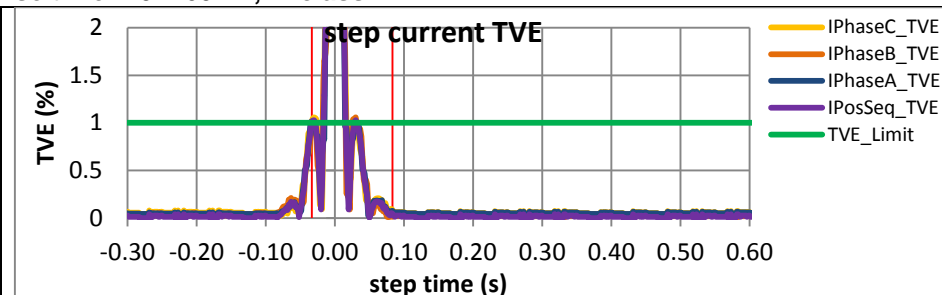


Figure 4085: Fs = 60 FPS, -10 degree phase step

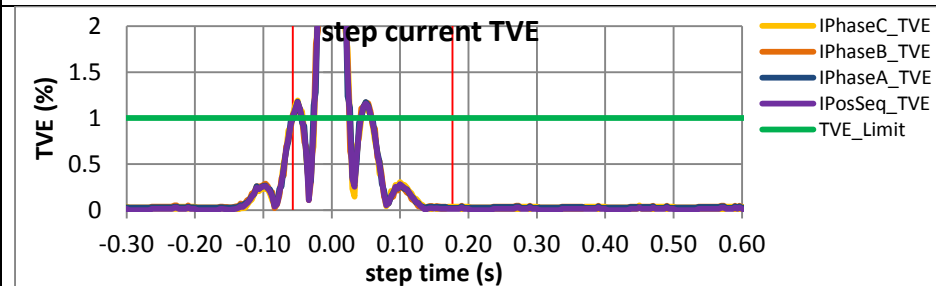


Figure 4086: Fs = 30 FPS, +10 degree phase step

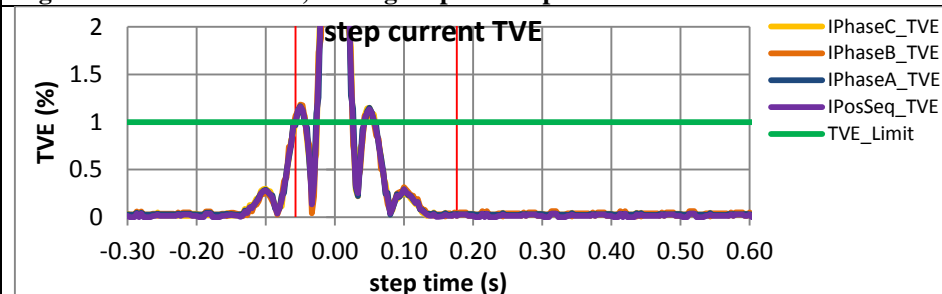


Figure 4087: Fs = 30 FPS, -10 degree phase step

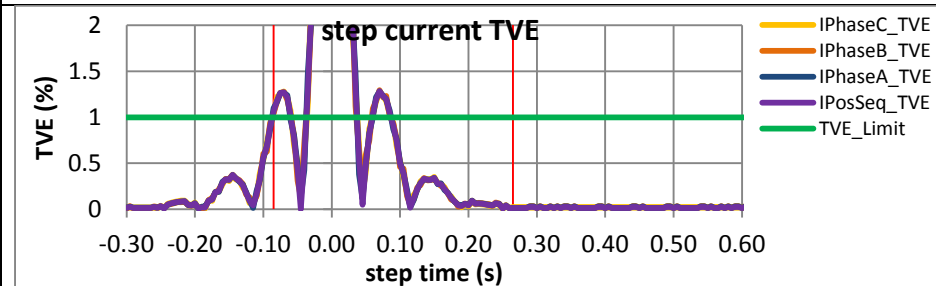


Figure 4088: Fs = 20 FPS, +10 degree phase step

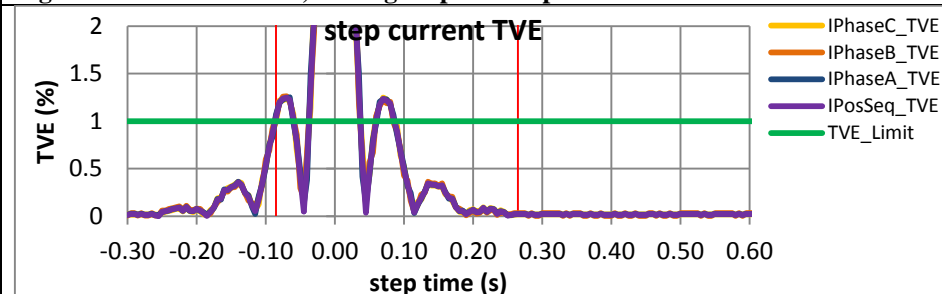


Figure 4089: Fs = 20 FPS, - 10 degree phase step

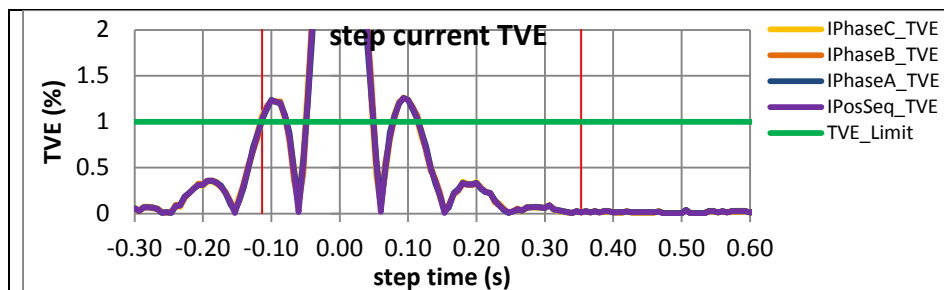


Figure 4090:  $F_s = 15$  FPS, +10 degree phase step

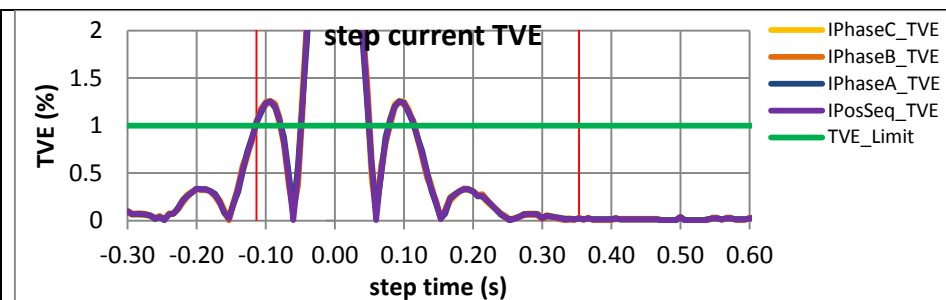


Figure 4091:  $F_s = 15$  FPS, -10 degree phase step

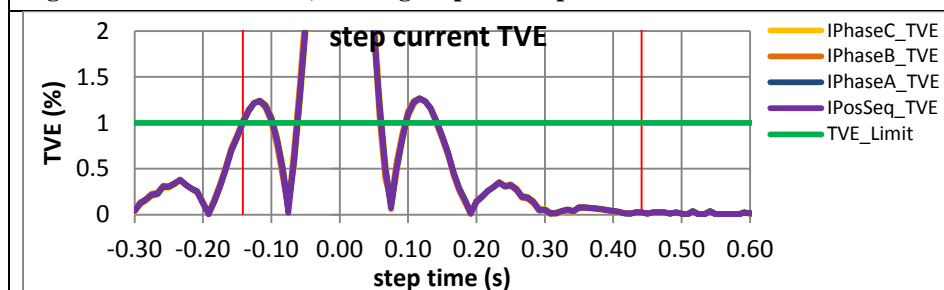


Figure 4092:  $F_s = 12$  FPS, +10 degree phase step

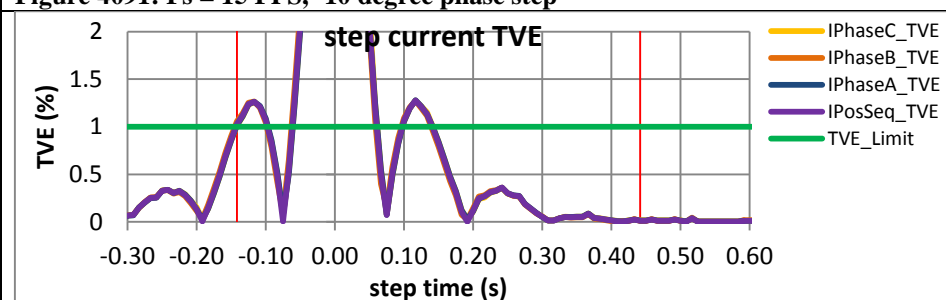


Figure 4093:  $F_s = 12$  FPS, -10 degree phase step

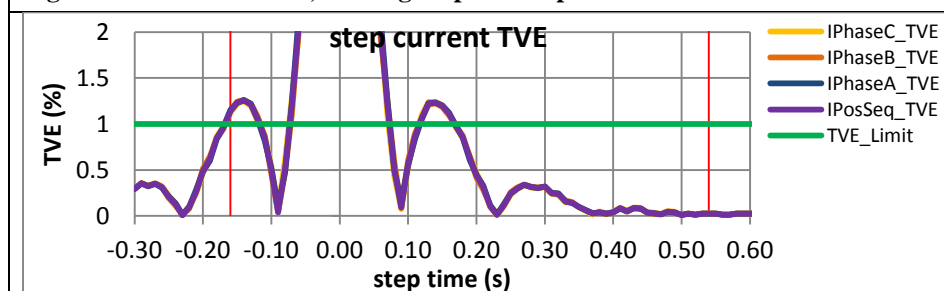


Figure 4094:  $F_s = 10$  FPS, +10 degree phase step

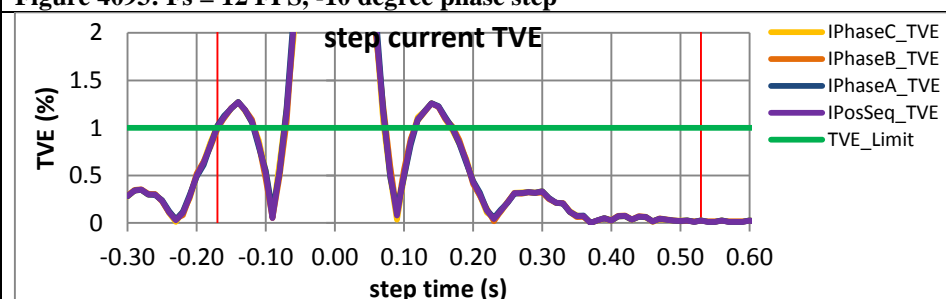


Figure 4095:  $F_s = 10$  FPS, -10 degree phase step

### 9.2.2 PMU A dynamic step change in phase current response time: F0 = 60 Hz, M class

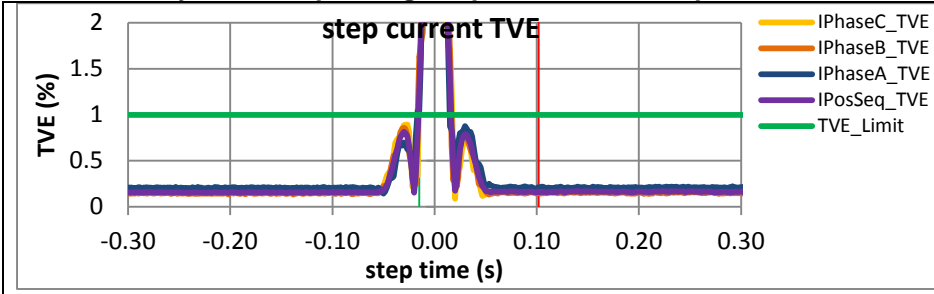


Figure 4096: Fs = 60 FPS, +10 degree phase step

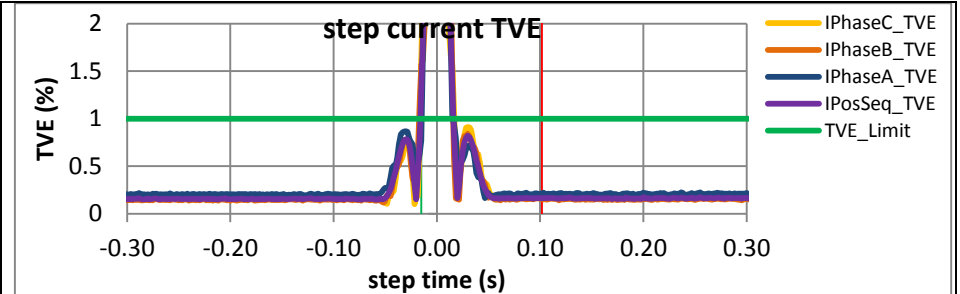


Figure 4097: Fs = 60 FPS, -10 degree phase step

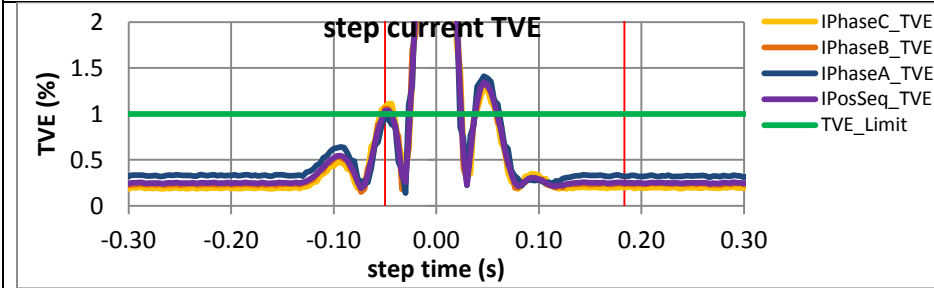


Figure 4098: Fs = 30 FPS, +10 degree phase step

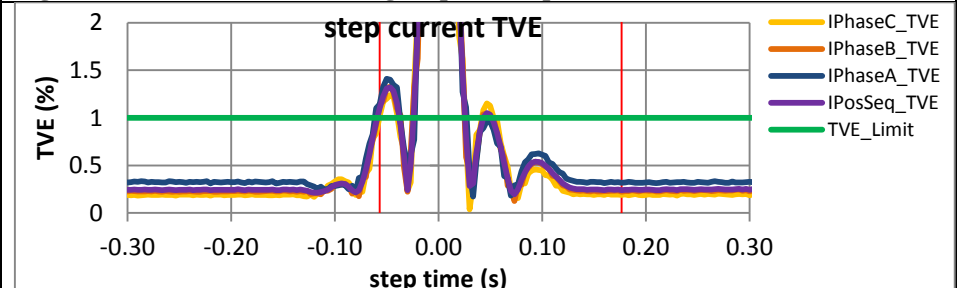


Figure 4099: Fs = 30 FPS, -10 degree phase step

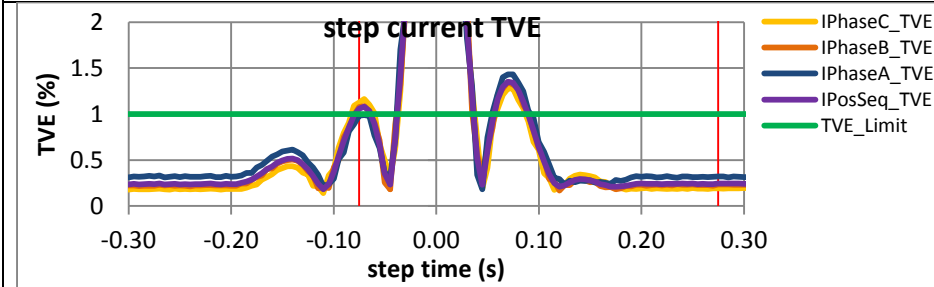


Figure 4100: Fs = 20 FPS, +10 degree phase step

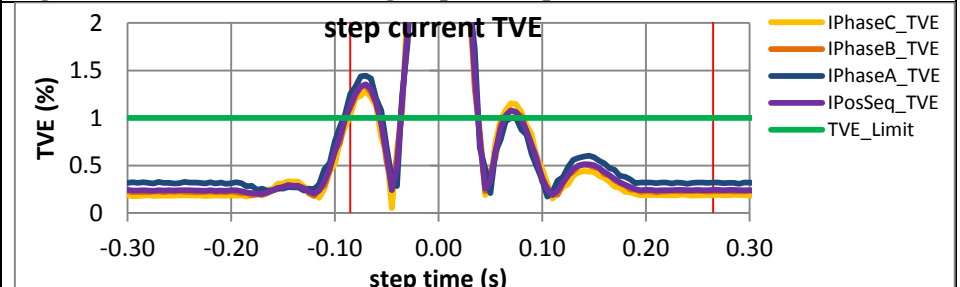


Figure 4101: Fs = 20 FPS, -10 degree phase step



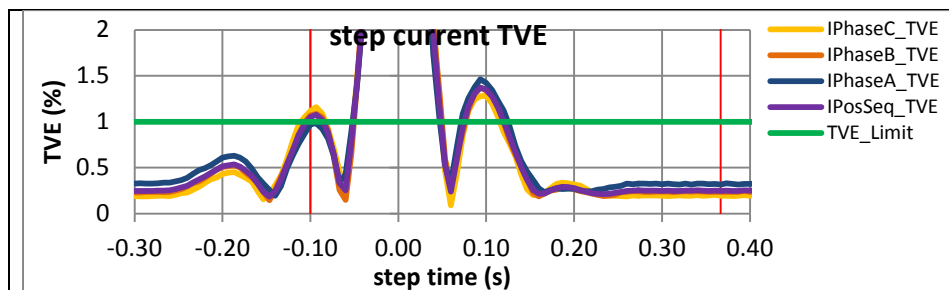


Figure 4102:  $F_s = 15$  FPS, +10 degree phase step

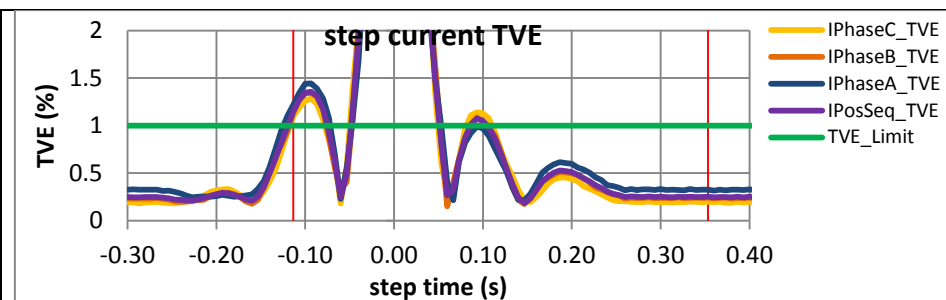


Figure 4103:  $F_s = 15$  FPS, -10 degree phase step

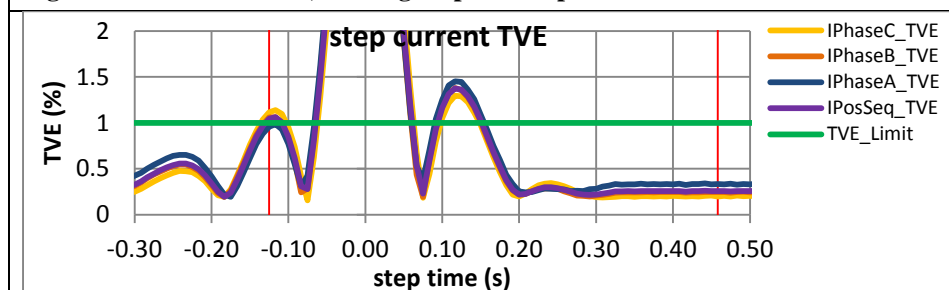


Figure 4104:  $F_s = 12$  FPS, +10 degree phase step

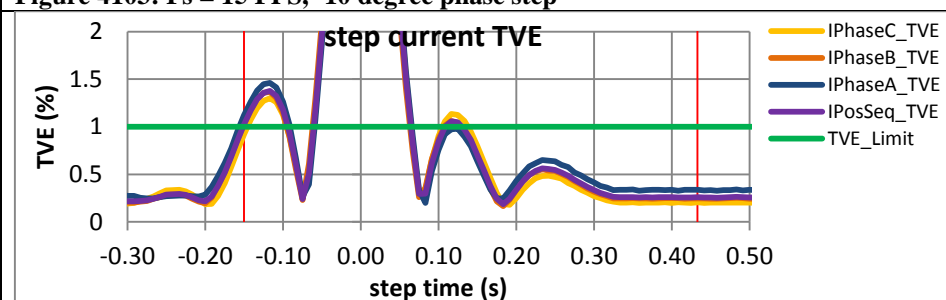


Figure 4105:  $F_s = 12$  FPS, -10 degree phase step

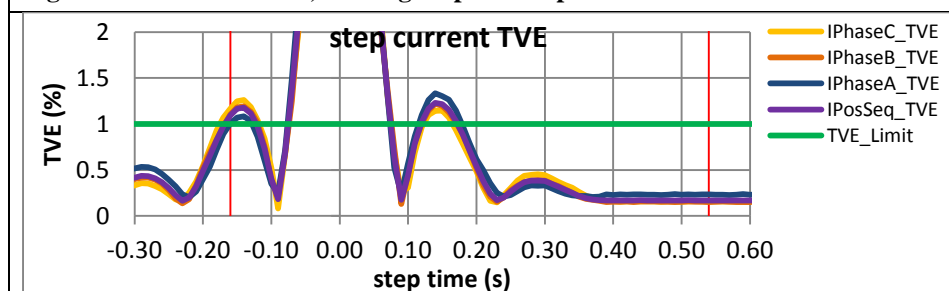


Figure 4106:  $F_s = 10$  FPS, +10 degree phase step

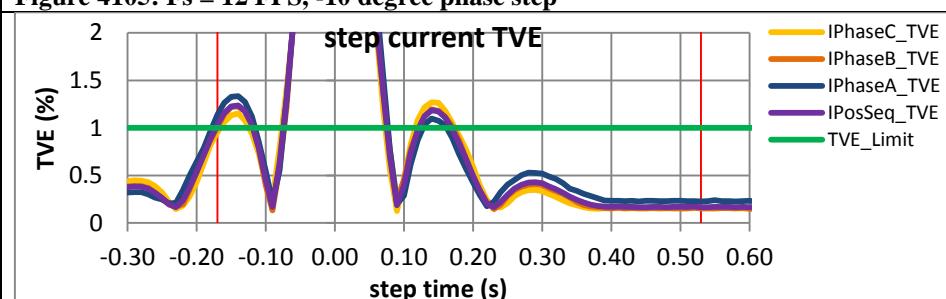


Figure 4107:  $F_s = 10$  FPS, -10 degree phase step

### 9.2.3 PMU B dynamic step change in phase current response time: F0 = 60 Hz, M class

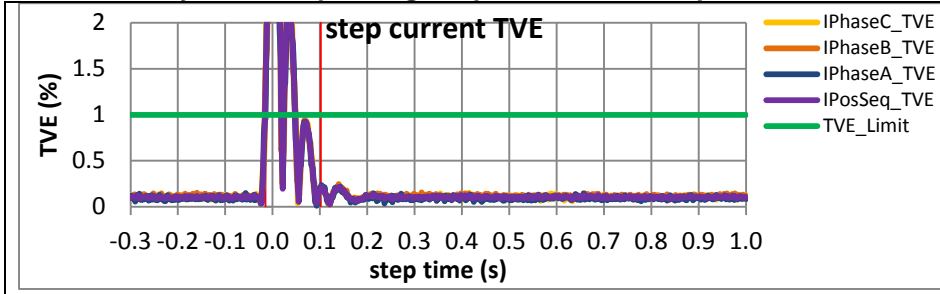


Figure 4108: Fs = 60 FPS, +10 degree phase step

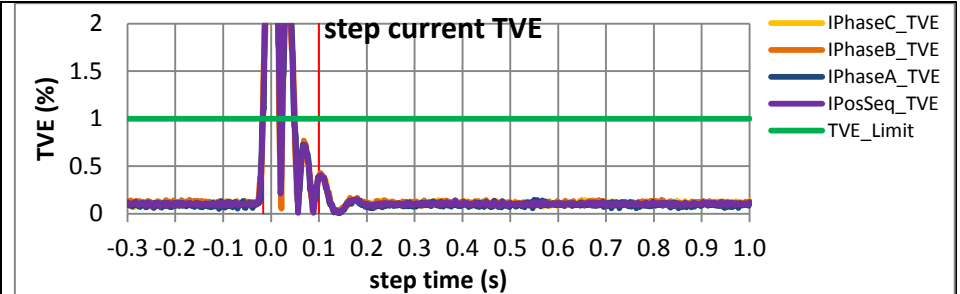


Figure 4109: Fs = 60 FPS, -10 degree phase step

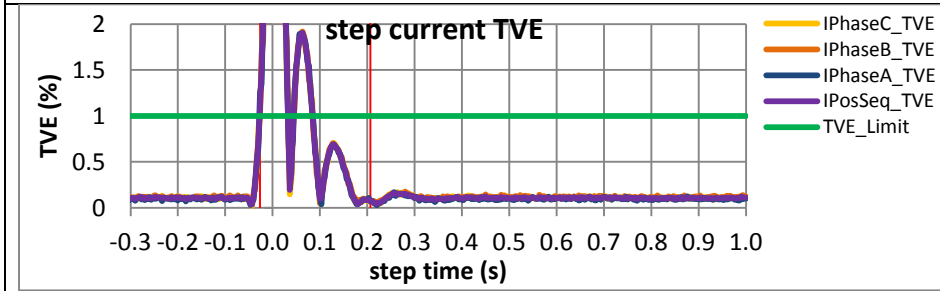


Figure 4110: Fs = 30 FPS, +10 degree phase step

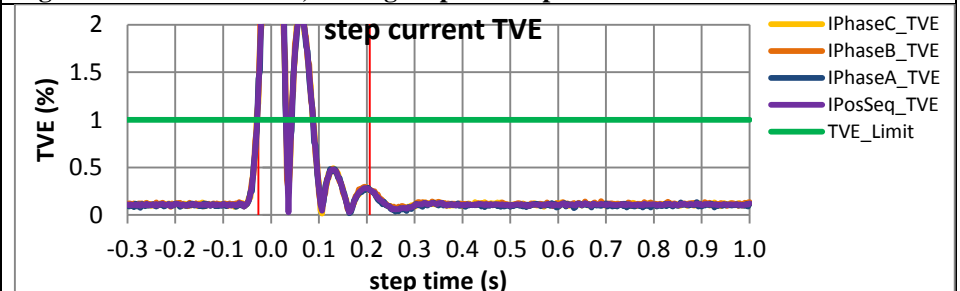


Figure 4111: Fs = 30 FPS, -10 degree phase step

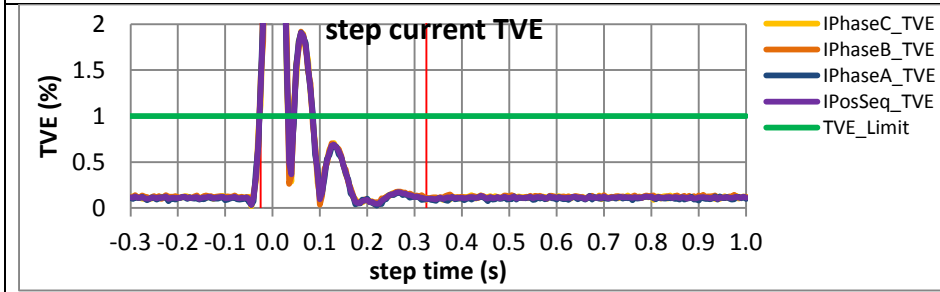


Figure 4112: Fs = 20 FPS, +10 degree phase step

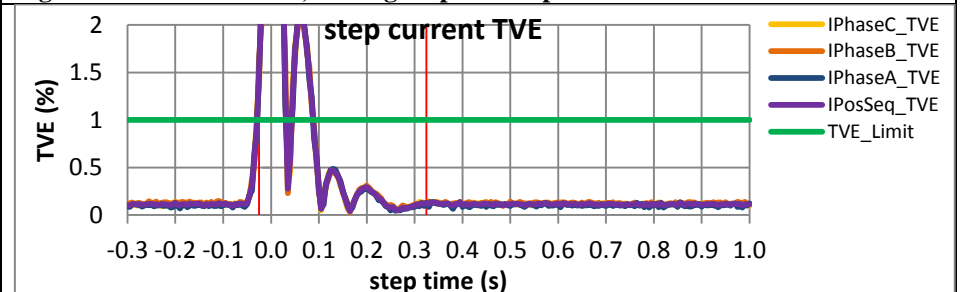


Figure 4113: Fs = 20 FPS, -10 degree phase step

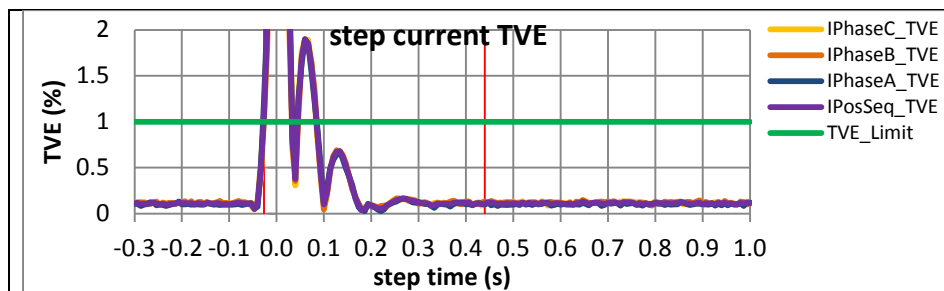


Figure 4114:  $F_s = 15$  FPS, +10 degree phase step

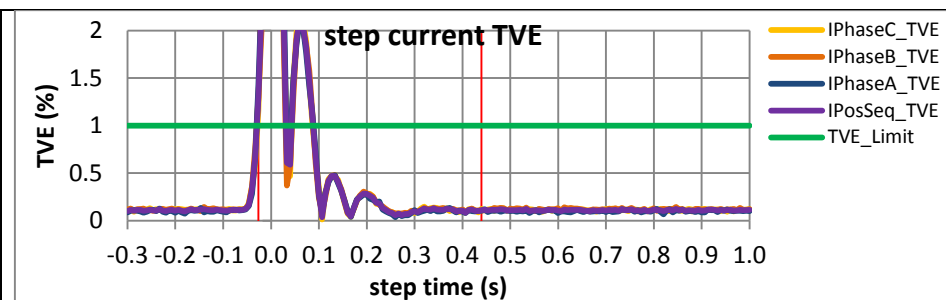


Figure 4115:  $F_s = 15$  FPS, -10 degree phase step

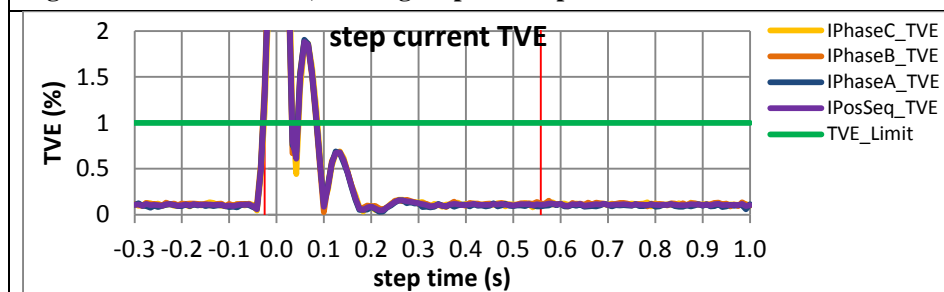


Figure 4116:  $F_s = 12$  FPS, +10 degree phase step

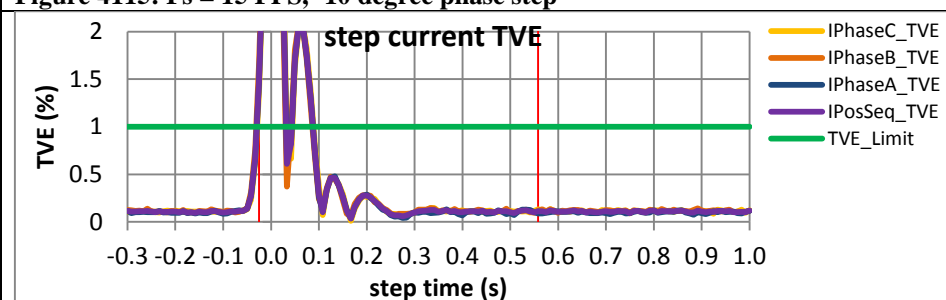


Figure 4117:  $F_s = 12$  FPS, -10 degree phase step

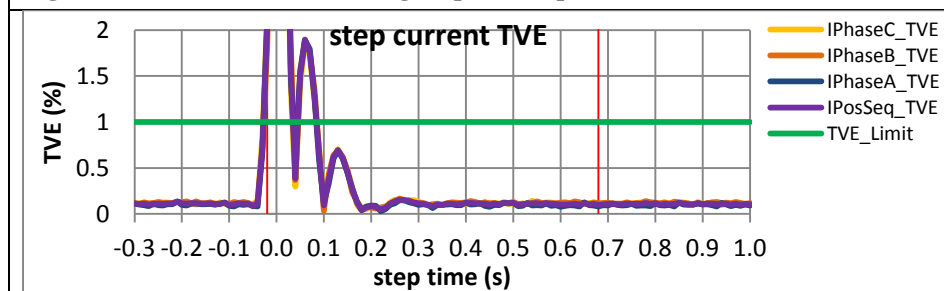


Figure 4118:  $F_s = 10$  FPS, +10 degree phase step

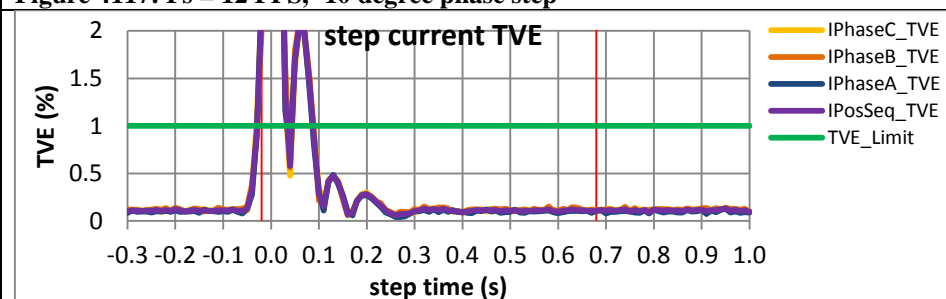


Figure 4119:  $F_s = 10$  FPS, -10 degree phase step

#### 9.2.4 PMU C dynamic step change in phase current response time: F0 = 60 Hz, M class

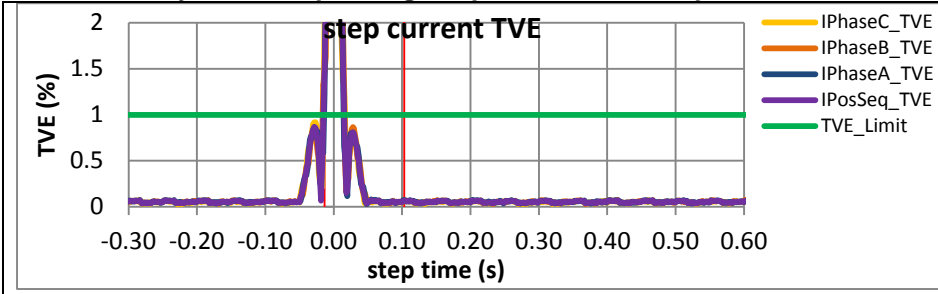


Figure 4120: Fs = 60 FPS, +10 degree phase step

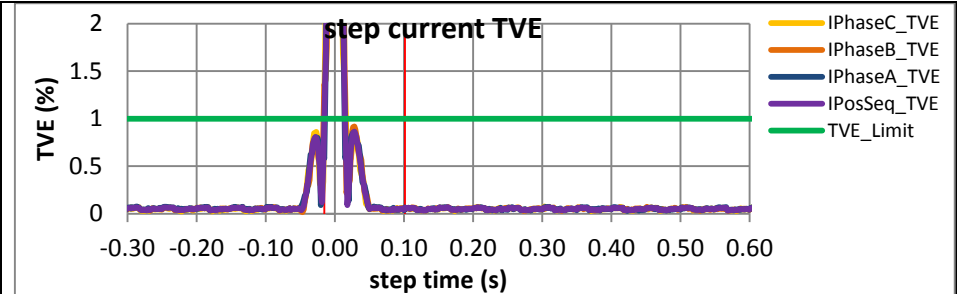


Figure 4121: Fs = 60 FPS, -10 degree phase step

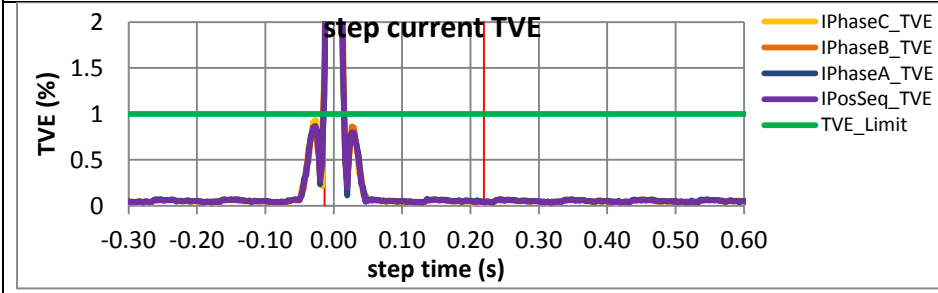


Figure 4122: Fs = 30 FPS, +10 degree phase step

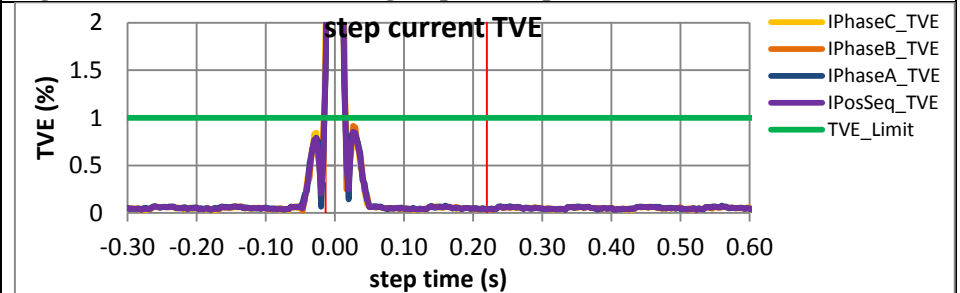


Figure 4123: Fs = 30 FPS, -10 degree phase step

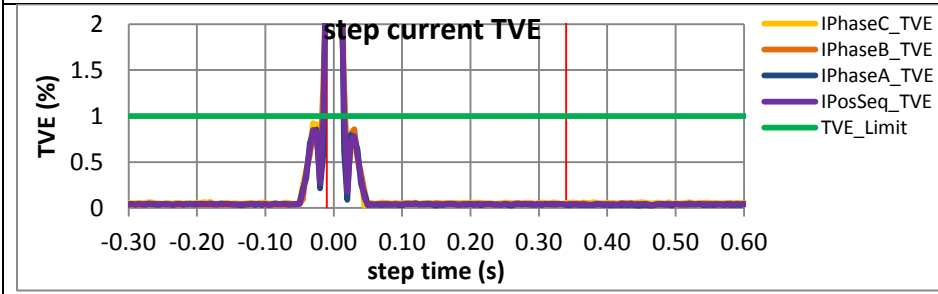


Figure 4124: Fs = 20 FPS, +10 degree phase step

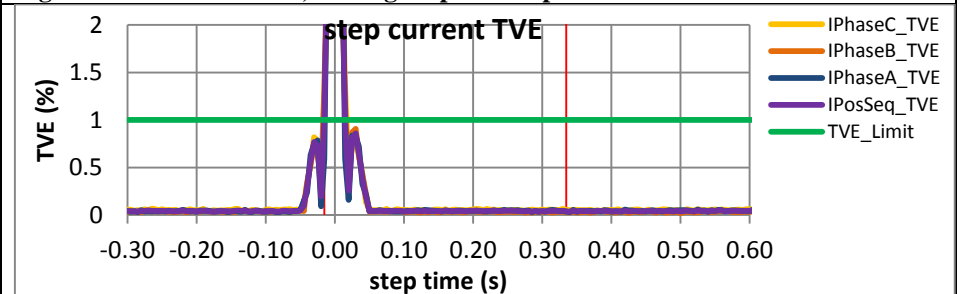


Figure 4125: Fs = 20 FPS, -10 degree phase step

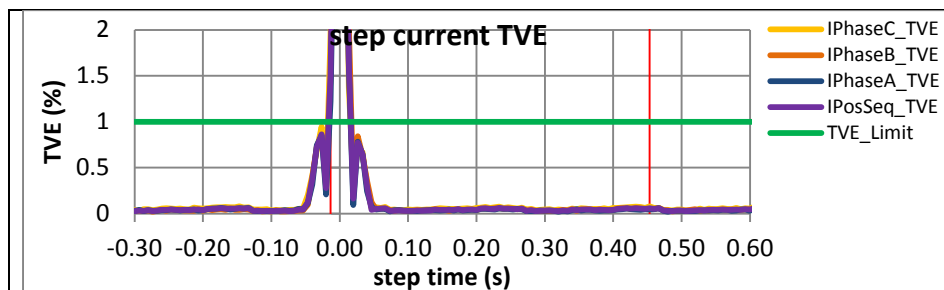


Figure 4126:  $F_s = 15$  FPS, +10 degree phase step

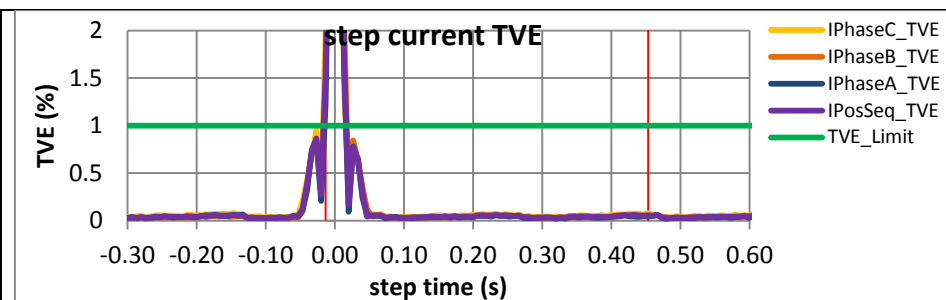


Figure 4127:  $F_s = 15$  FPS, -10 degree phase step

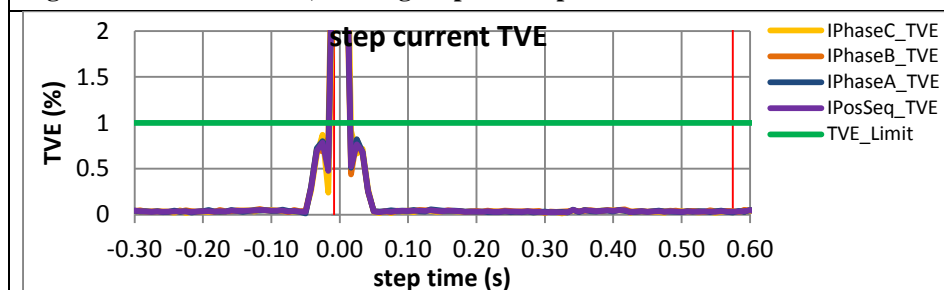


Figure 4128:  $F_s = 12$  FPS, +10 degree phase step

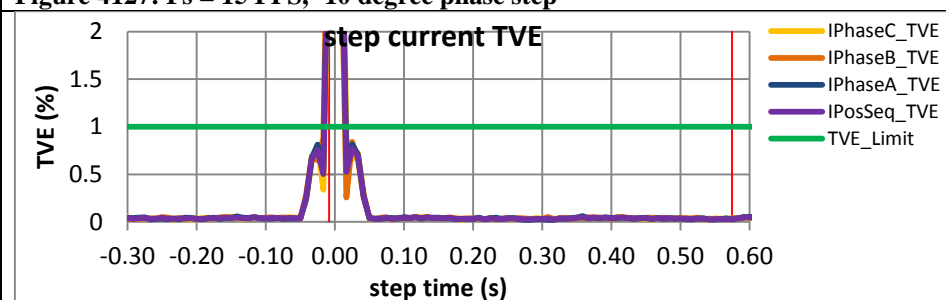


Figure 4129:  $F_s = 12$  FPS, -10 degree phase step

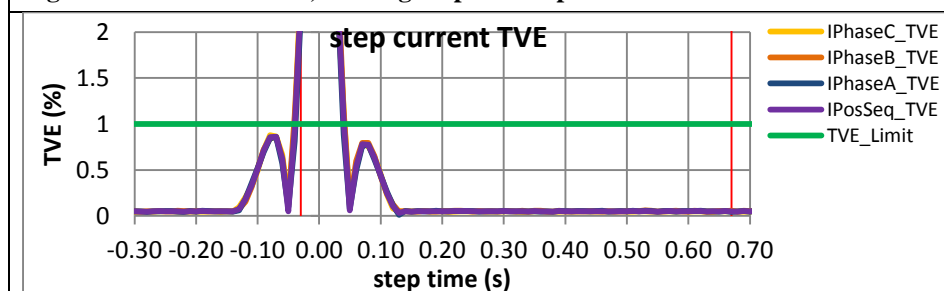


Figure 4130:  $F_s = 10$  FPS, +10 degree phase step

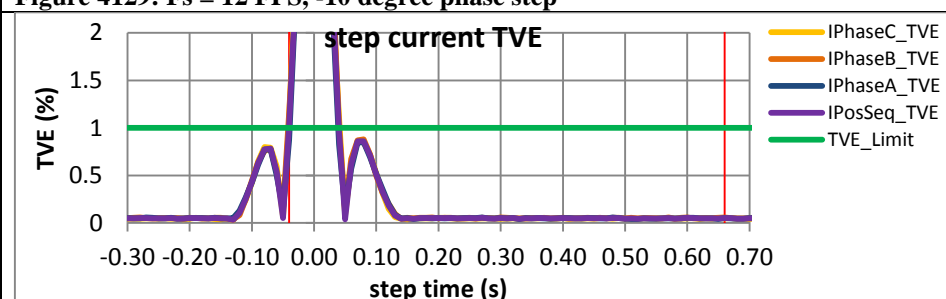
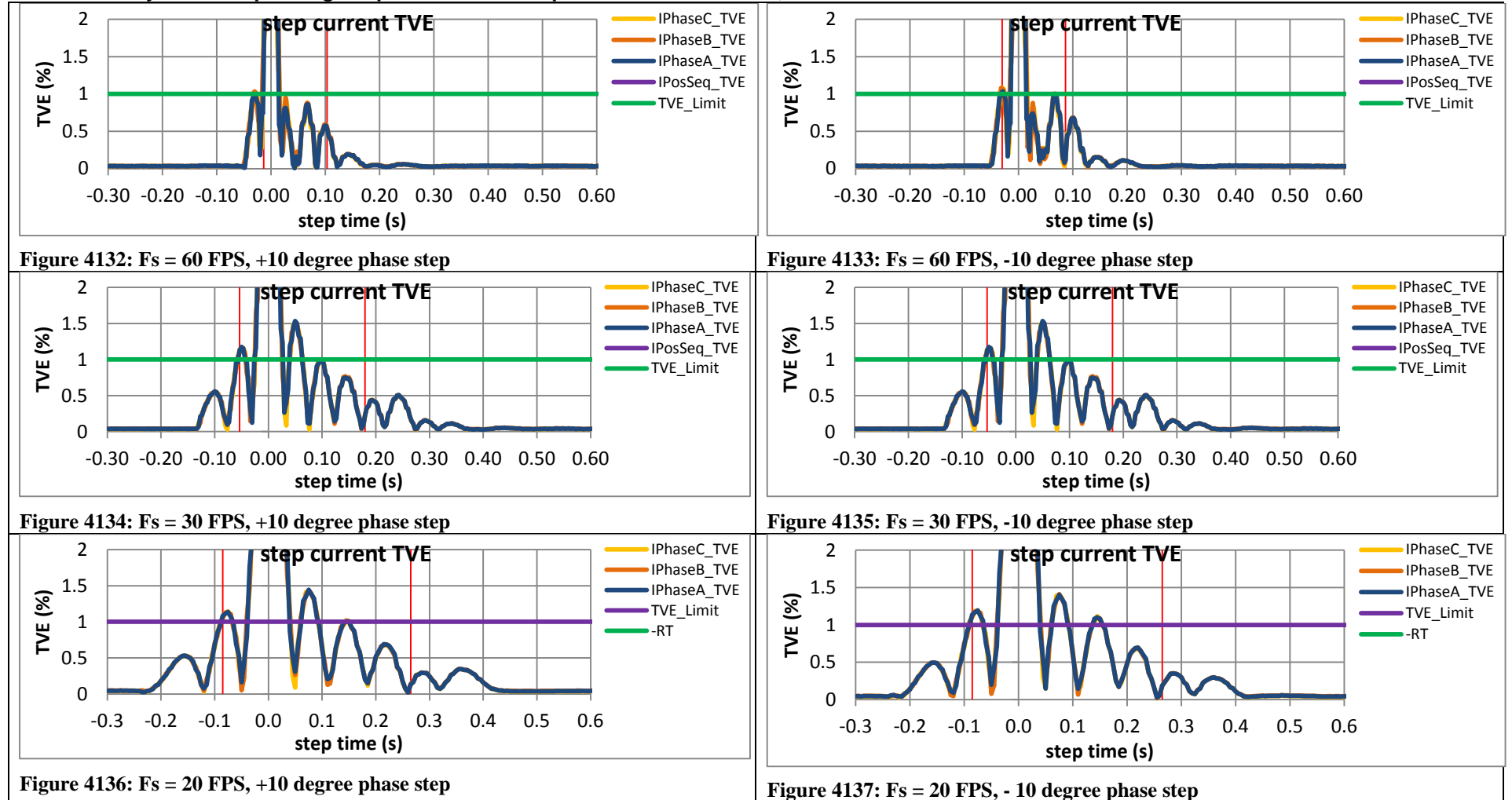


Figure 4131:  $F_s = 10$  FPS, -10 degree phase step

### 9.2.5 PMU D dynamic step change in phase current response time: F0 = 60 Hz, M class



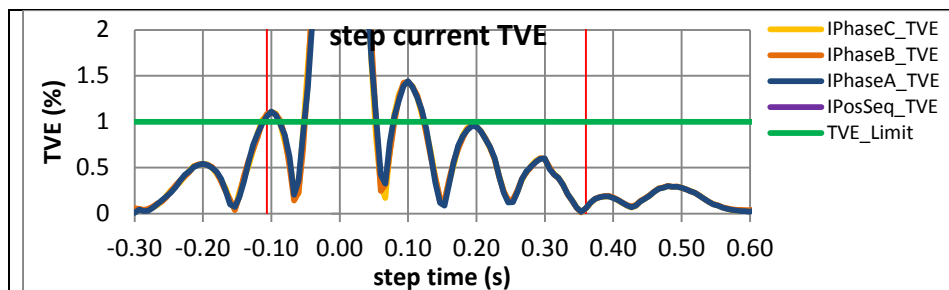


Figure 4138:  $F_s = 15$  FPS, +10 degree phase step

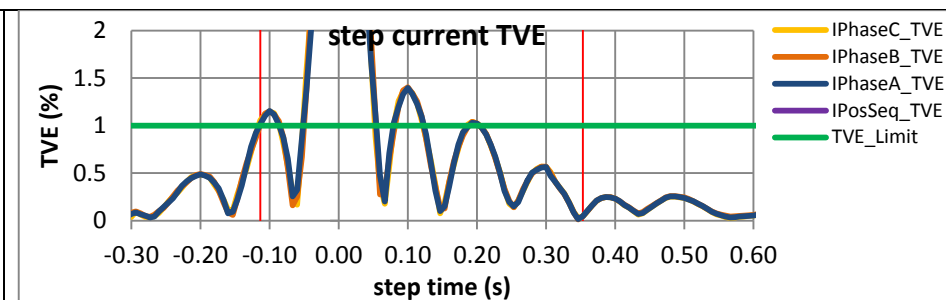


Figure 4139:  $F_s = 15$  FPS, -10 degree phase step

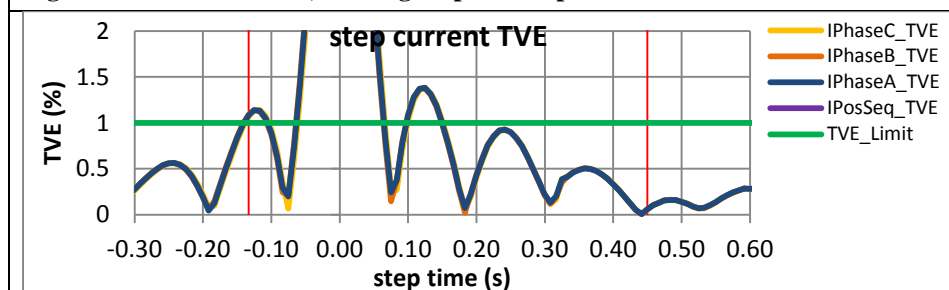


Figure 4140:  $F_s = 12$  FPS, +10 degree phase step

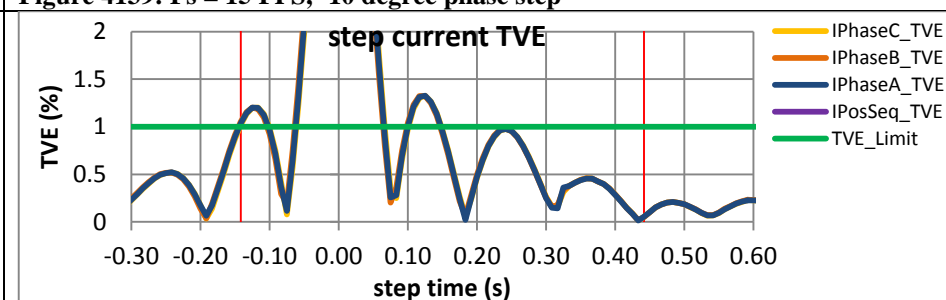


Figure 4141:  $F_s = 12$  FPS, -10 degree phase step

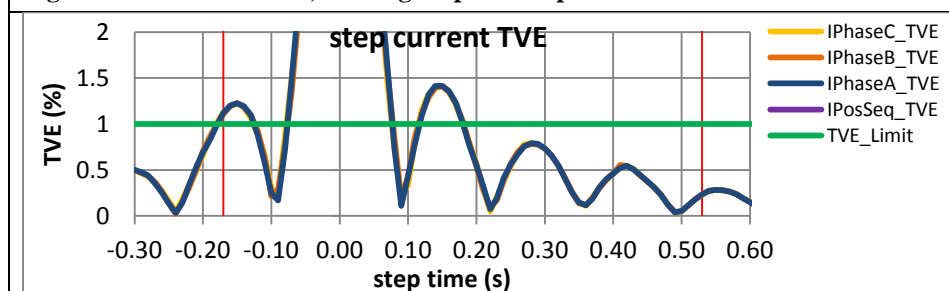


Figure 4142:  $F_s = 10$  FPS, +10 degree phase step

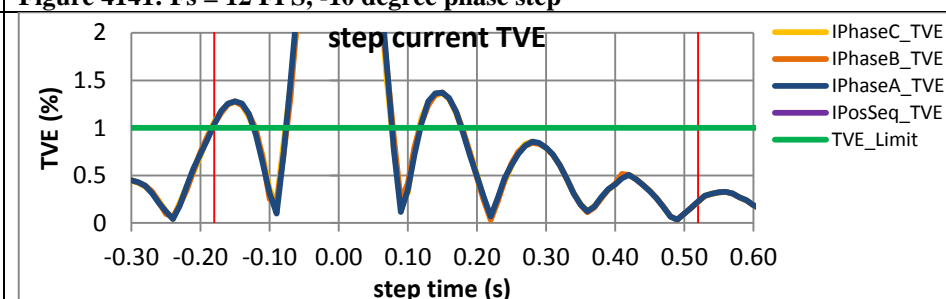


Figure 4143:  $F_s = 10$  FPS, -10 degree phase step

### 9.2.6 PMU E dynamic step change in phase current response time: F0 = 60 Hz, M class

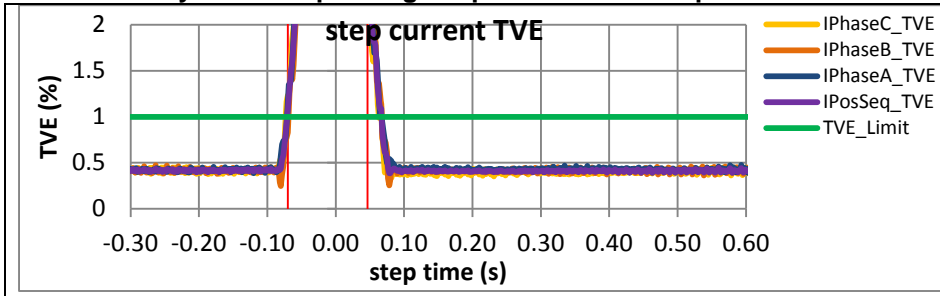


Figure 4144: Fs = 60 FPS, +10 degree phase step

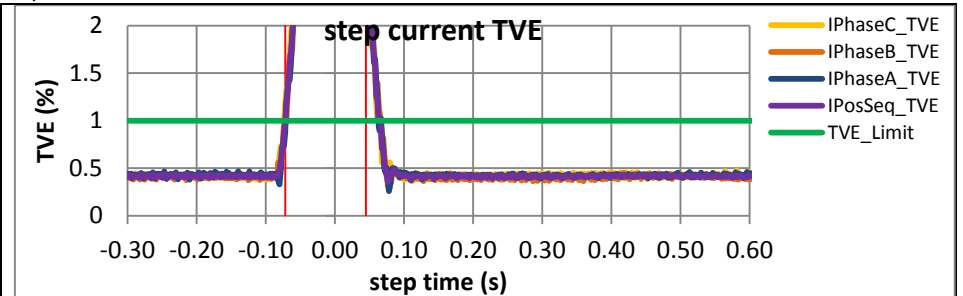


Figure 4145: Fs = 60 FPS, -10 degree phase step

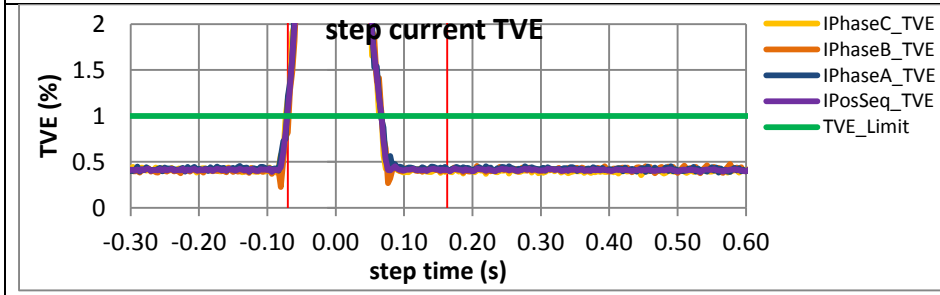


Figure 4146: Fs = 30 FPS, +10 degree phase step

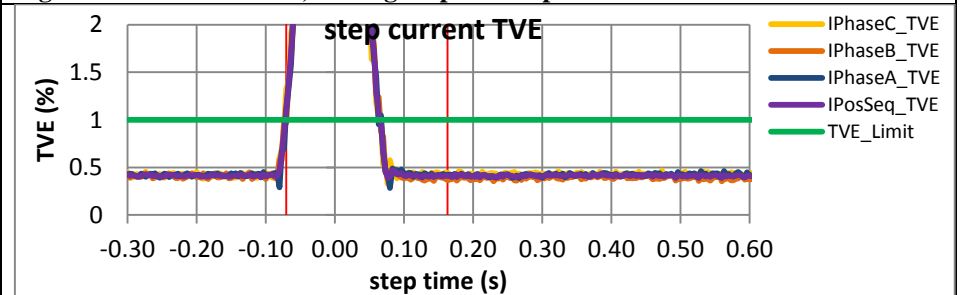


Figure 4147: Fs = 30 FPS, -10 degree phase step

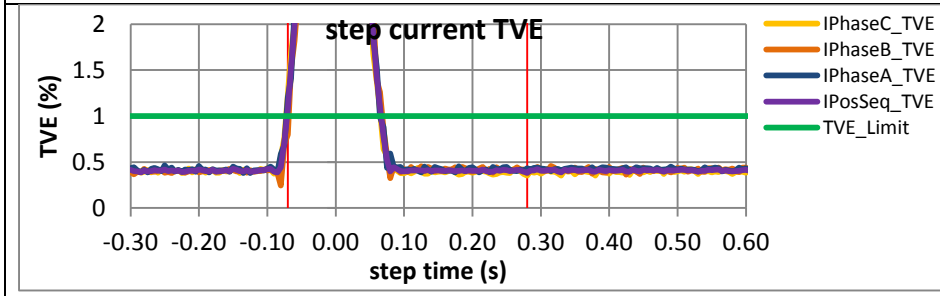


Figure 4148: Fs = 20 FPS, +10 degree phase step

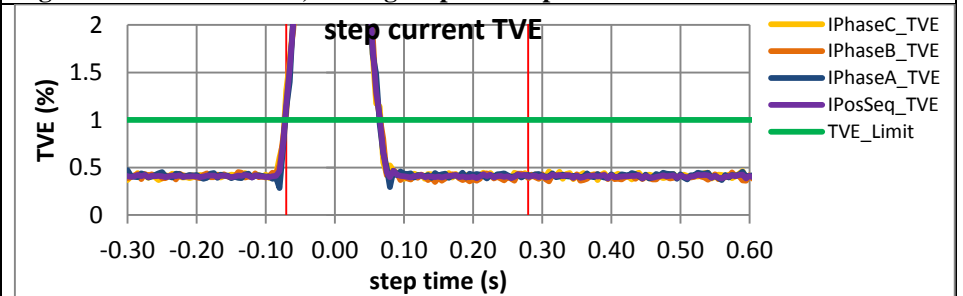


Figure 4149: Fs = 20 FPS, -10 degree phase step



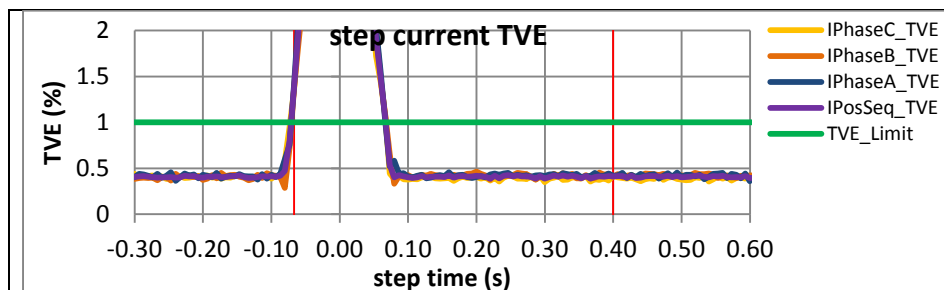


Figure 4150:  $F_s = 15$  FPS, +10 degree phase step

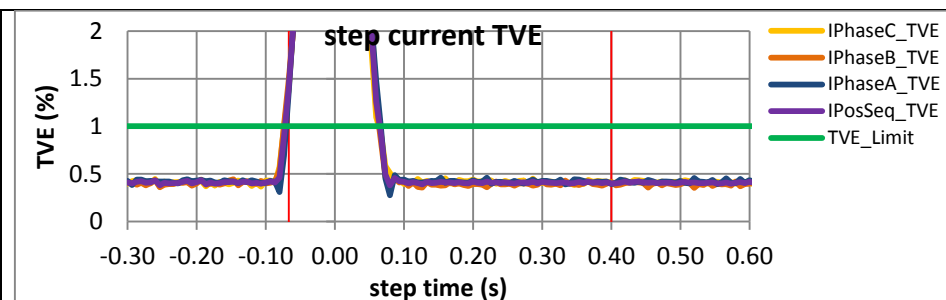


Figure 4151:  $F_s = 15$  FPS, -10 degree phase step

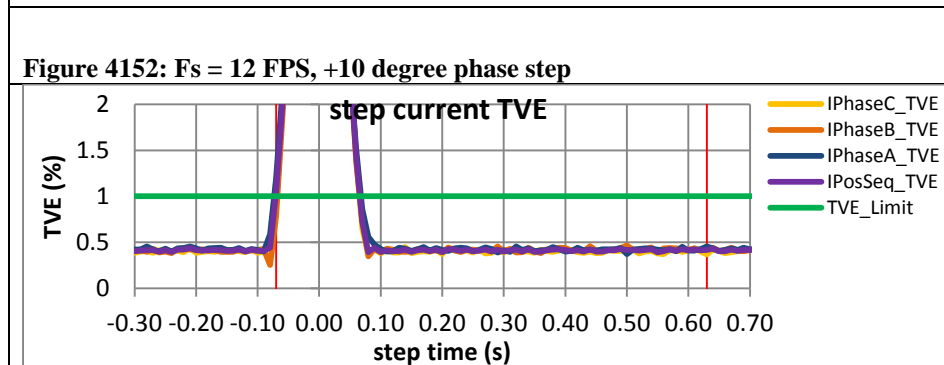


Figure 4154:  $F_s = 10$  FPS, +10 degree phase step

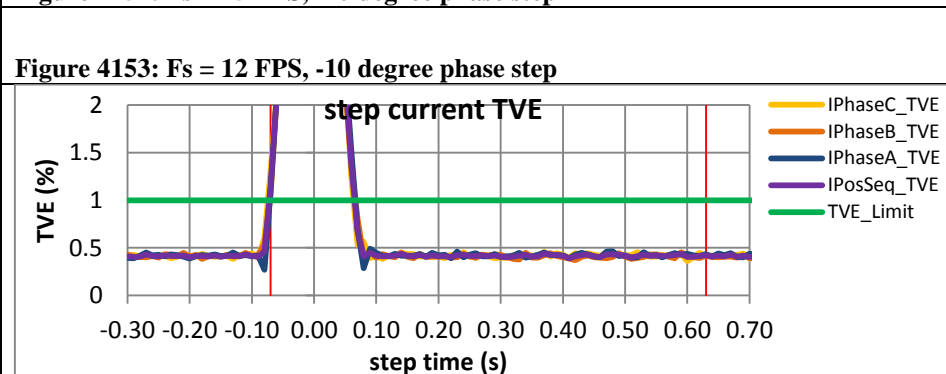
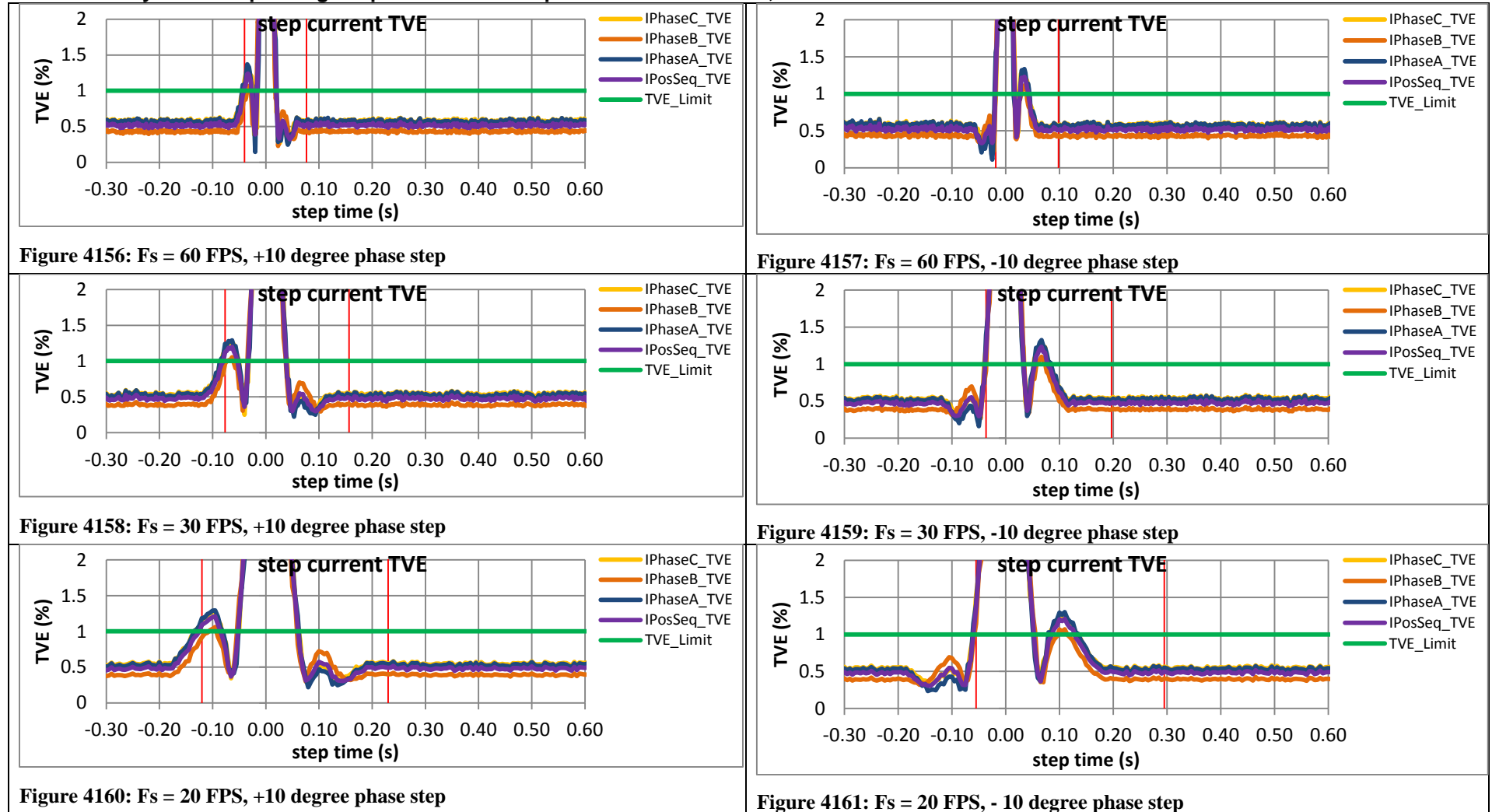


Figure 4155:  $F_s = 10$  FPS, -10 degree phase step

### 9.2.7 PMU F dynamic step change in phase current response time: F0 = 60 Hz, M class



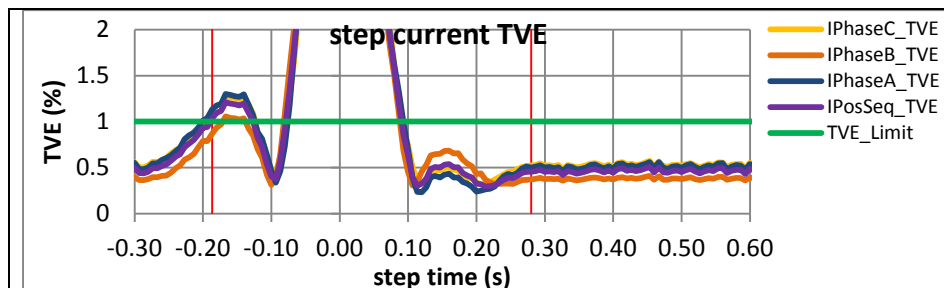


Figure 4162: Fs = 15 FPS, +10 degree phase step

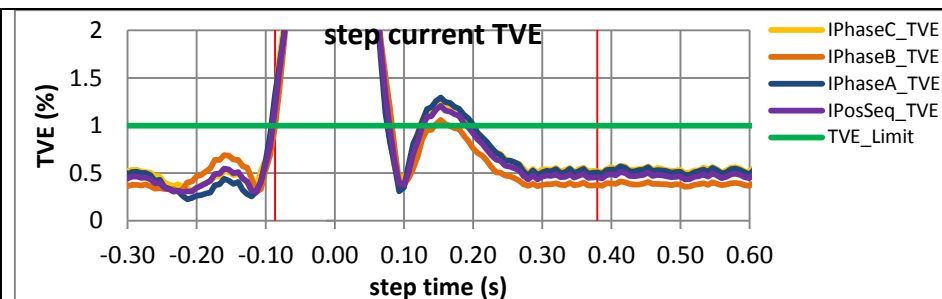


Figure 4163: Fs = 15 FPS, -10 degree phase step

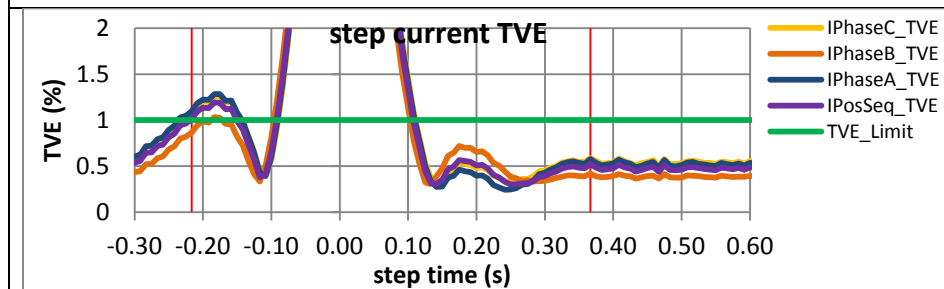


Figure 4164: Fs = 12 FPS, +10 degree phase step

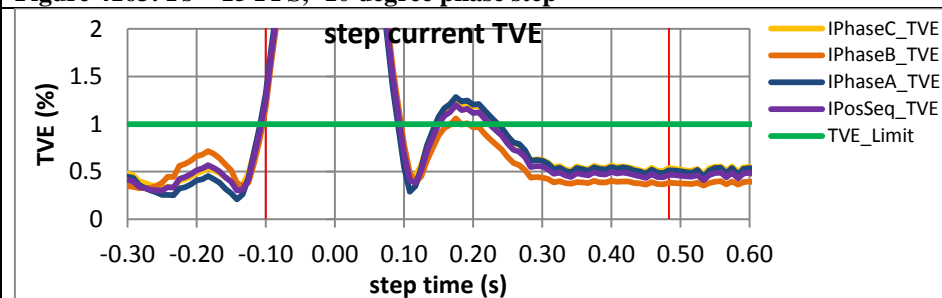


Figure 4165: Fs = 12 FPS, -10 degree phase step

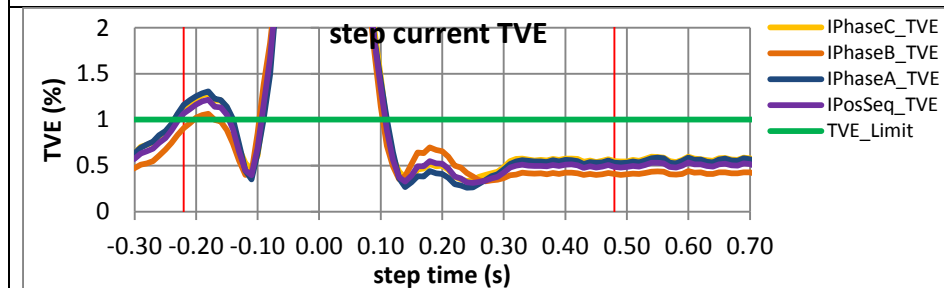


Figure 4166: Fs = 10 FPS, +10 degree phase step

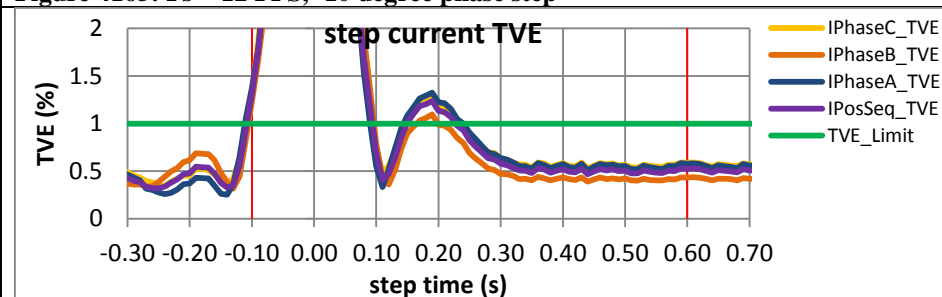


Figure 4167: Fs = 10 FPS, -10 degree phase step

### 9.2.8 PMU G dynamic step change in phase current response time: F0 = 60 Hz, M class

Figure 4168: Fs = 60 FPS is not supported by this PMU

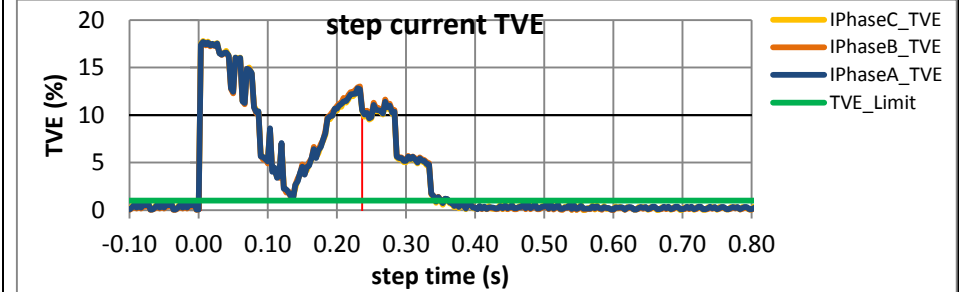
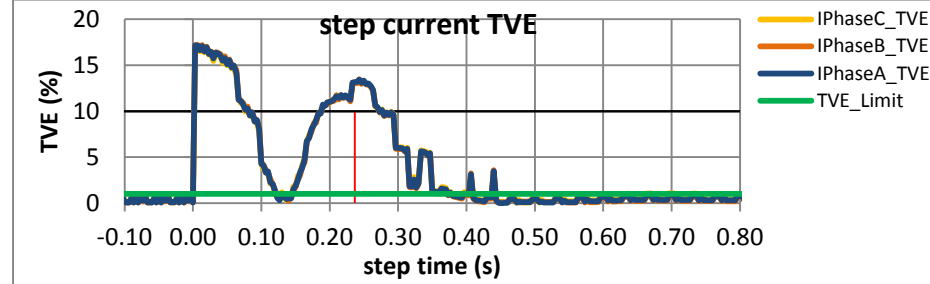


Figure 4169: Fs = 30 FPS, +10 degree phase step

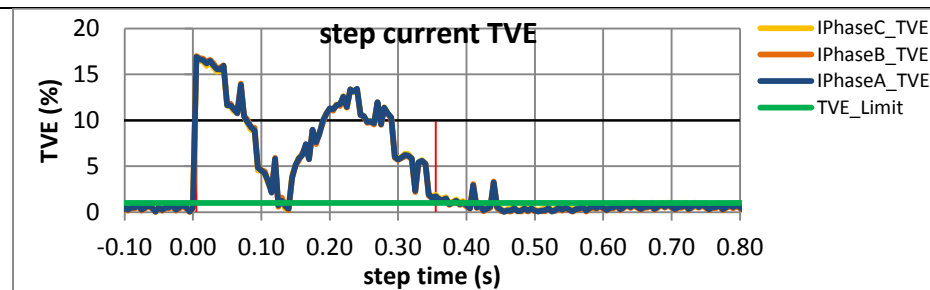


Figure 4170: Fs = 30 FPS, -10 degree phase step

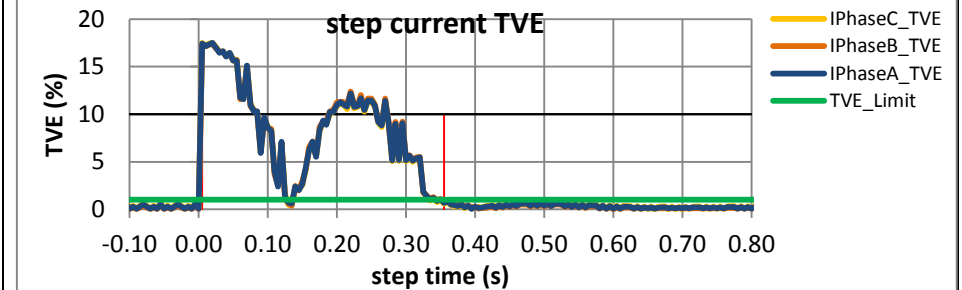


Figure 4171: Fs = 20 FPS, +10 degree phase step

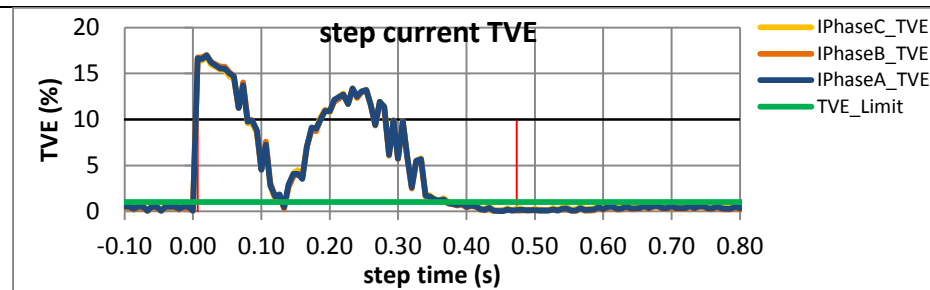


Figure 4172: Fs = 20 FPS, - 10 degree phase step

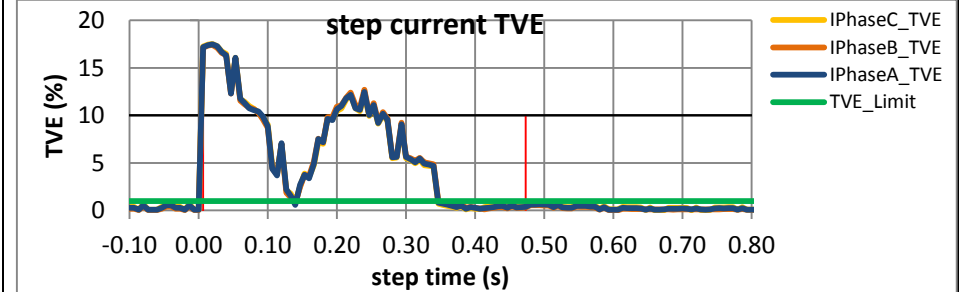


Figure 4173: Fs = 15 FPS, +10 degree phase step



Figure 4174: Fs = 15 FPS, -10 degree phase step



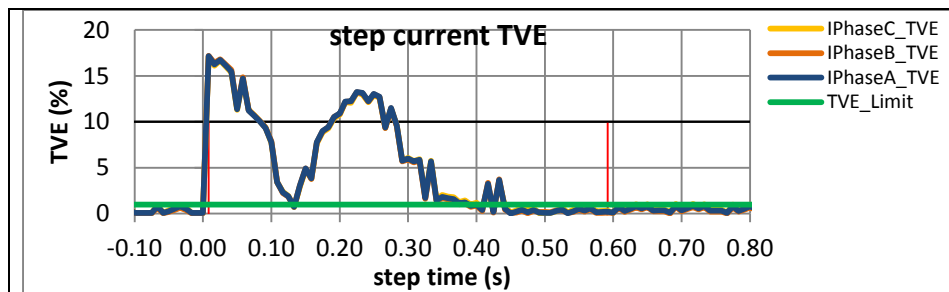


Figure 4175:  $F_s = 12$  FPS, +10 degree phase step

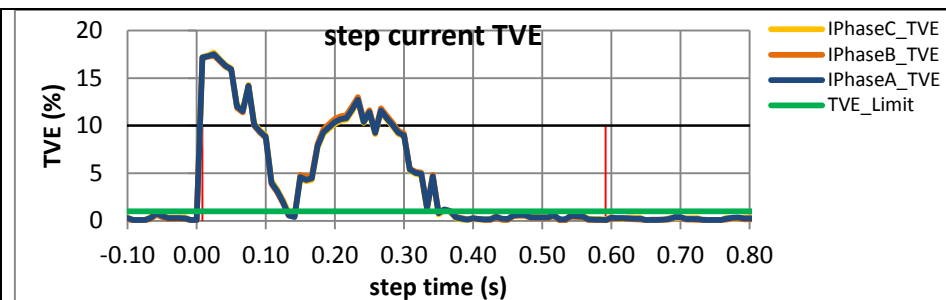


Figure 4176:  $F_s = 12$  FPS, -10 degree phase step

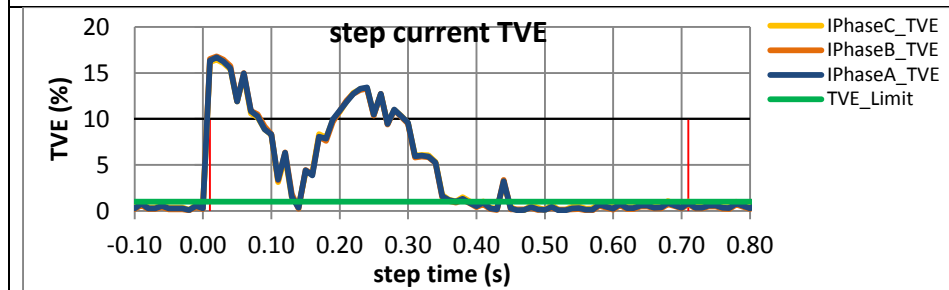


Figure 4177:  $F_s = 10$  FPS, +10 degree phase step

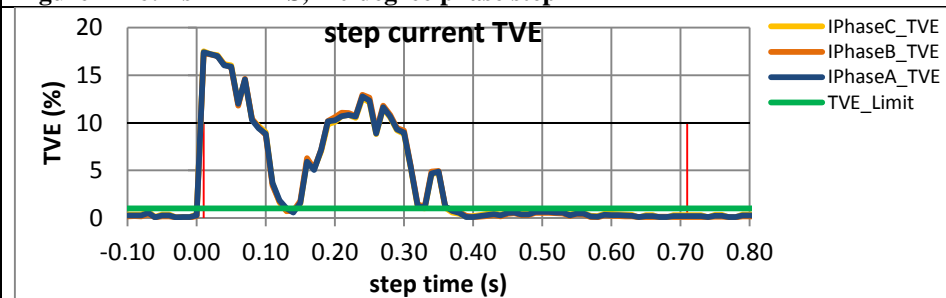


Figure 4178:  $F_s = 10$  FPS, -10 degree phase step

### 9.2.9 PMU H dynamic step change in phase current response time: F0 = 60 Hz, M class

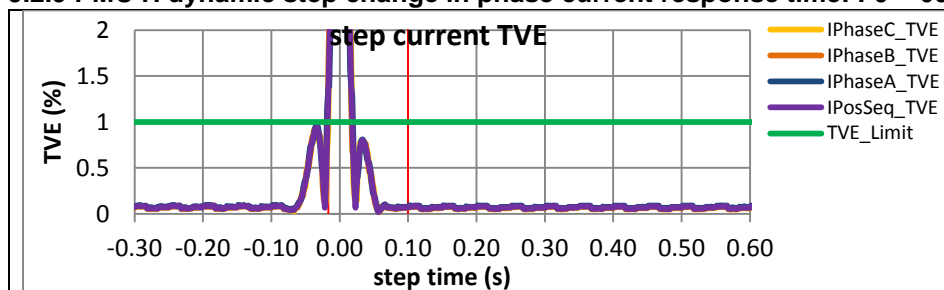


Figure 4179: Fs = 60 FPS, +10 degree phase step

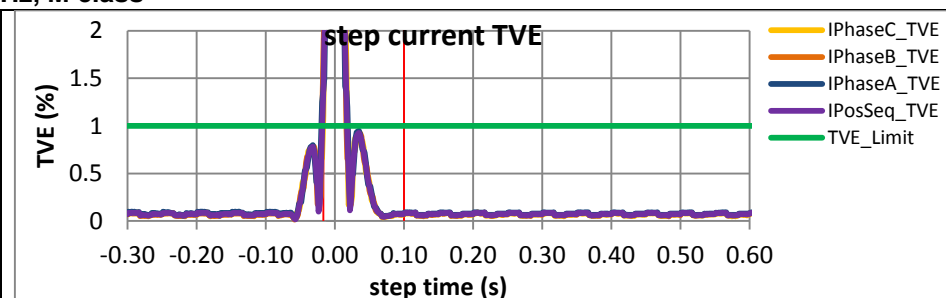


Figure 4180: Fs = 60 FPS, -10 degree phase step

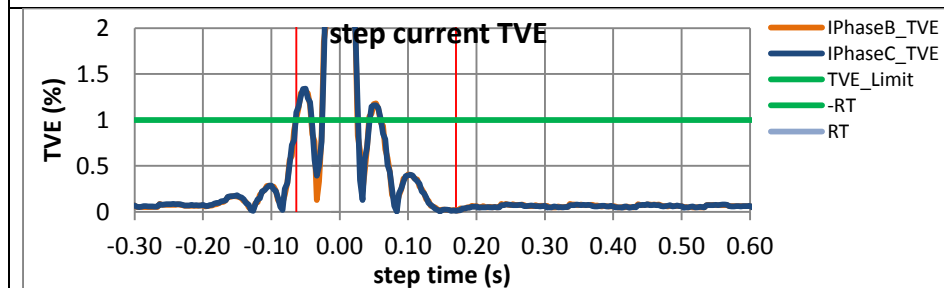


Figure 4181: Fs = 30 FPS, +10 degree phase step

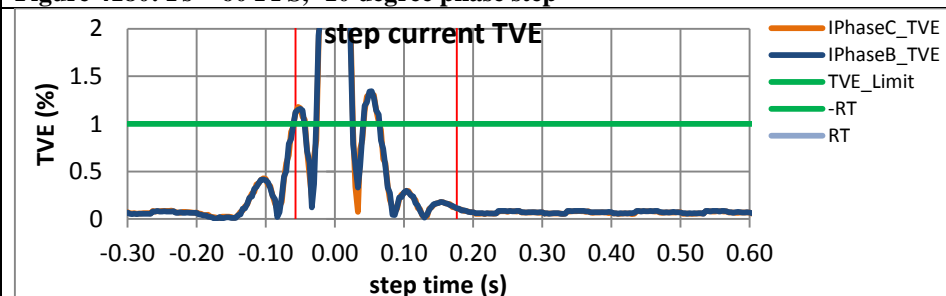


Figure 4182: Fs = 30 FPS, -10 degree phase step

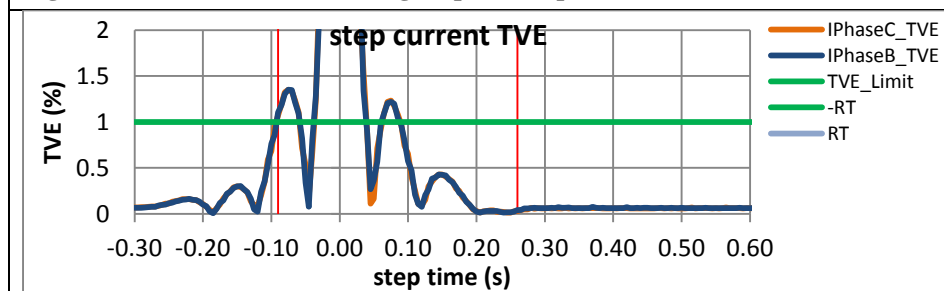


Figure 4183: Fs = 20 FPS, +10 degree phase step

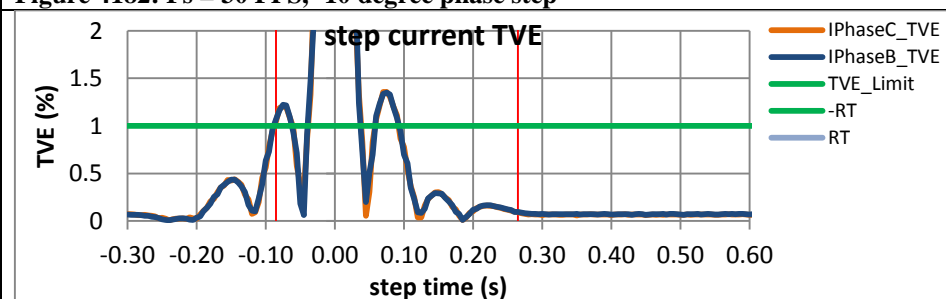


Figure 4184: Fs = 20 FPS, -10 degree phase step

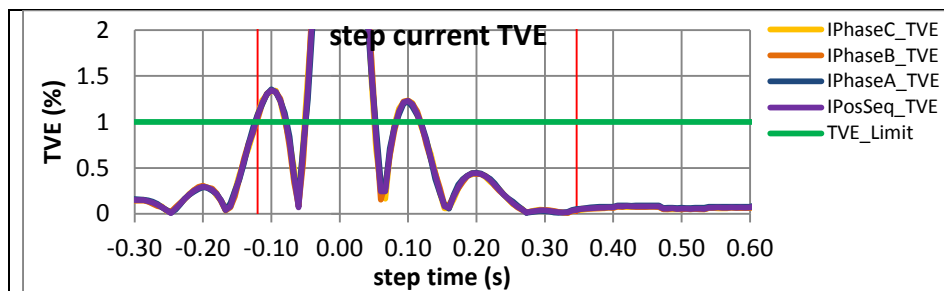


Figure 4185: Fs = 15 FPS, +10 degree phase step

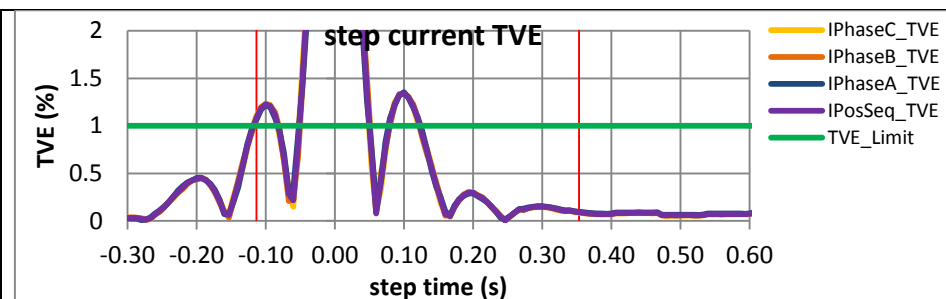


Figure 4186: Fs = 15 FPS, -10 degree phase step

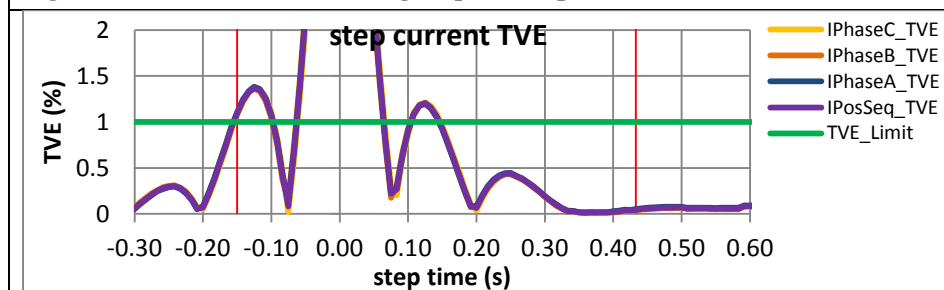


Figure 4187: Fs = 12 FPS, +10 degree phase step

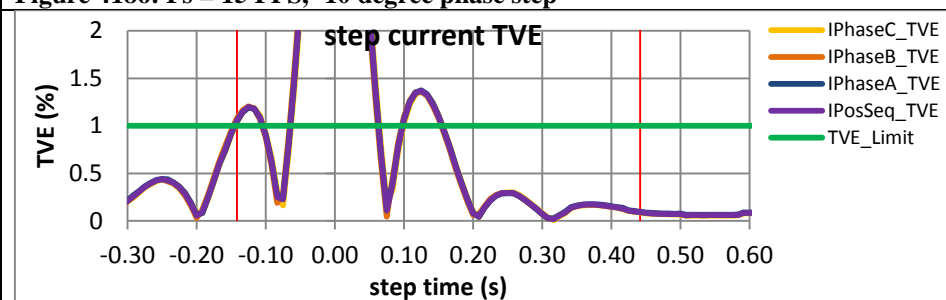


Figure 4188: Fs = 12 FPS, -10 degree phase step

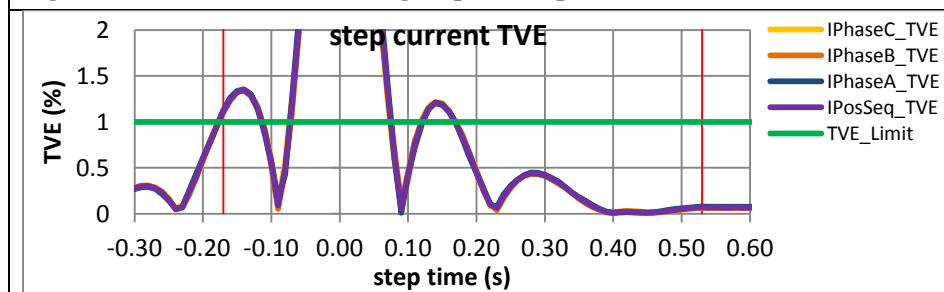


Figure 4189: Fs = 10 FPS, +10 degree phase step

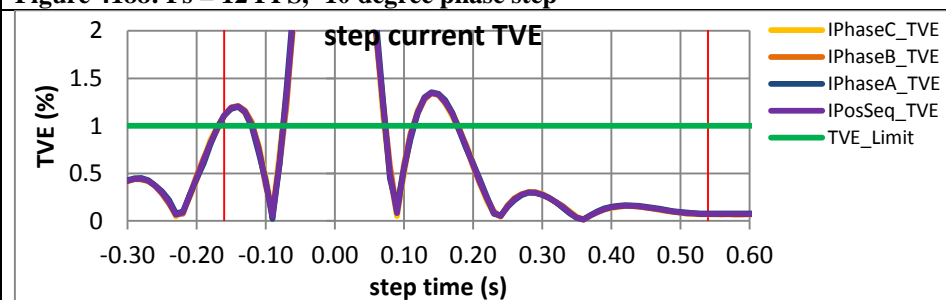


Figure 4190: Fs = 10 FPS, -10 degree phase step

### 9.2.10 PMU I dynamic step change in phase current response time: F0 = 60 Hz, M class

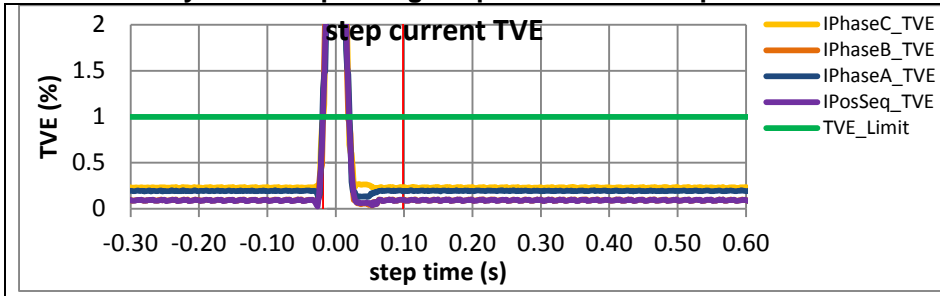


Figure 4191: Fs = 60 FPS, +10 degree phase step

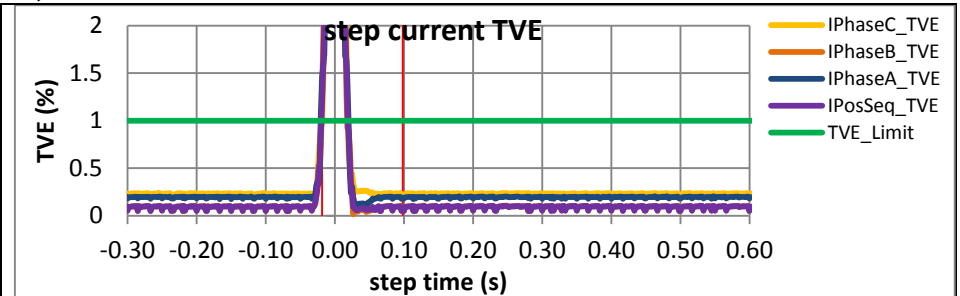


Figure 4192: Fs = 60 FPS, -10 degree phase step

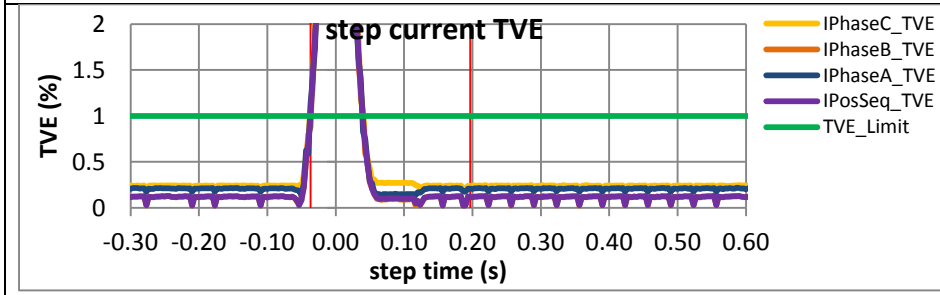


Figure 4193: Fs = 30 FPS, +10 degree phase step

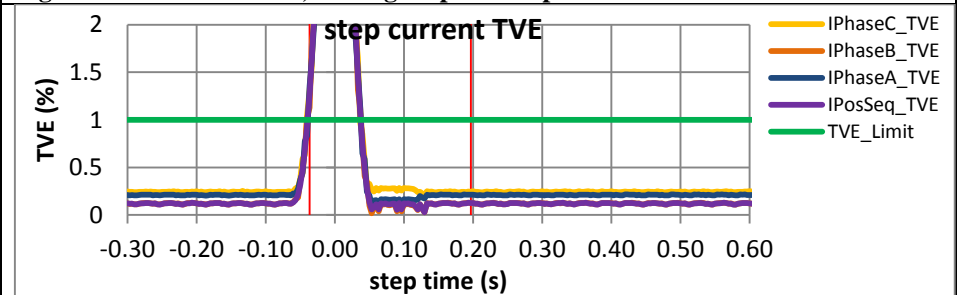


Figure 4194: Fs = 30 FPS, -10 degree phase step

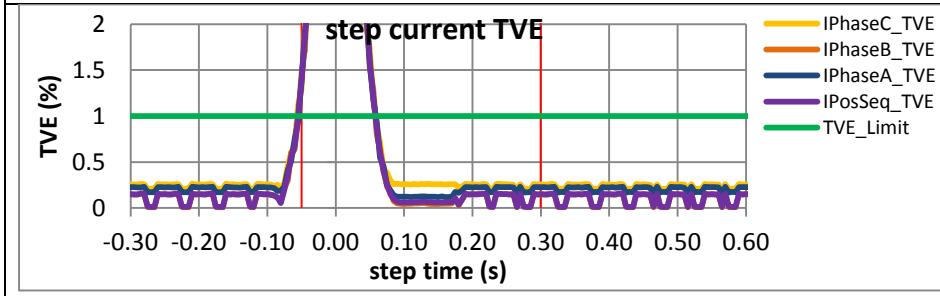


Figure 4195: Fs = 20 FPS, +10 degree phase step

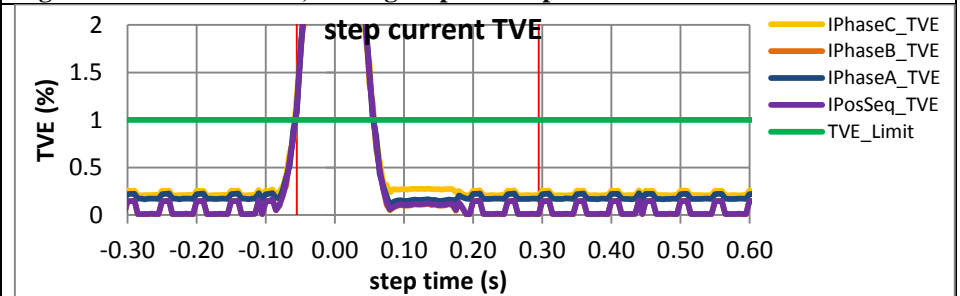


Figure 4196: Fs = 20 FPS, -10 degree phase step



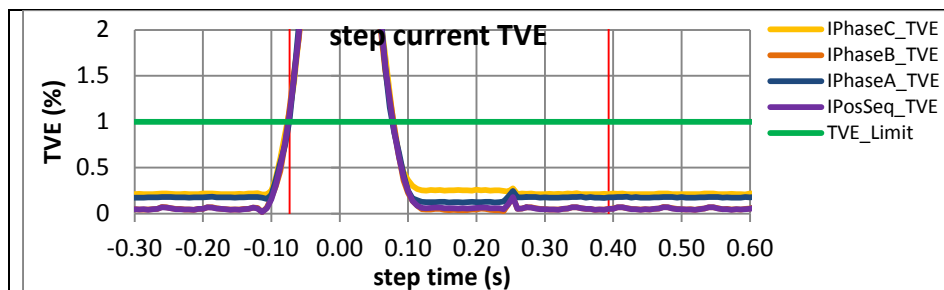


Figure 4197:  $F_s = 15$  FPS, +10 degree phase step

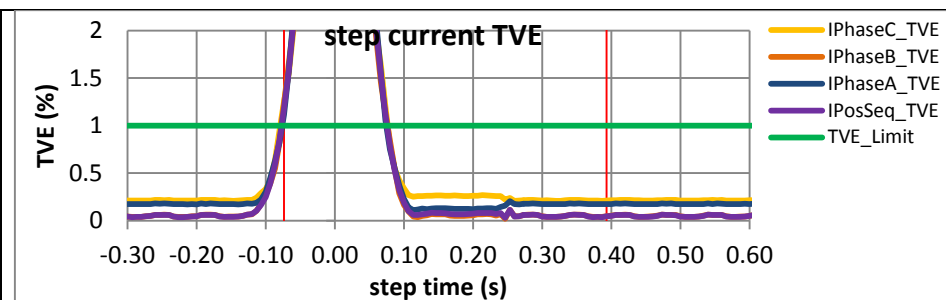


Figure 4198:  $F_s = 15$  FPS, -10 degree phase step

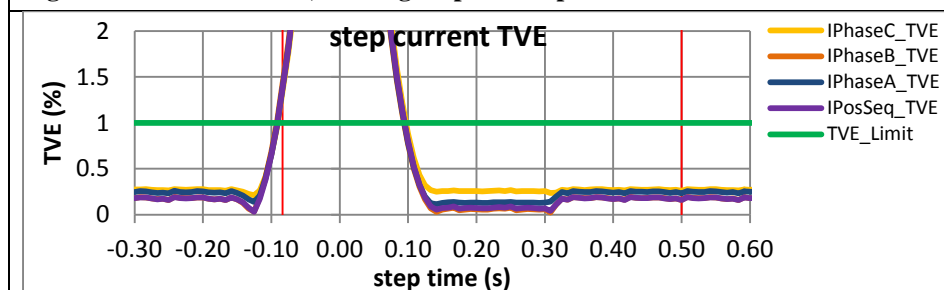


Figure 4199:  $F_s = 12$  FPS, +10 degree phase step

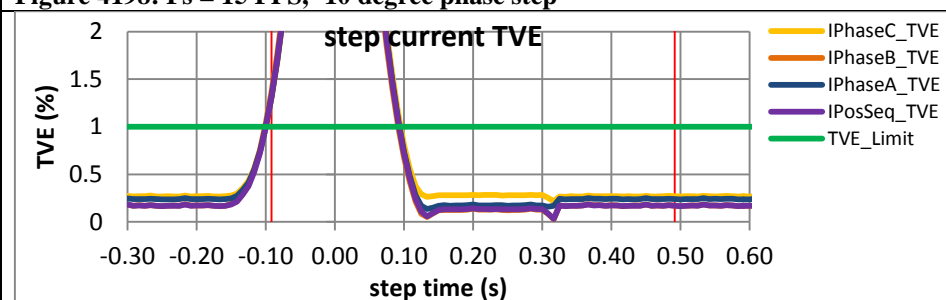


Figure 4200:  $F_s = 12$  FPS, -10 degree phase step

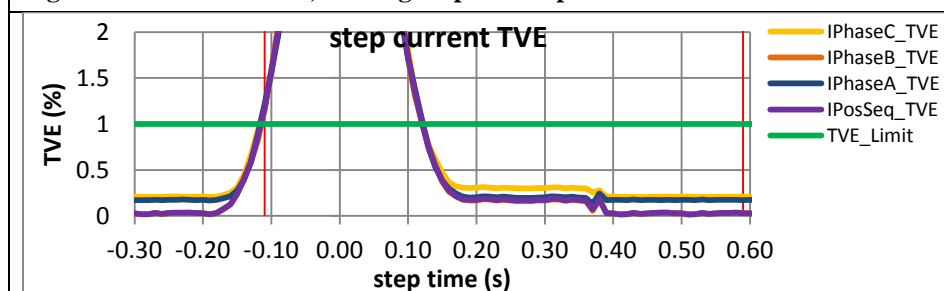


Figure 4201:  $F_s = 10$  FPS, +10 degree phase step

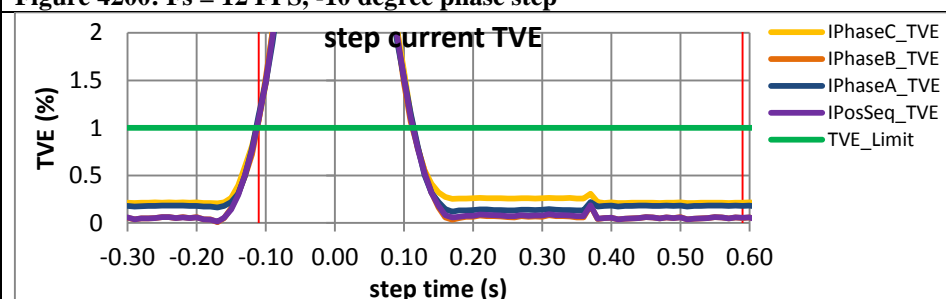


Figure 4202:  $F_s = 10$  FPS, -10 degree phase step

### 9.2.11 PMU J dynamic step change in phase current response time: F0 = 60 Hz, M class

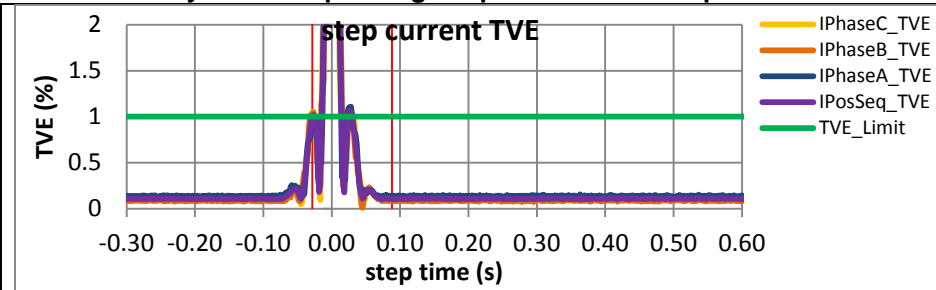


Figure 4203: Fs = 60 FPS, +10 degree phase step

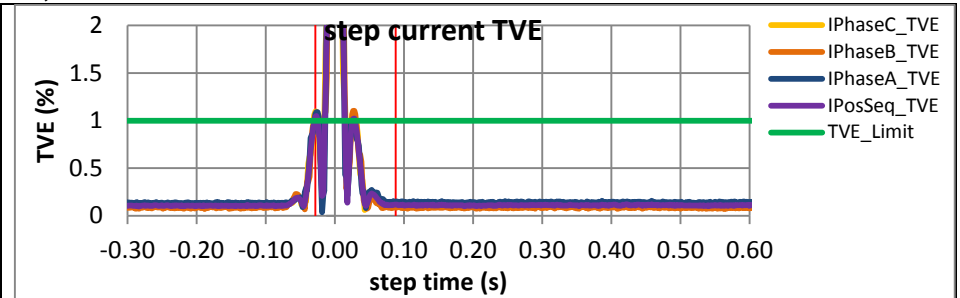


Figure 4204: Fs = 60 FPS, -10 degree phase step

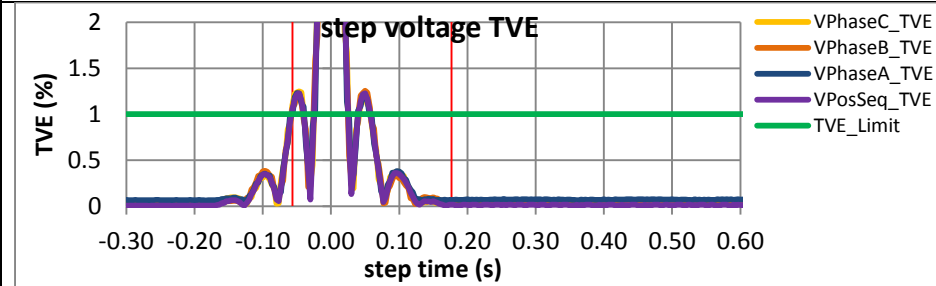


Figure 4205: Fs = 30 FPS, +10 degree phase step

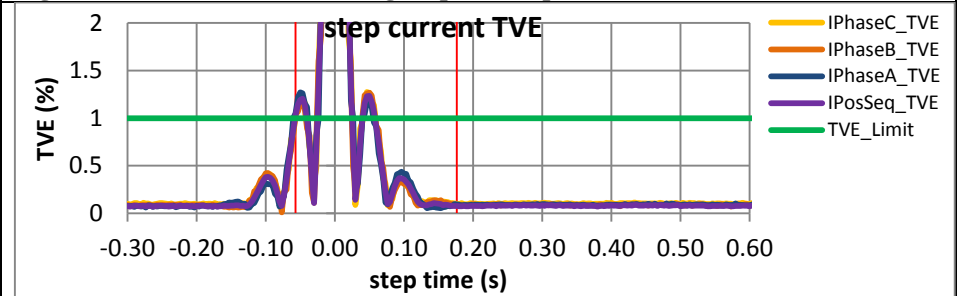


Figure 4206: Fs = 30 FPS, -10 degree phase step

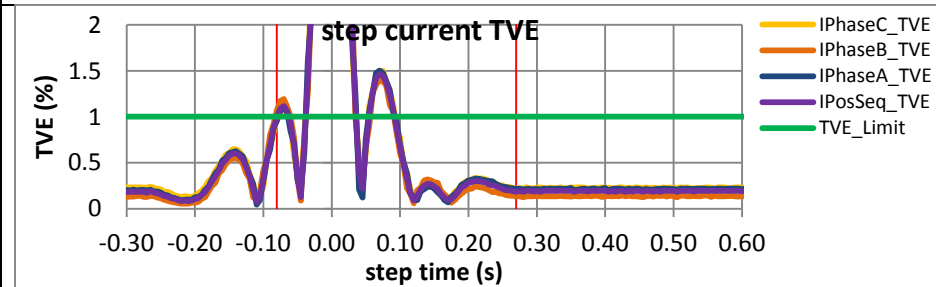


Figure 4207: Fs = 20 FPS, +10 degree phase step

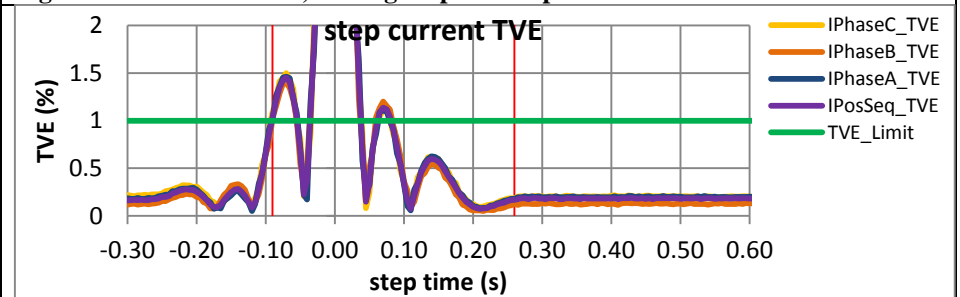


Figure 4208: Fs = 20 FPS, -10 degree phase step

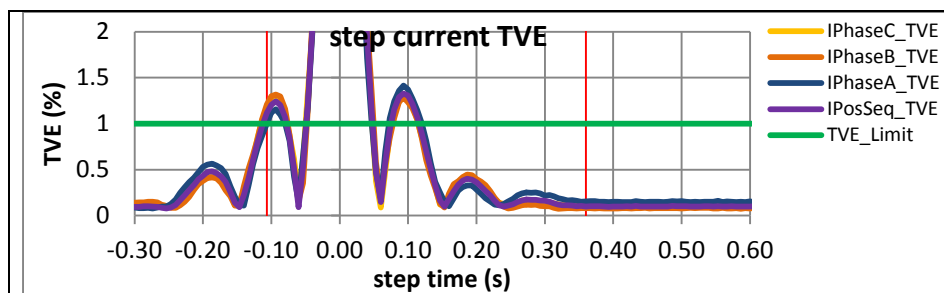


Figure 4209:  $F_s = 15$  FPS, +10 degree phase step

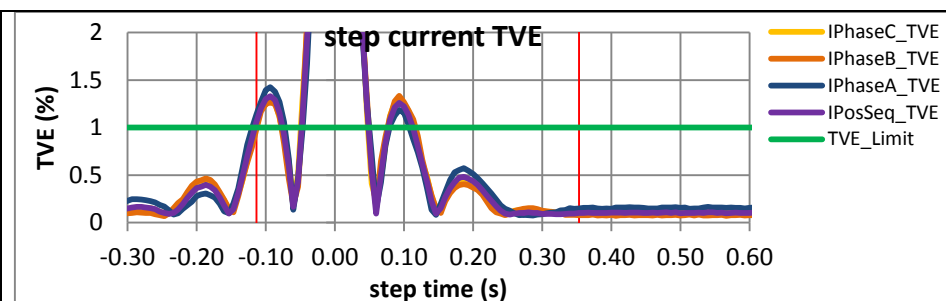


Figure 4210:  $F_s = 15$  FPS, -10 degree phase step

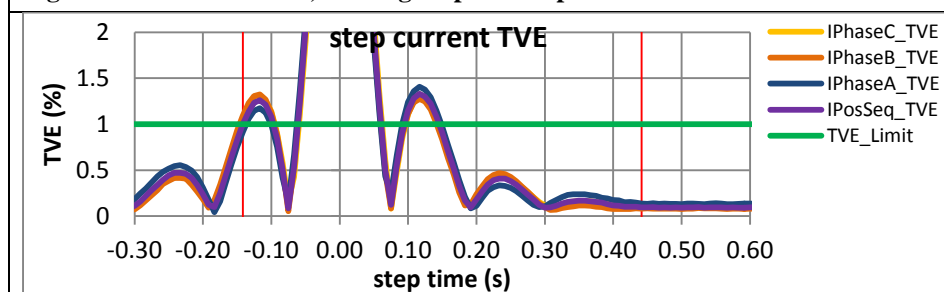


Figure 4211:  $F_s = 12$  FPS, +10 degree phase step

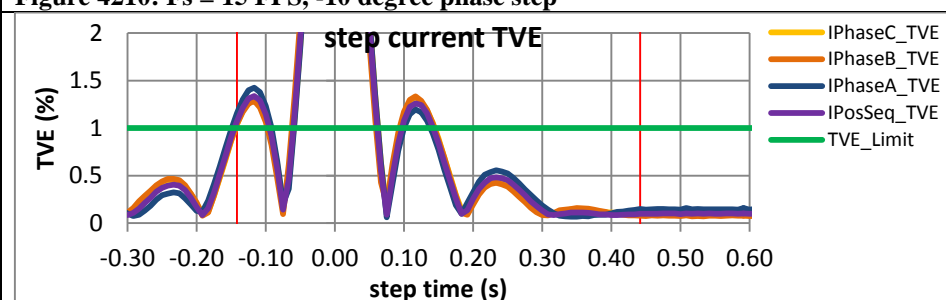


Figure 4212:  $F_s = 12$  FPS, -10 degree phase step

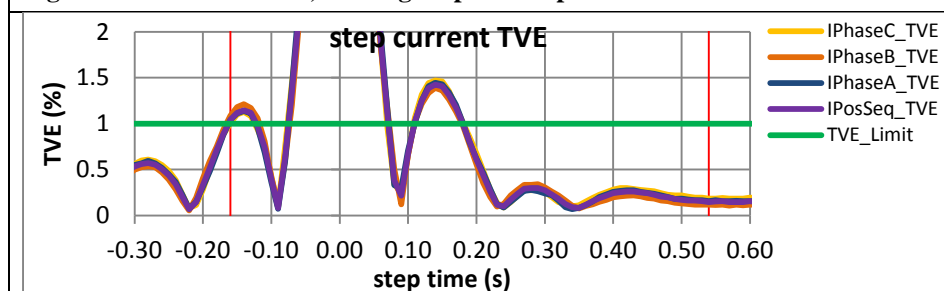


Figure 4213:  $F_s = 10$  FPS, +10 degree phase step

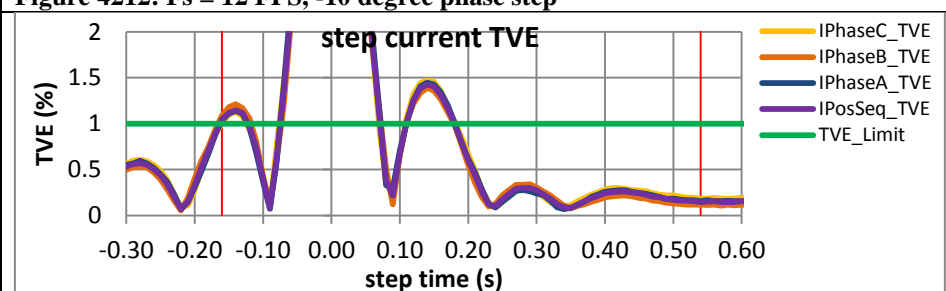


Figure 4214:  $F_s = 10$  FPS, -10 degree phase step

### 9.3 Dynamic step change in phase voltage response time: F0 = 60 Hz, P Class

#### 9.3.1 C37.118.1a Annex C dynamic step change in phase voltage response time: F0 = 60 Hz, P class

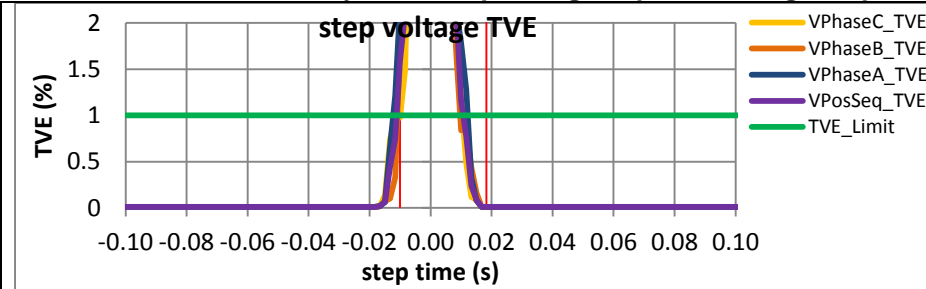


Figure 4215: Fs = 60 FPS, +10 degree phase step

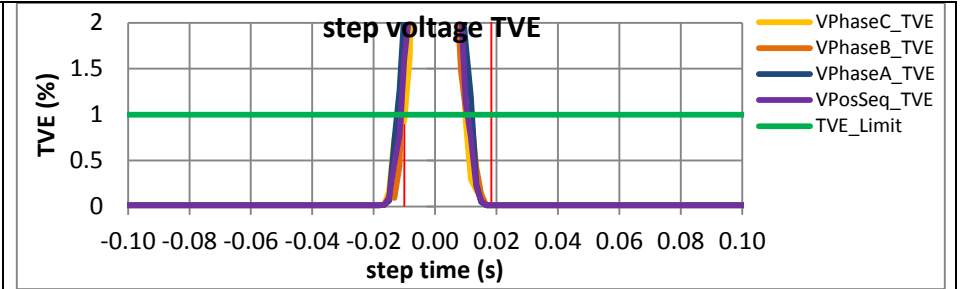


Figure 4216: Fs = 60 FPS, -10 degree phase step

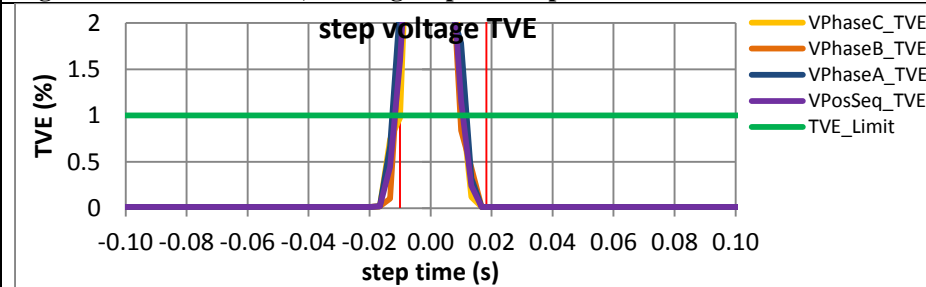


Figure 4217: Fs = 30 FPS, +10 degree phase step

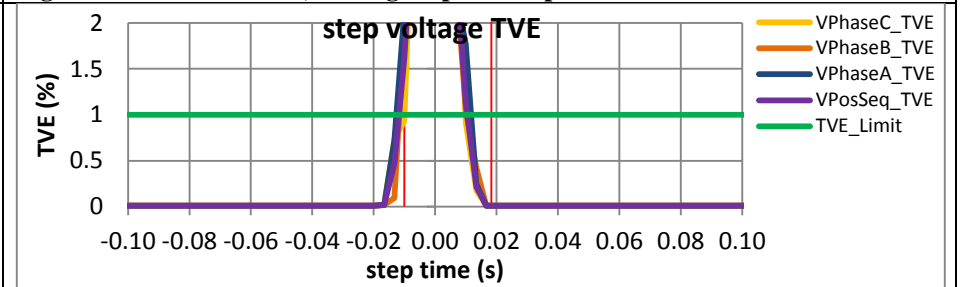


Figure 4218: Fs = 30 FPS, -10 degree phase step

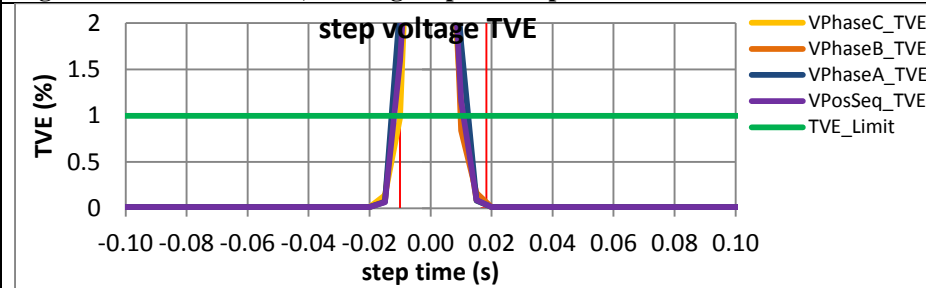


Figure 4219: Fs = 20 FPS, +10 degree phase step

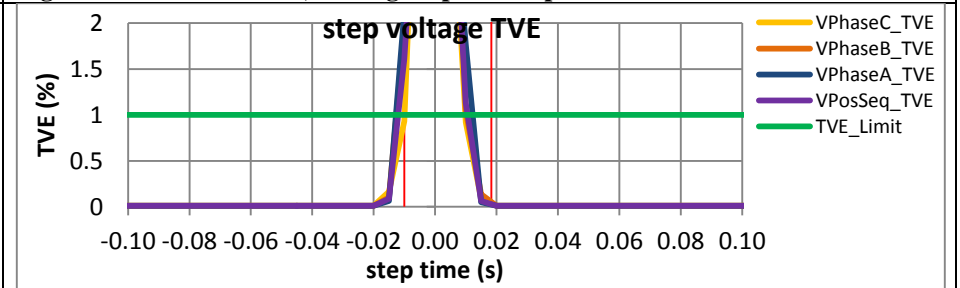


Figure 4220: Fs = 20 FPS, -10 degree phase step

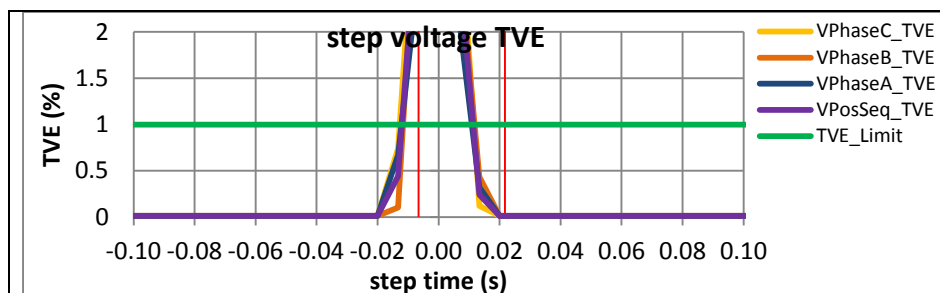


Figure 4221: Fs = 15 FPS, +10 degree phase step

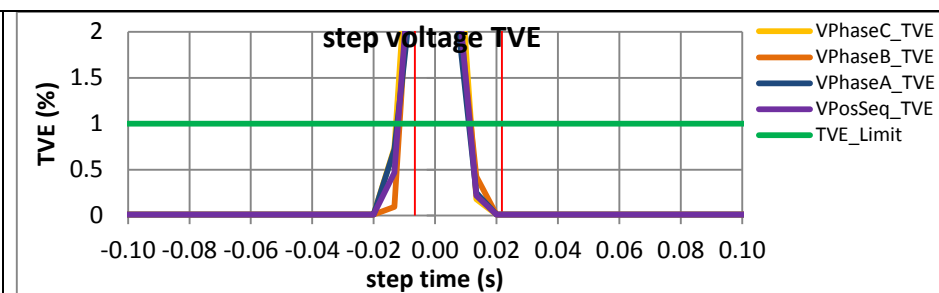


Figure 4222: Fs = 15 FPS, -10 degree phase step

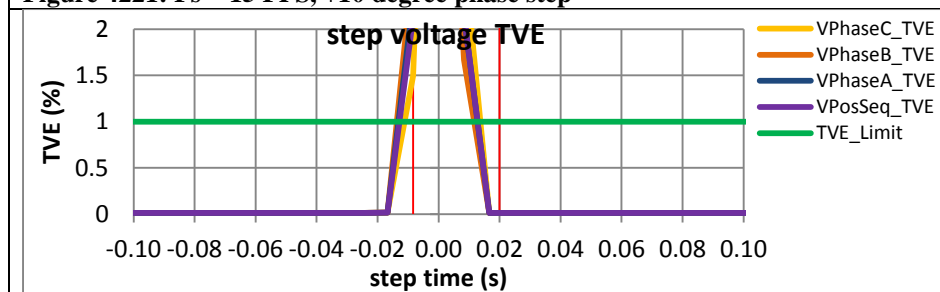


Figure 4223: Fs = 12 FPS, +10 degree phase step

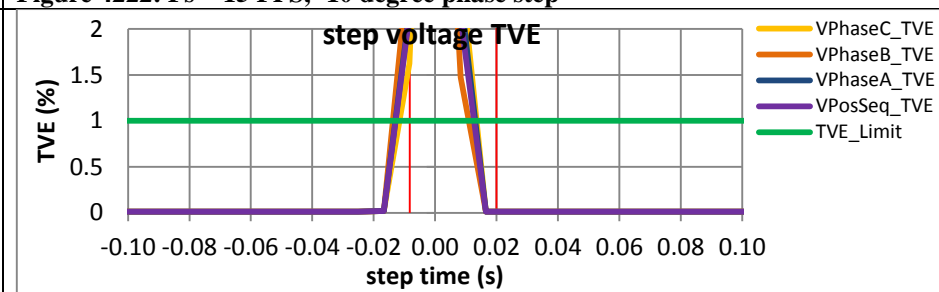


Figure 4224: Fs = 12 FPS, -10 degree phase step

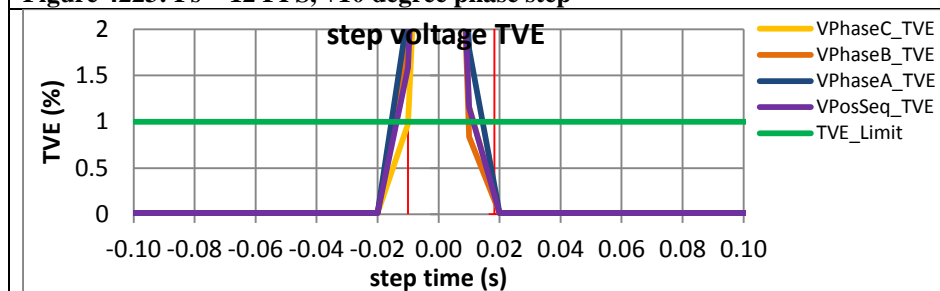


Figure 4225: Fs = 10 FPS, +10 degree phase step

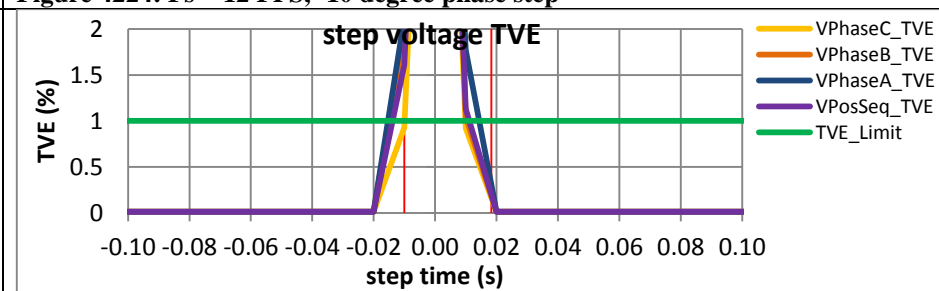


Figure 4226: Fs = 10 FPS, -10 degree phase step

### 9.3.2 PMU A dynamic step change in phase voltage response time: F0 = 60 Hz, P class

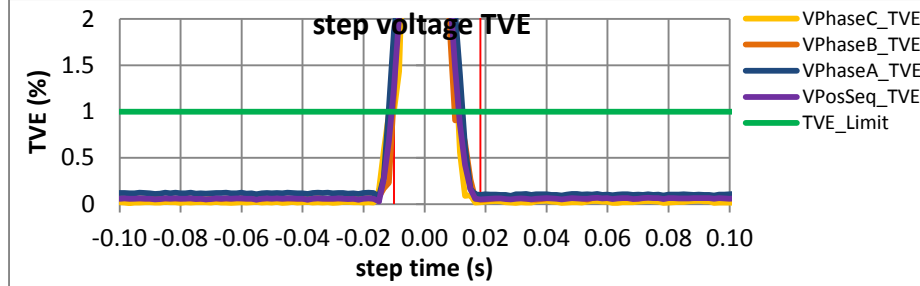


Figure 4227: Fs = 60 FPS, +10 degree phase step

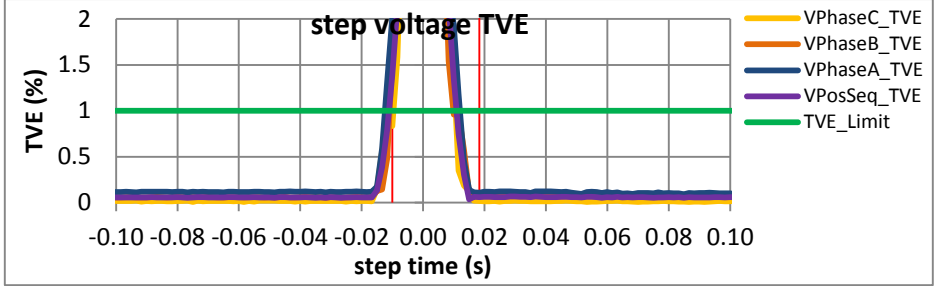


Figure 4228: Fs = 60 FPS, -10 degree phase step

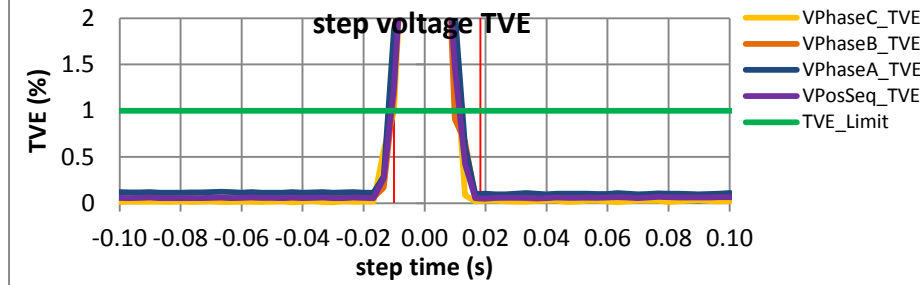


Figure 4229: Fs = 30 FPS, +10 degree phase step

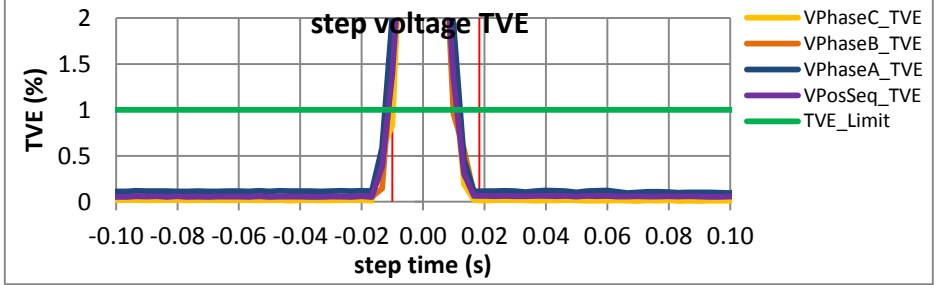


Figure 4230: Fs = 30 FPS, -10 degree phase step

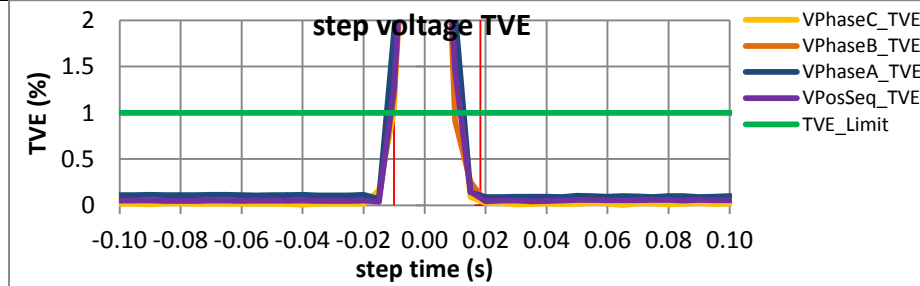


Figure 4231: Fs = 20 FPS, +10 degree phase step

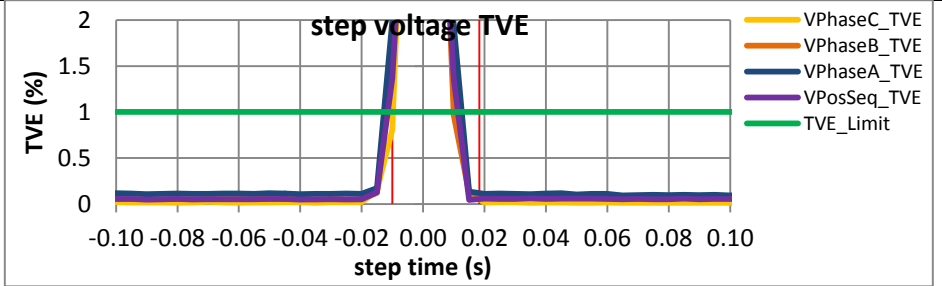


Figure 4232: Fs = 20 FPS, -10 degree phase step

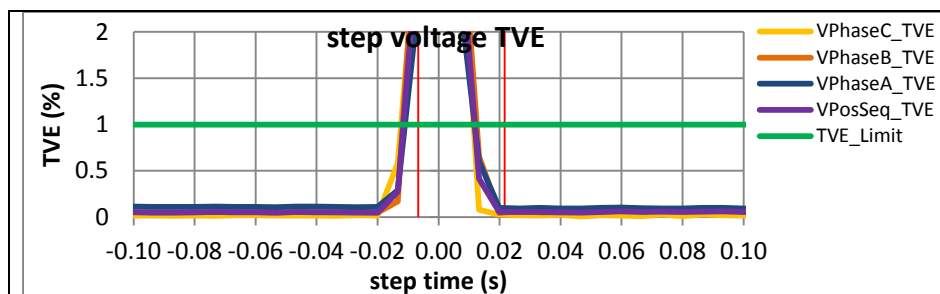


Figure 4233: Fs = 15 FPS, +10 degree phase step

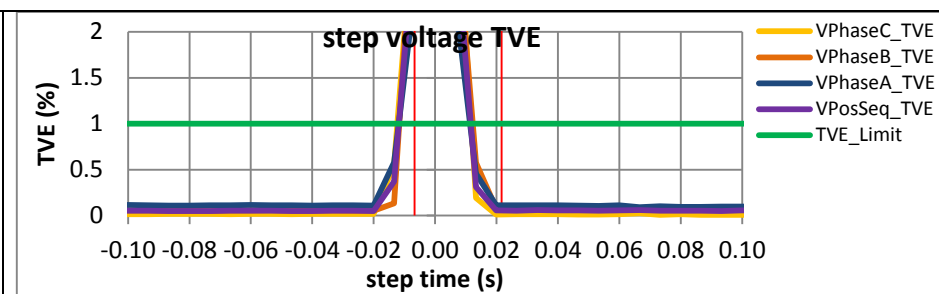


Figure 4234: Fs = 15 FPS, -10 degree phase step

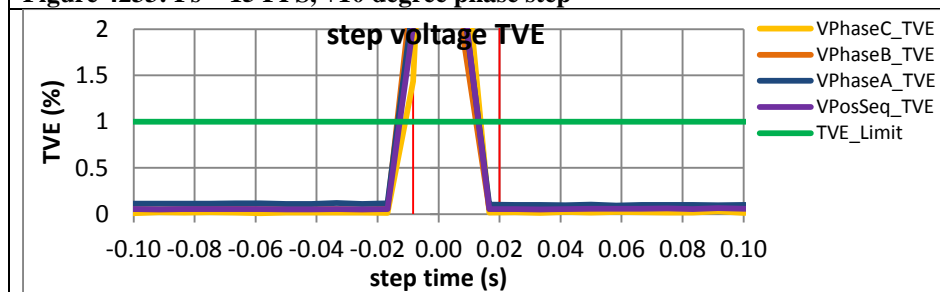


Figure 4235: Fs = 12 FPS, +10 degree phase step

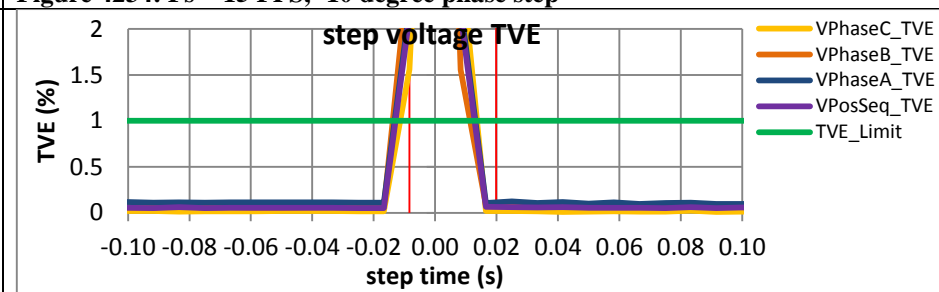


Figure 4236: Fs = 12 FPS, -10 degree phase step

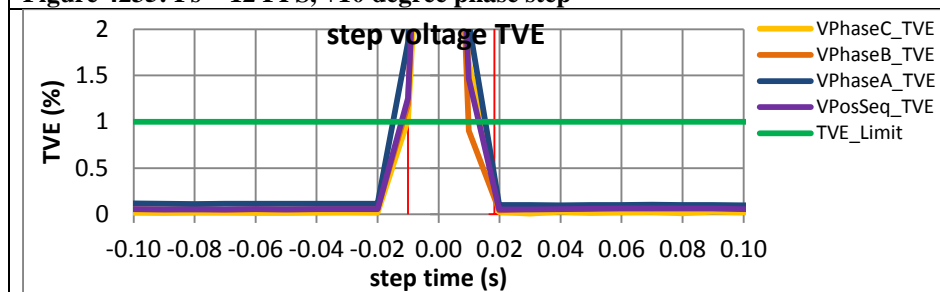


Figure 4237: Fs = 10 FPS, +10 degree phase step

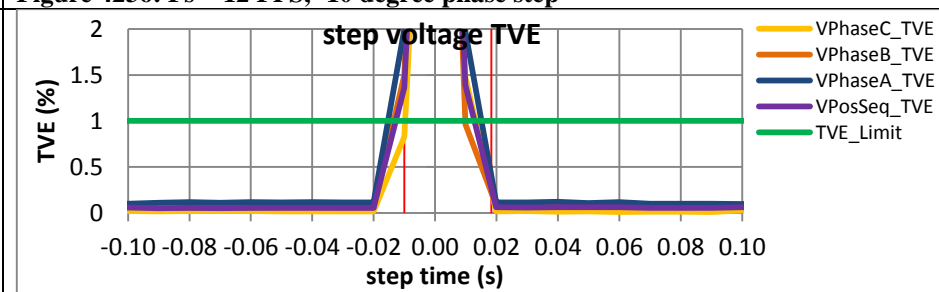


Figure 4238: Fs = 10 FPS, -10 degree phase step

### 9.3.3 PMU B dynamic step change in phase voltage response time: F0 = 60 Hz, P class

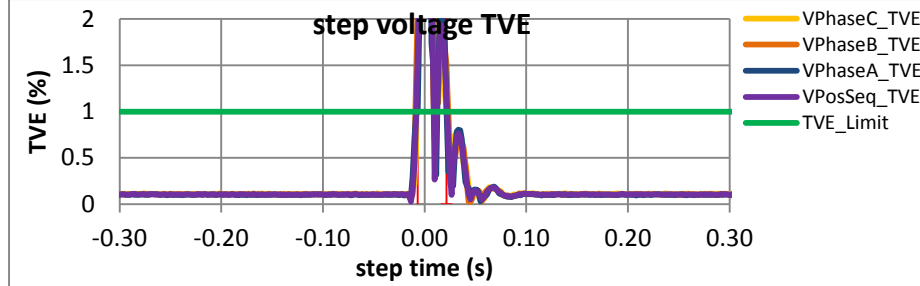


Figure 4239: Fs = 60 FPS, +10 degree phase step

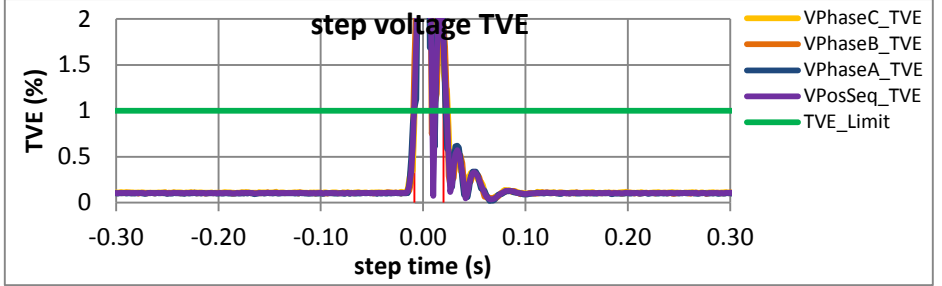


Figure 4240: Fs = 60 FPS, -10 degree phase step

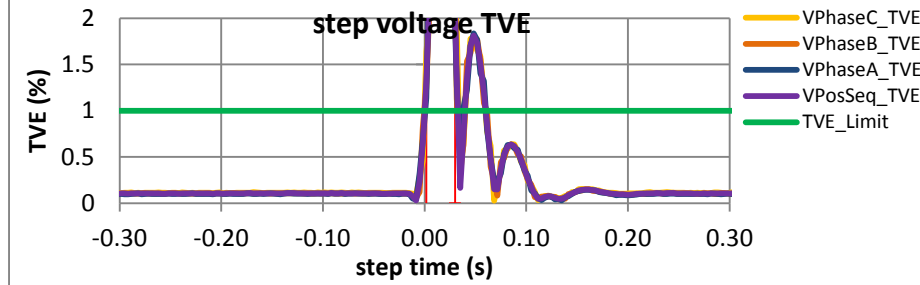


Figure 4241: Fs = 30 FPS, +10 degree phase step

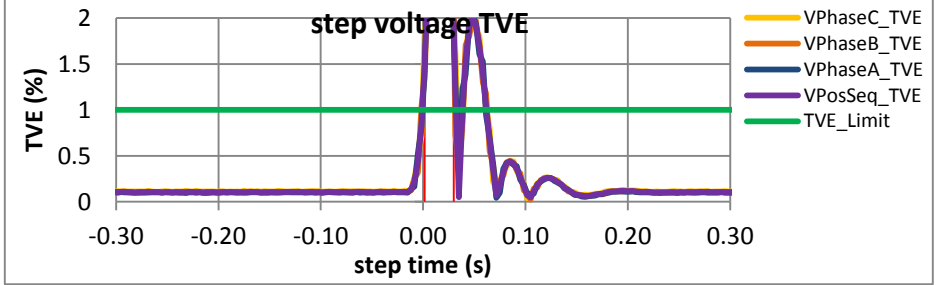


Figure 4242: Fs = 30 FPS, -10 degree phase step

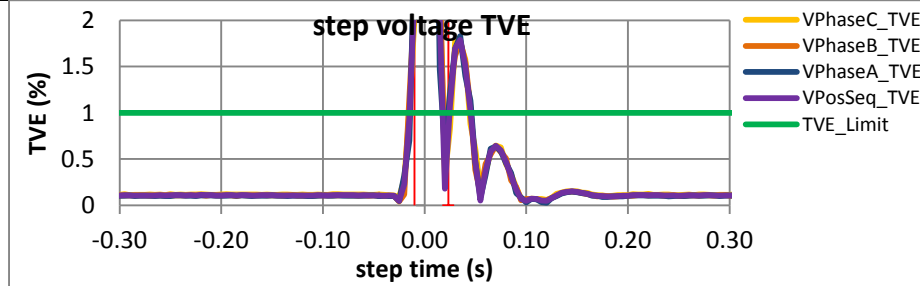


Figure 4243: Fs = 20 FPS, +10 degree phase step

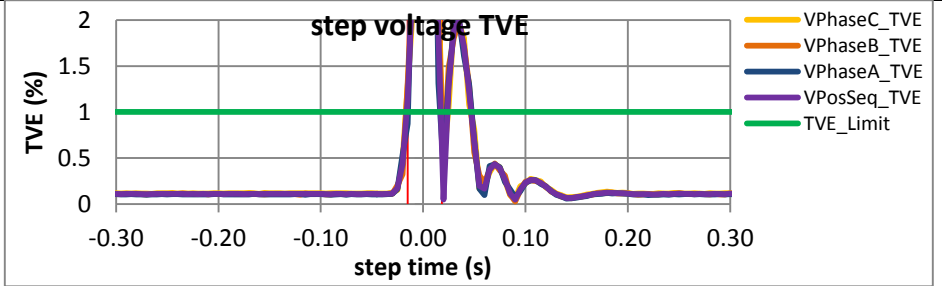


Figure 4244: Fs = 20 FPS, -10 degree phase step



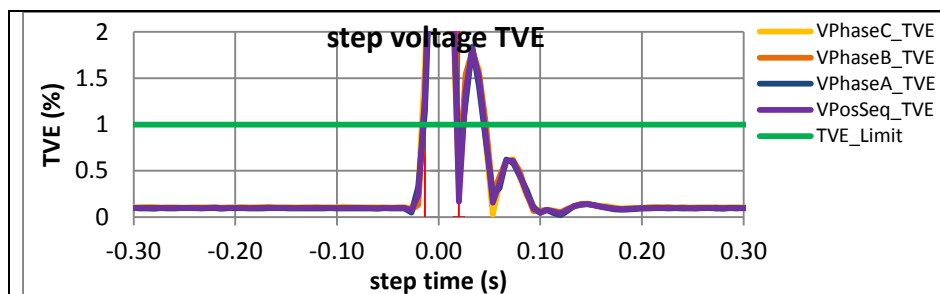


Figure 4245: Fs = 15 FPS, +10 degree phase step

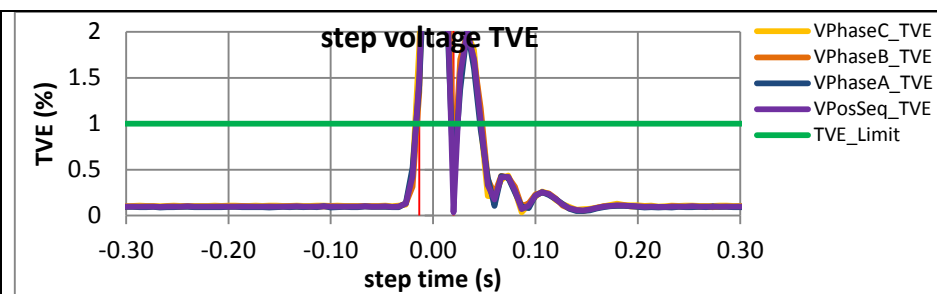


Figure 4246: Fs = 15 FPS, -10 degree phase step

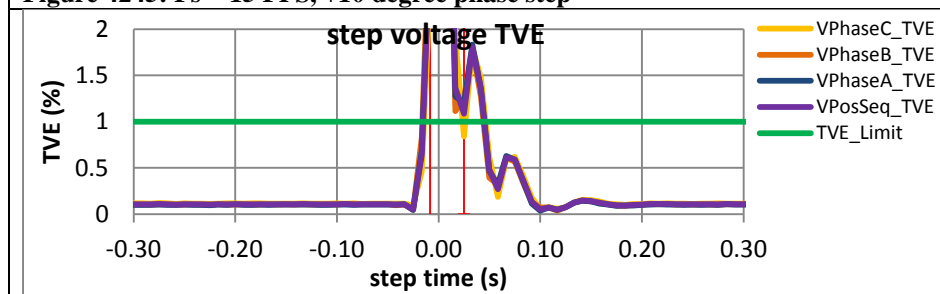


Figure 4247: Fs = 12 FPS, +10 degree phase step

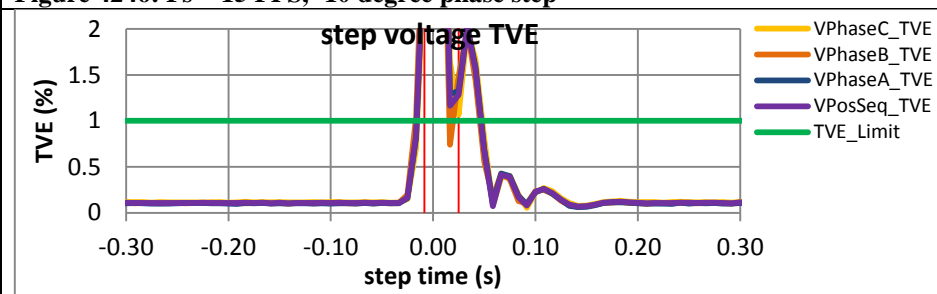


Figure 4248: Fs = 12 FPS, -10 degree phase step

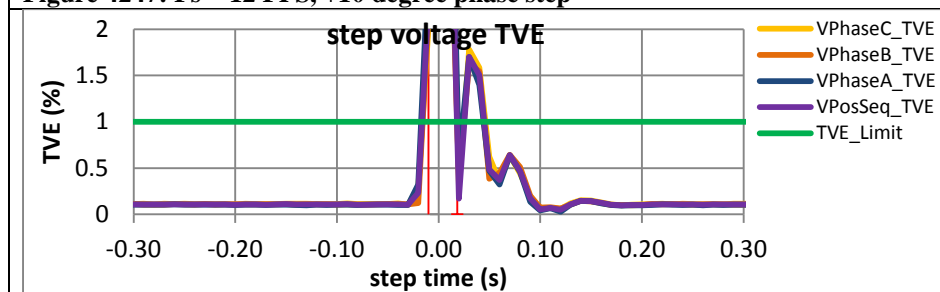


Figure 4249: Fs = 10 FPS, +10 degree phase step

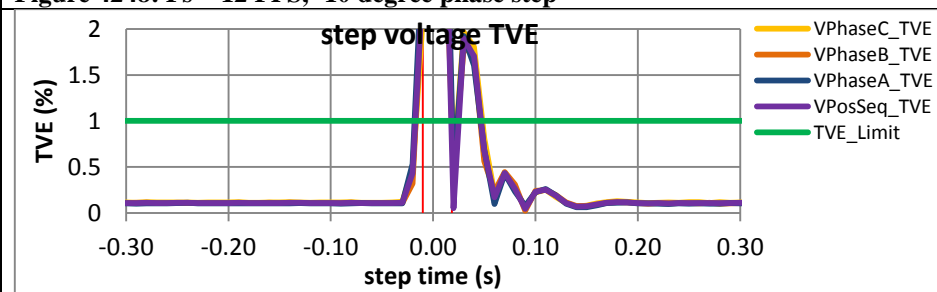


Figure 4250: Fs = 10 FPS, -10 degree phase step

### 9.3.4 PMU C dynamic step change in phase voltage response time: F0 = 60 Hz, P class

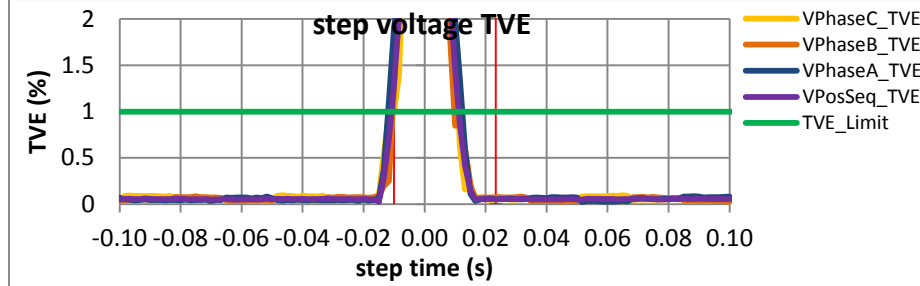


Figure 4251: Fs = 60 FPS, +10 degree phase step

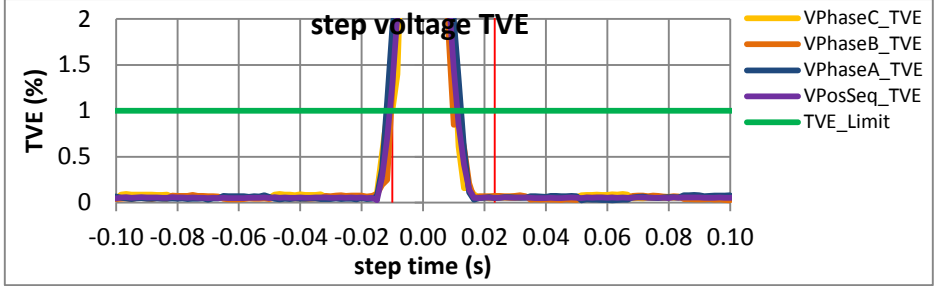


Figure 4252: Fs = 60 FPS, -10 degree phase step

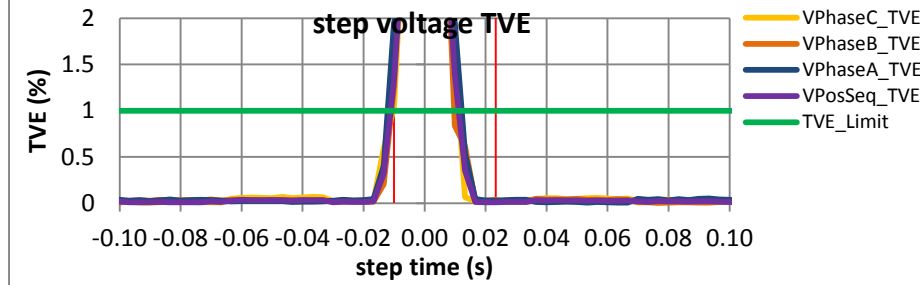


Figure 4253: Fs = 30 FPS, +10 degree phase step

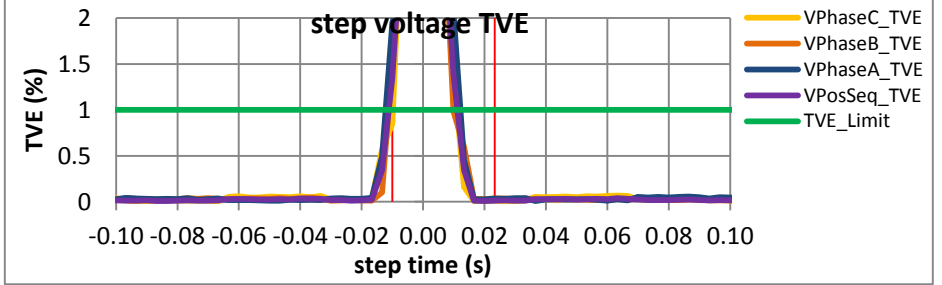


Figure 4254: Fs = 30 FPS, -10 degree phase step

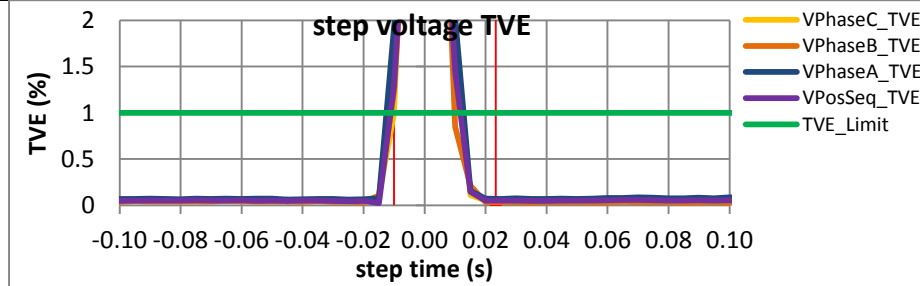


Figure 4255: Fs = 20 FPS, +10 degree phase step

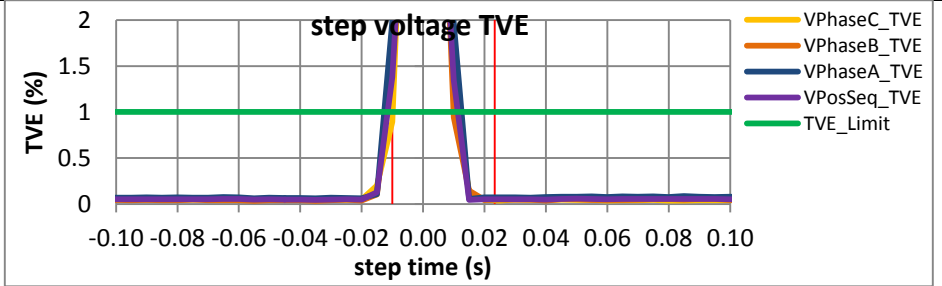


Figure 4256: Fs = 20 FPS, -10 degree phase step

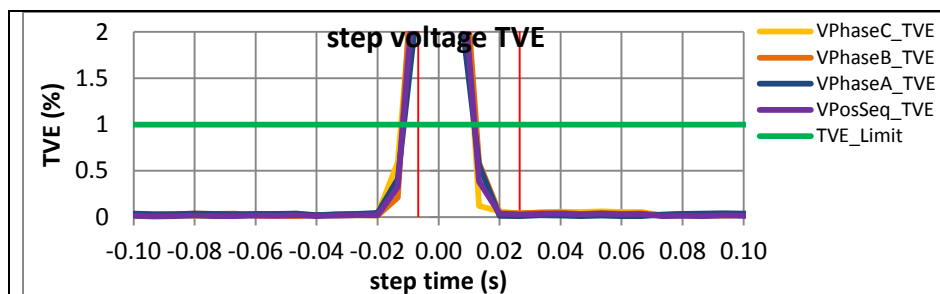


Figure 4257: Fs = 15 FPS, +10 degree phase step

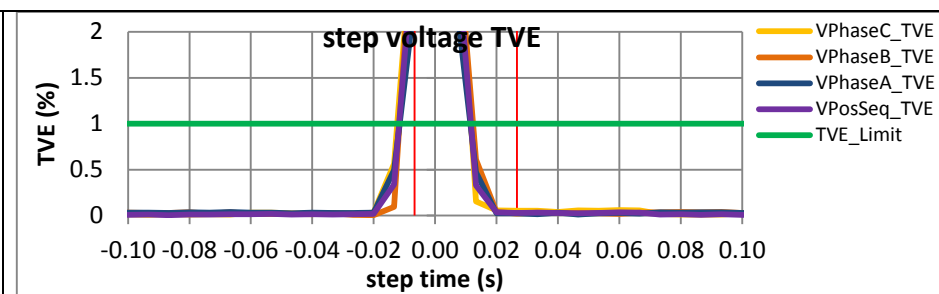


Figure 4258: Fs = 15 FPS, -10 degree phase step

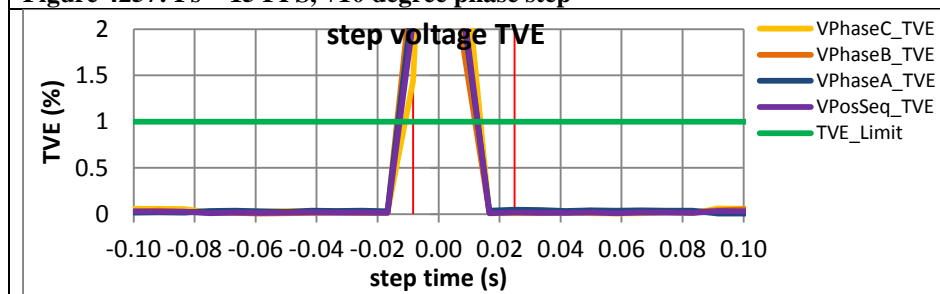


Figure 4259: Fs = 12 FPS, +10 degree phase step

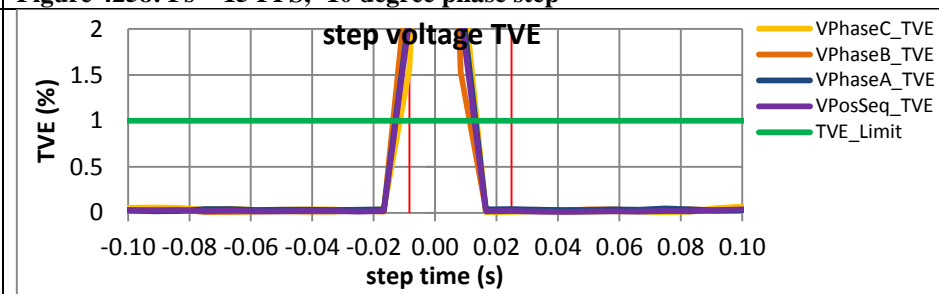


Figure 4260: Fs = 12 FPS, -10 degree phase step

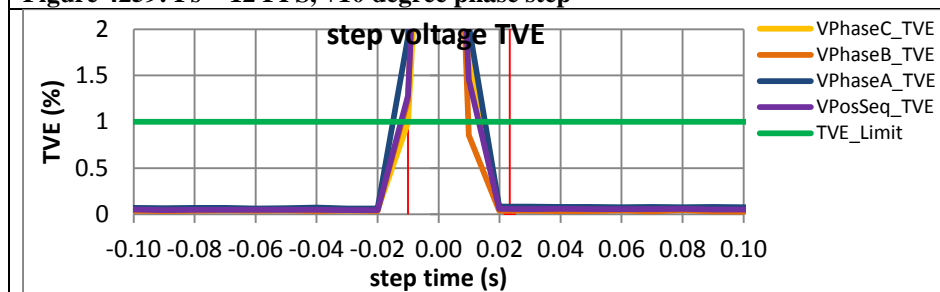


Figure 4261: Fs = 10 FPS, +10 degree phase step

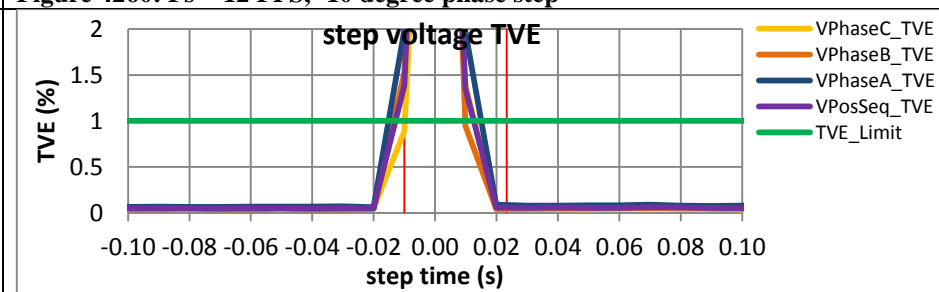
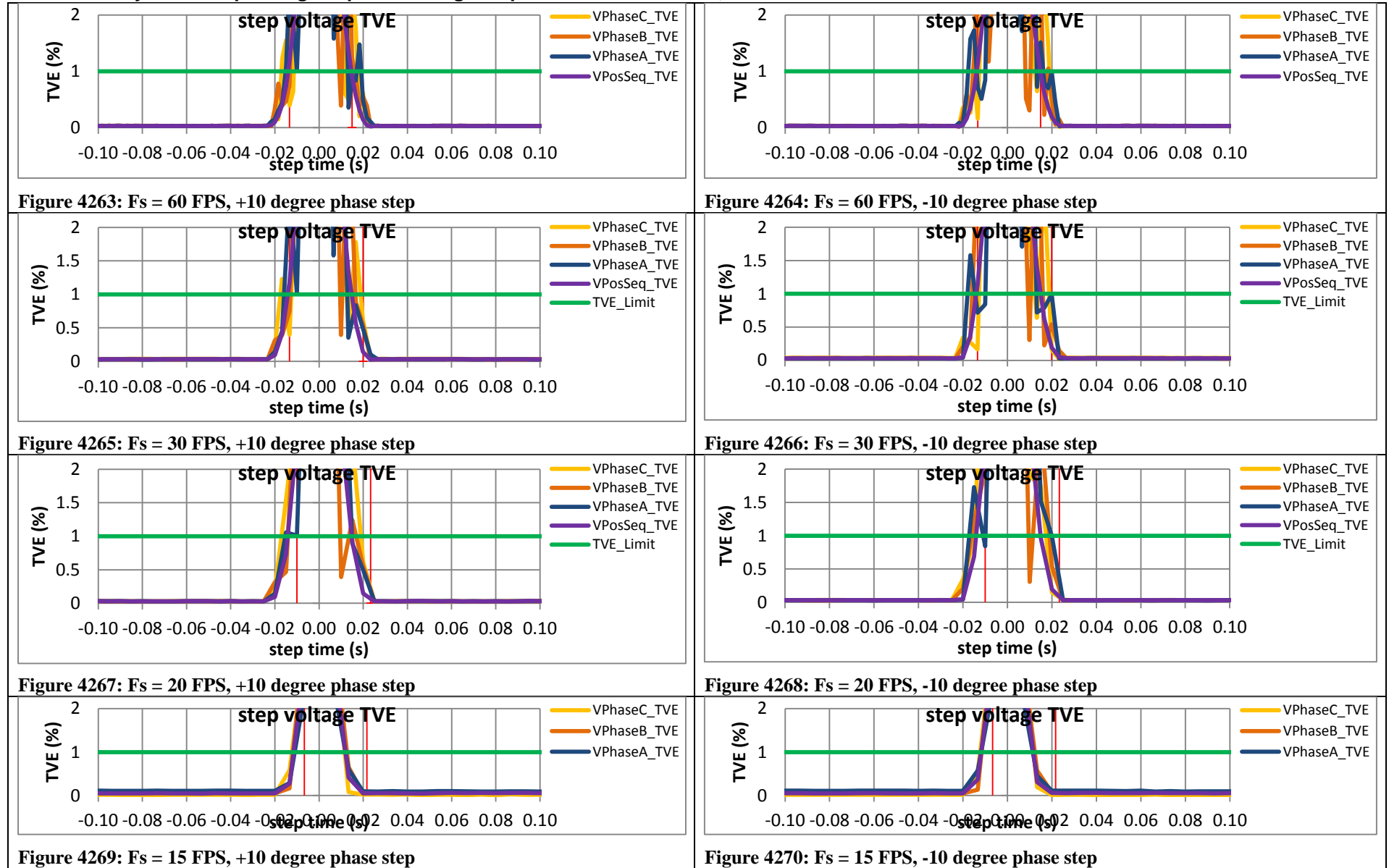


Figure 4262: Fs = 10 FPS, -10 degree phase step

### 9.3.5 PMU D dynamic step change in phase voltage response time: F0 = 60 Hz, P class



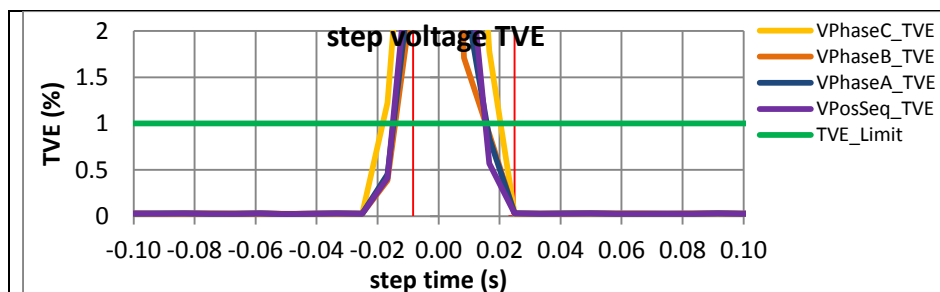


Figure 4271:  $F_s = 12$  FPS, +10 degree phase step

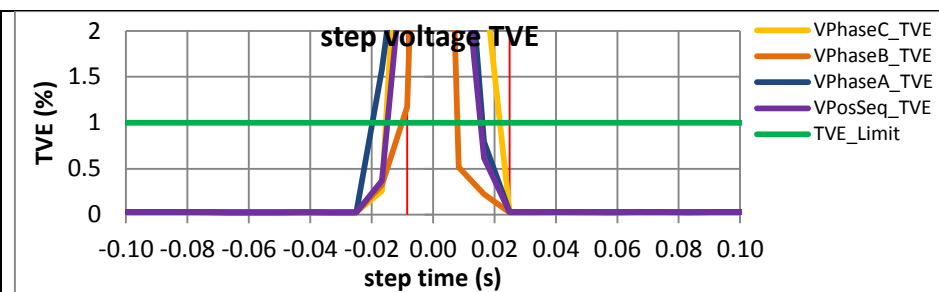


Figure 4272:  $F_s = 12$  FPS, -10 degree phase step

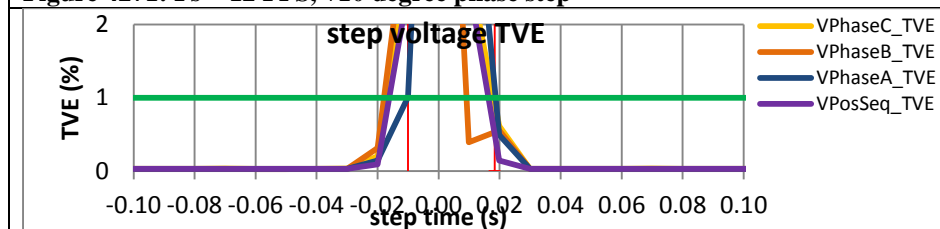


Figure 4273:  $F_s = 10$  FPS, +10 degree phase step

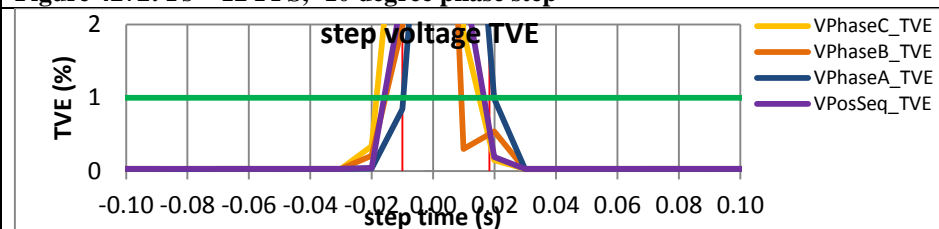
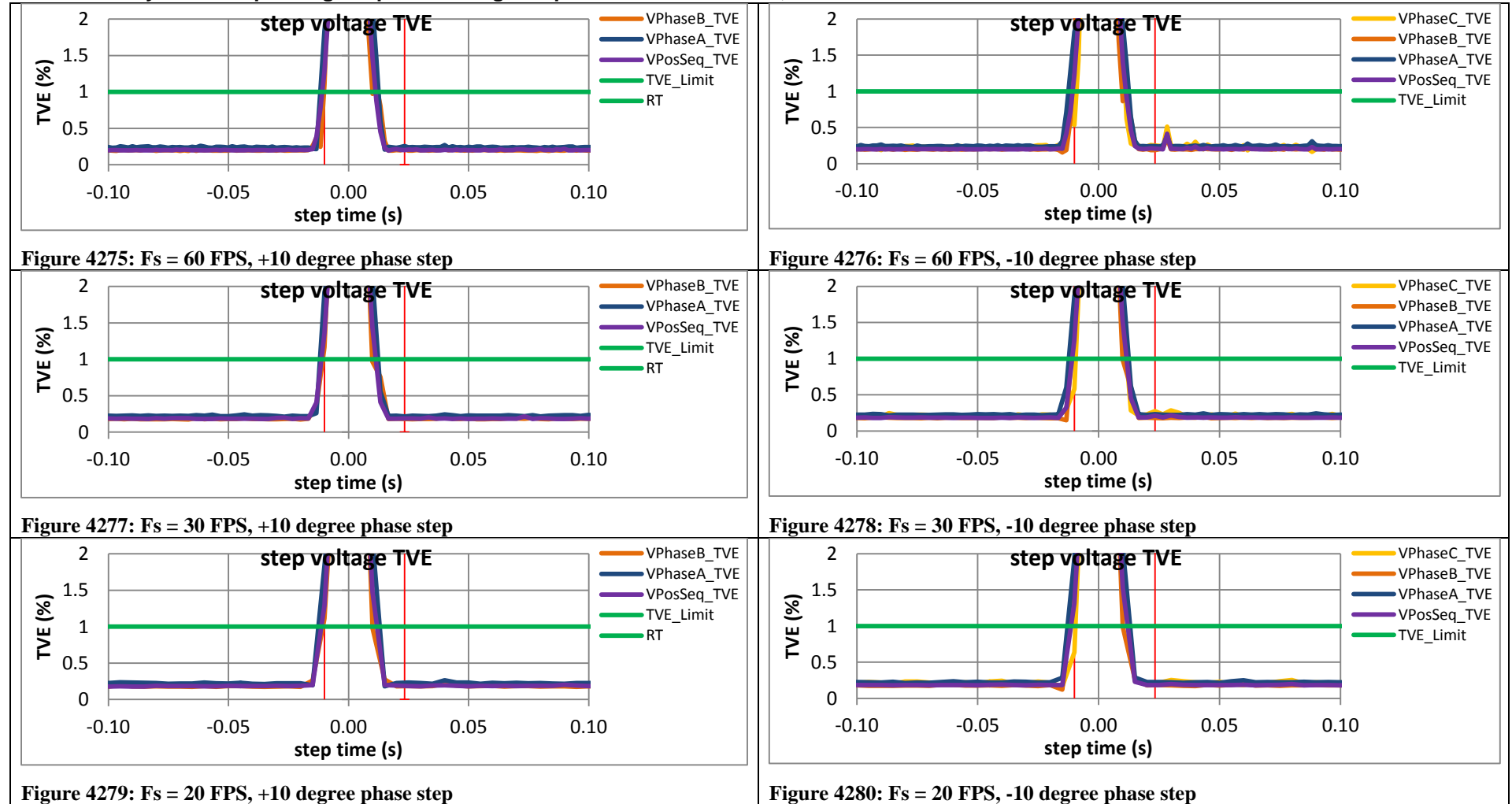


Figure 4274:  $F_s = 10$  FPS, -10 degree phase step

### 9.3.6 PMU E dynamic step change in phase voltage response time: F0 = 60 Hz, P class

PMU E does not support P class.

### 9.3.7 PMU F dynamic step change in phase voltage response time: F0 = 60 Hz, P class



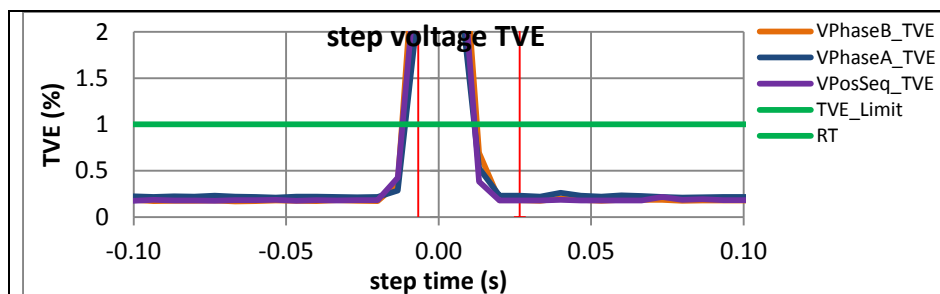


Figure 4281:  $F_s = 15$  FPS, +10 degree phase step

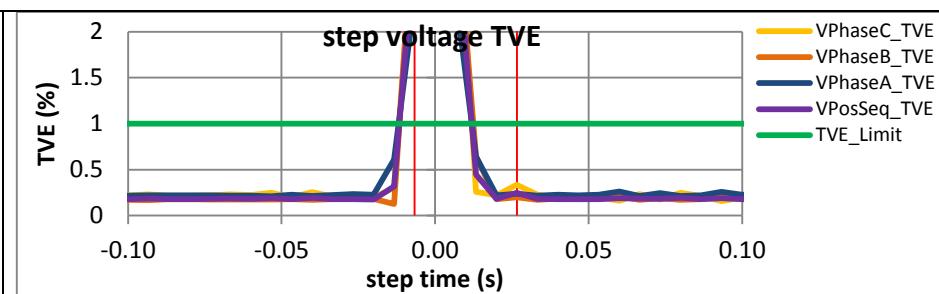


Figure 4282:  $F_s = 15$  FPS, -10 degree phase step

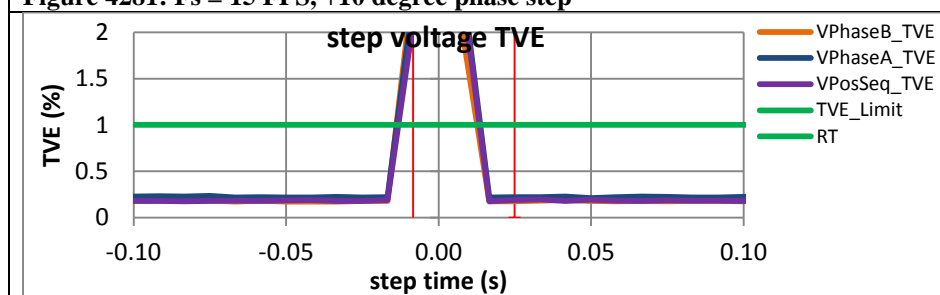


Figure 4283:  $F_s = 12$  FPS, +10 degree phase step

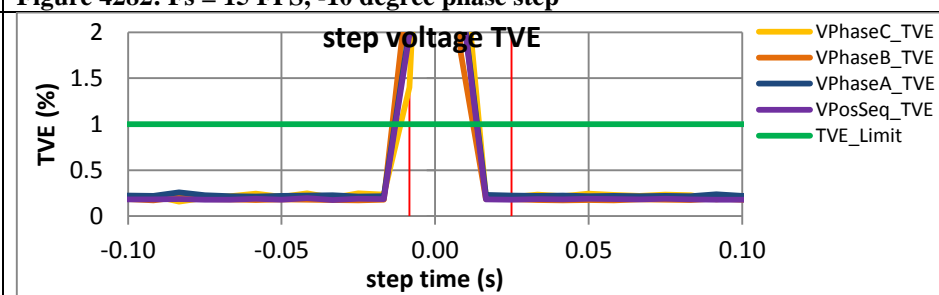


Figure 4284:  $F_s = 12$  FPS, -10 degree phase step

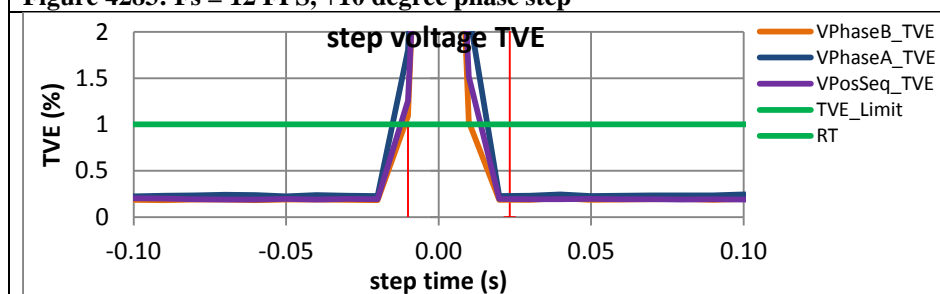


Figure 4285:  $F_s = 10$  FPS, +10 degree phase step

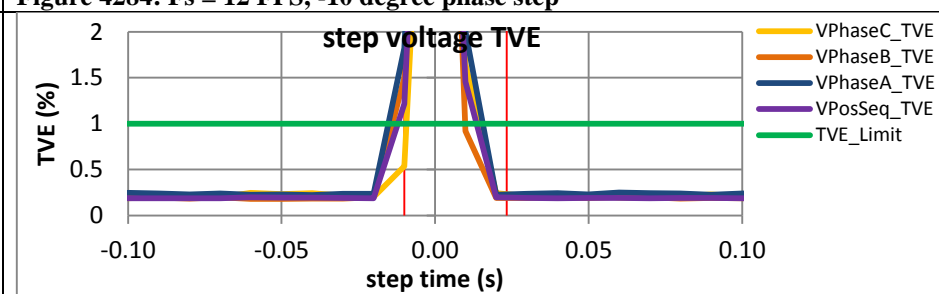
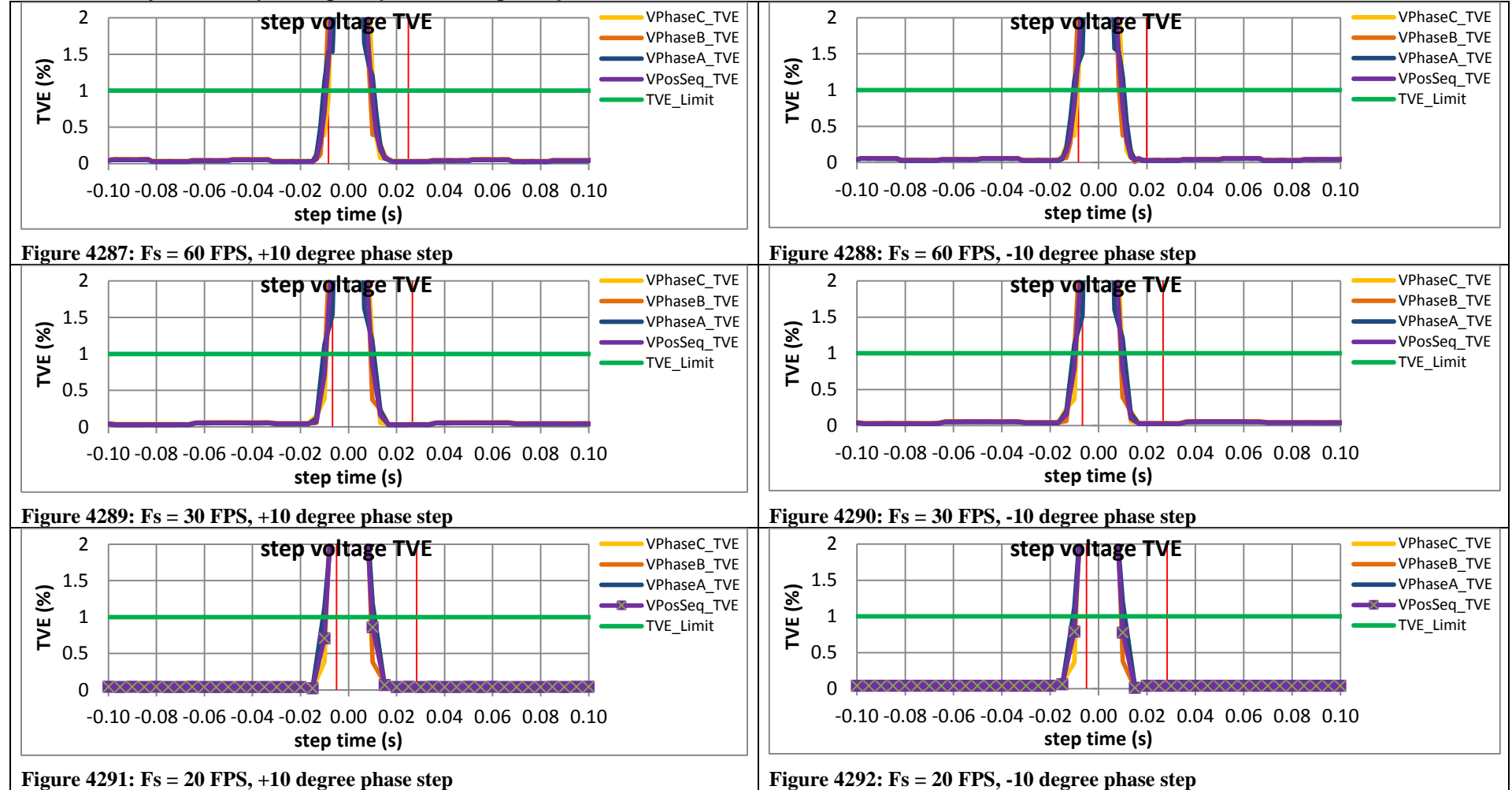


Figure 4286:  $F_s = 10$  FPS, -10 degree phase step

### 9.3.8 PMU G dynamic step change in phase voltage response time: F0 = 60 Hz, P class

PMU G does not support P class.

### 9.3.9 PMU H dynamic step change in phase voltage response time: F0 = 60 Hz, P class





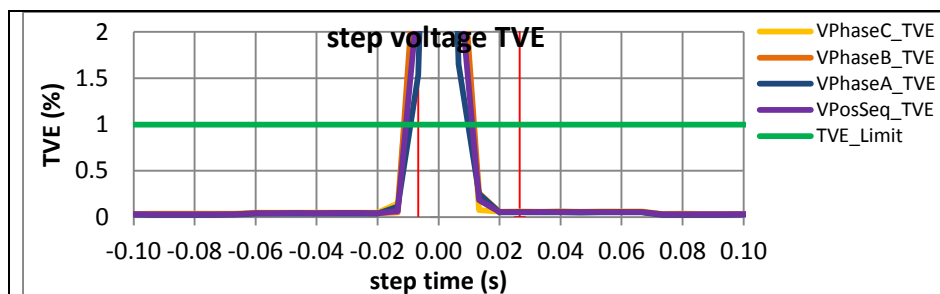


Figure 4293: Fs = 15 FPS, +10 degree phase step

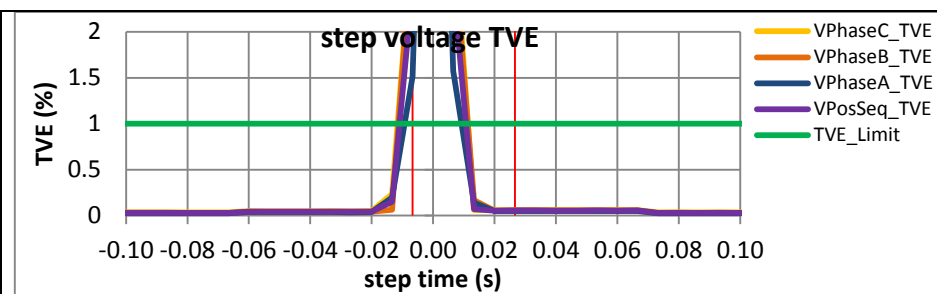


Figure 4294: Fs = 15 FPS, -10 degree phase step

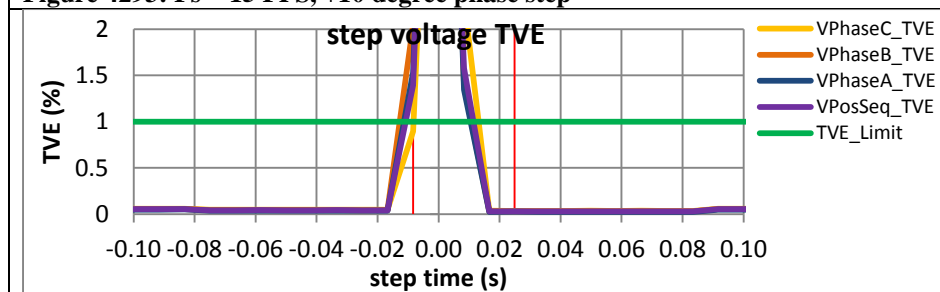


Figure 4295: Fs = 12 FPS, +10 degree phase step

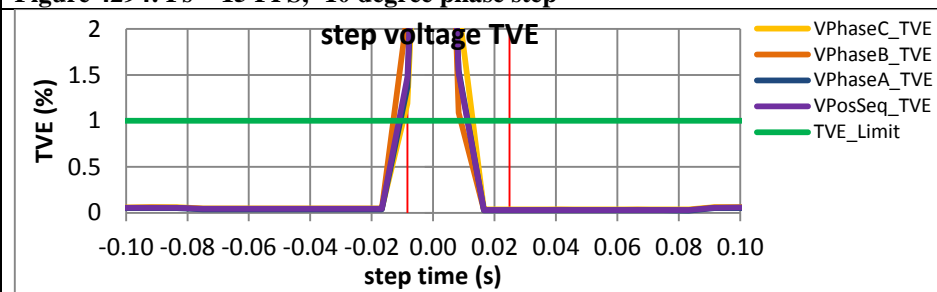


Figure 4296: Fs = 12 FPS, -10 degree phase step

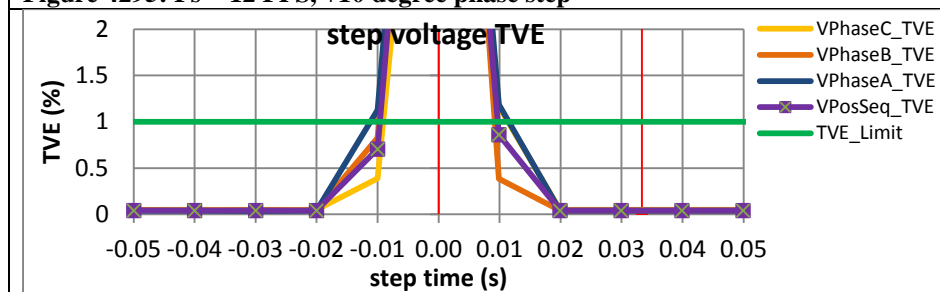


Figure 4297: Fs = 10 FPS, +10 degree phase step

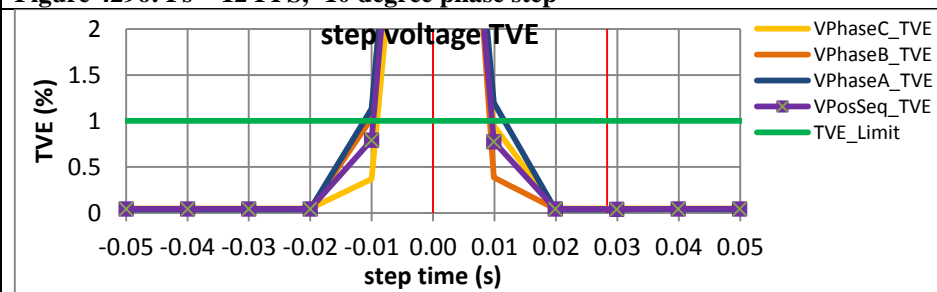
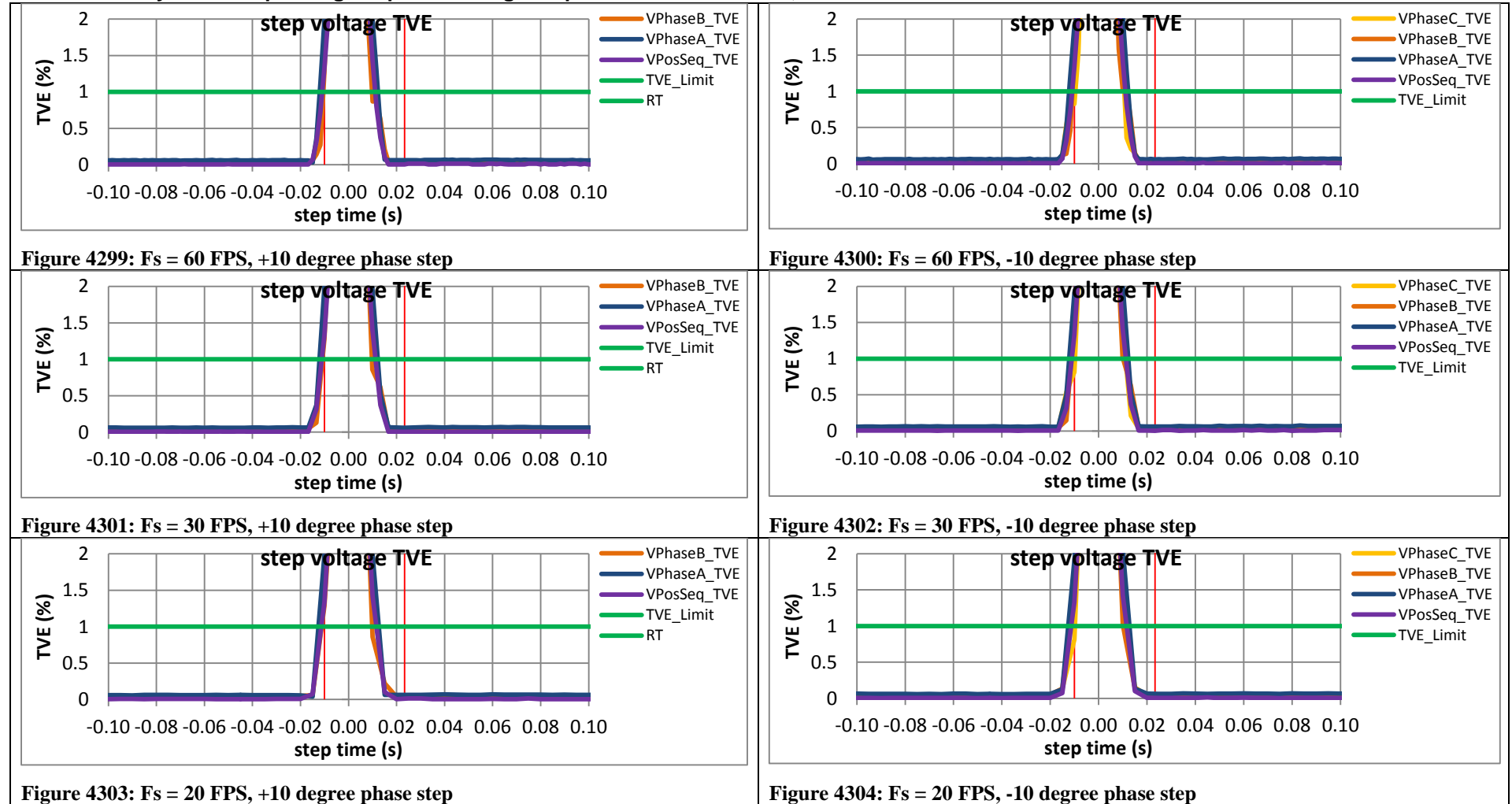


Figure 4298: Fs = 10 FPS, -10 degree phase step

### 9.3.10 PMU I dynamic step change in phase voltage response time: F0 = 60 Hz, P class

PMU I does not support P class

### 9.3.11 PMU J dynamic step change in phase voltage response time: F0 = 60 Hz, P class



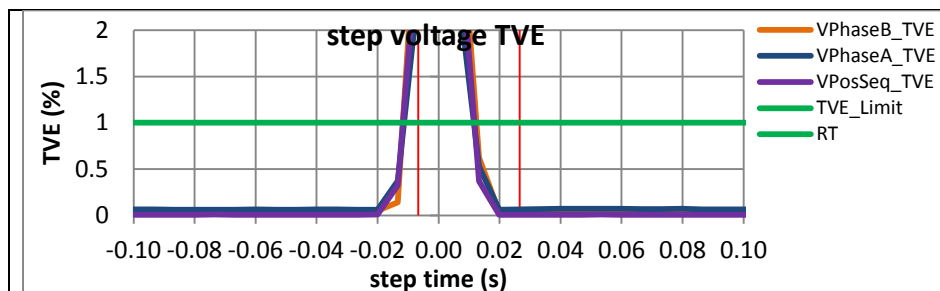


Figure 4305:  $F_s = 15$  FPS, +10 degree phase step

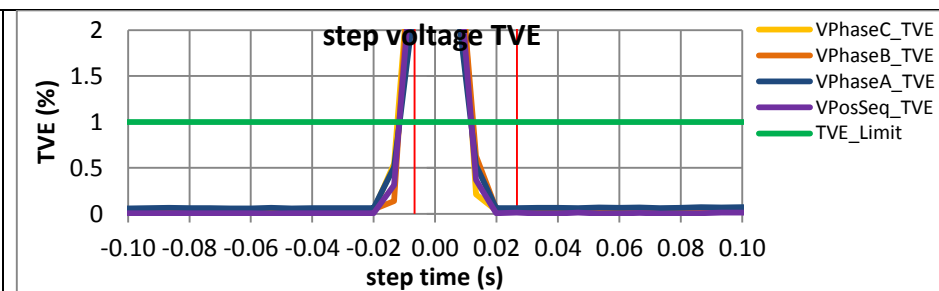


Figure 4306:  $F_s = 15$  FPS, -10 degree phase step

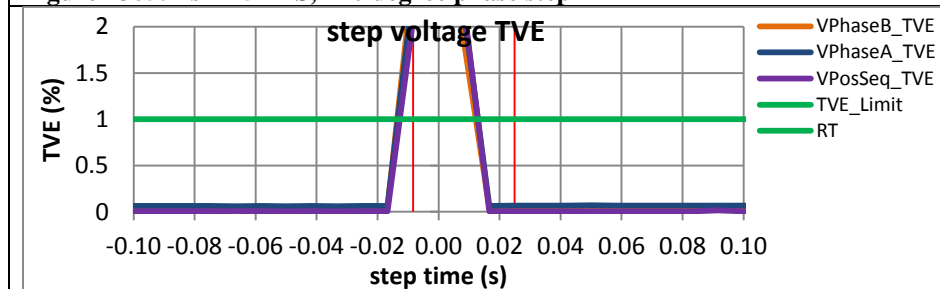


Figure 4307:  $F_s = 12$  FPS, +10 degree phase step

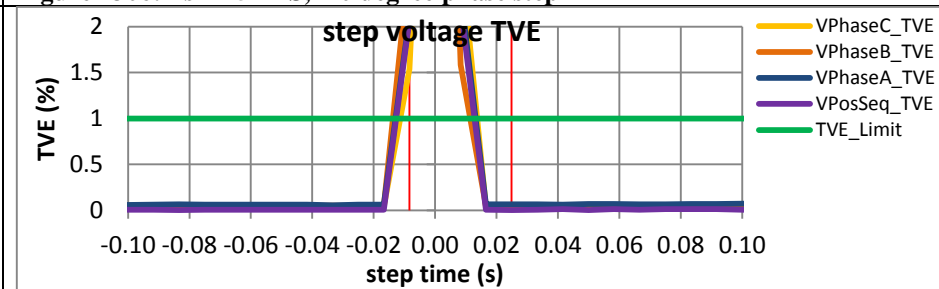


Figure 4308:  $F_s = 12$  FPS, -10 degree phase step

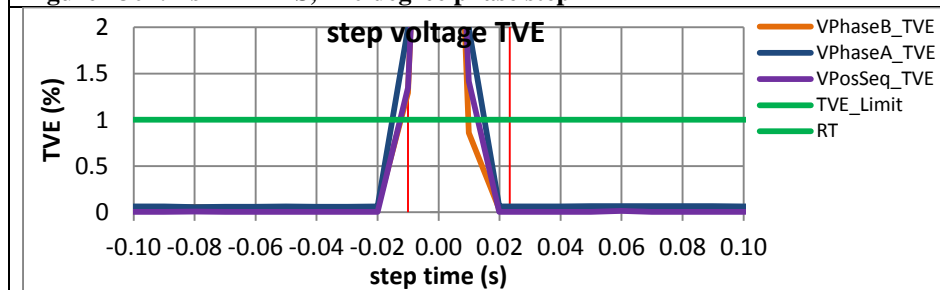


Figure 4309:  $F_s = 10$  FPS, +10 degree phase step

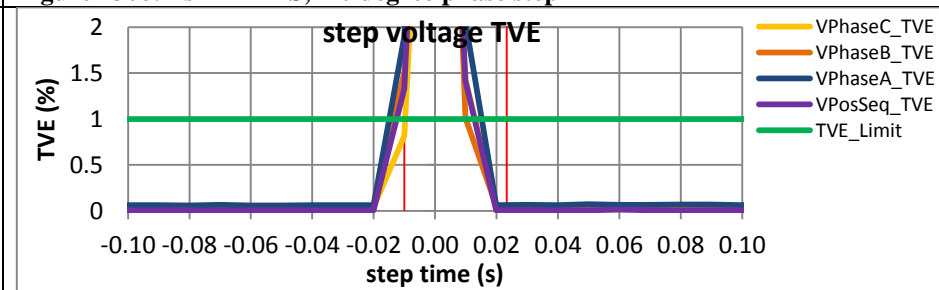


Figure 4310:  $F_s = 10$  FPS, -10 degree phase step

## 9.4 Dynamic step change in phase current response time: $F_0 = 60$ Hz, P Class

### 9.4.1 C37.118.1-2011 Annex C dynamic step change in phase current response time: $F_0 = 60$ Hz, P class

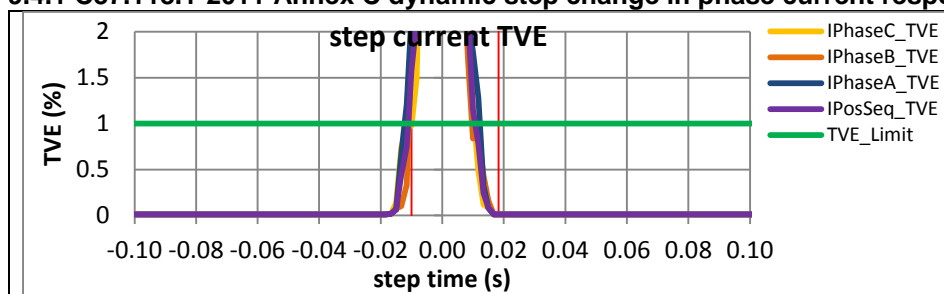


Figure 4311:  $F_s = 60$  FPS, +10 degree phase step

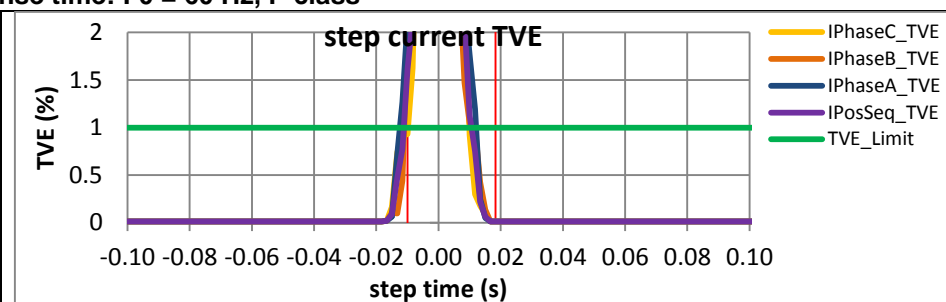


Figure 4312:  $F_s = 60$  FPS, -10 degree phase step

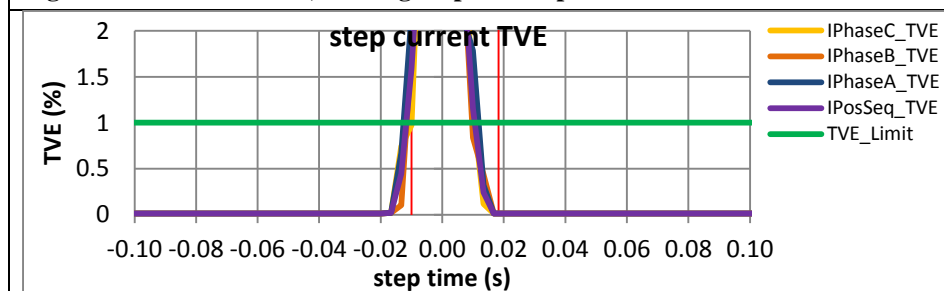


Figure 4313:  $F_s = 30$  FPS, +10 degree phase step

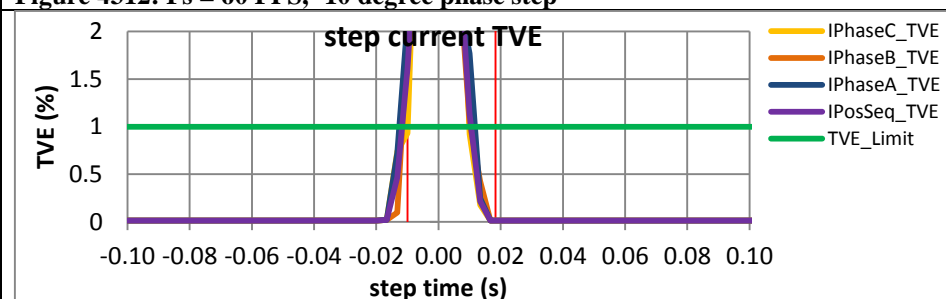


Figure 4314:  $F_s = 30$  FPS, -10 degree phase step

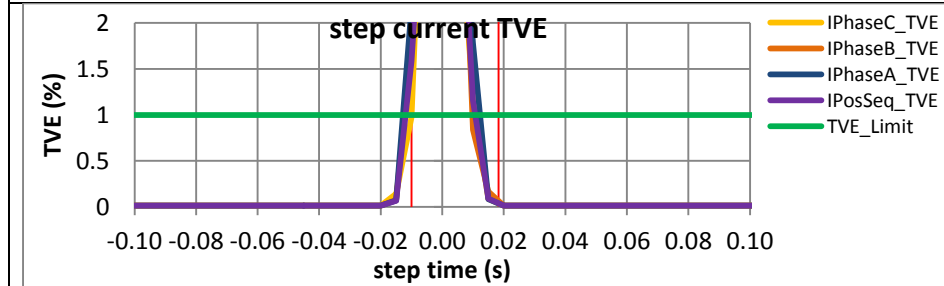


Figure 4315:  $F_s = 20$  FPS, +10 degree phase step

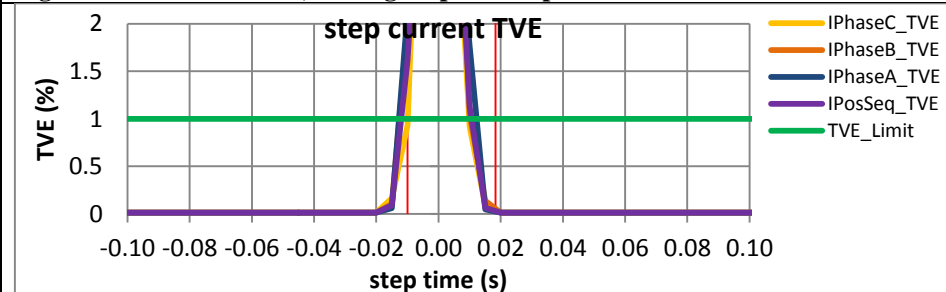


Figure 4316:  $F_s = 20$  FPS, -10 degree phase step

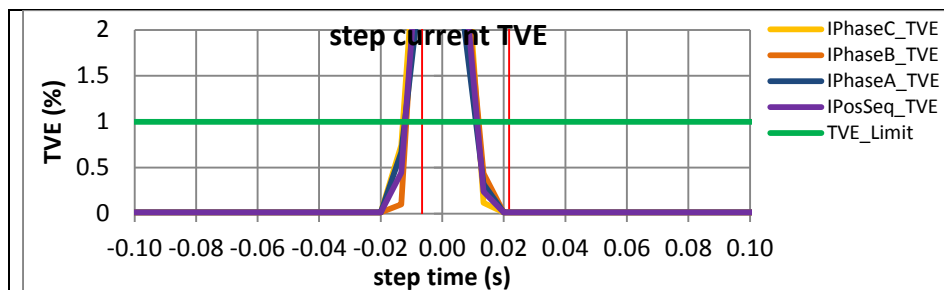


Figure 4317:  $F_s = 15$  FPS, +10 degree phase step

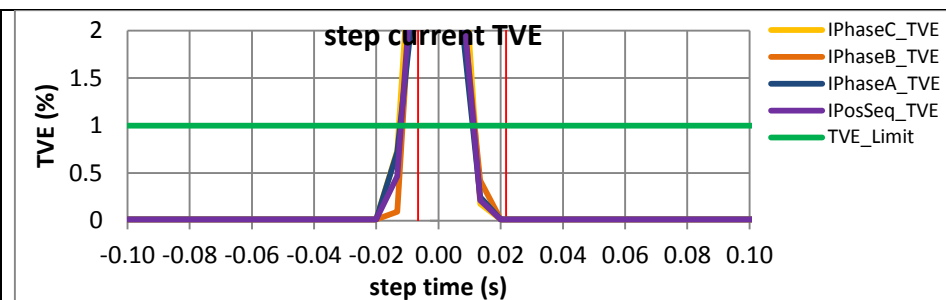


Figure 4318:  $F_s = 15$  FPS, -10 degree phase step

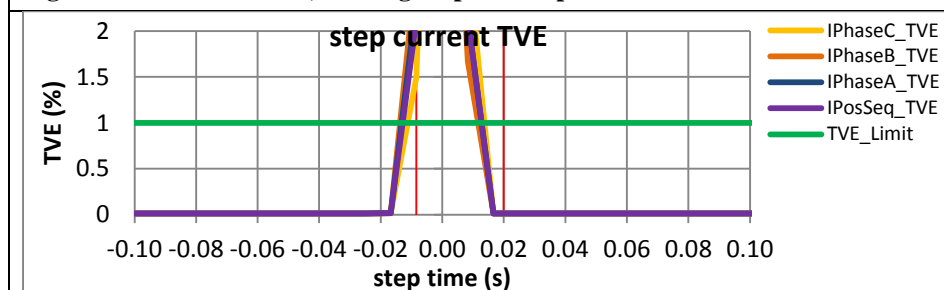


Figure 4319:  $F_s = 12$  FPS, +10 degree phase step

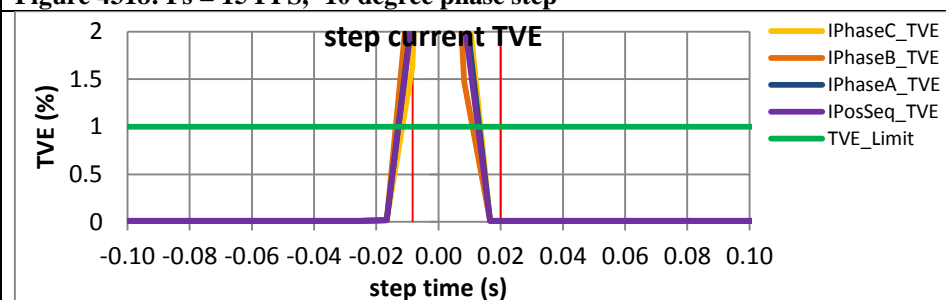


Figure 4320:  $F_s = 12$  FPS, -10 degree phase step

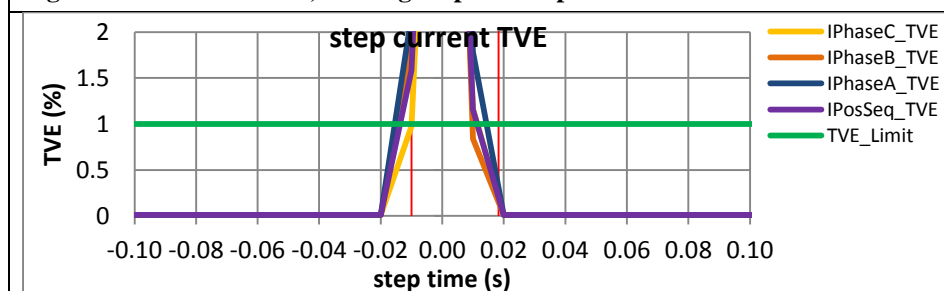


Figure 4321:  $F_s = 10$  FPS, +10 degree phase step

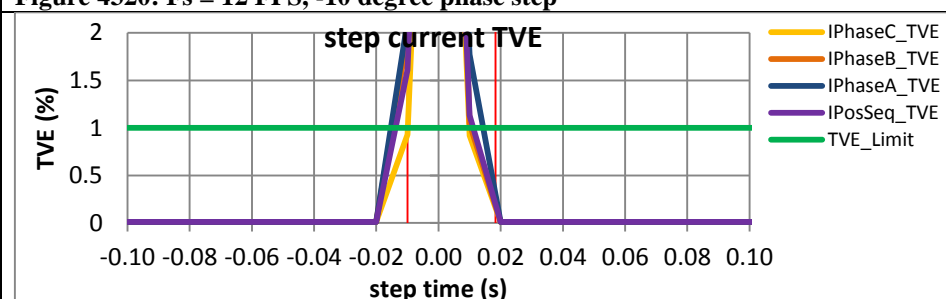


Figure 4322:  $F_s = 10$  FPS, -10 degree phase step

#### 9.4.2 PMU A dynamic step change in phase current response time: F0 = 60 Hz, P class

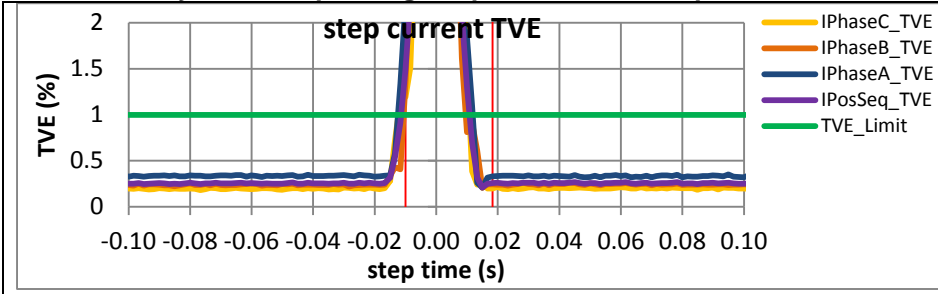


Figure 4323: Fs = 60 FPS, +10 degree phase step

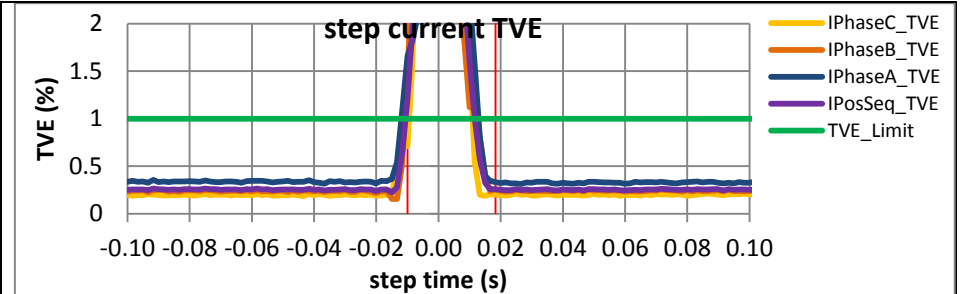


Figure 4324: Fs = 60 FPS, -10 degree phase step

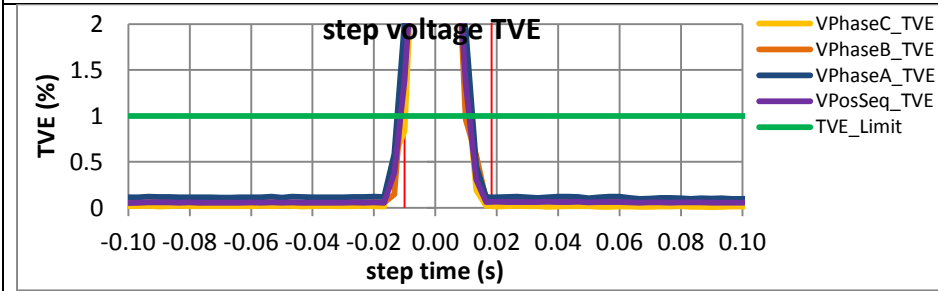


Figure 4325: Fs = 30 FPS, +10 degree phase step

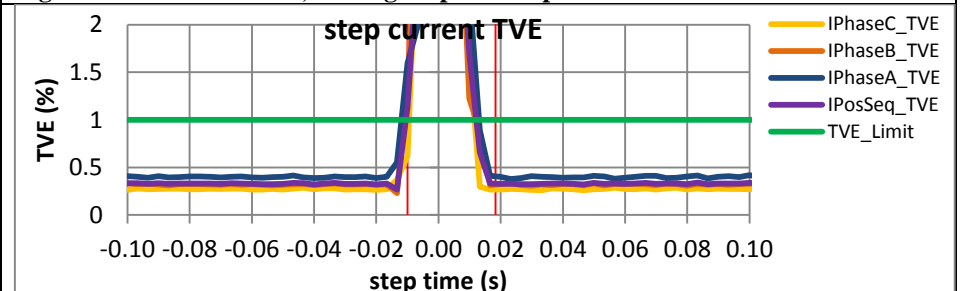


Figure 4326: Fs = 30 FPS, -10 degree phase step

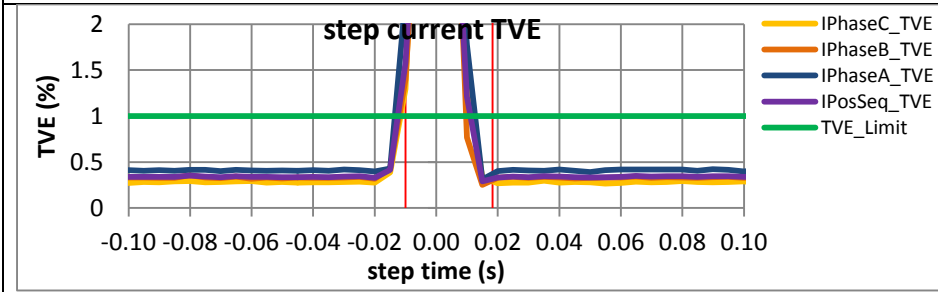


Figure 4327: Fs = 20 FPS, +10 degree phase step

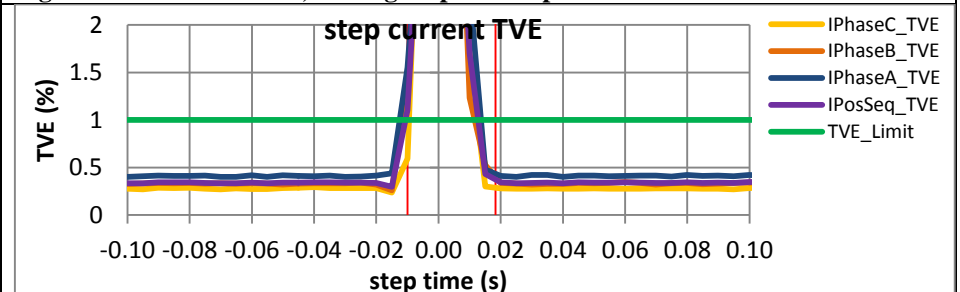


Figure 4328: Fs = 20 FPS, -10 degree phase step

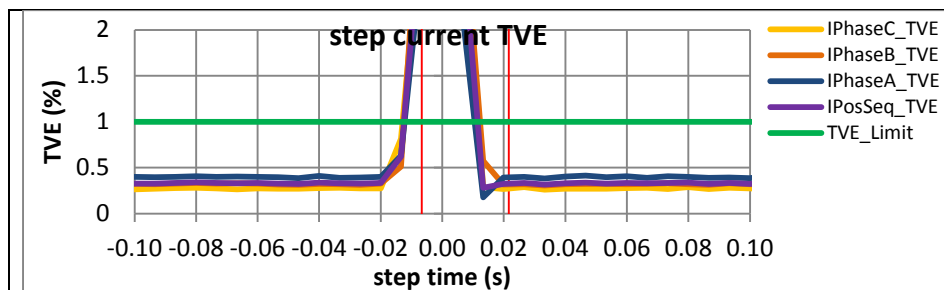


Figure 4329: Fs = 15 FPS, +10 degree phase step

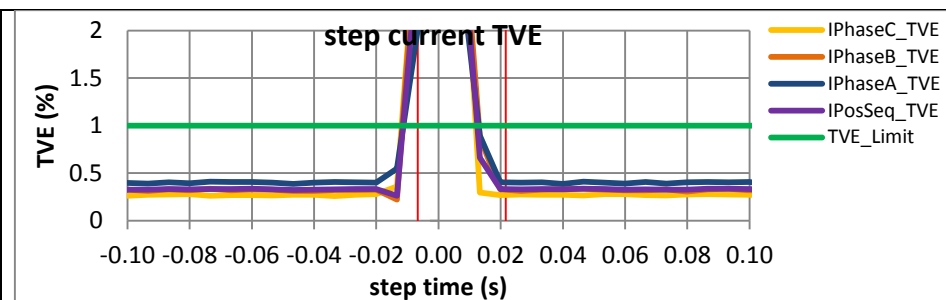


Figure 4330: Fs = 15 FPS, -10 degree phase step

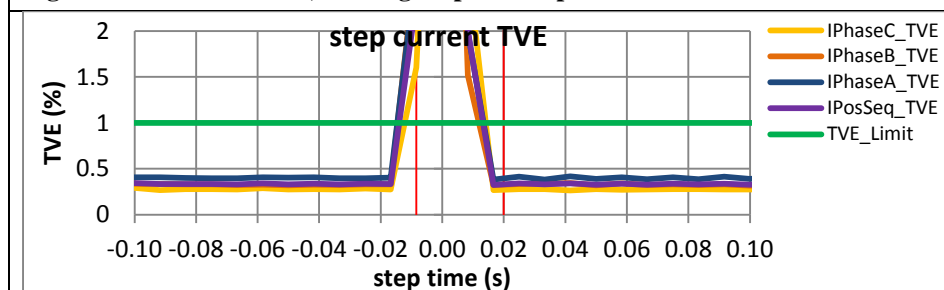


Figure 4331: Fs = 12 FPS, +10 degree phase step

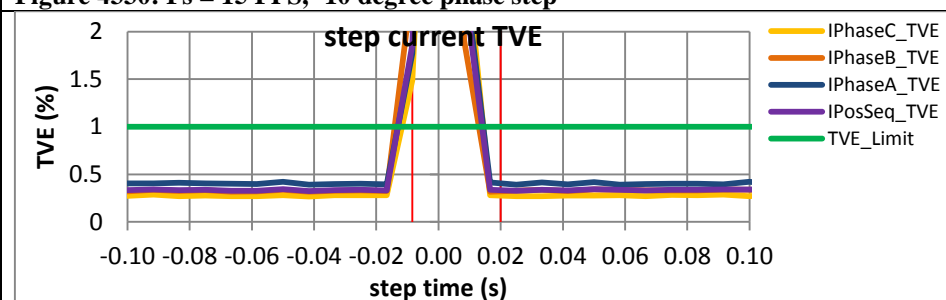


Figure 4332: Fs = 12 FPS, -10 degree phase step

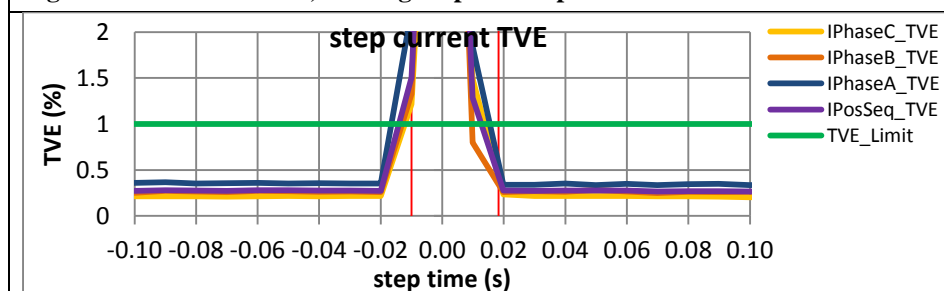


Figure 4333: Fs = 10 FPS, +10 degree phase step

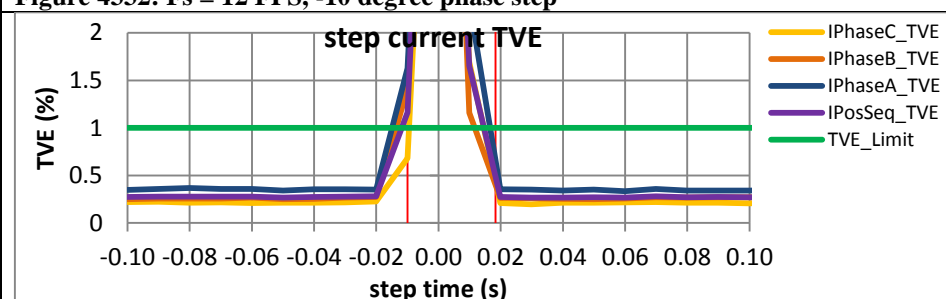


Figure 4334: Fs = 10 FPS, -10 degree phase step

#### 9.4.3 PMU B dynamic step change in phase current response time: F0 = 60 Hz, P class

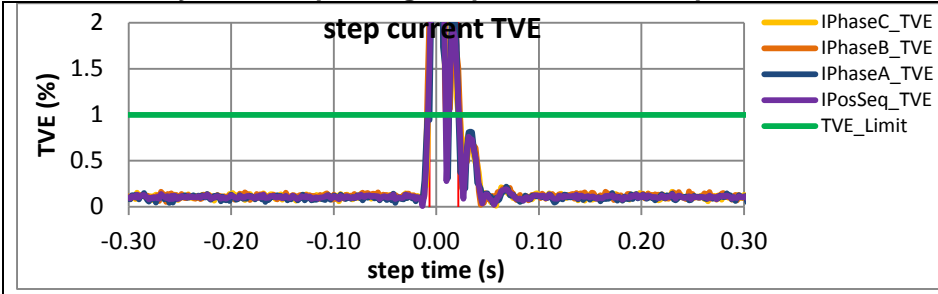


Figure 4335: Fs = 60 FPS, +10 degree phase step

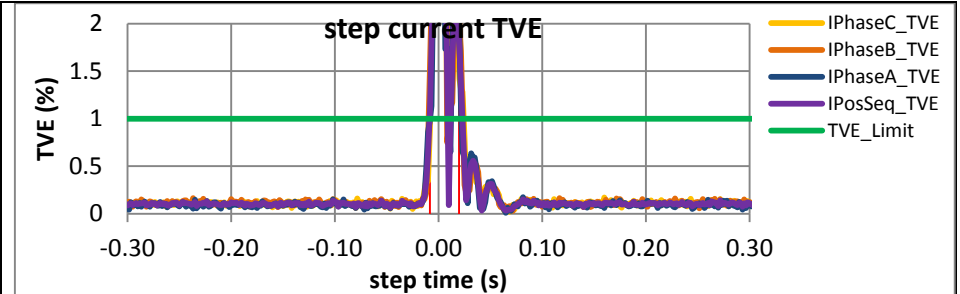


Figure 4336: Fs = 60 FPS, -10 degree phase step

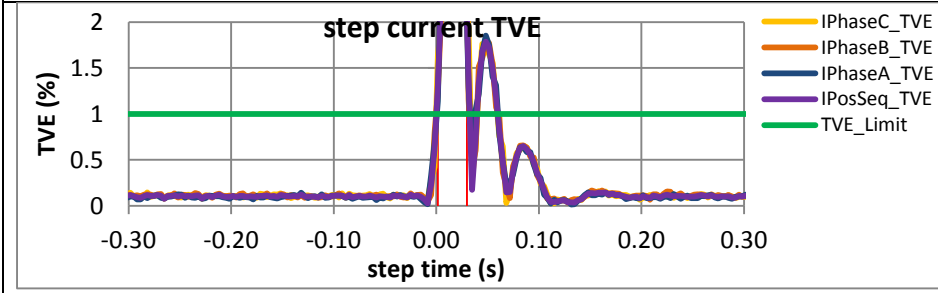


Figure 4337: Fs = 30 FPS, +10 degree phase step

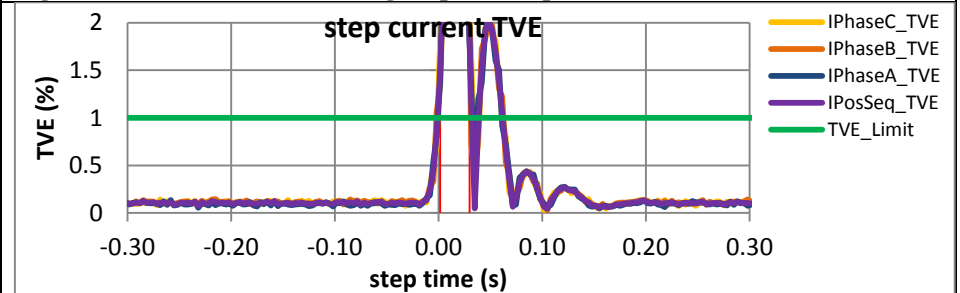


Figure 4338: Fs = 30 FPS, -10 degree phase step

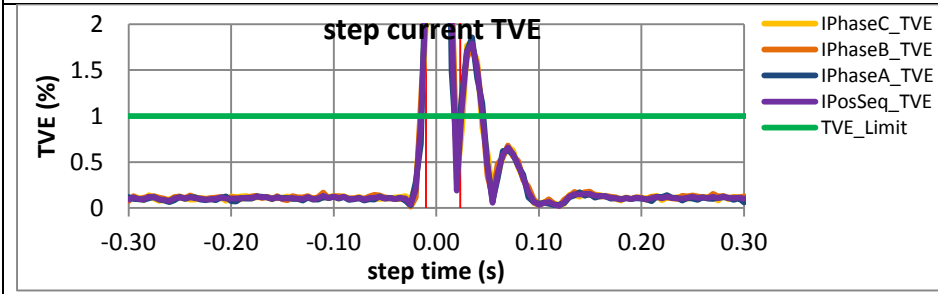


Figure 4339: Fs = 20 FPS, +10 degree phase step

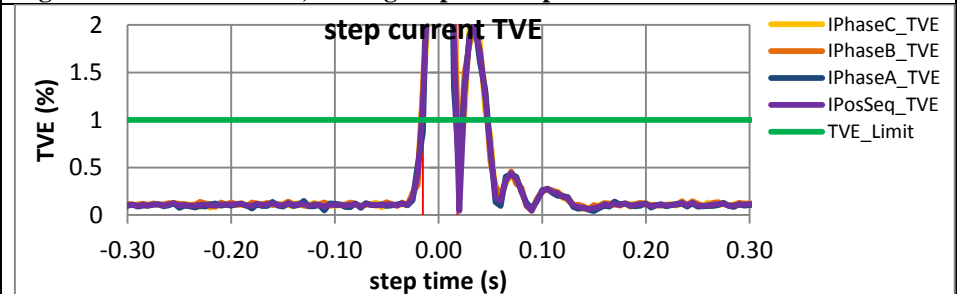


Figure 4340: Fs = 20 FPS, -10 degree phase step



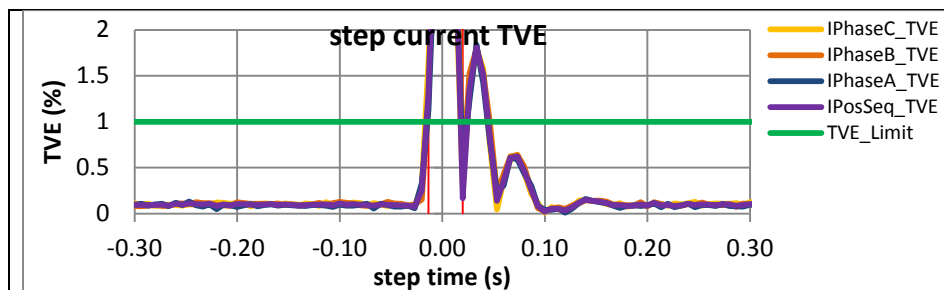


Figure 4341:  $F_s = 15$  FPS, +10 degree phase step

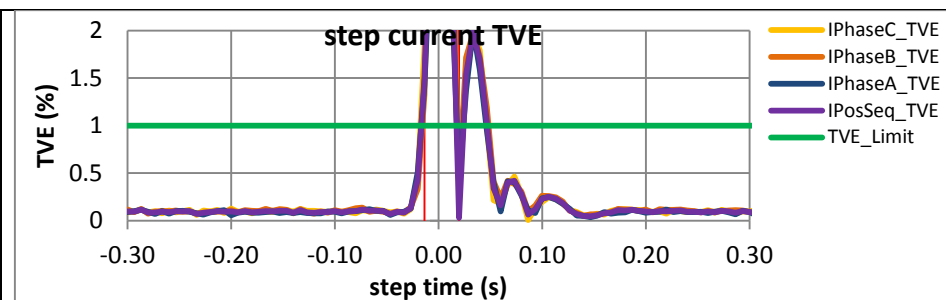


Figure 4342:  $F_s = 15$  FPS, -10 degree phase step

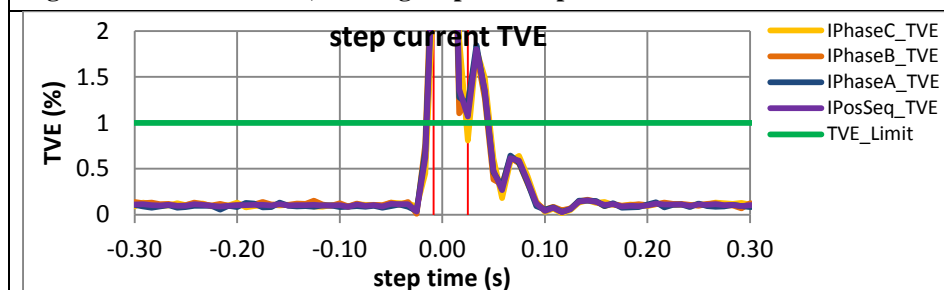


Figure 4343:  $F_s = 12$  FPS, +10 degree phase step

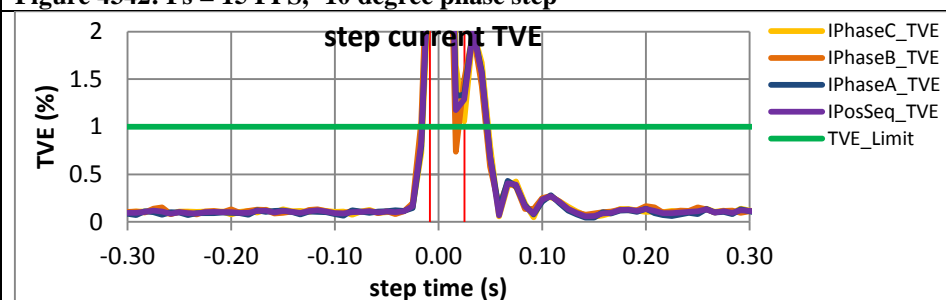


Figure 4344:  $F_s = 12$  FPS, -10 degree phase step

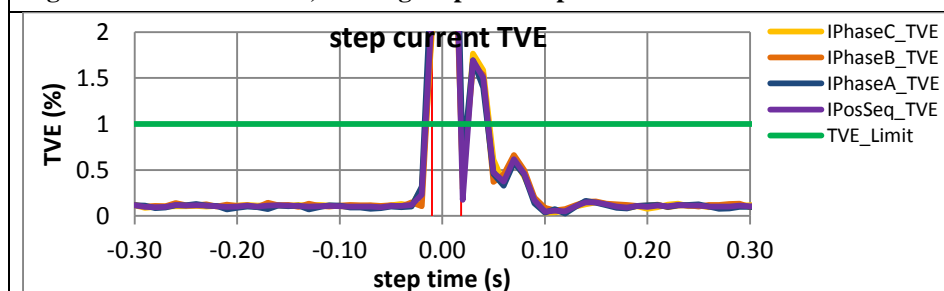


Figure 4345:  $F_s = 10$  FPS, +10 degree phase step

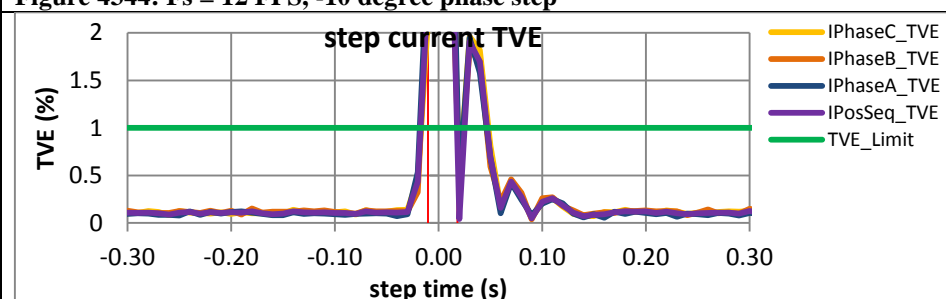


Figure 4346:  $F_s = 10$  FPS, -10 degree phase step

#### 9.4.4 PMU C dynamic step change in phase current response time: F0 = 60 Hz, P class

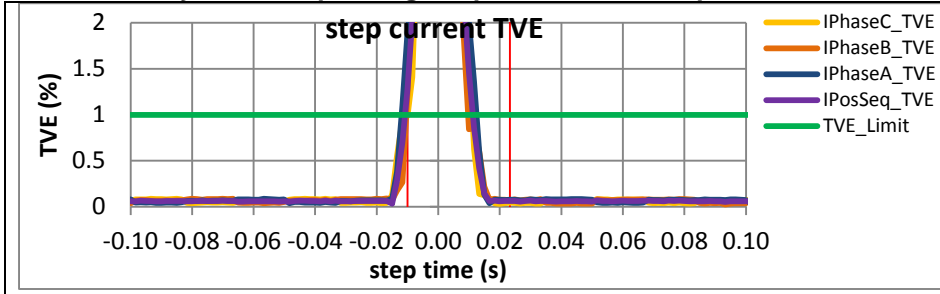


Figure 4347: Fs = 60 FPS, +10 degree phase step

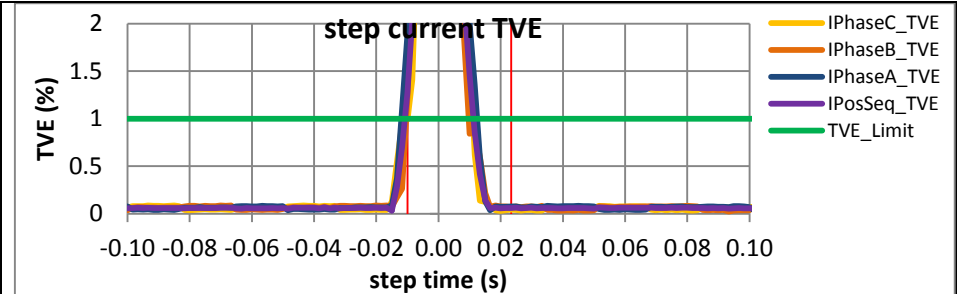


Figure 4348: Fs = 60 FPS, -10 degree phase step

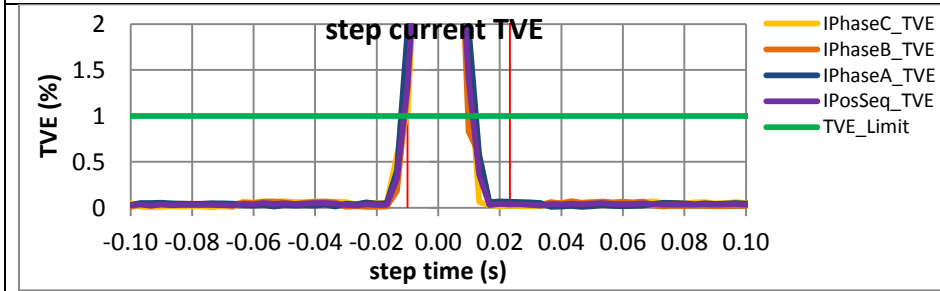


Figure 4349: Fs = 30 FPS, +10 degree phase step

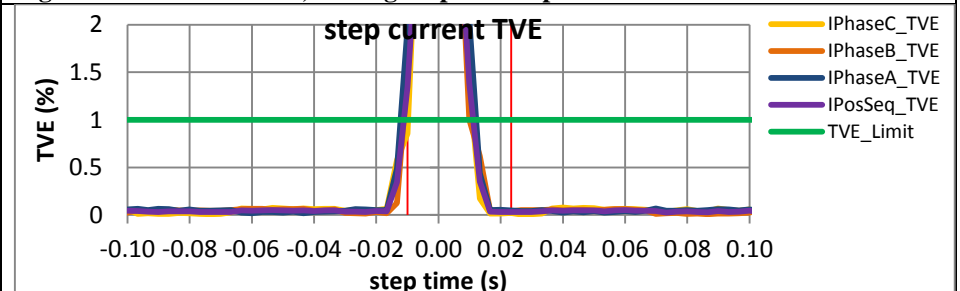


Figure 4350: Fs = 30 FPS, -10 degree phase step

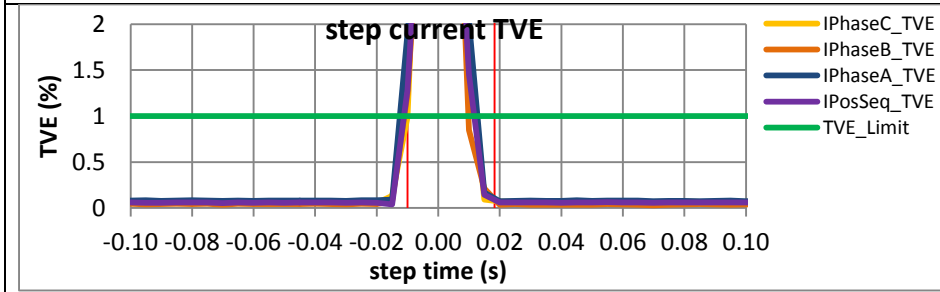


Figure 4351: Fs = 20 FPS, +10 degree phase step

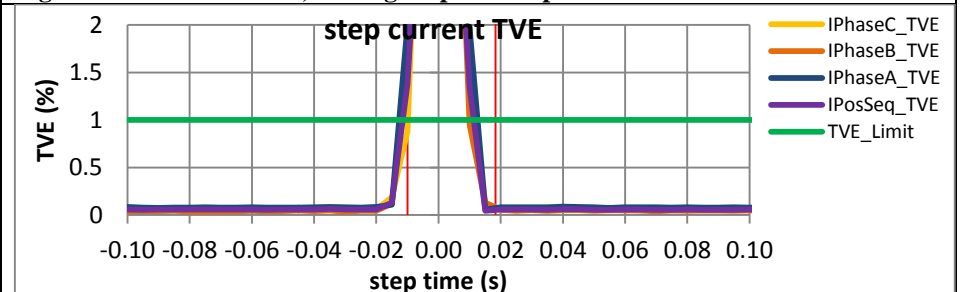


Figure 4352: Fs = 20 FPS, -10 degree phase step

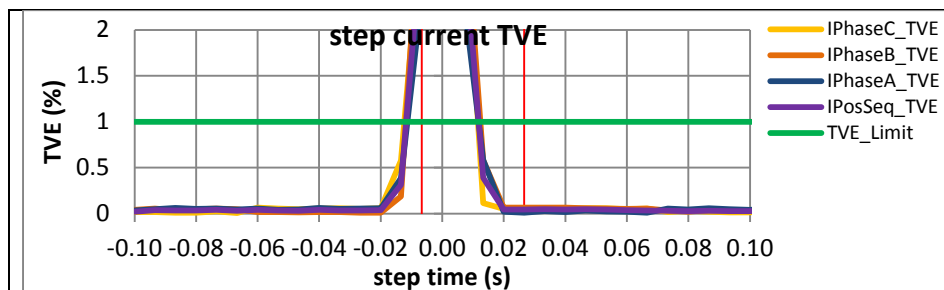


Figure 4353: Fs = 15 FPS, +10 degree phase step

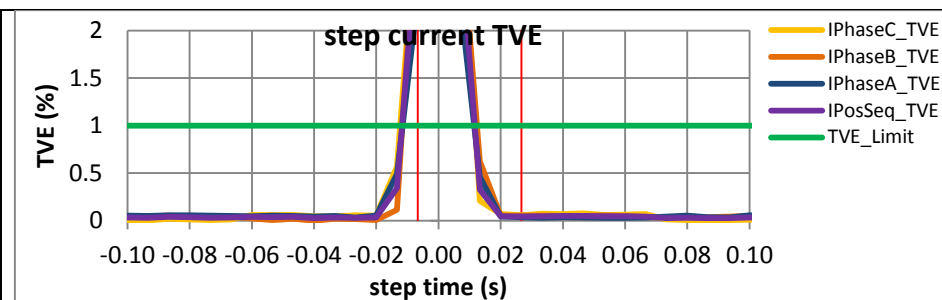


Figure 4354: Fs = 15 FPS, -10 degree phase step

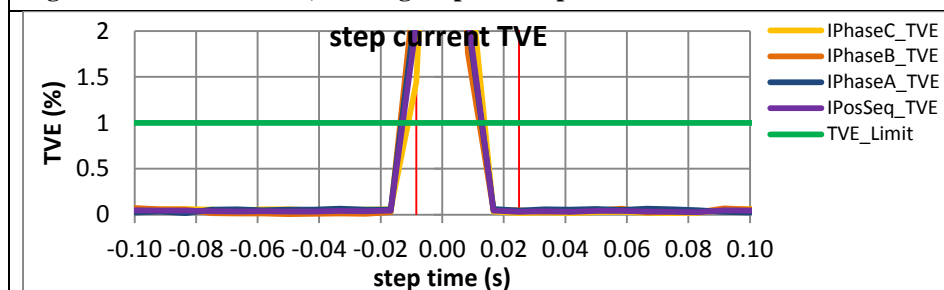


Figure 4355: Fs = 12 FPS, +10 degree phase step

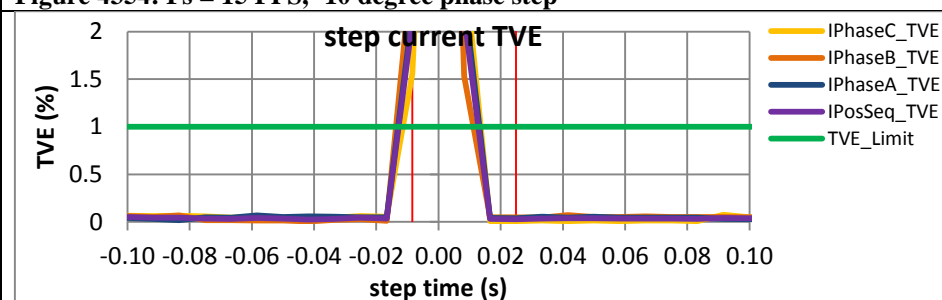


Figure 4356: Fs = 12 FPS, -10 degree phase step

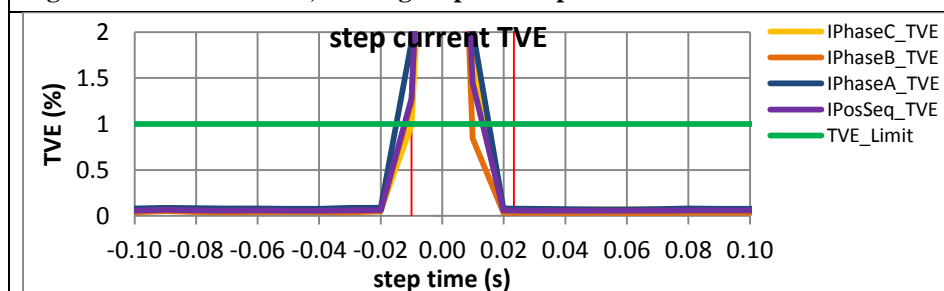


Figure 4357: Fs = 10 FPS, +10 degree phase step

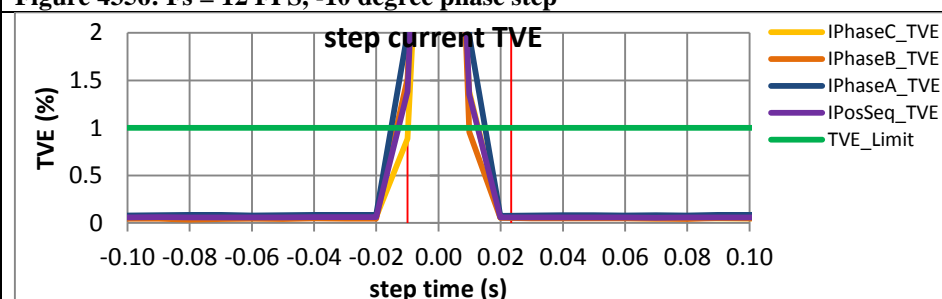


Figure 4358: Fs = 10 FPS, -10 degree phase step

#### 9.4.5 PMU D dynamic step change in phase current response time: F0 = 60 Hz, P class

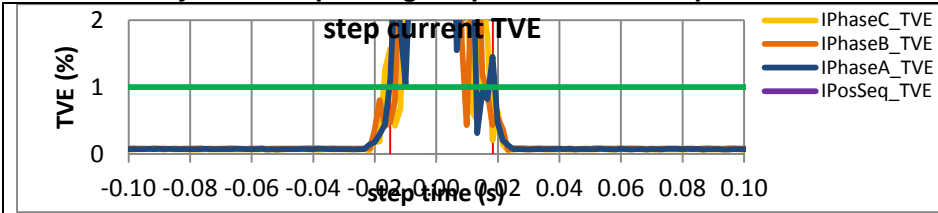


Figure 4359: Fs = 60 FPS, +10 degree phase step

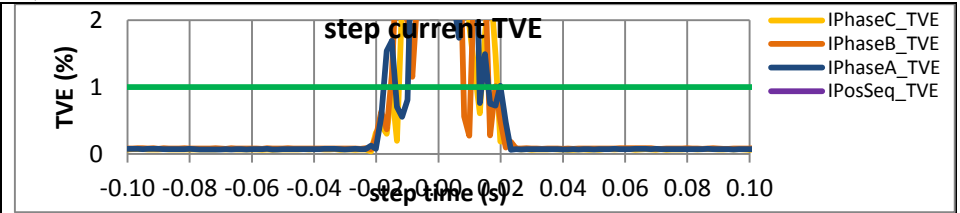


Figure 4360: Fs = 60 FPS, -10 degree phase step

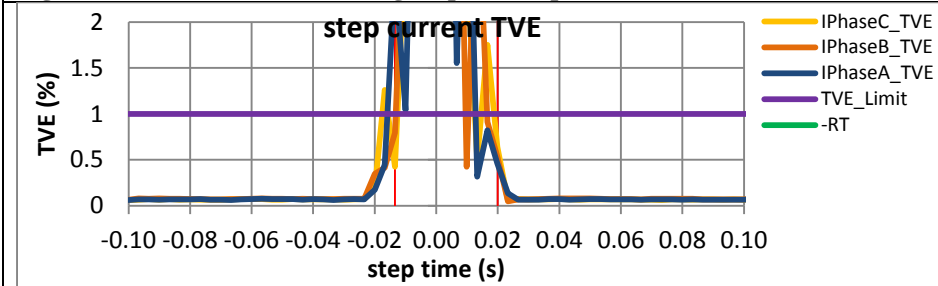


Figure 4361: Fs = 30 FPS, +10 degree phase step

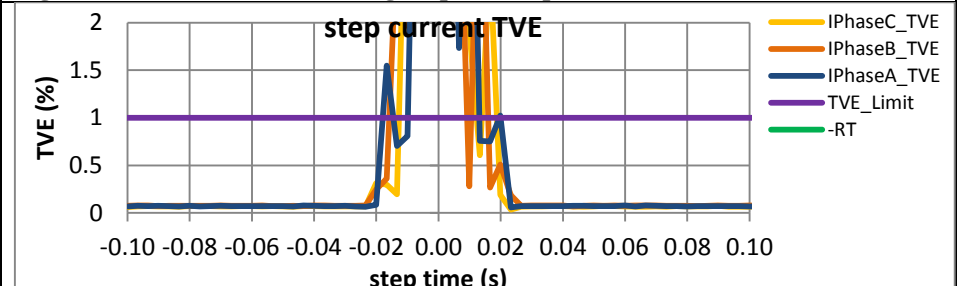


Figure 4362: Fs = 30 FPS, -10 degree phase step

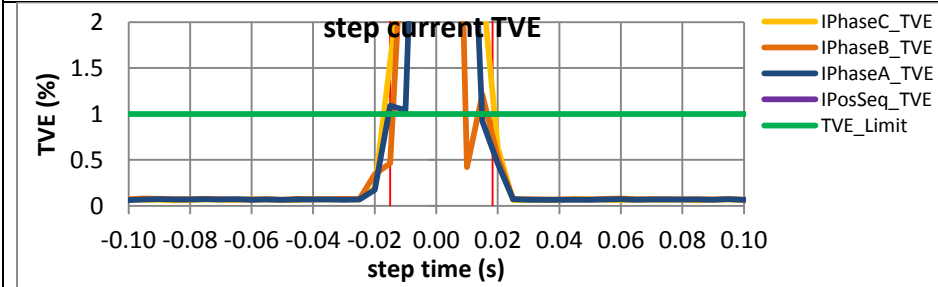


Figure 4363: Fs = 20 FPS, +10 degree phase step

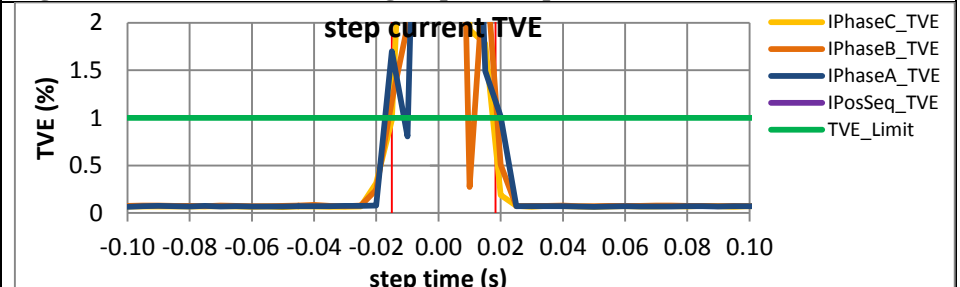


Figure 4364: Fs = 20 FPS, -10 degree phase step

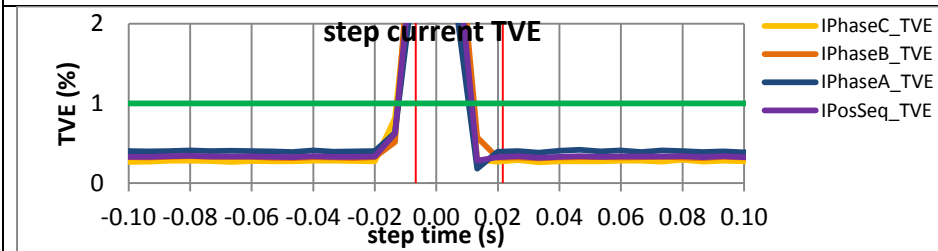


Figure 4365: Fs = 15 FPS, +10 degree phase step

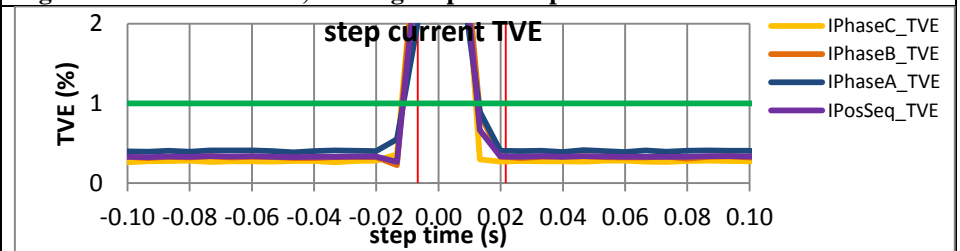


Figure 4366: Fs = 15 FPS, -10 degree phase step

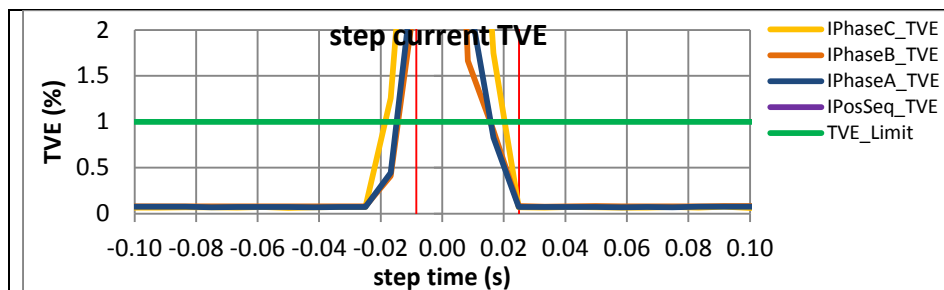


Figure 4367:  $F_s = 12$  FPS, +10 degree phase step

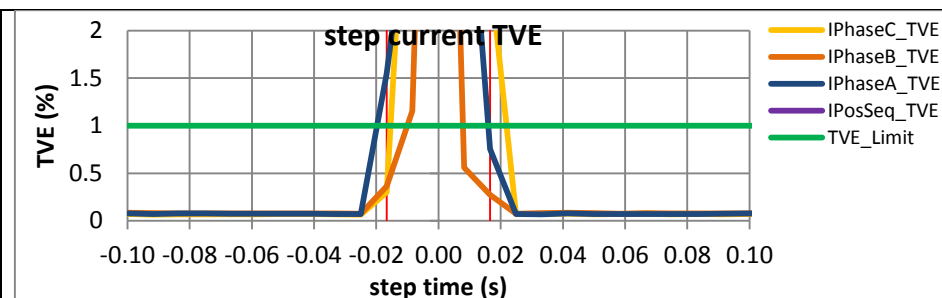


Figure 4368:  $F_s = 12$  FPS, -10 degree phase step

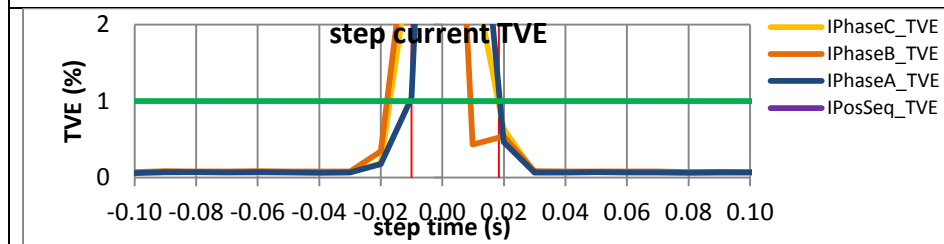


Figure 4369:  $F_s = 10$  FPS, +10 degree phase step

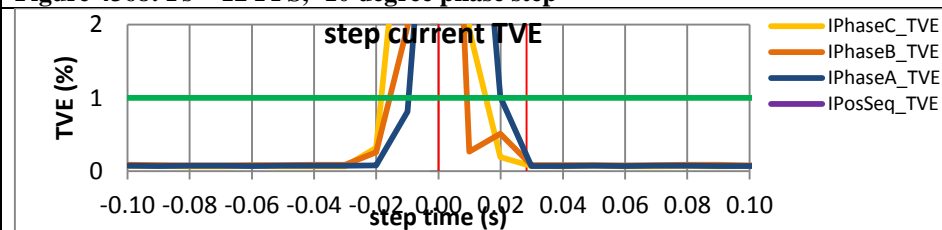
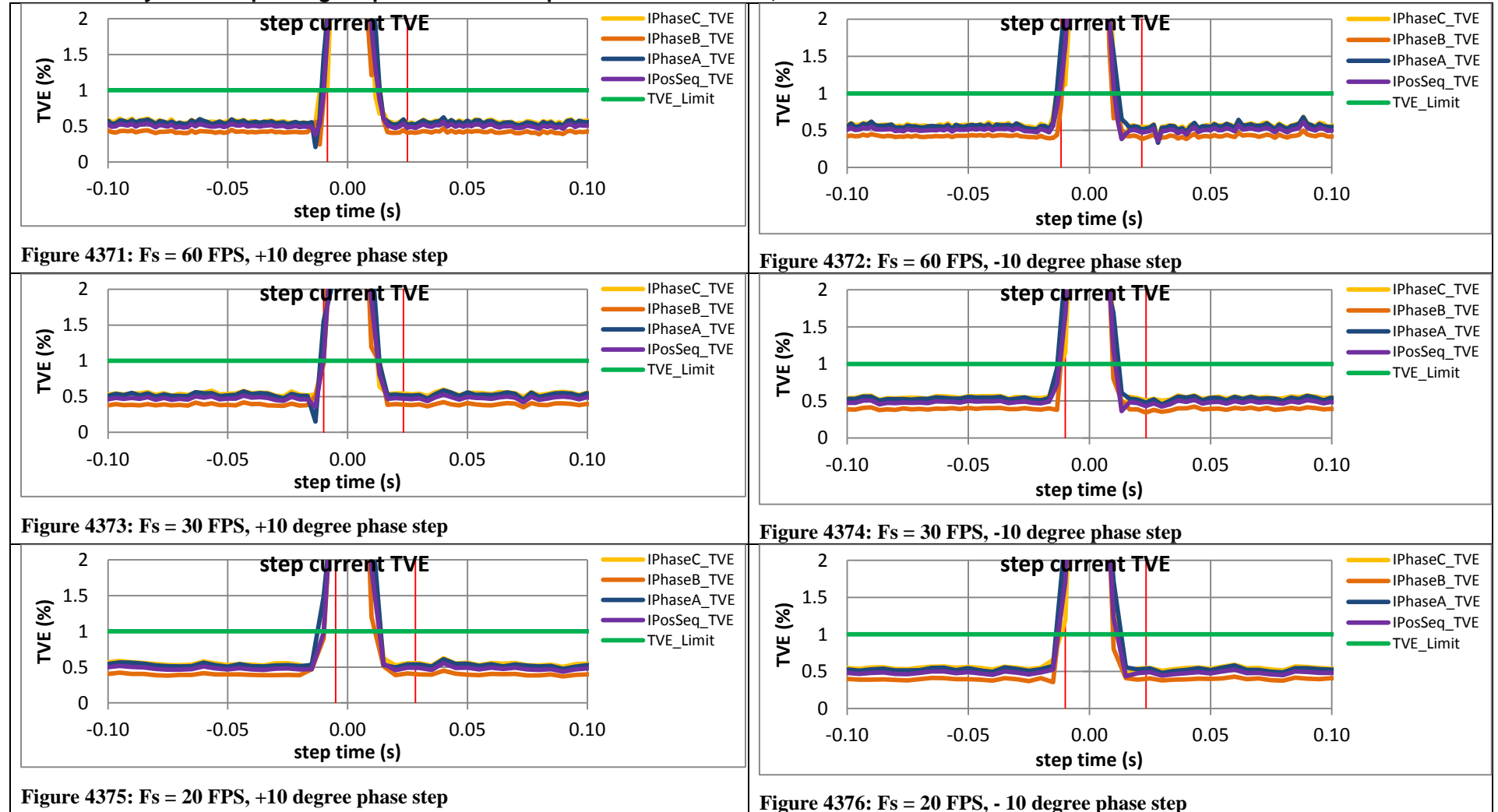


Figure 4370:  $F_s = 10$  FPS, -10 degree phase step

#### 9.4.6 PMU E dynamic step change in phase current response time: F0 = 60 Hz, P class

PMU E does not support P class.

#### 9.4.7 PMU F dynamic step change in phase current response time: F0 = 60 Hz, P class



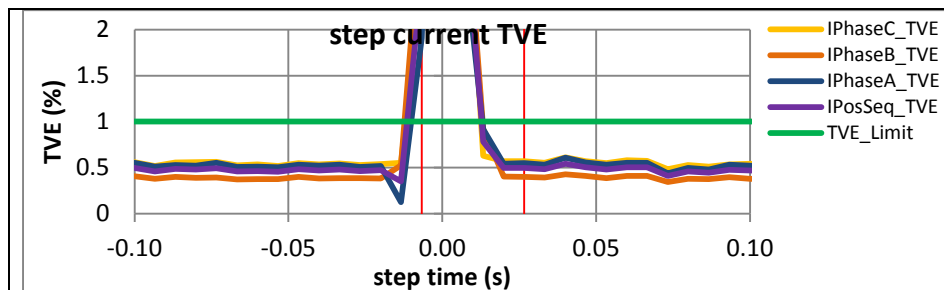


Figure 4377: Fs = 15 FPS, +10 degree phase step

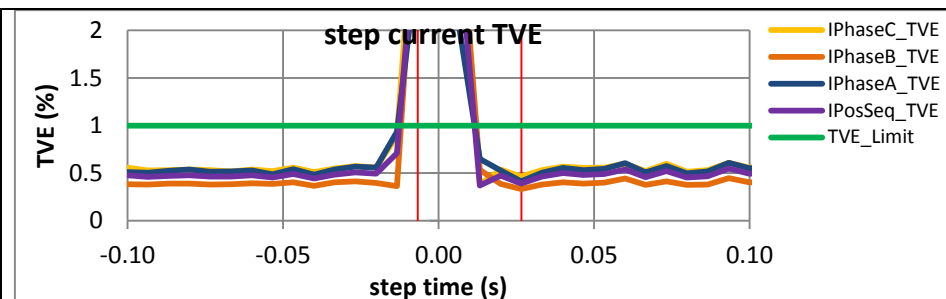


Figure 4378: Fs = 15 FPS, -10 degree phase step

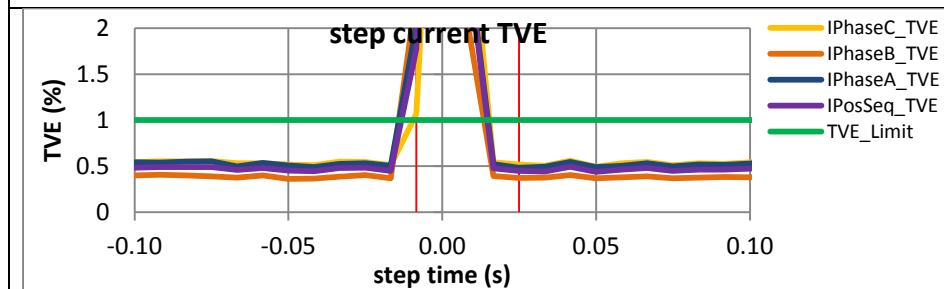


Figure 4379: Fs = 12 FPS, +10 degree phase step

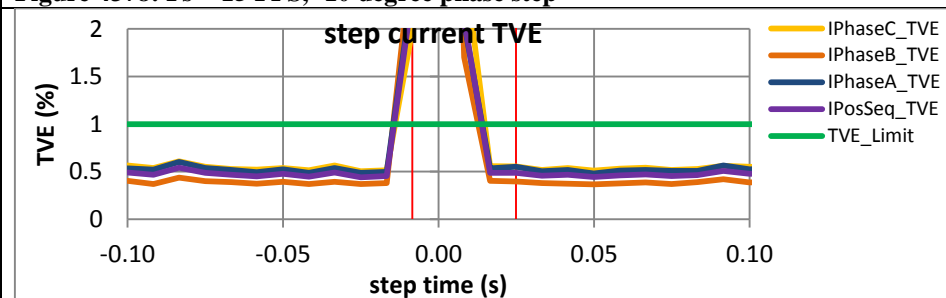


Figure 4380: Fs = 12 FPS, -10 degree phase step

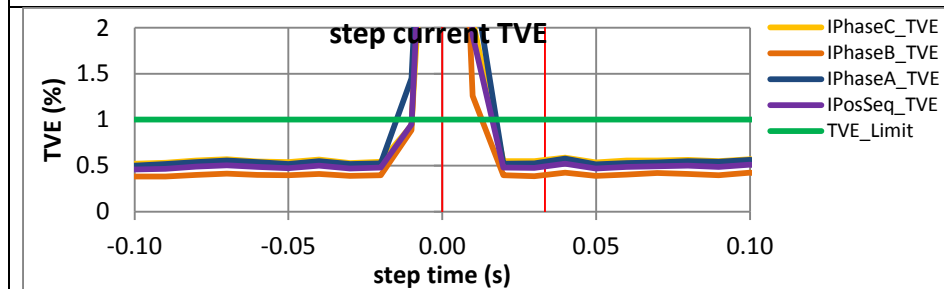


Figure 4381: Fs = 10 FPS, +10 degree phase step

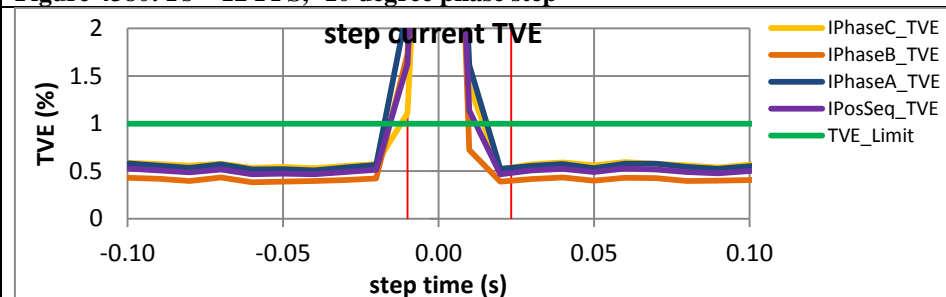
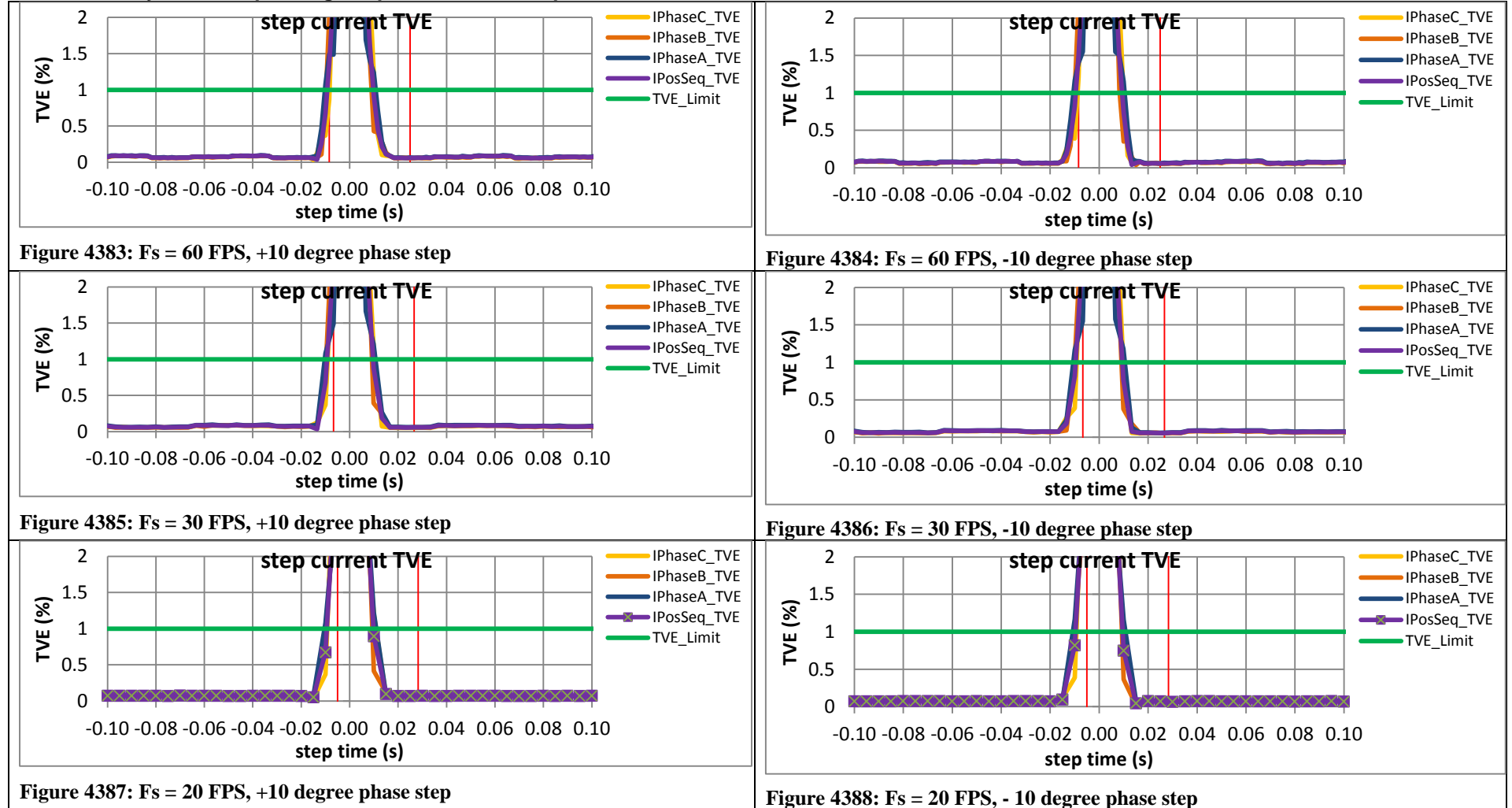


Figure 4382: Fs = 10 FPS, -10 degree phase step

#### 9.4.8 PMU G dynamic step change in phase current response time: F0 = 60 Hz, P class

PMU G does not support P class.

#### 9.4.9 PMU H dynamic step change in phase current response time: F0 = 60 Hz, P class





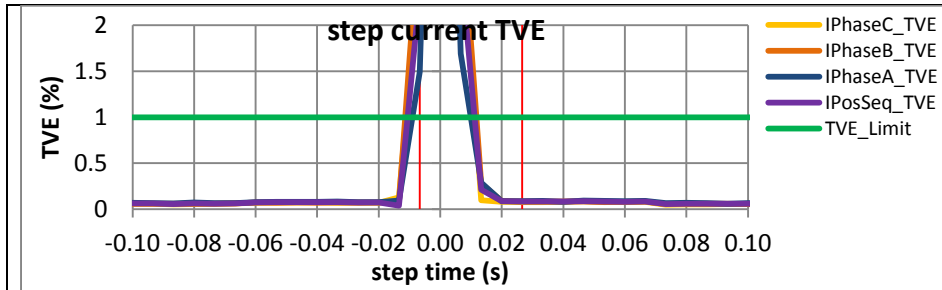


Figure 4389: Fs = 15 FPS, +10 degree phase step

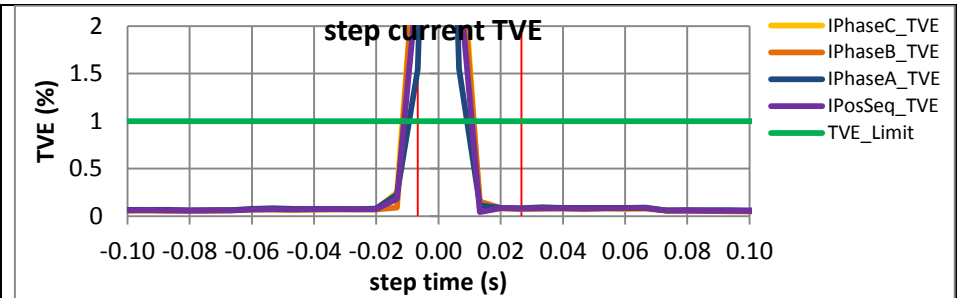


Figure 4390: Fs = 15 FPS, -10 degree phase step

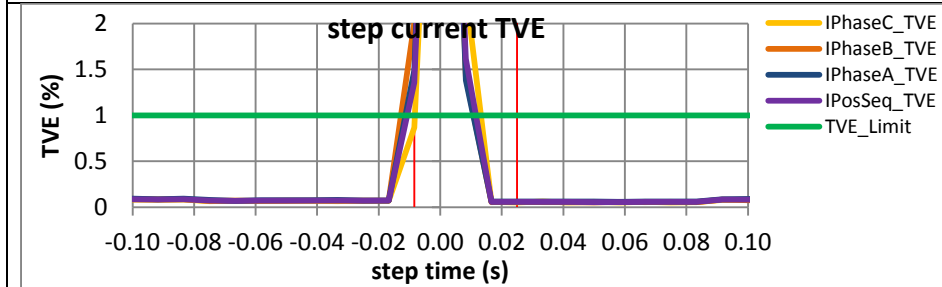


Figure 4391: Fs = 12 FPS, +10 degree phase step

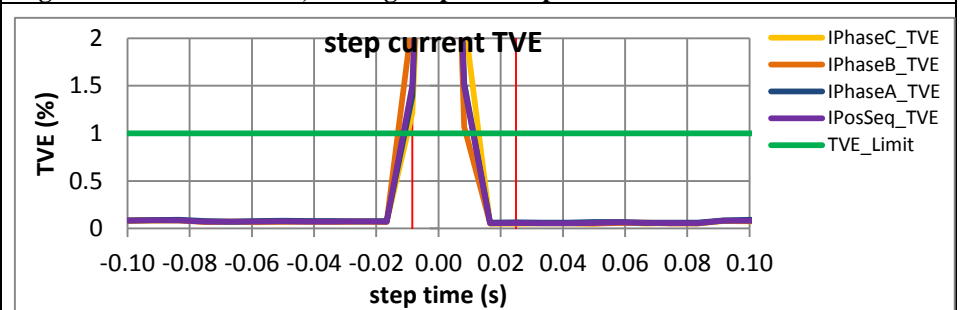


Figure 4392: Fs = 12 FPS, -10 degree phase step

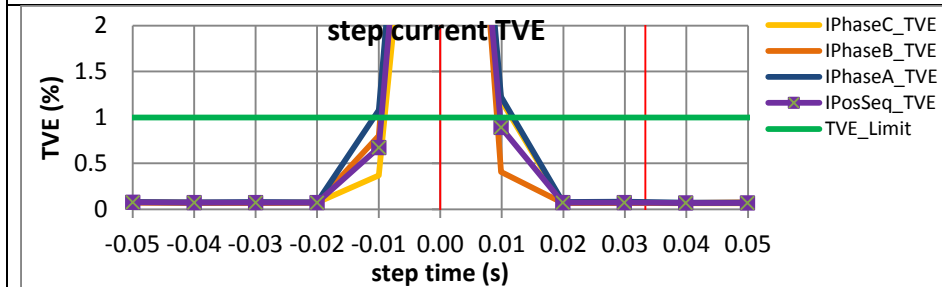


Figure 4393: Fs = 10 FPS, +10 degree phase step

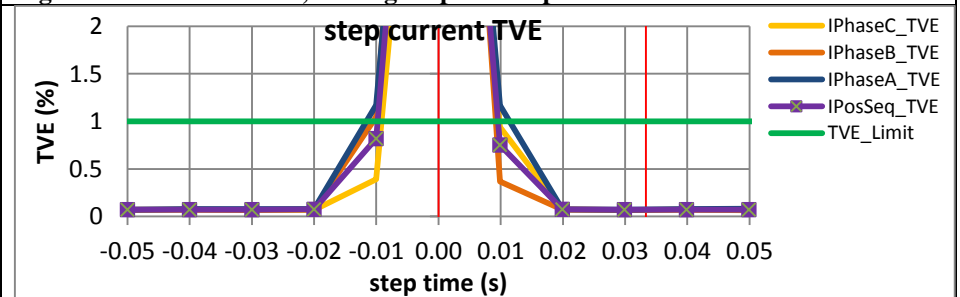


Figure 4394: Fs = 10 FPS, -10 degree phase step

#### 9.4.10 PMU I dynamic step change in phase current response time: F0 = 60 Hz, P class

PMU I does not support P class

#### 9.4.11 PMU J dynamic step change in phase current response time: F0 = 60 Hz, P class

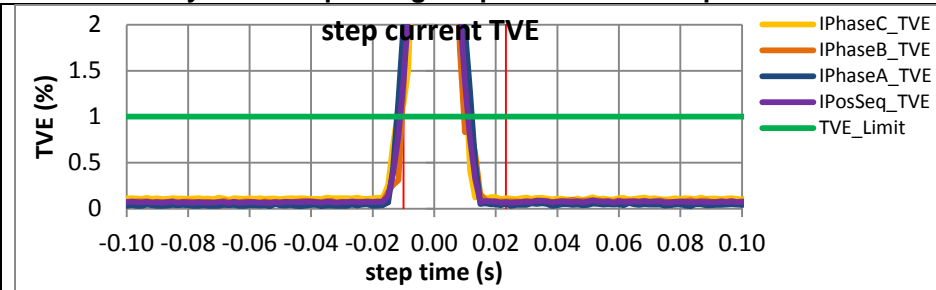


Figure 4395: Fs = 60 FPS, +10 degree phase step

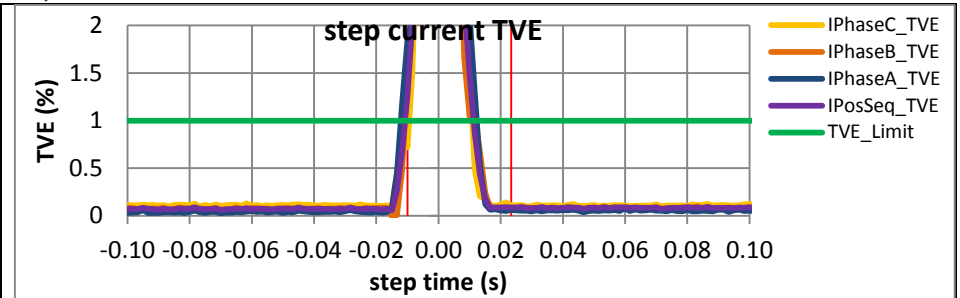


Figure 4396: Fs = 60 FPS, -10 degree phase step

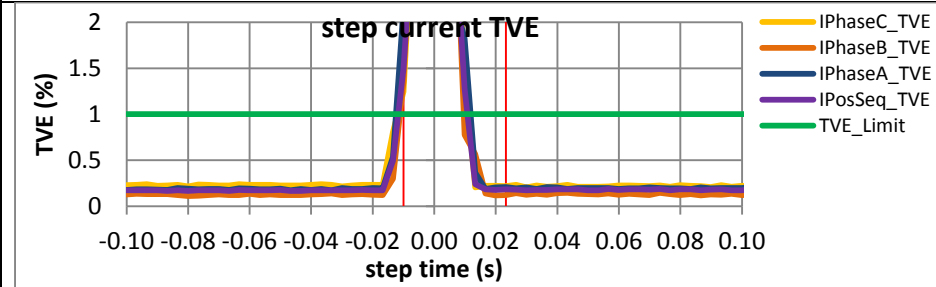


Figure 4397: Fs = 30 FPS, +10 degree phase step

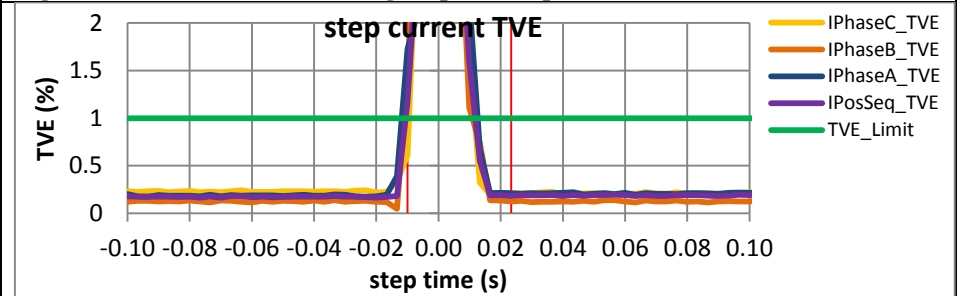


Figure 4398: Fs = 30 FPS, -10 degree phase step

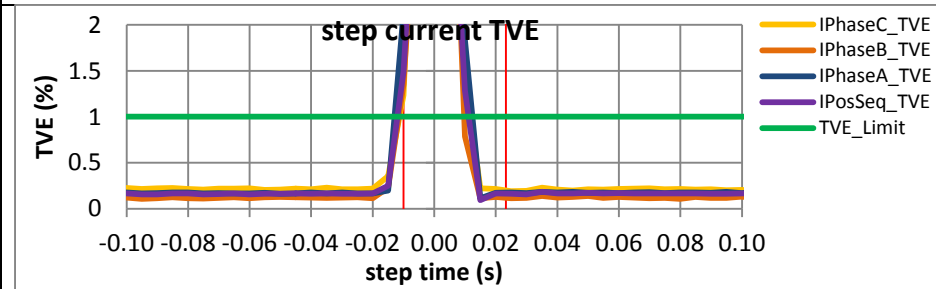


Figure 4399: Fs = 20 FPS, +10 degree phase step

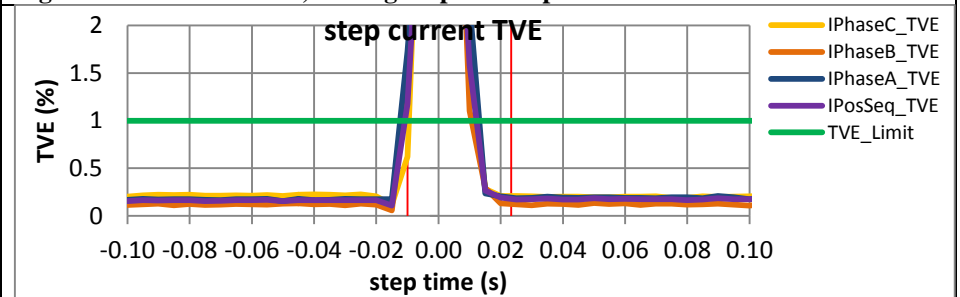


Figure 4400: Fs = 20 FPS, -10 degree phase step

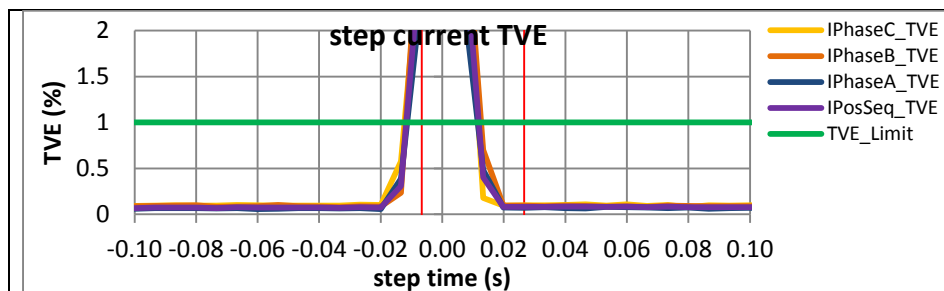


Figure 4401:  $F_s = 15$  FPS, +10 degree phase step

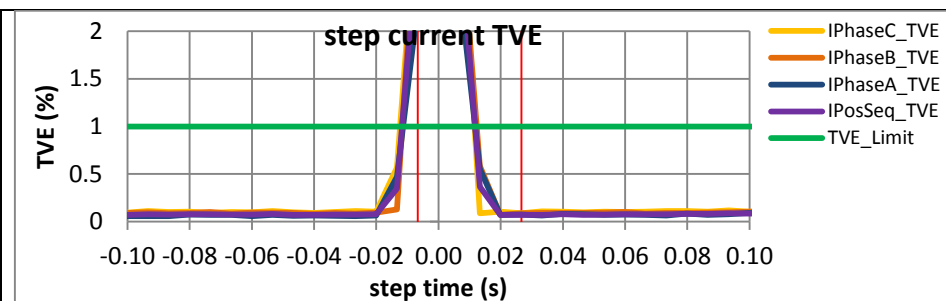


Figure 4402:  $F_s = 15$  FPS, -10 degree phase step

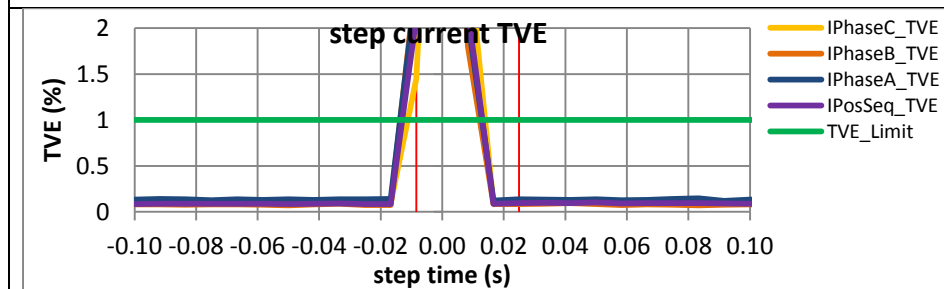


Figure 4403:  $F_s = 12$  FPS, +10 degree phase step

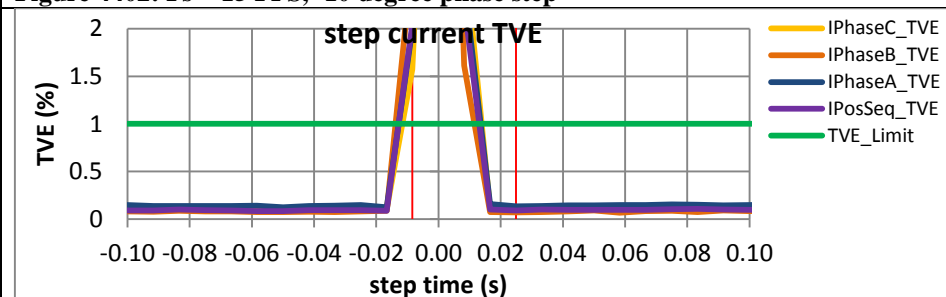


Figure 4404:  $F_s = 12$  FPS, -10 degree phase step

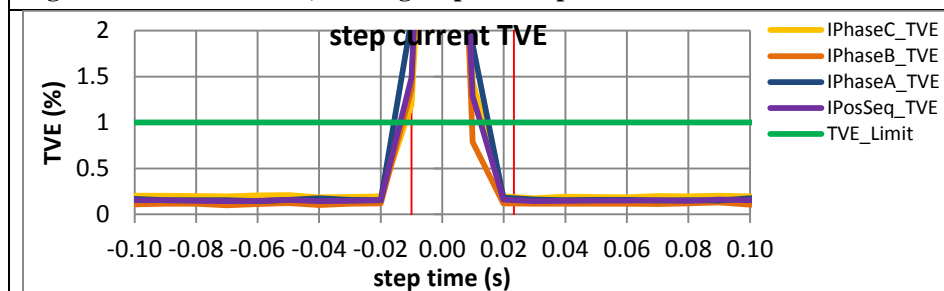


Figure 4405:  $F_s = 10$  FPS, +10 degree phase step

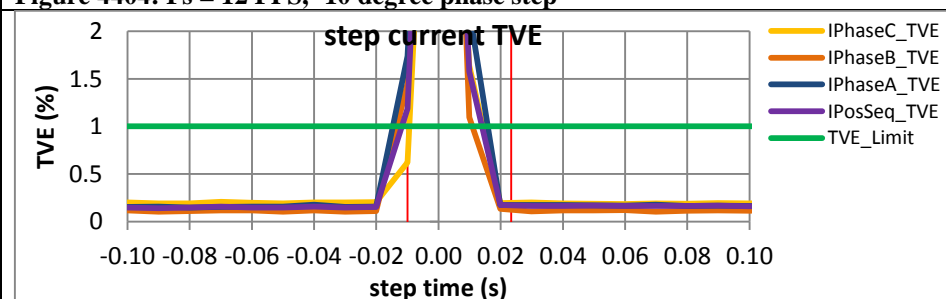
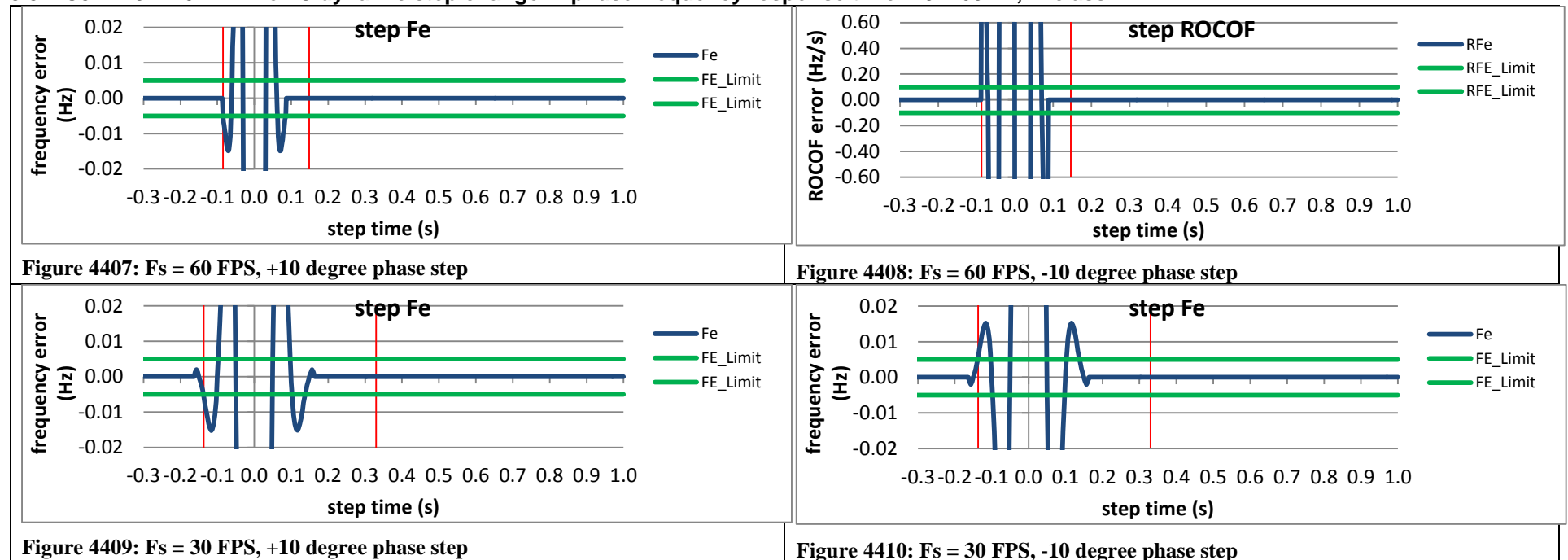


Figure 4406:  $F_s = 10$  FPS, -10 degree phase step

## 9.5 Dynamic step change in phase: frequency response time

Fs (FPS)	10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P
PMU A	P	P	P	P	P	P	P	P	P	P	P	P
PMU B	P	F	P	F	P	F	P	F	P	F	P	F
PMU C	P	F	P	F	P	F	P	F	P	P	P	F
PMU D	P	P	P	P	P	P	P	P	P	P	P	P
PMU E	P	-	-	-	P	-	P	-	P	-	P	-
PMU F	P	P	P	P	P	F	P	F	P	F	P	F
PMU G	P	-	P	-	P	-	P	-	P	-	P	-
PMU H	P	P	P	P	P	P	P	P	P	P	P	P
PMU I	P	-	P	-	P	-	P	-	P	-	P	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P

### 9.5.1 C37.118.1-2011 Annex C dynamic step change in phase frequency response time: F0 = 60 Hz, M class



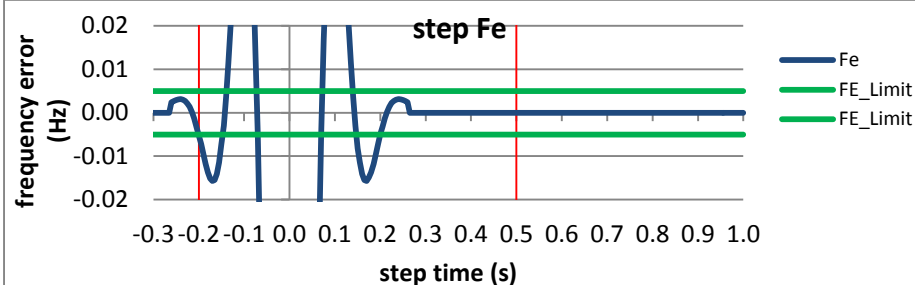


Figure 4411:  $F_s = 20$  FPS, +10 degree phase step

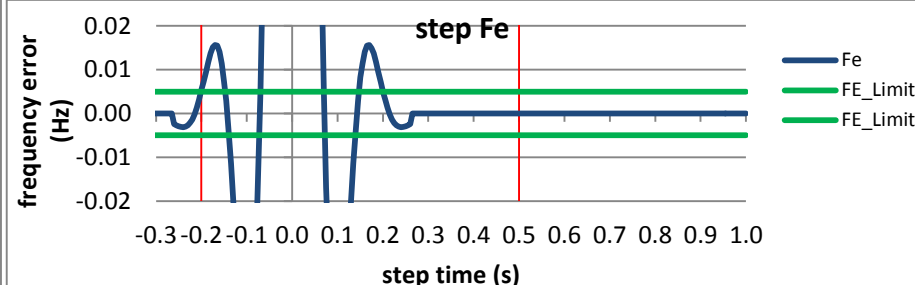


Figure 4412:  $F_s = 20$  FPS, -10 degree phase step

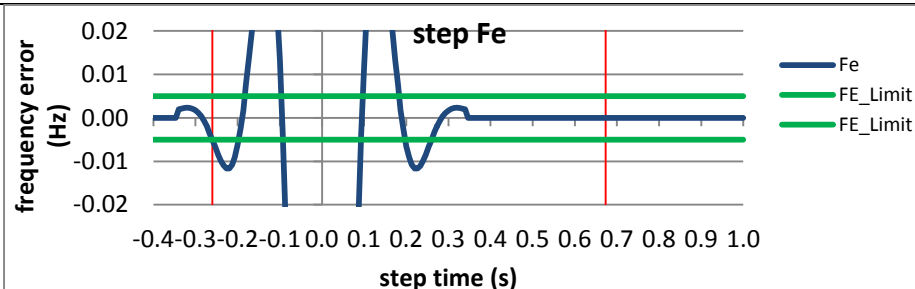


Figure 4413:  $F_s = 15$  FPS, +10 degree phase step

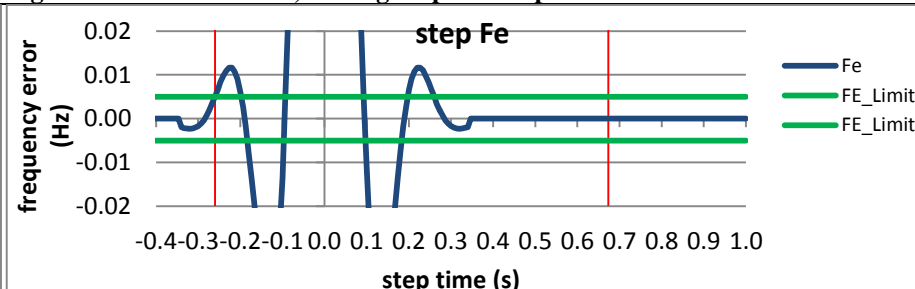


Figure 4414:  $F_s = 15$  FPS, -10 degree phase step

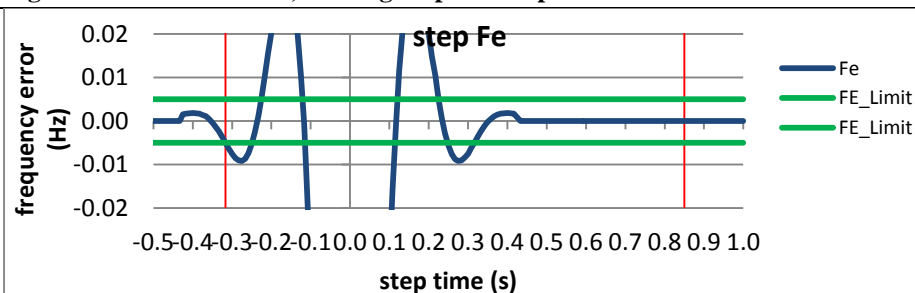


Figure 4415:  $F_s = 12$  FPS, +10 degree phase step

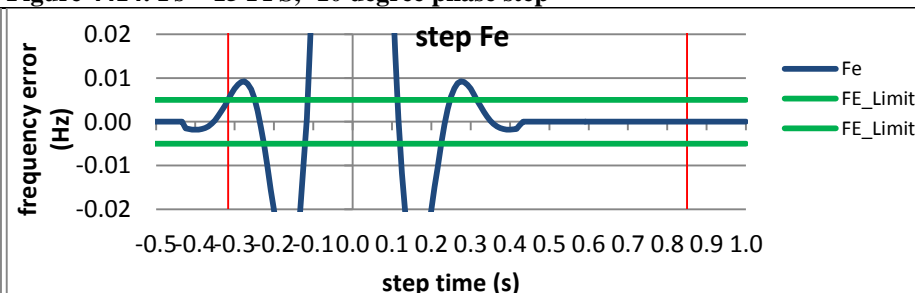


Figure 4416:  $F_s = 12$  FPS, -10 degree phase step

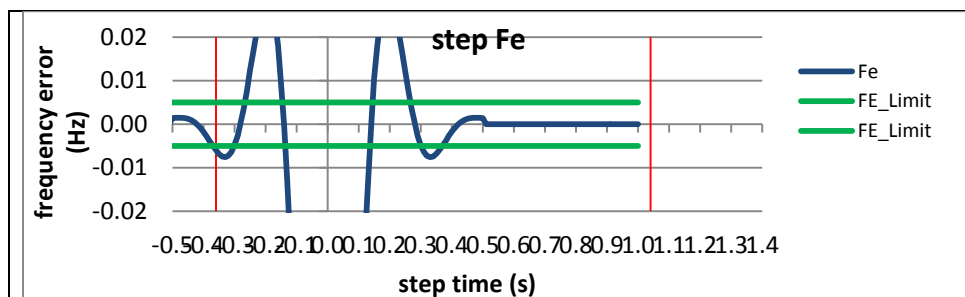


Figure 4417:  $F_s = 10$  FPS, +10 degree phase step

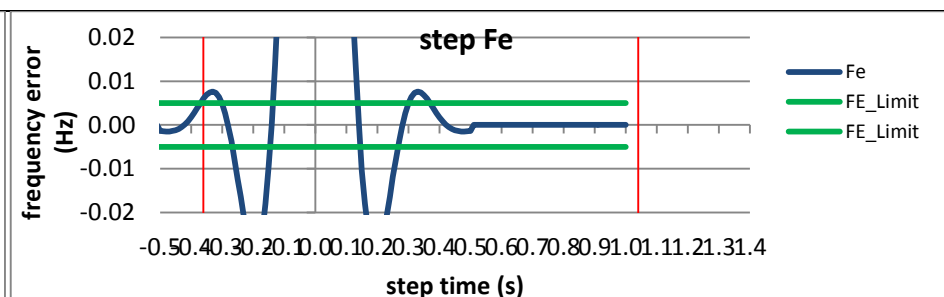
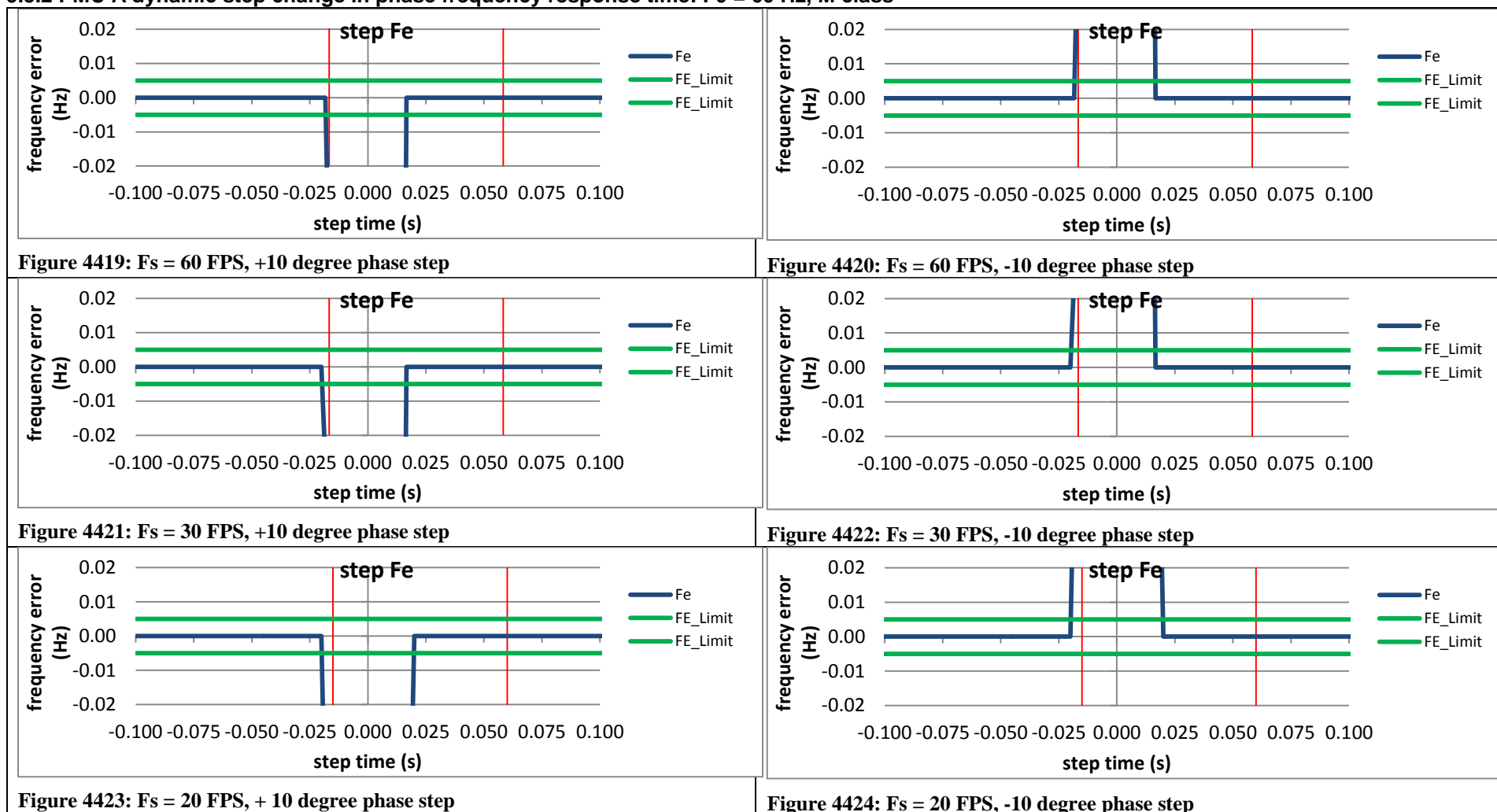
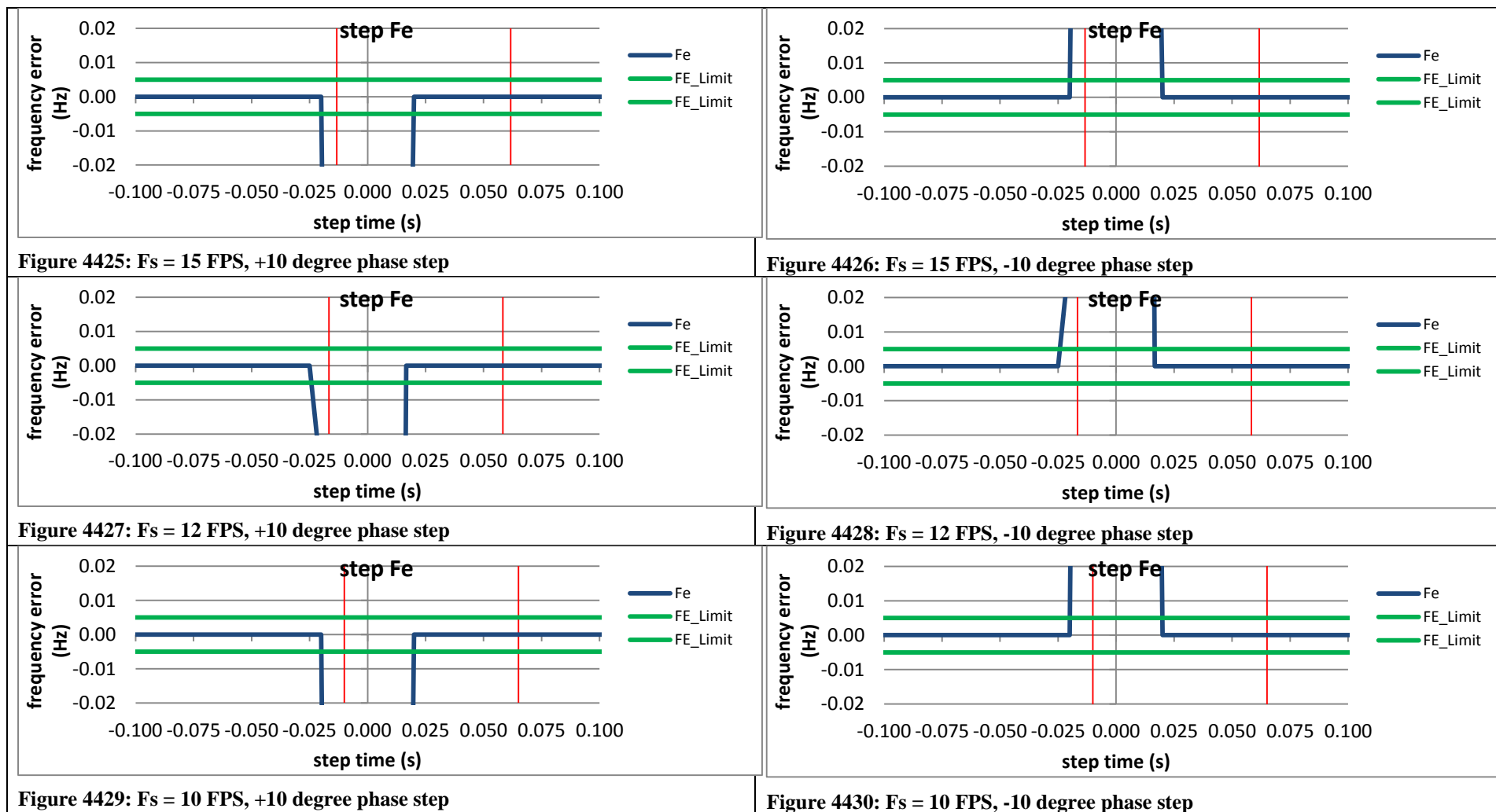


Figure 4418:  $F_s = 10$  FPS, -10 degree phase step

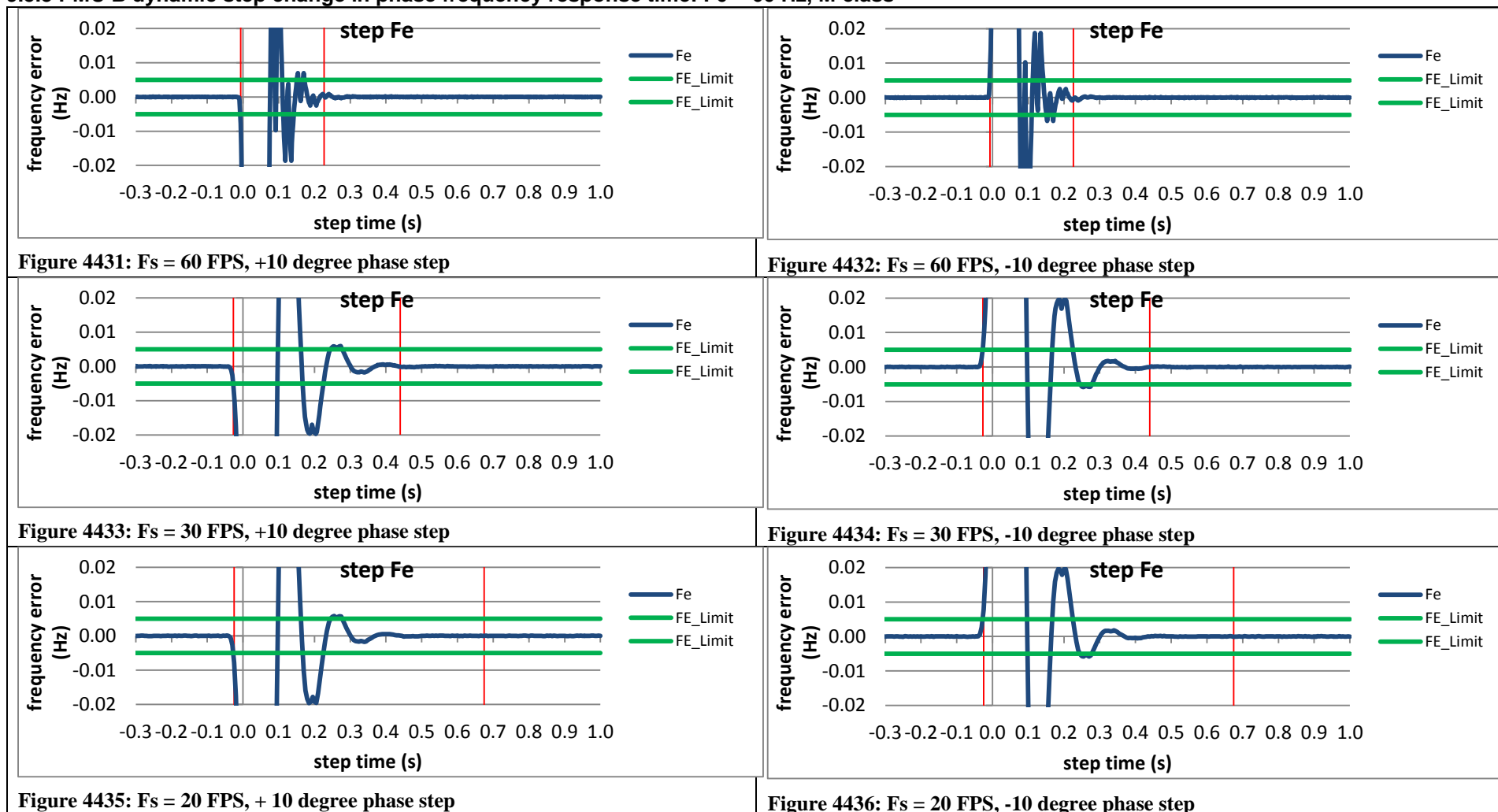
### 9.5.2 PMU A dynamic step change in phase frequency response time: $F_0 = 60$ Hz, M class

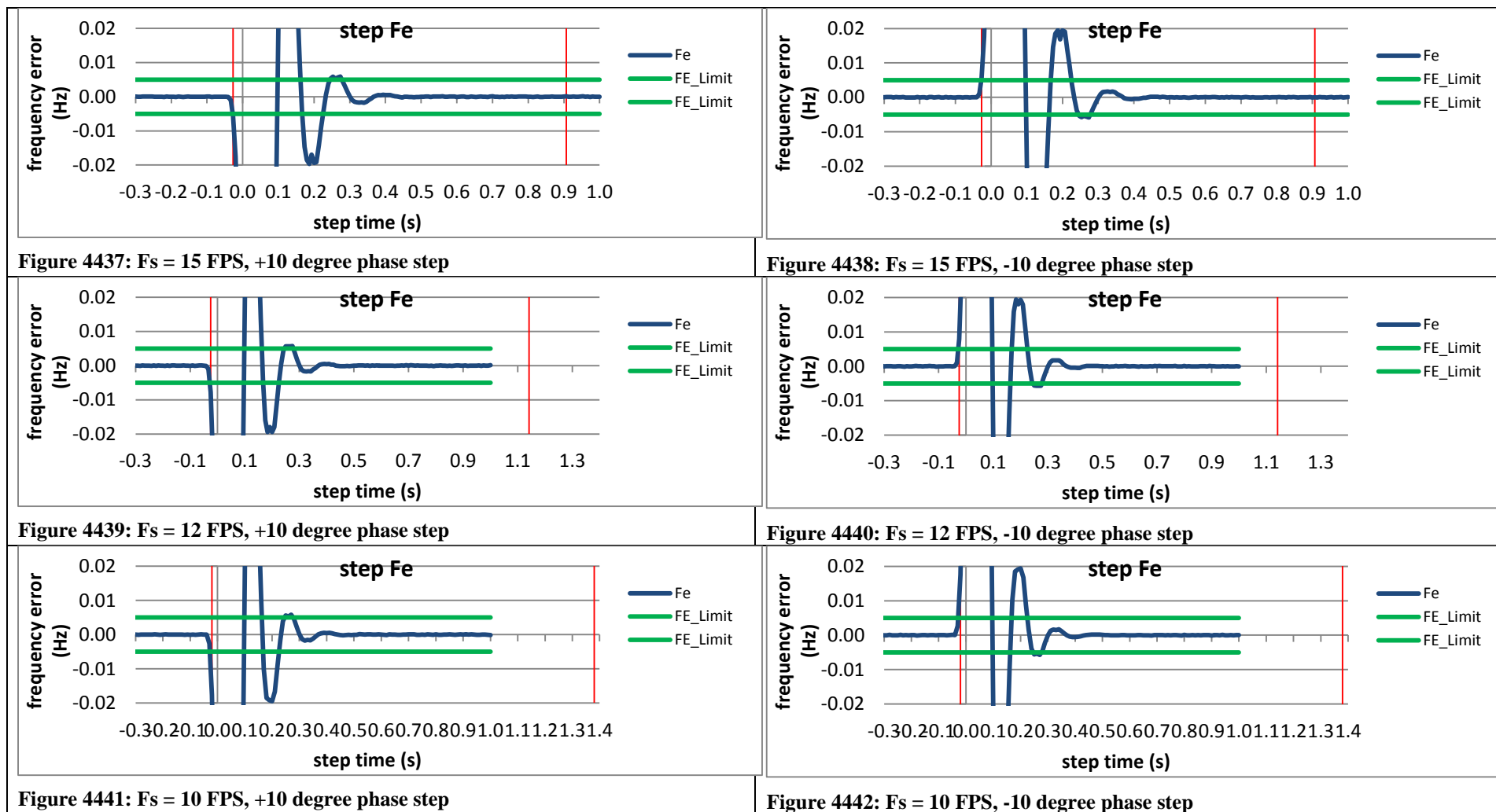






### 9.5.3 PMU B dynamic step change in phase frequency response time: $F_0 = 60$ Hz, M class





#### 9.5.4 PMU C dynamic step change in phase frequency response time: $F_0 = 60$ Hz, M class

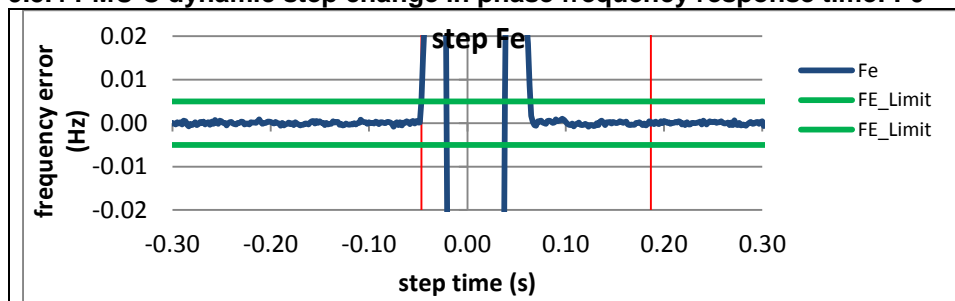


Figure 4443:  $F_s = 60$  FPS, +10 degree phase step

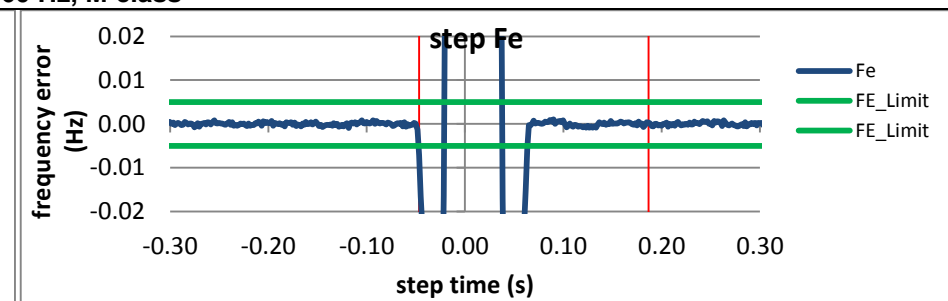


Figure 4444:  $F_s = 60$  FPS, -10 degree phase step

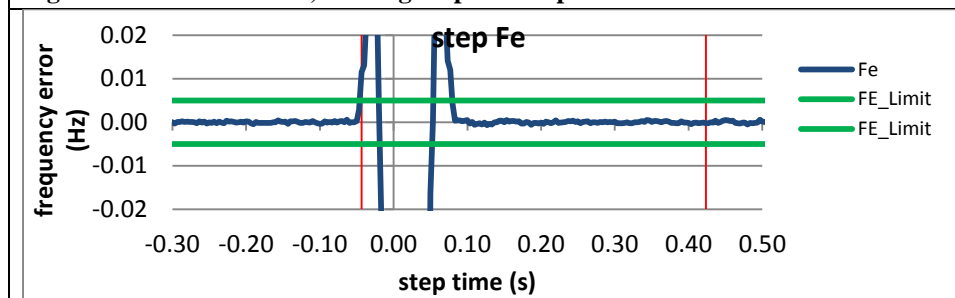


Figure 4445:  $F_s = 30$  FPS, +10 degree phase step

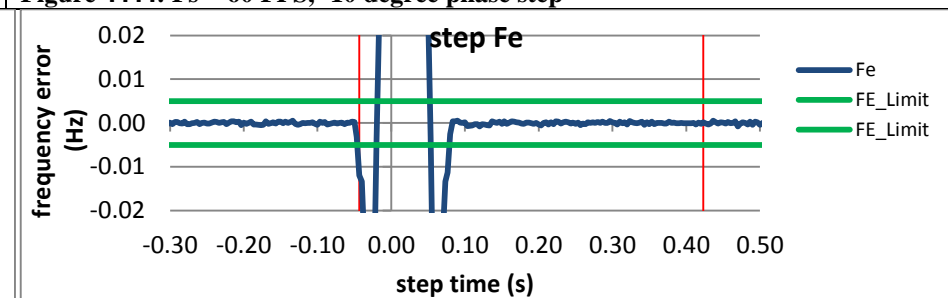


Figure 4446:  $F_s = 30$  FPS, -10 degree phase step

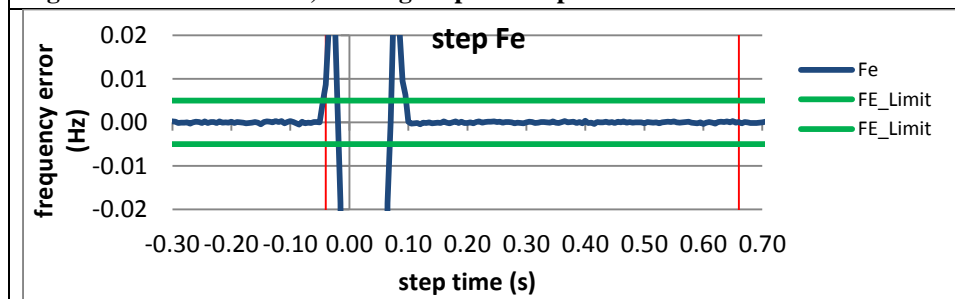


Figure 4447:  $F_s = 20$  FPS, + 10 degree phase step

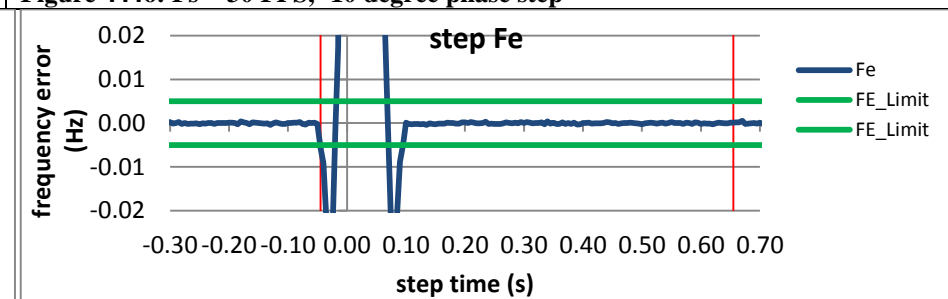
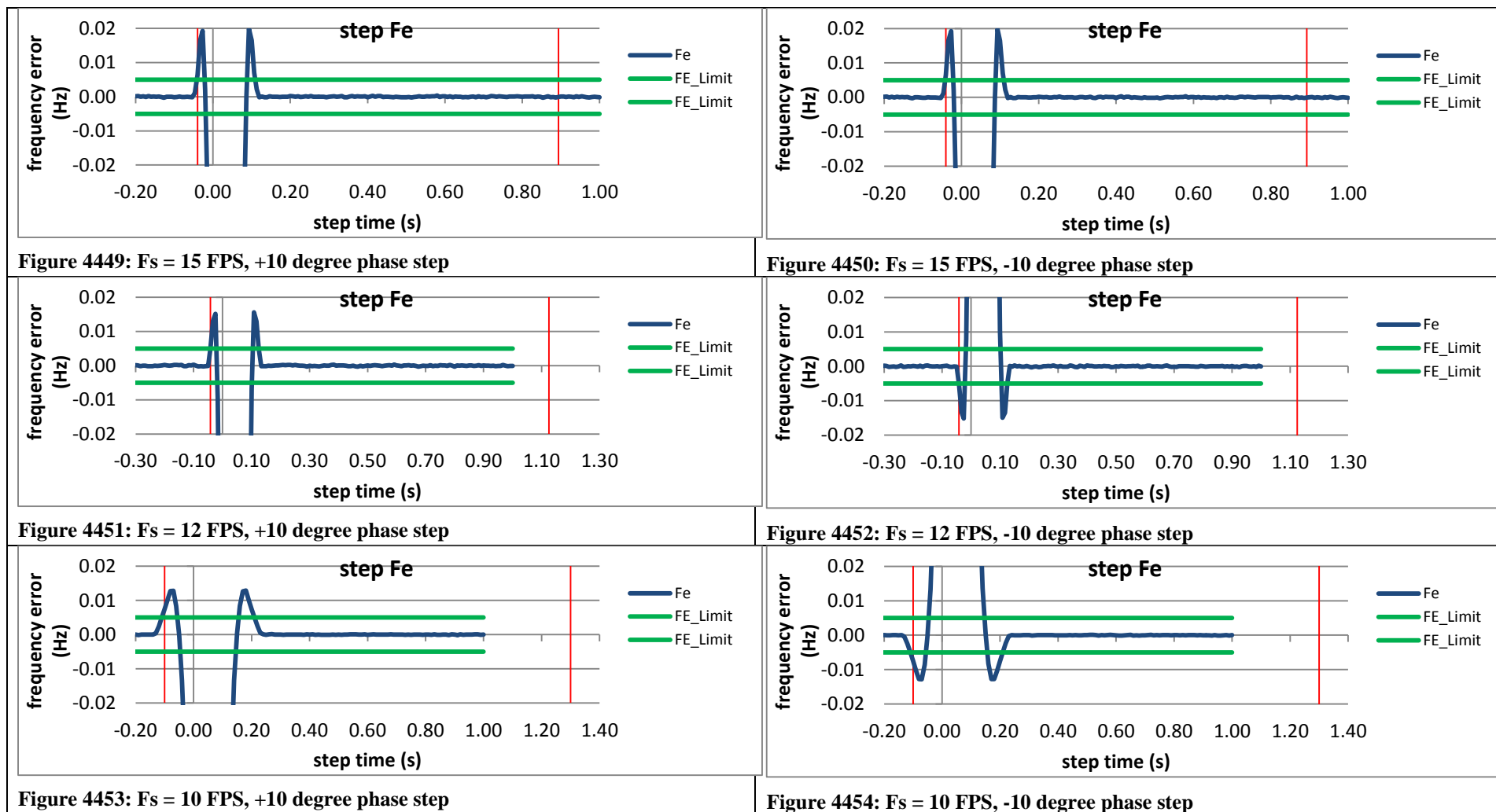
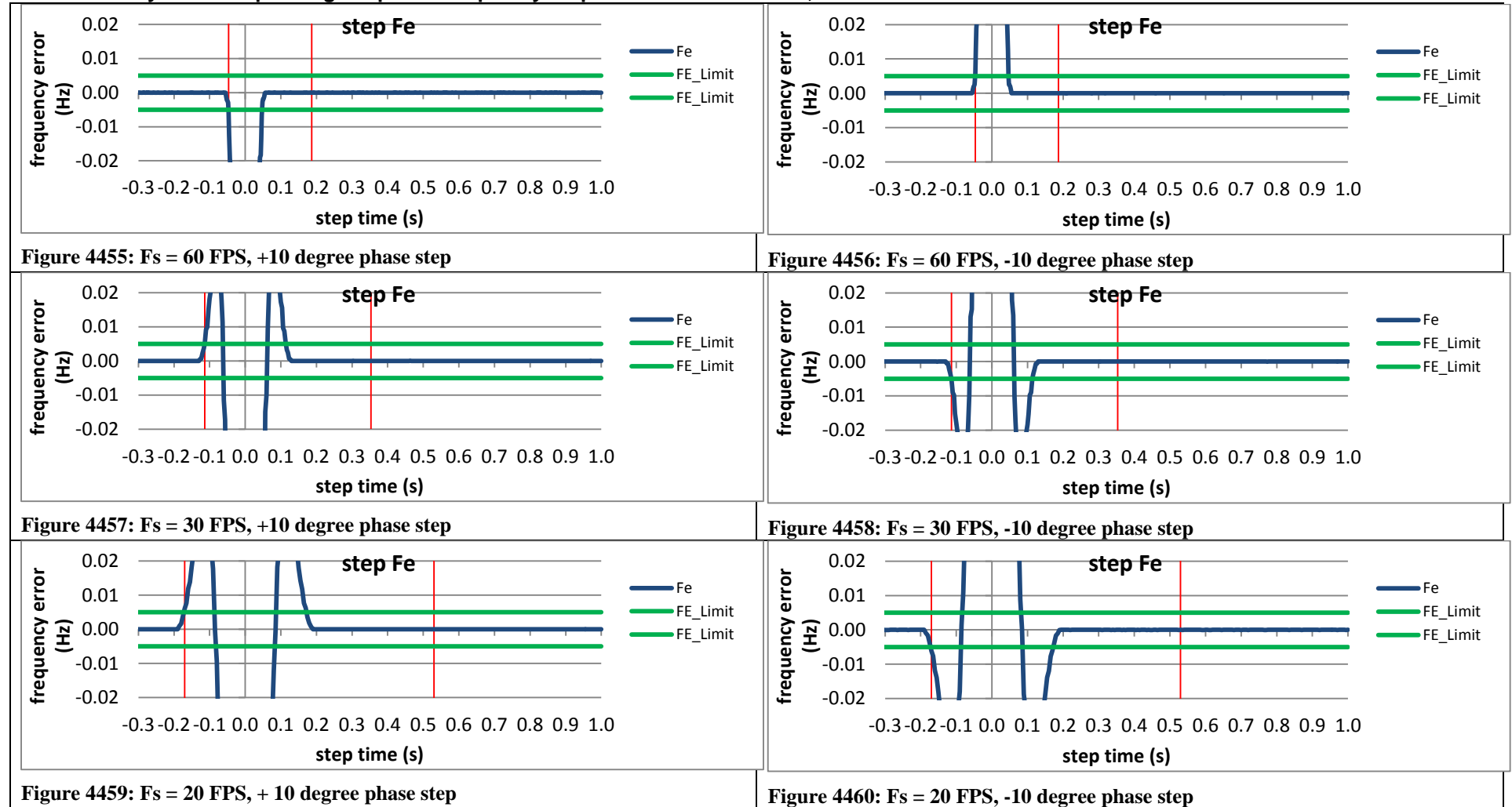
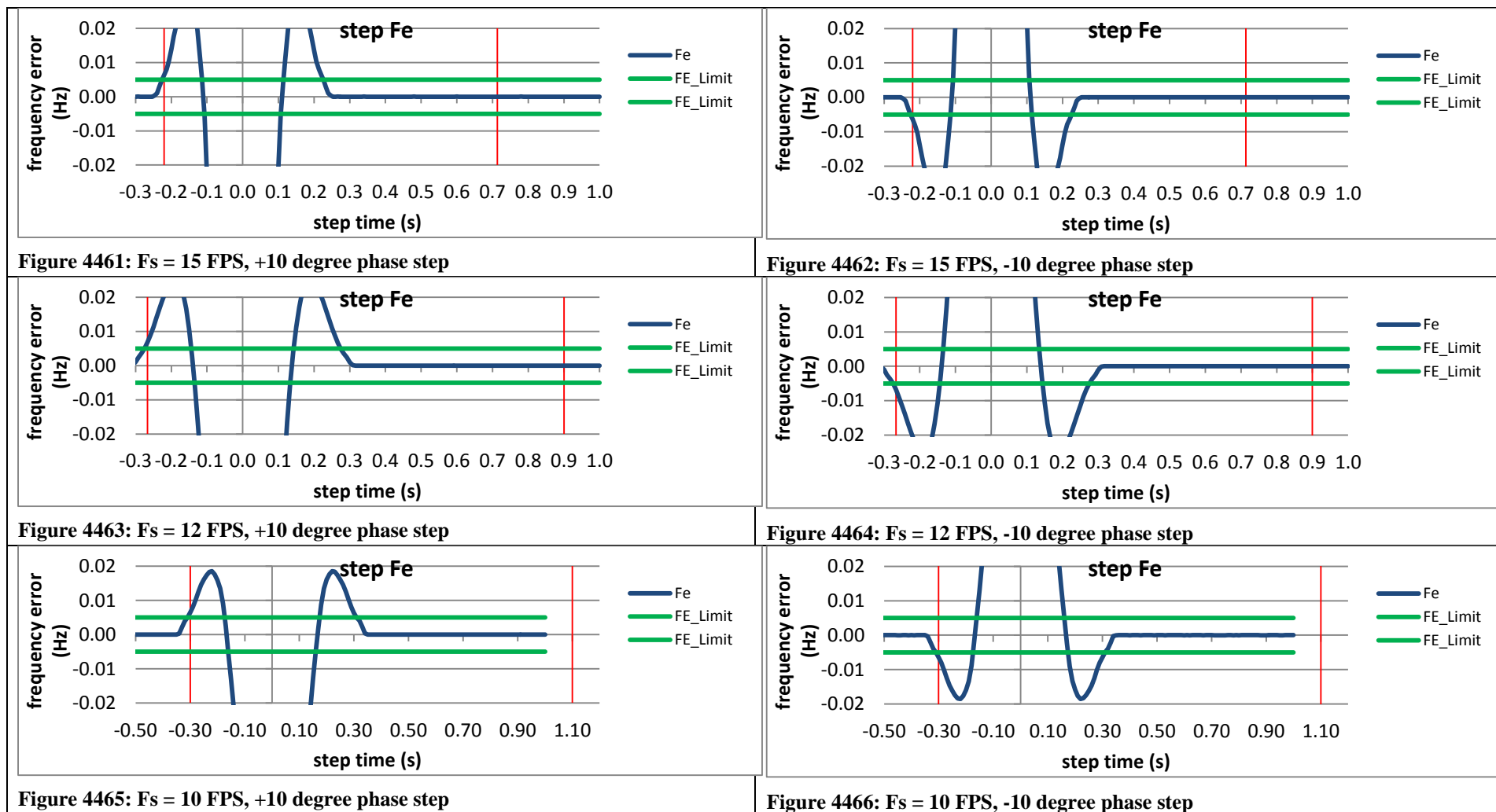


Figure 4448:  $F_s = 20$  FPS, -10 degree phase step

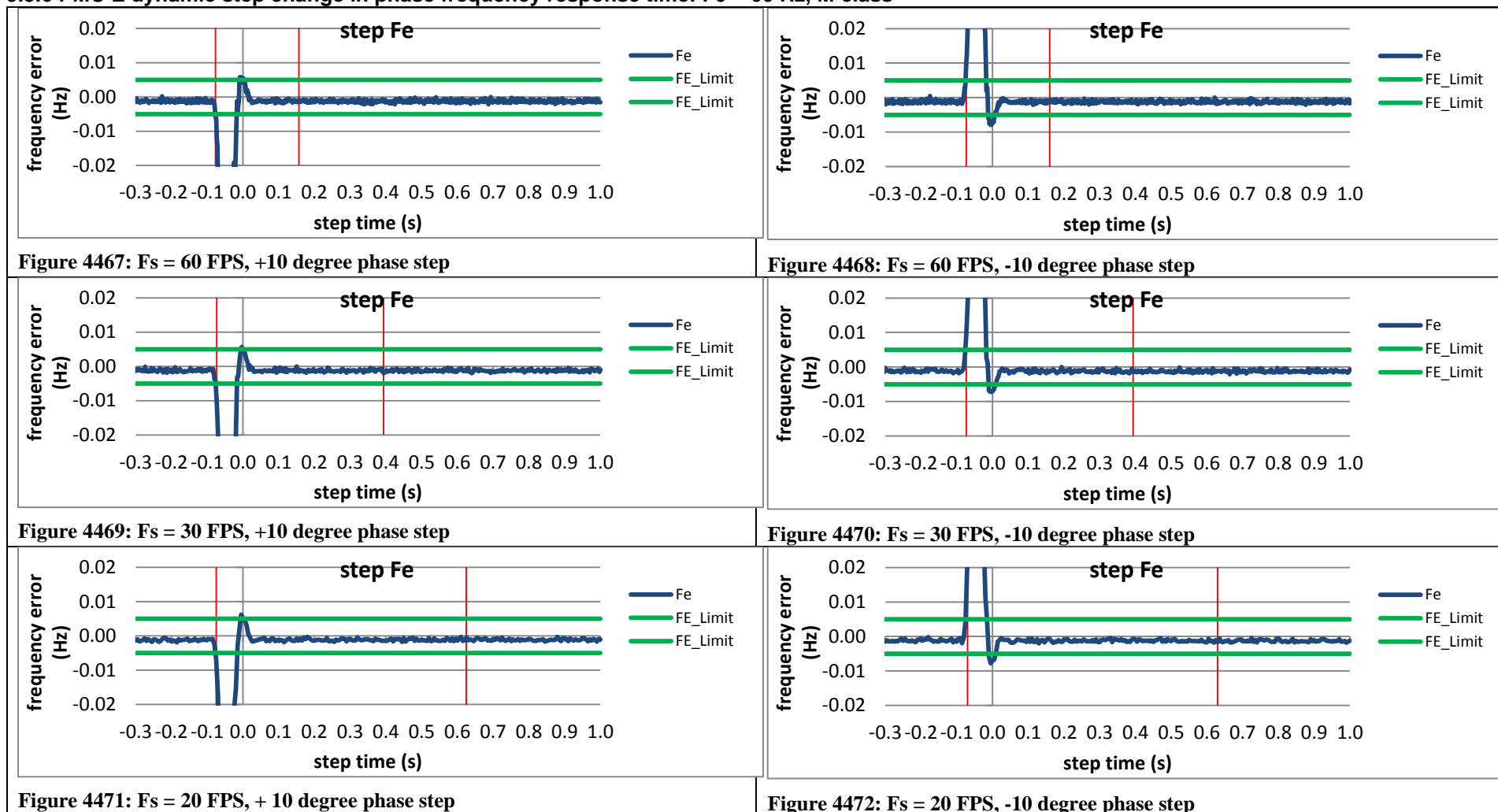


### 9.5.5 PMU D dynamic step change in phase frequency response time: $F_0 = 60$ Hz, M class





# 9.5.6 PMU E dynamic step change in phase frequency response time: F0 = 60 Hz, M class



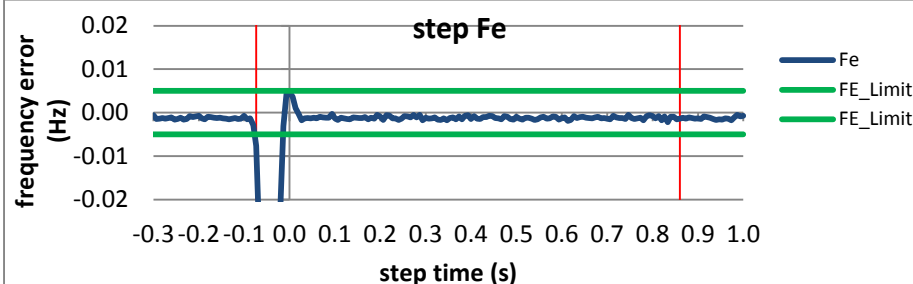


Figure 4473:  $F_s = 15$  FPS, +10 degree phase step

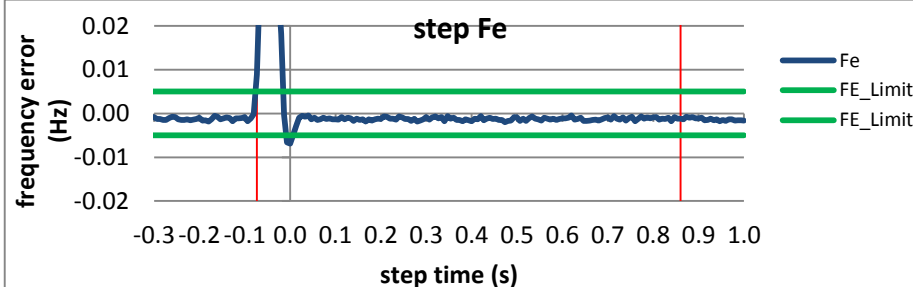


Figure 4474:  $F_s = 15$  FPS, -10 degree phase step

Figure 4475:  $F_s = 12$  FPS, +10 degree phase step

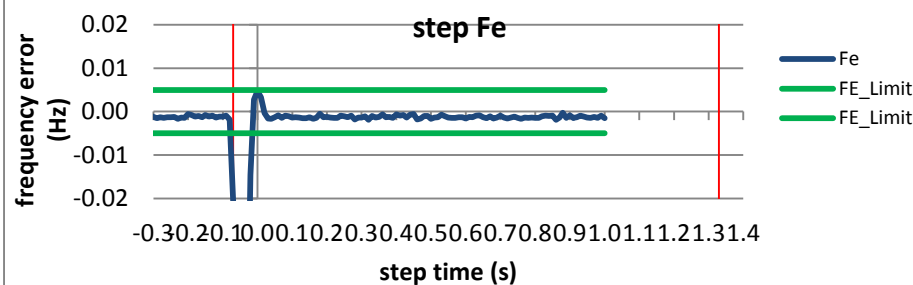


Figure 4477:  $F_s = 10$  FPS, +10 degree phase step

Figure 4476:  $F_s = 12$  FPS, -10 degree phase step

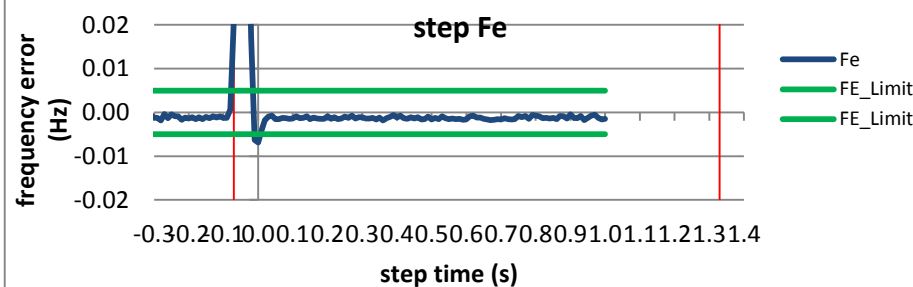
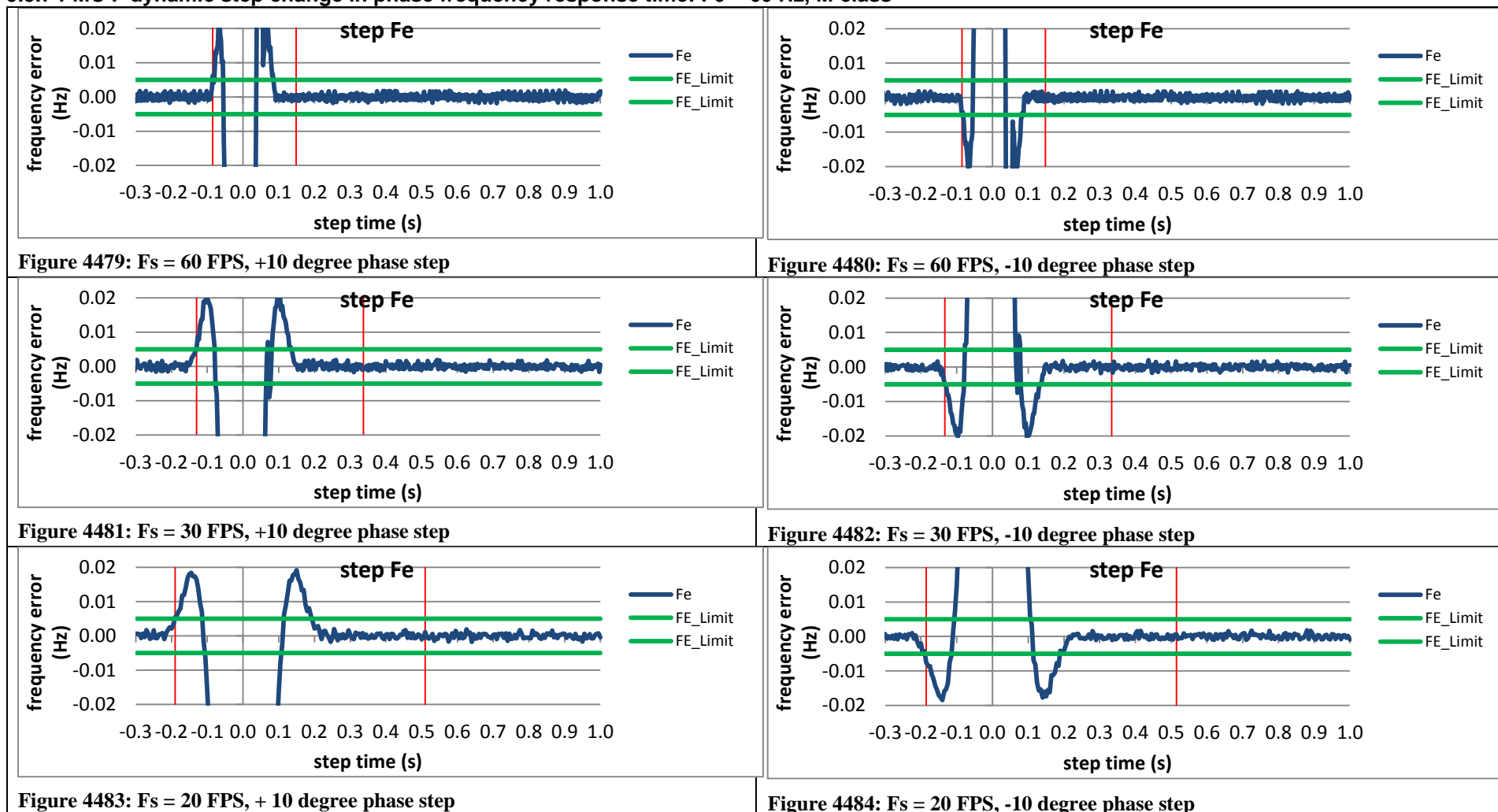
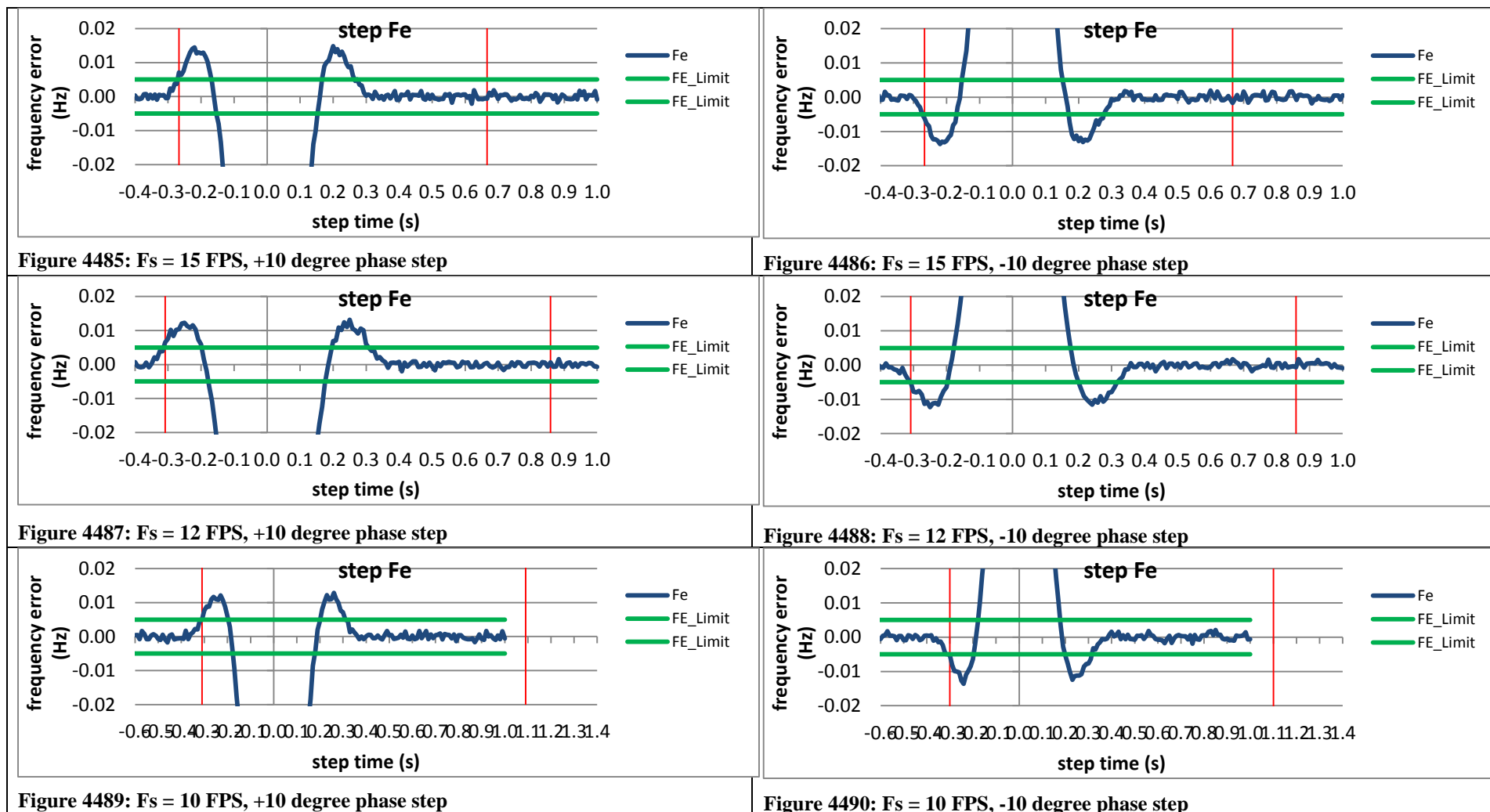


Figure 4478:  $F_s = 10$  FPS, -10 degree phase step



### 9.5.7 PMU F dynamic step change in phase frequency response time: F0 = 60 Hz, M class





### 9.5.8 PMU G dynamic step change in phase frequency response time: $F_0 = 60$ Hz, M class

Figure 4491:  $F_s = 60$  FPS, +10 degree phase step

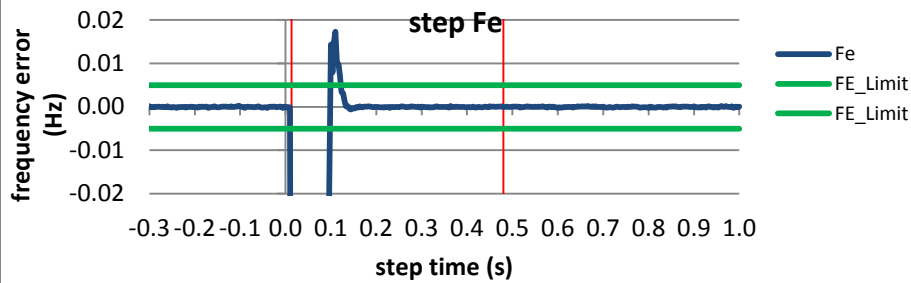


Figure 4492:  $F_s = 60$  FPS, -10 degree phase step

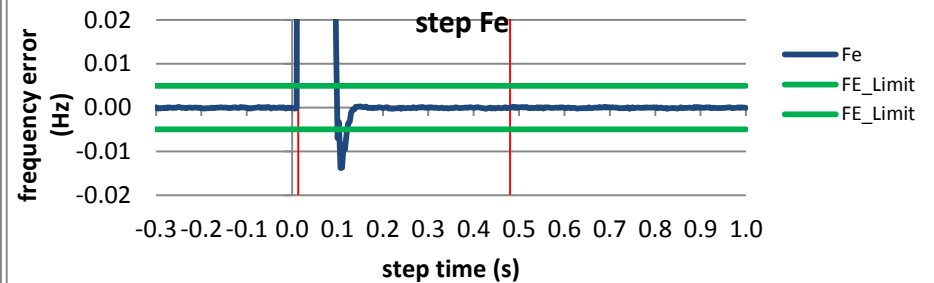


Figure 4493:  $F_s = 30$  FPS, +10 degree phase step

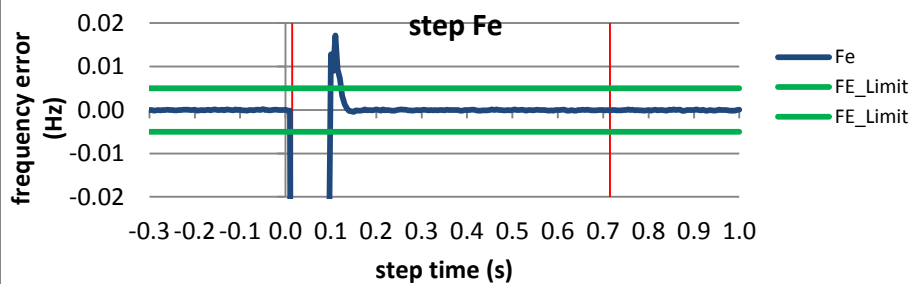


Figure 4494:  $F_s = 30$  FPS, -10 degree phase step

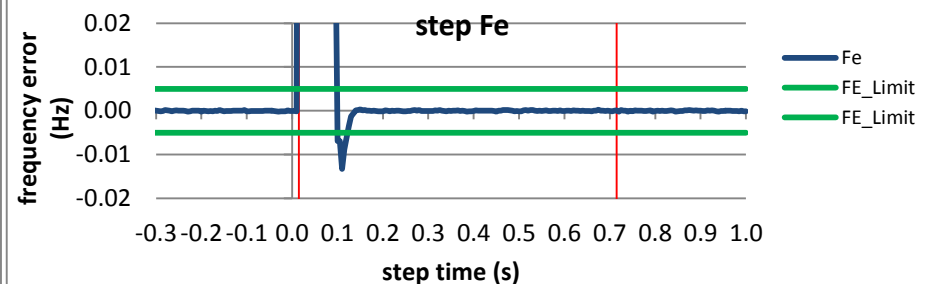


Figure 4495:  $F_s = 20$  FPS, + 10 degree phase step

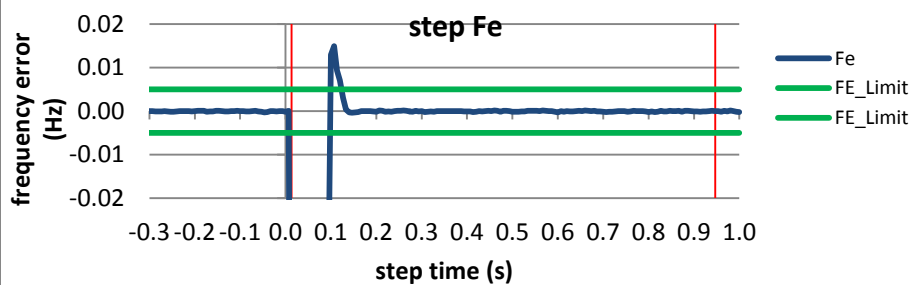


Figure 4496:  $F_s = 20$  FPS, -10 degree phase step

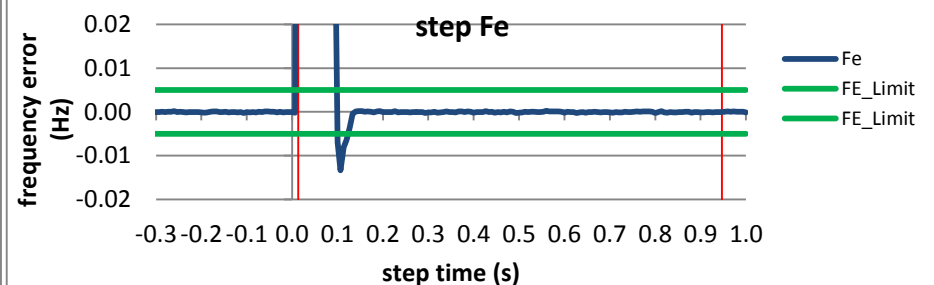
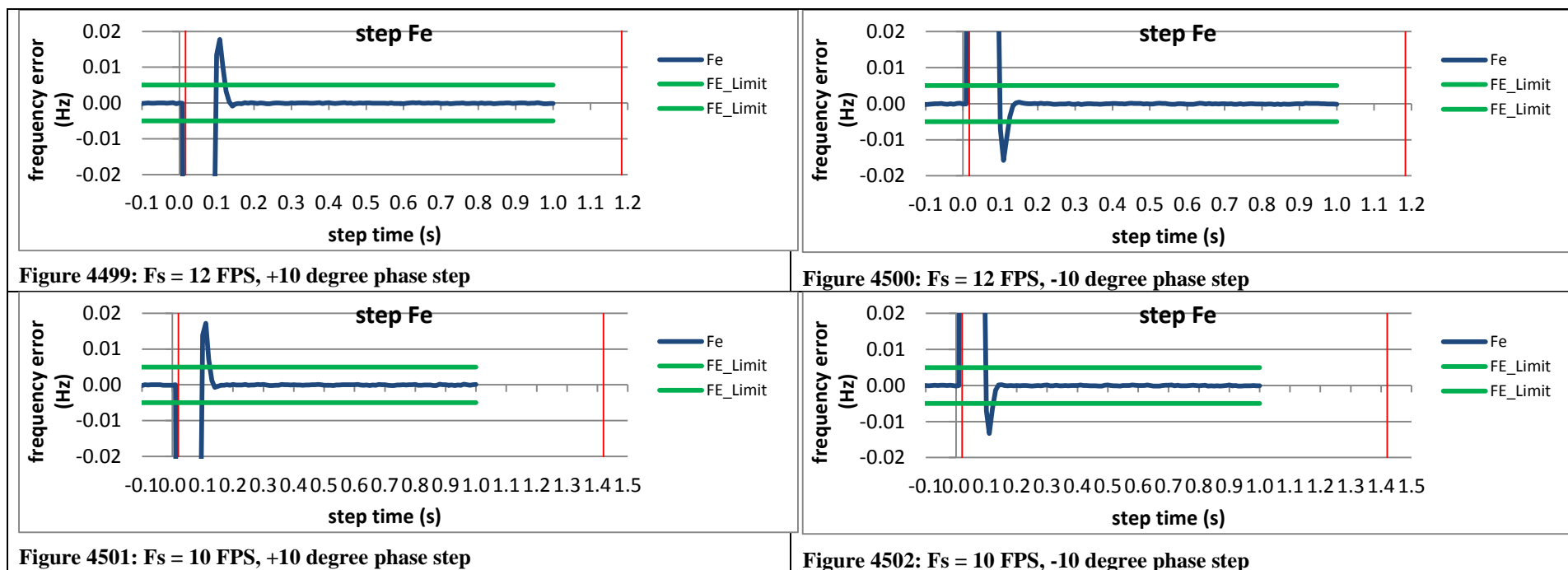


Figure 4497:  $F_s = 15$  FPS, +10 degree phase step



Figure 4498:  $F_s = 15$  FPS, -10 degree phase step





### 9.5.9 PMU H dynamic step change in phase frequency response time: $F_0 = 60$ Hz, M class

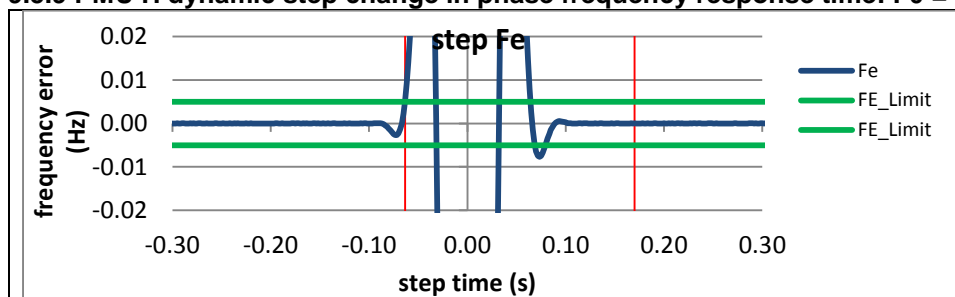


Figure 4503:  $F_s = 60$  FPS, +10 degree phase step

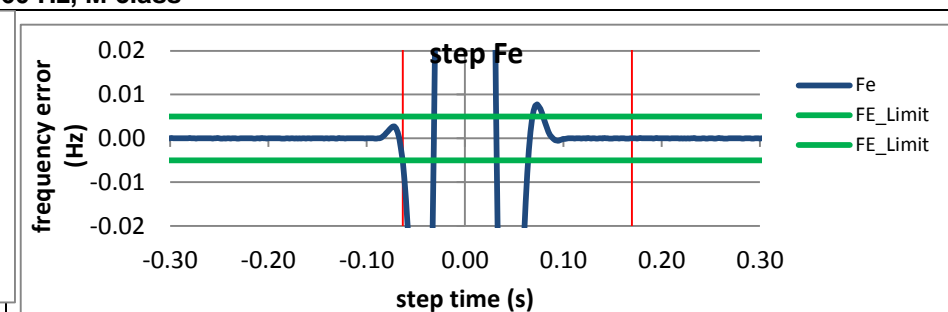


Figure 4504:  $F_s = 60$  FPS, -10 degree phase step

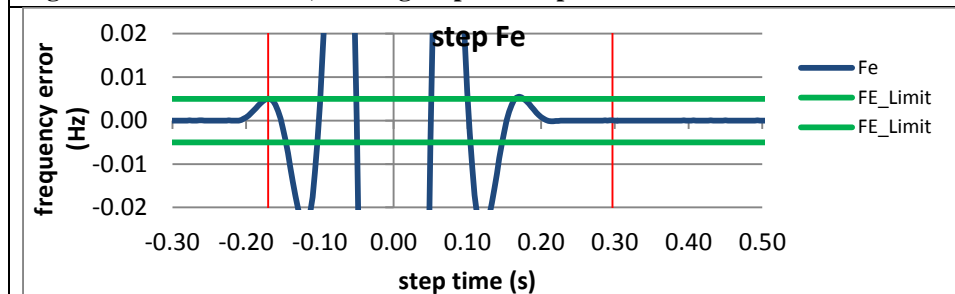


Figure 4505:  $F_s = 30$  FPS, +10 degree phase step

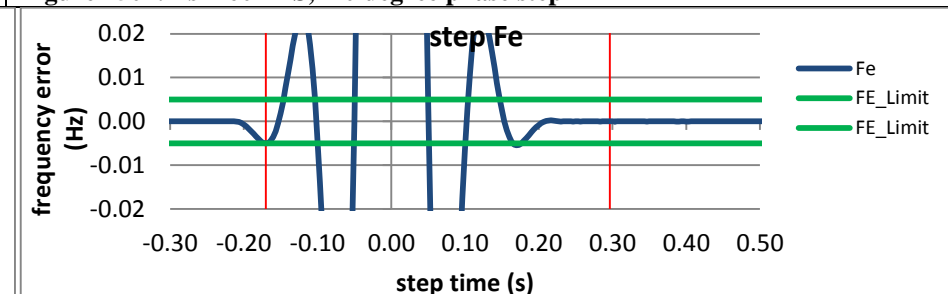


Figure 4506:  $F_s = 30$  FPS, -10 degree phase step

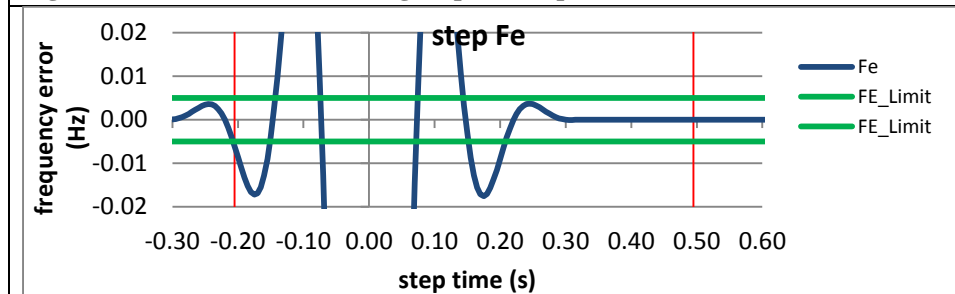


Figure 4507:  $F_s = 20$  FPS, + 10 degree phase step

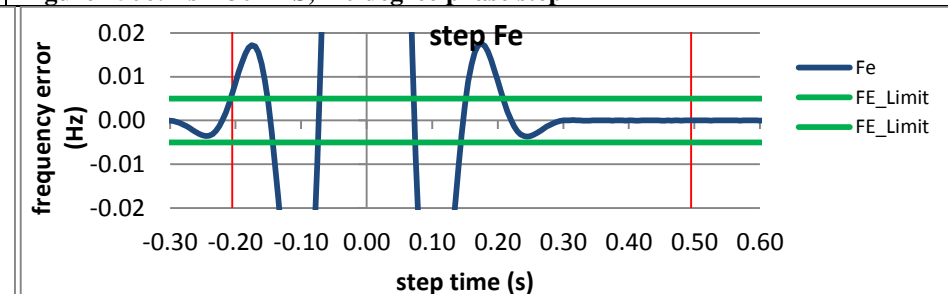


Figure 4508:  $F_s = 20$  FPS, -10 degree phase step

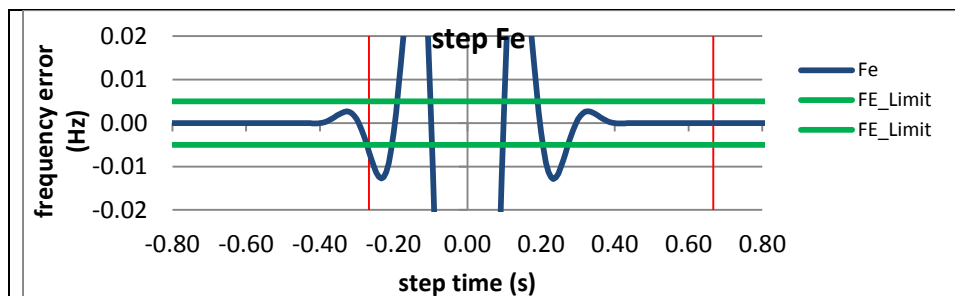


Figure 4509:  $F_s = 15$  FPS, +10 degree phase step

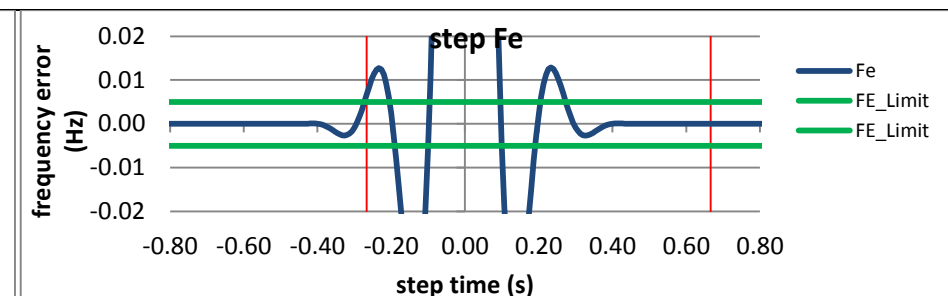


Figure 4510:  $F_s = 15$  FPS, -10 degree phase step

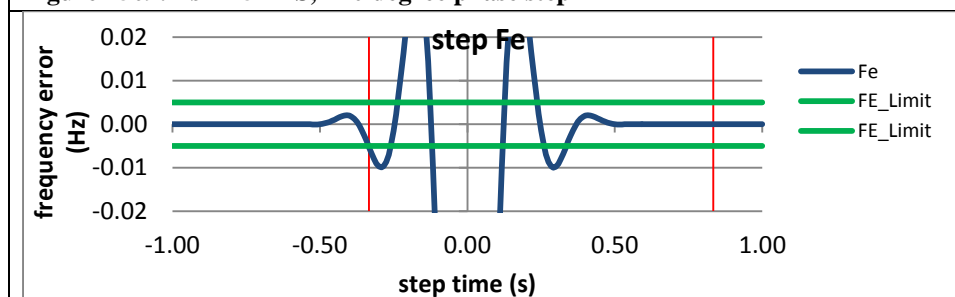


Figure 4511:  $F_s = 12$  FPS, +10 degree phase step

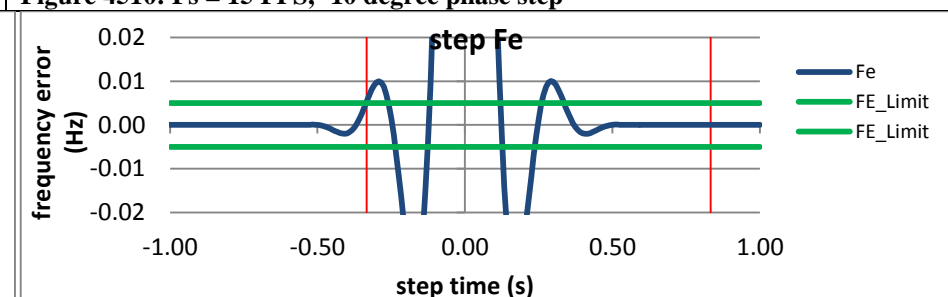


Figure 4512:  $F_s = 12$  FPS, -10 degree phase step

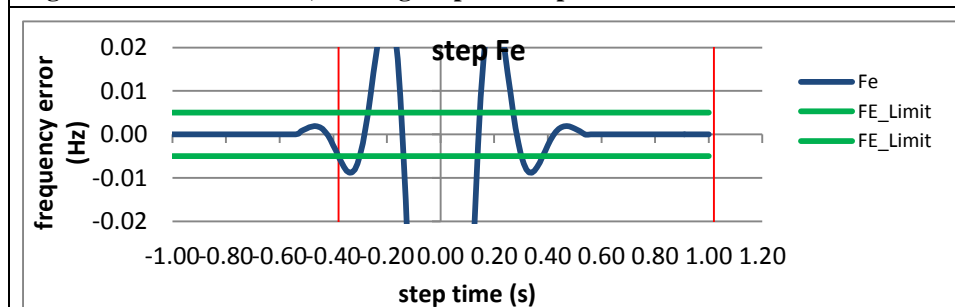


Figure 4513:  $F_s = 10$  FPS, +10 degree phase step

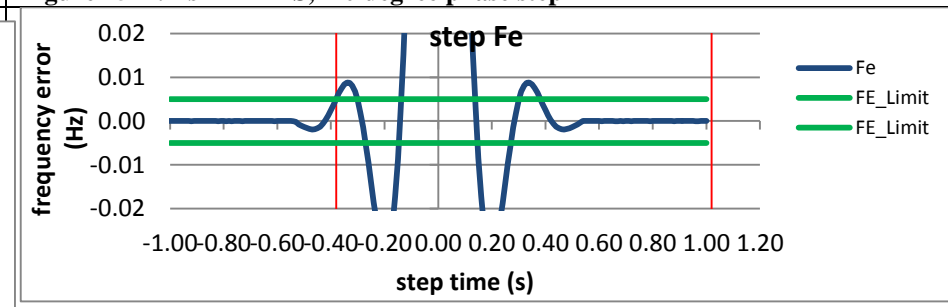
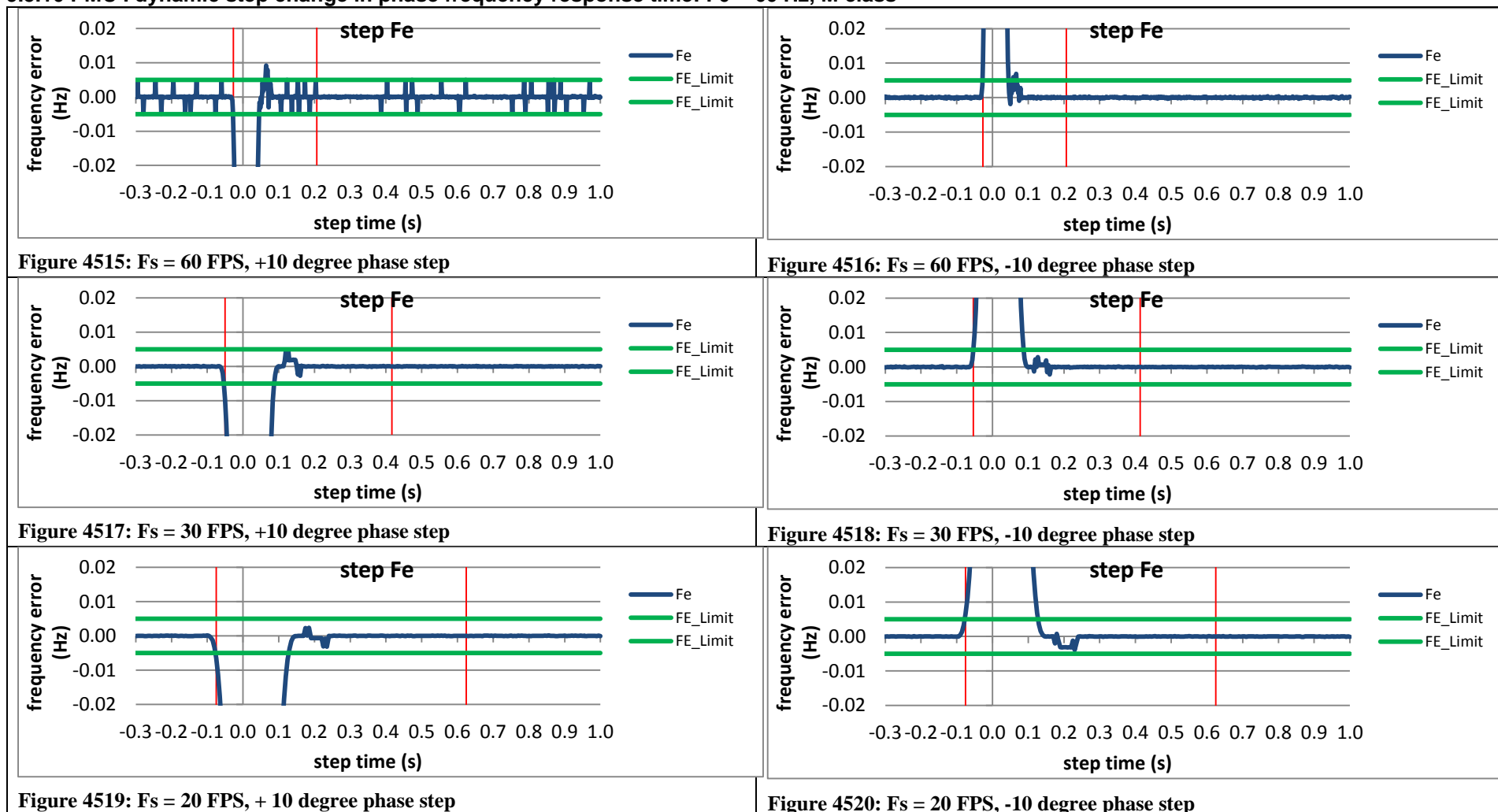
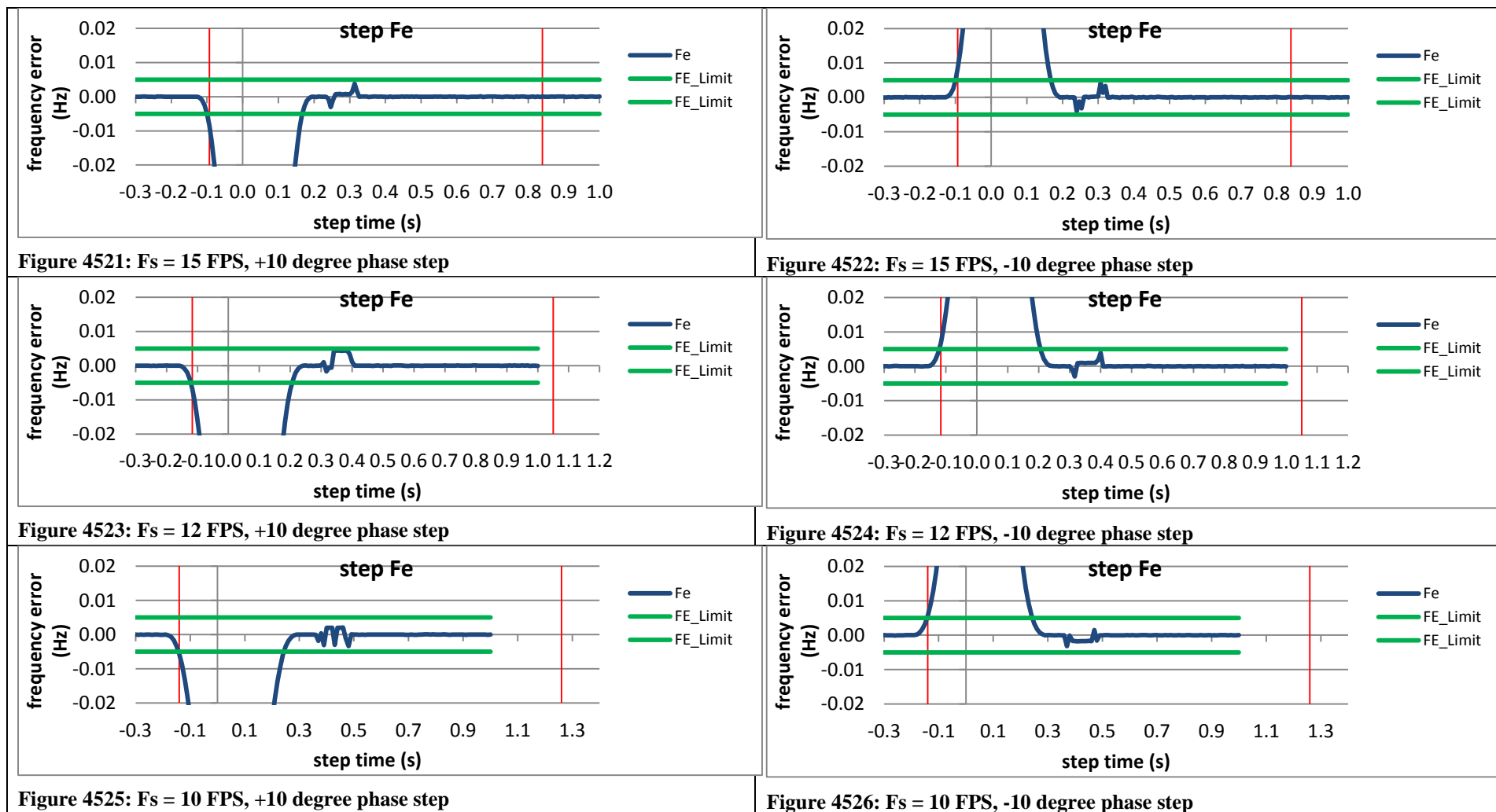


Figure 4514:  $F_s = 10$  FPS, -10 degree phase step

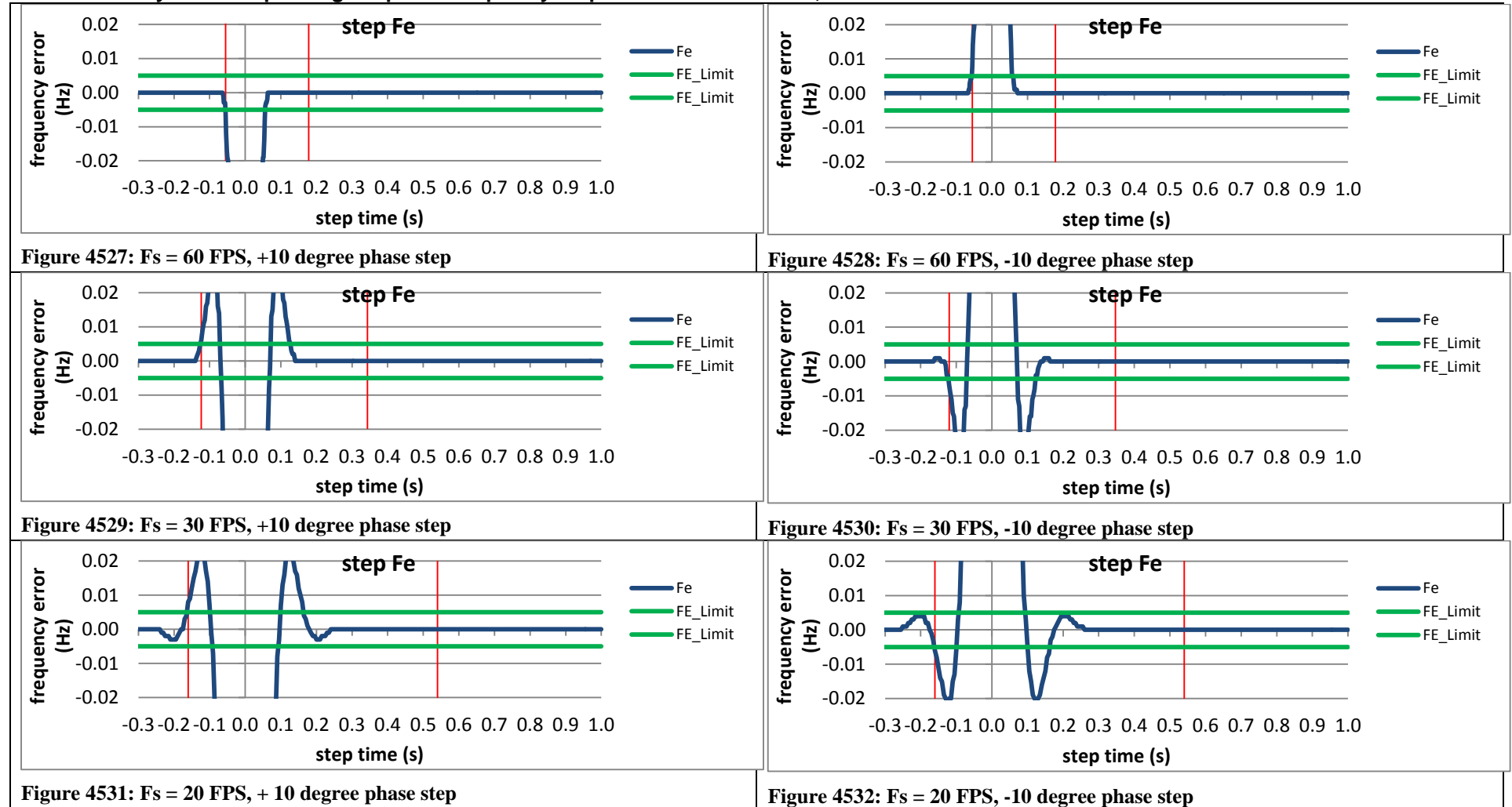
# 9.5.10 PMU I dynamic step change in phase frequency response time: $F_0 = 60$ Hz, M class







### 9.5.11 PMU J dynamic step change in phase frequency response time: $F_0 = 60$ Hz, M class



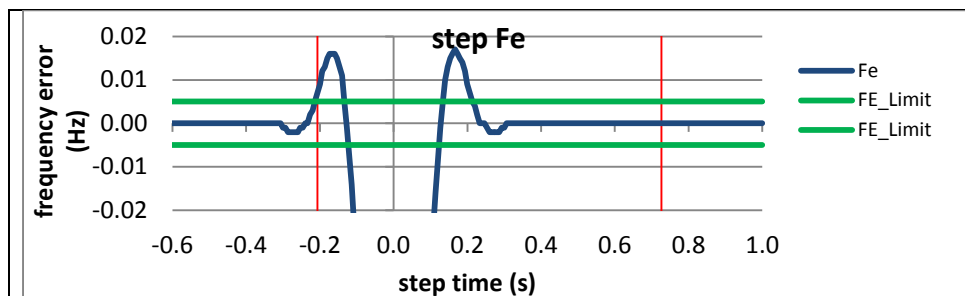


Figure 4533:  $F_s = 15$  FPS, +10 degree phase step

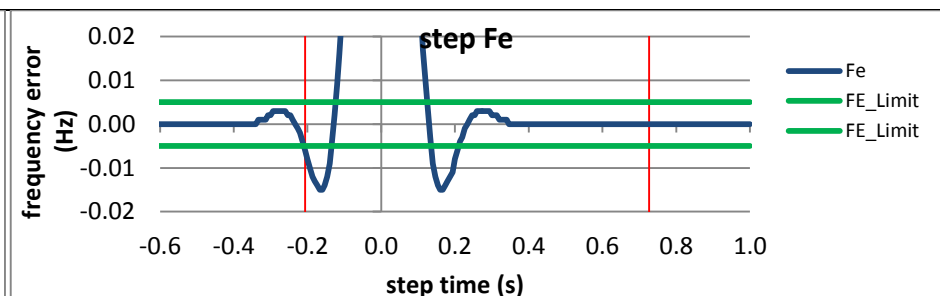


Figure 4534:  $F_s = 15$  FPS, -10 degree phase step

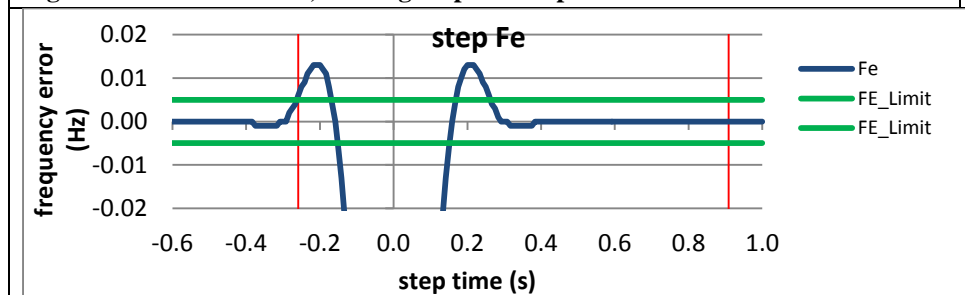


Figure 4535:  $F_s = 12$  FPS, +10 degree phase step

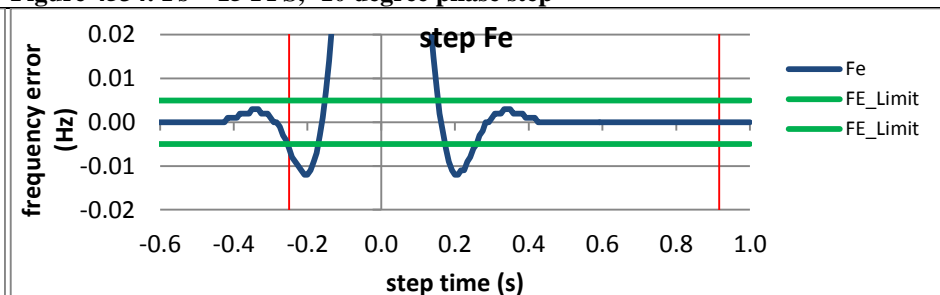


Figure 4536:  $F_s = 12$  FPS, -10 degree phase step

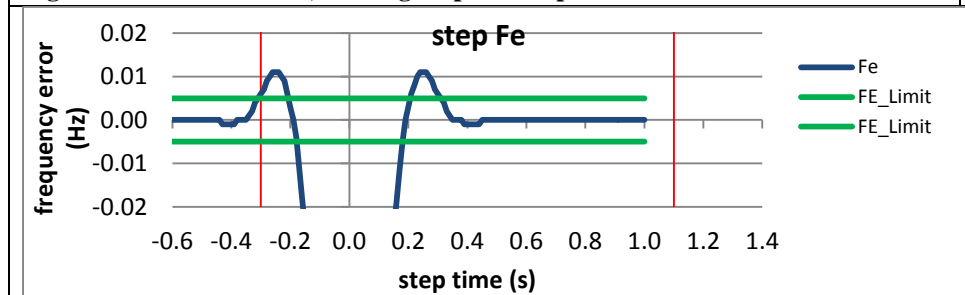


Figure 4537:  $F_s = 10$  FPS, +10 degree phase step

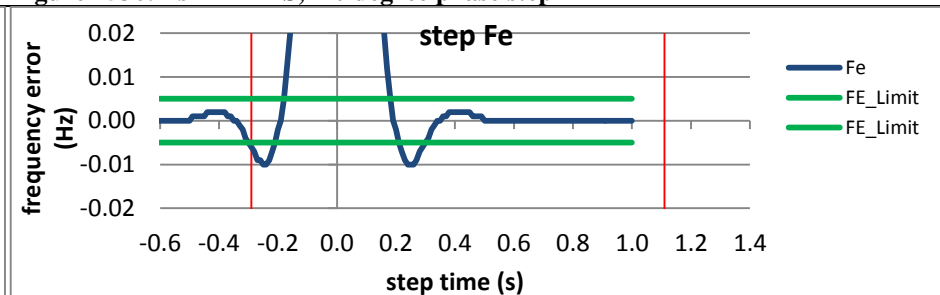
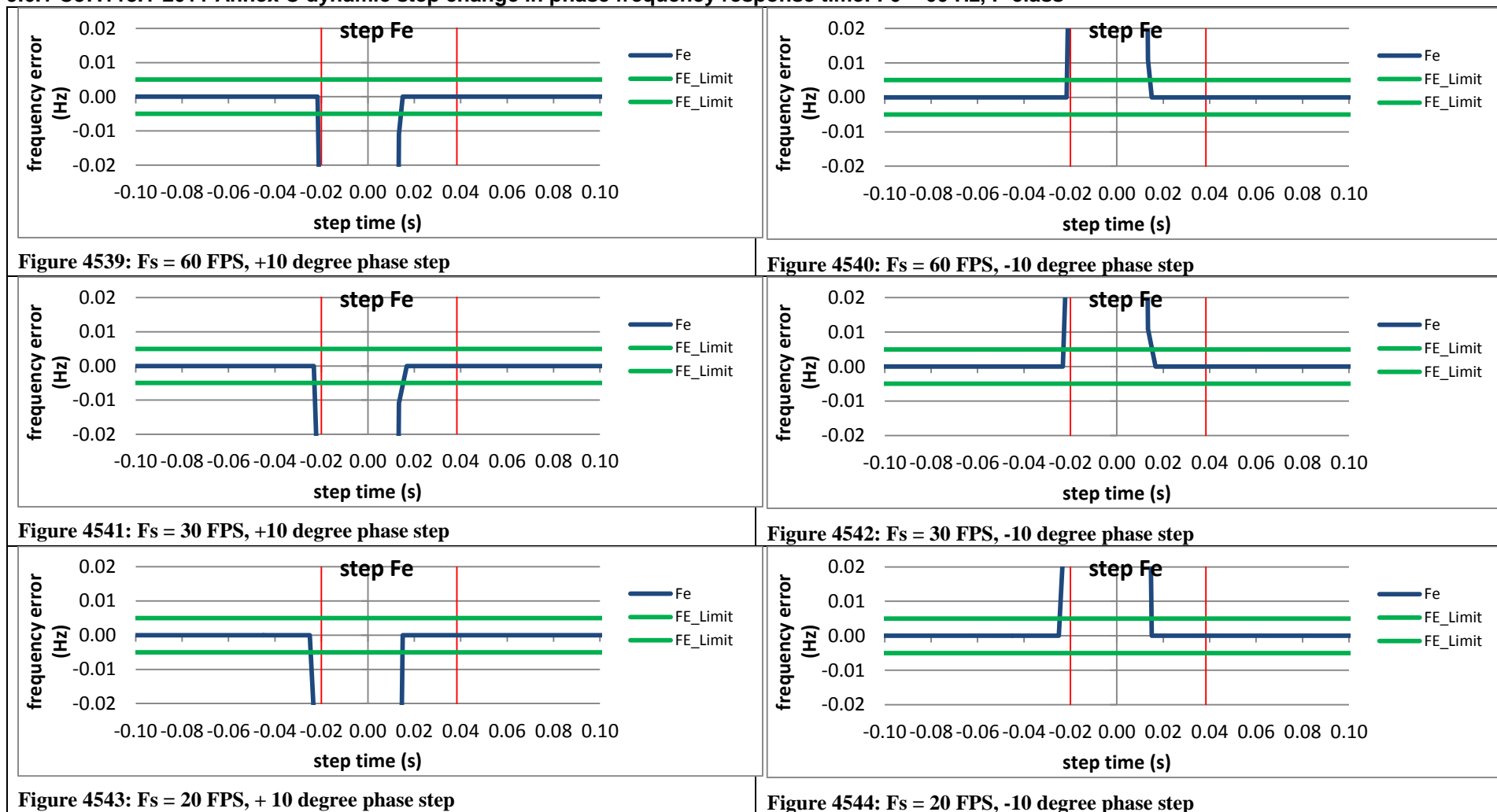
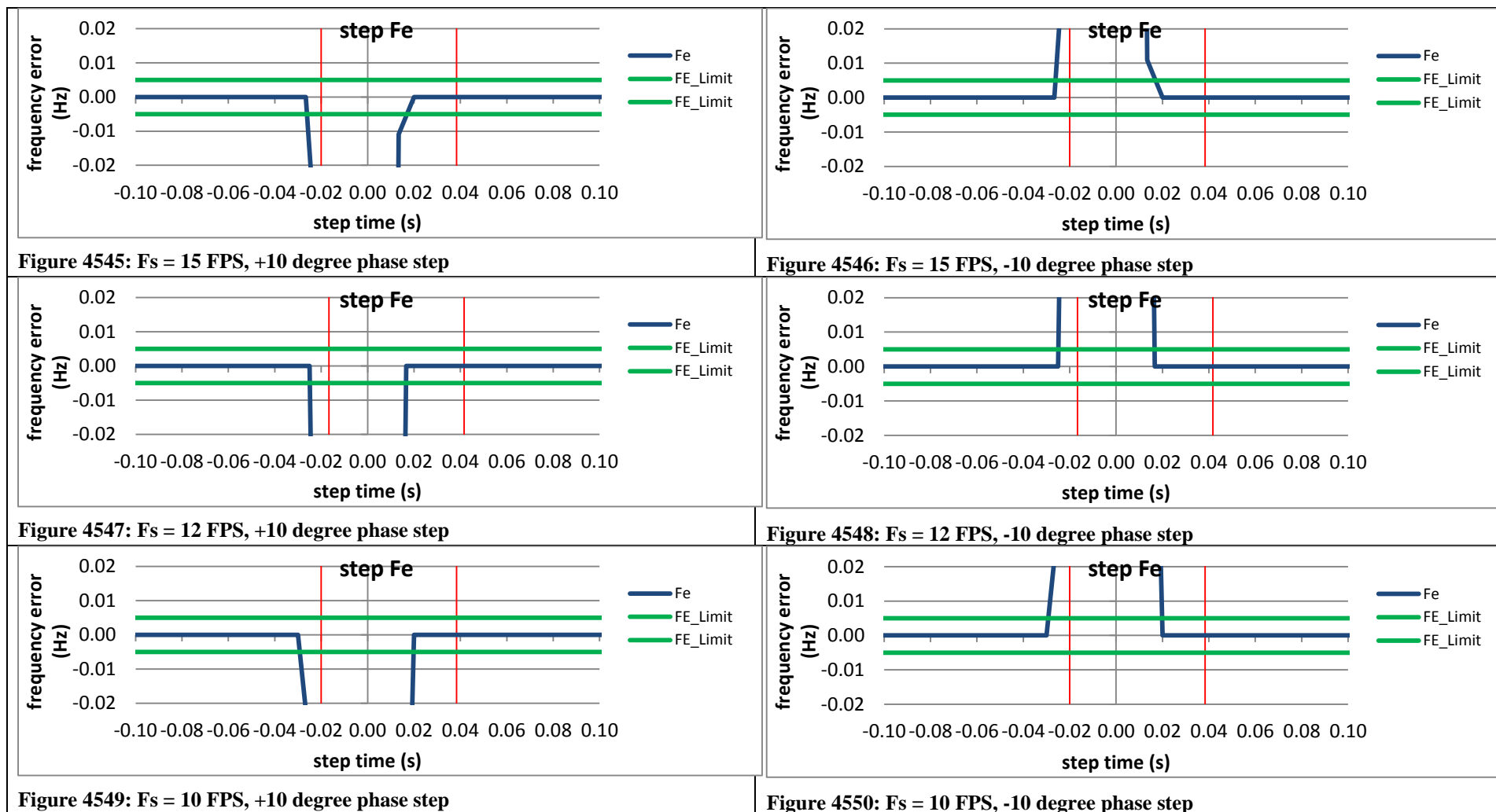


Figure 4538:  $F_s = 10$  FPS, -10 degree phase step

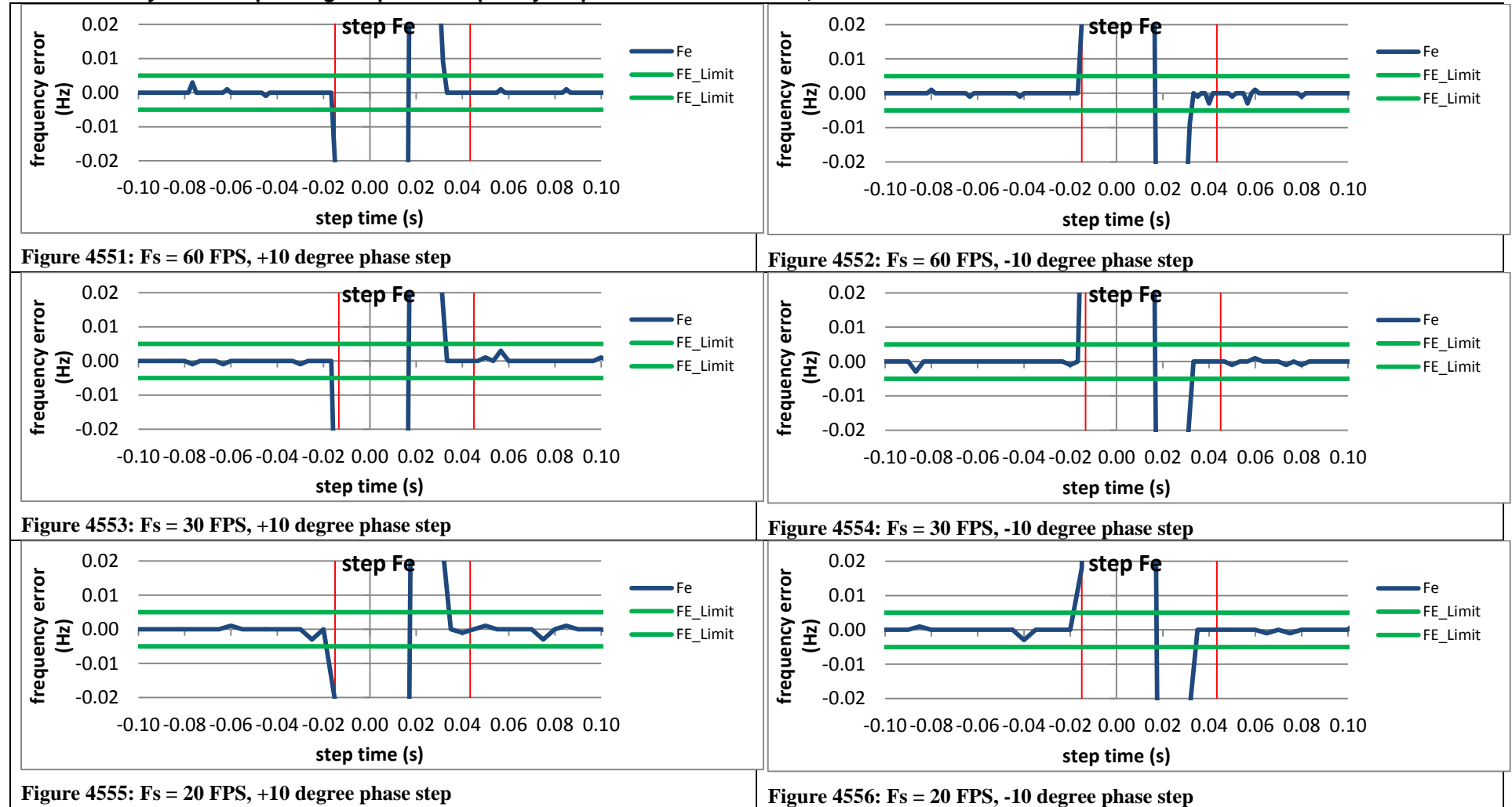
## 9.6 Dynamic step change in phase frequency response time: $F_0 = 60$ Hz, P Class

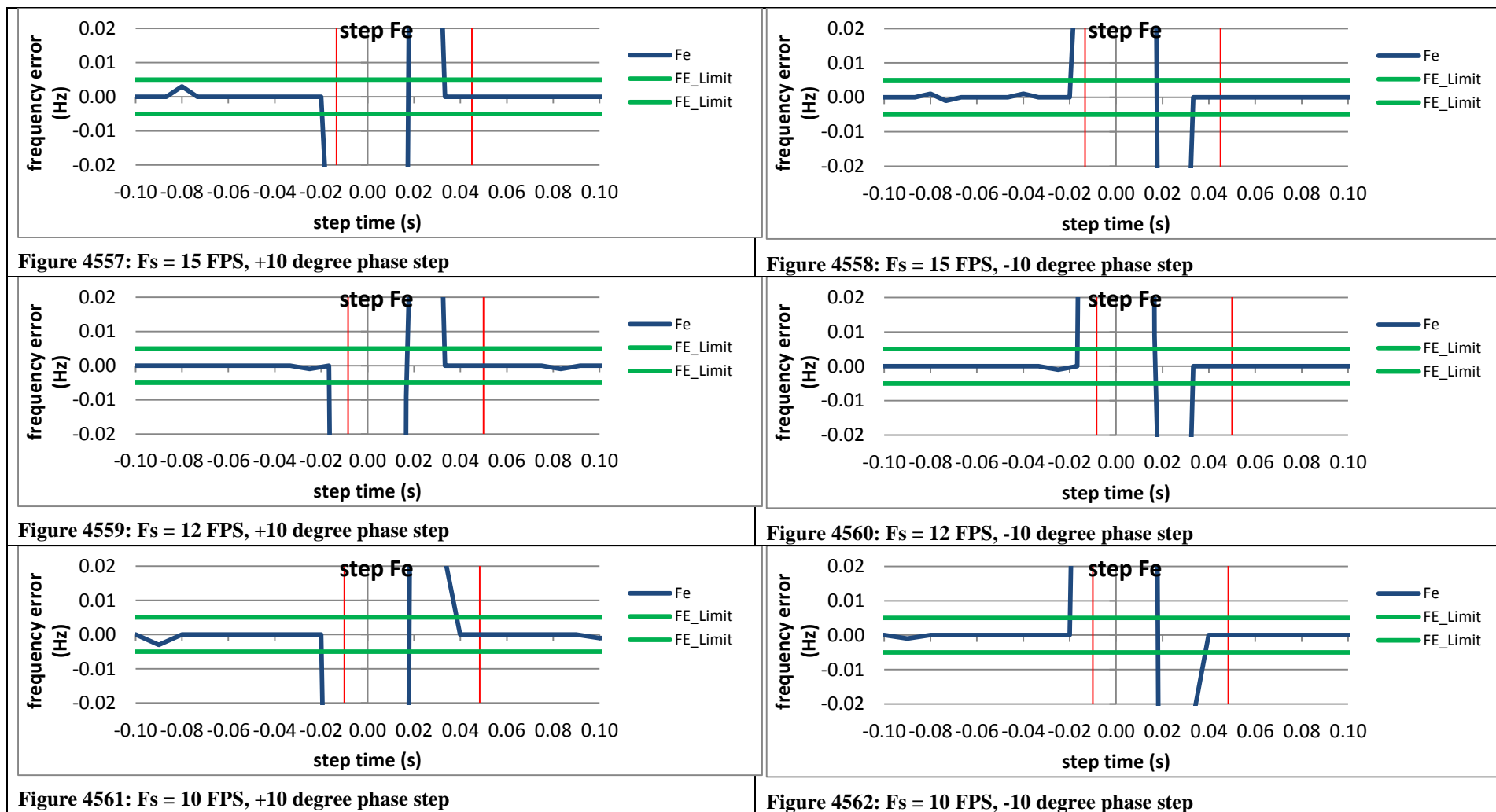
### 9.6.1 C37.118.1-2011 Annex C dynamic step change in phase frequency response time: $F_0 = 60$ Hz, P class



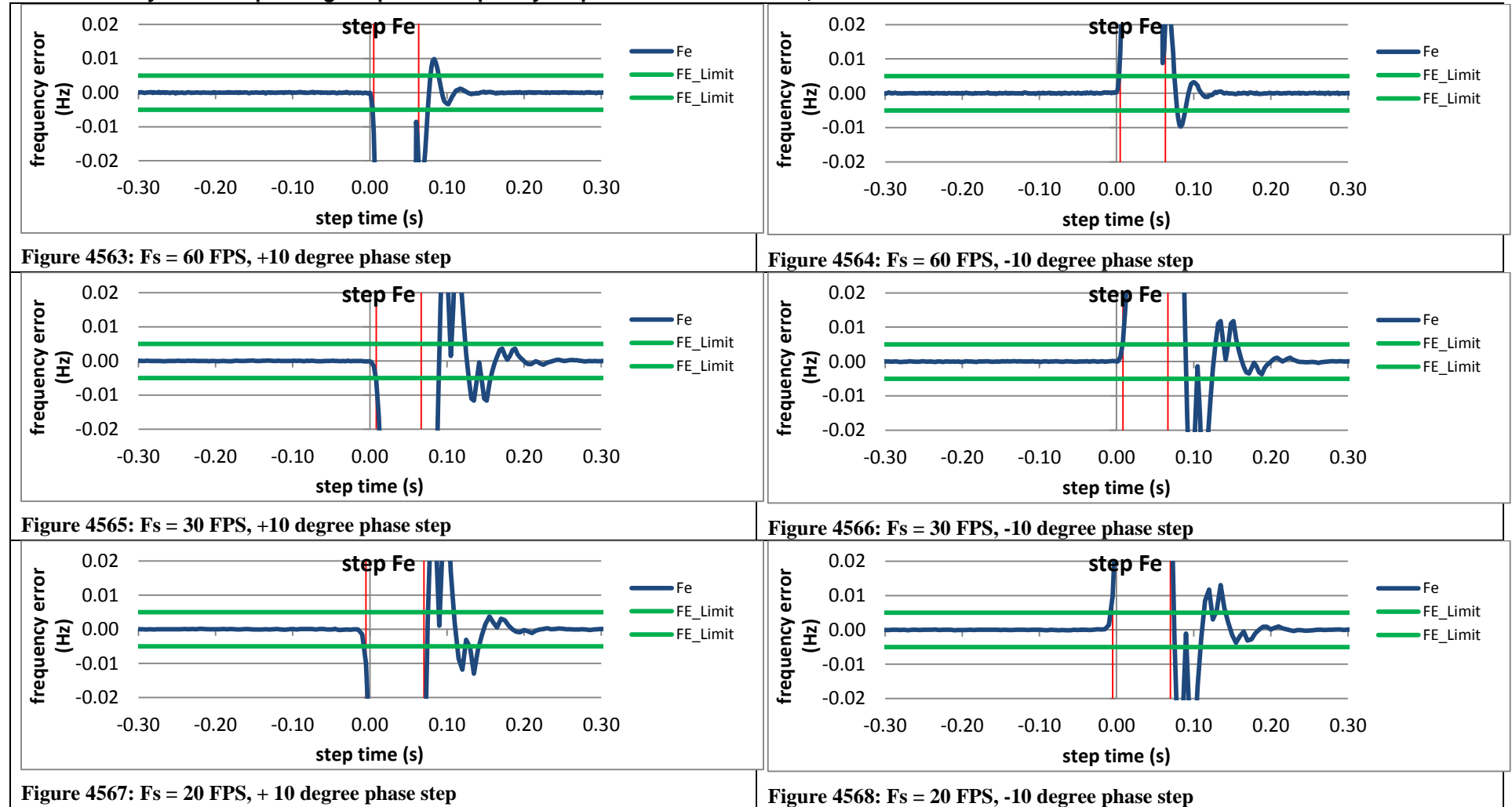


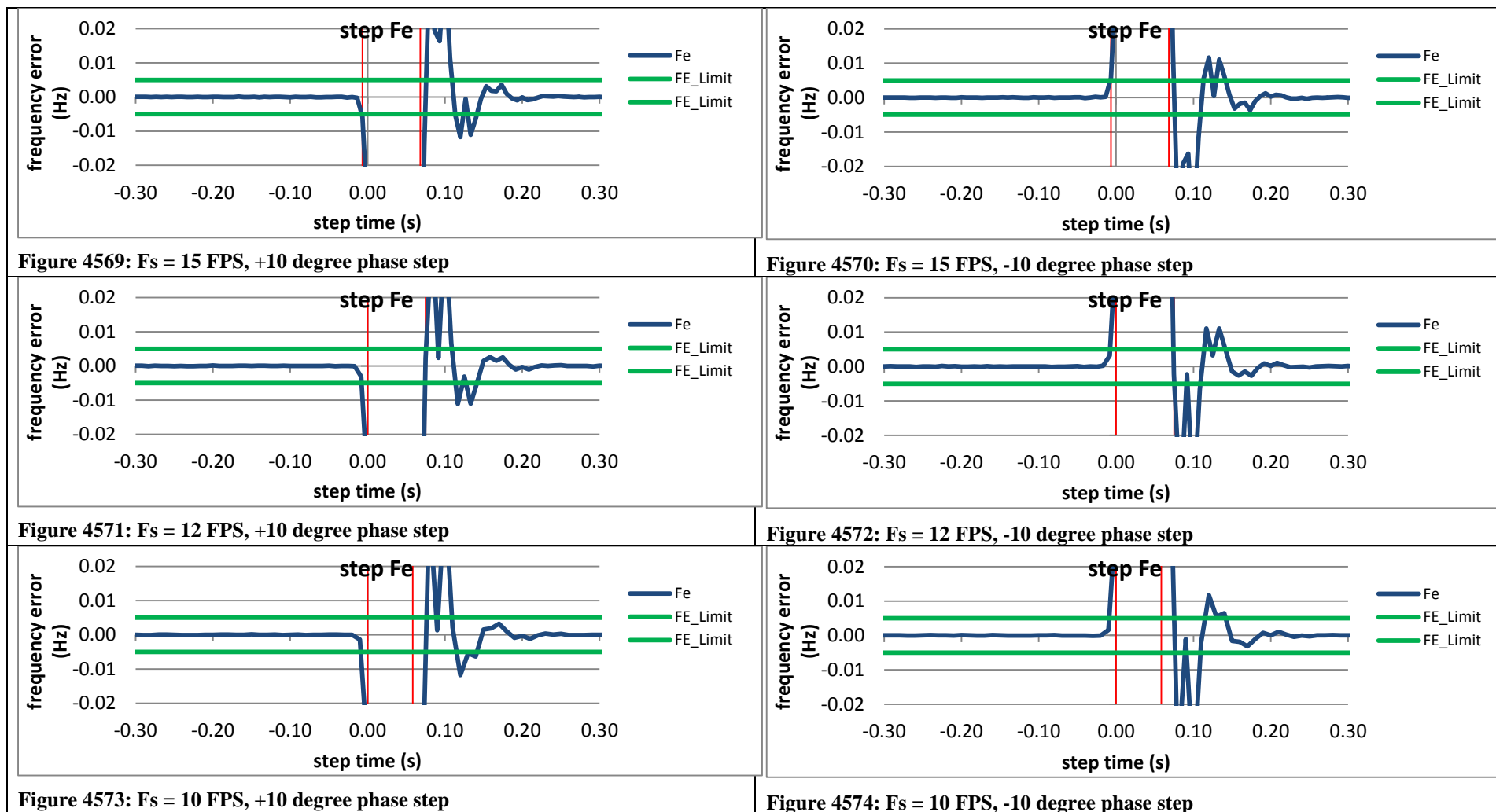
### 9.6.2 PMU A dynamic step change in phase frequency response time: $F_0 = 60$ Hz, P class





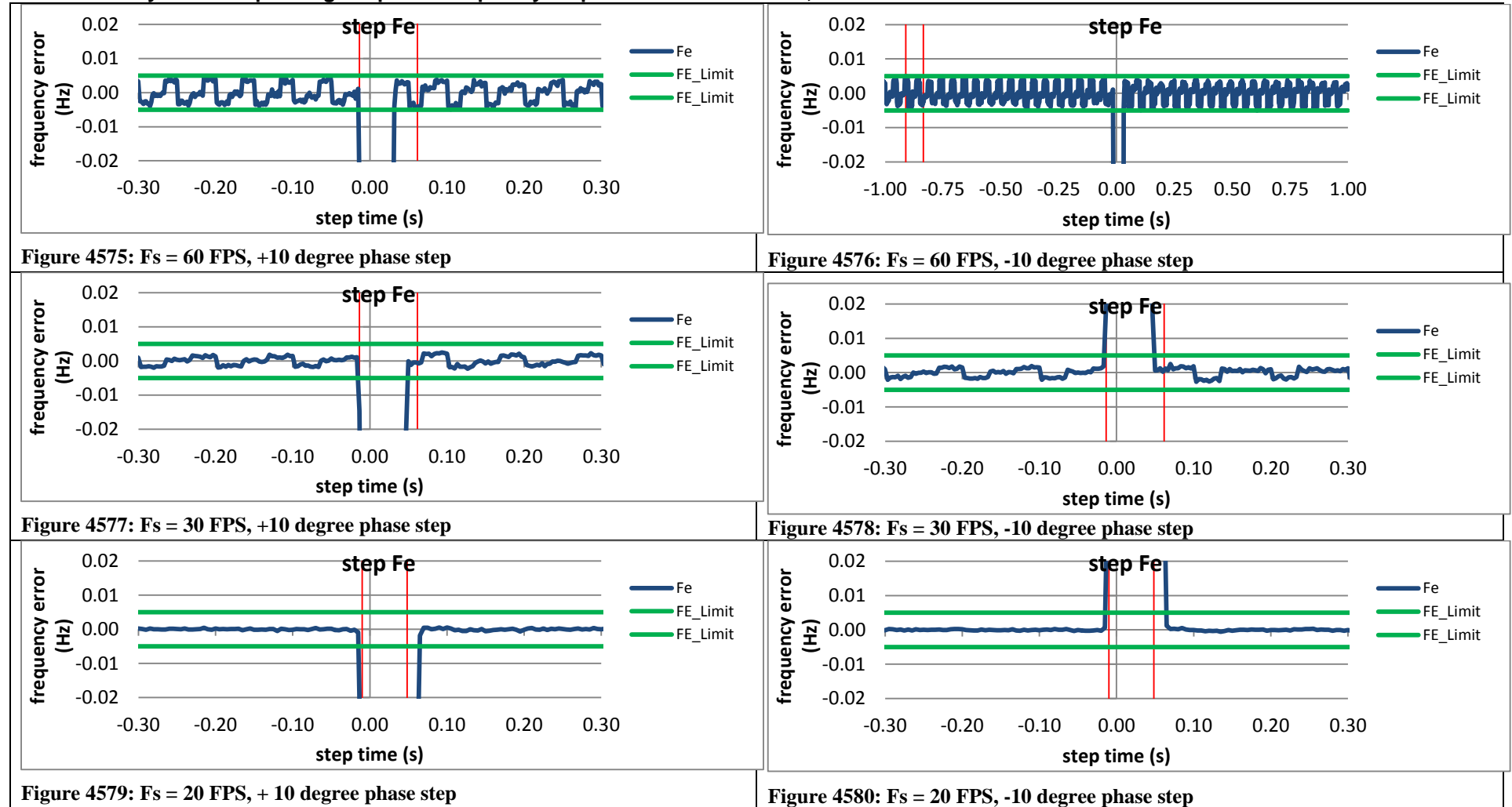
### 9.6.3 PMU B dynamic step change in phase frequency response time: $F_0 = 60$ Hz, P class







#### 9.6.4 PMU C dynamic step change in phase frequency response time: $F_0 = 60$ Hz, P class



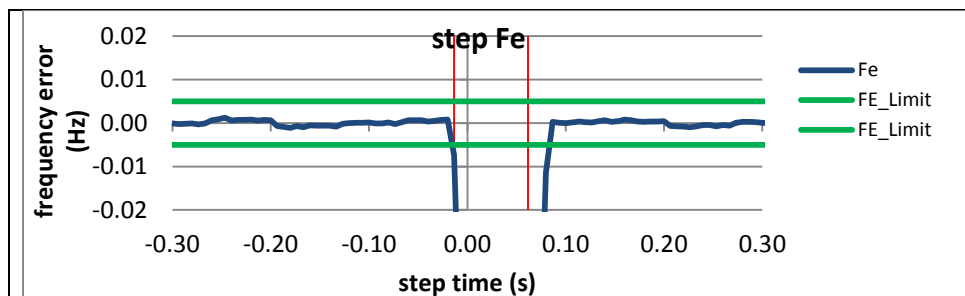


Figure 4581:  $F_s = 15$  FPS, +10 degree phase step

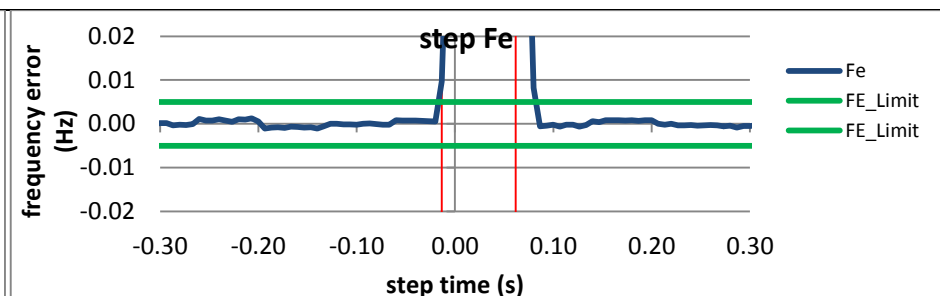


Figure 4582:  $F_s = 15$  FPS, -10 degree phase step

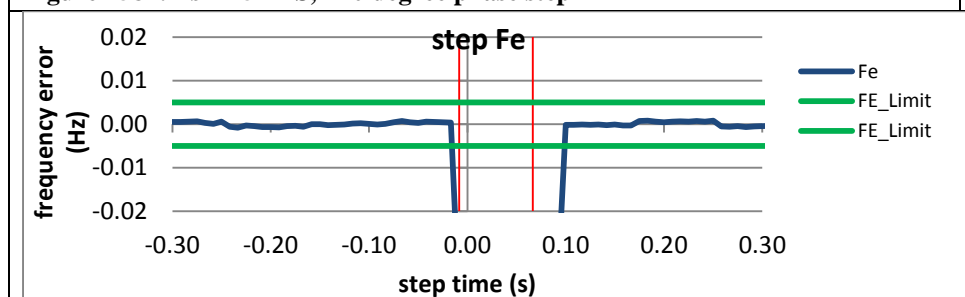


Figure 4583:  $F_s = 12$  FPS, +10 degree phase step

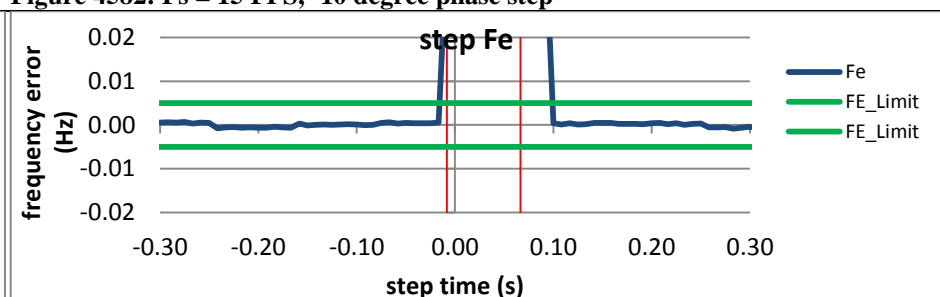


Figure 4584:  $F_s = 12$  FPS, -10 degree phase step

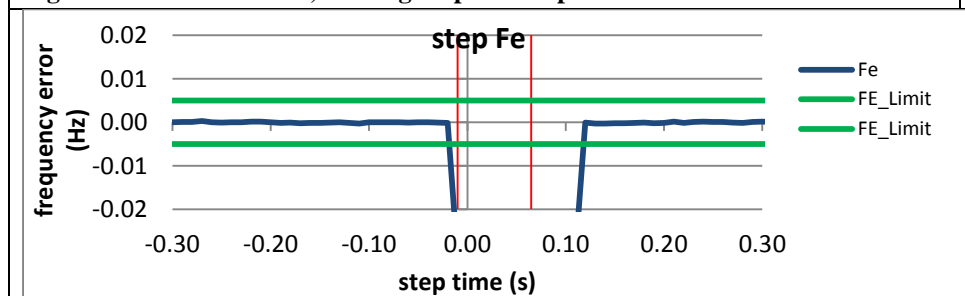


Figure 4585:  $F_s = 10$  FPS, +10 degree phase step

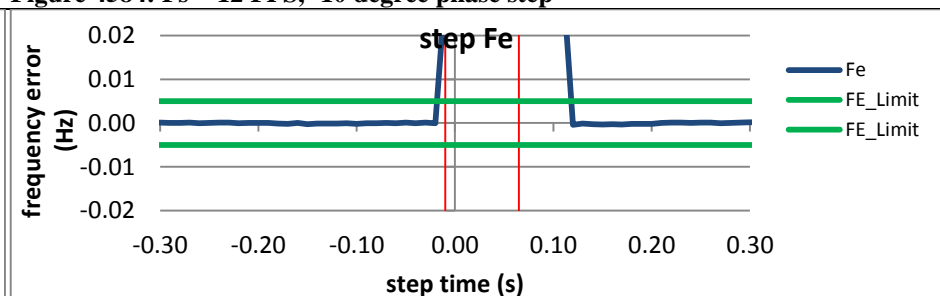


Figure 4586:  $F_s = 10$  FPS, -10 degree phase step

# 9.6.5 PMU D dynamic step change in phase frequency response time: F0 = 60 Hz, P class

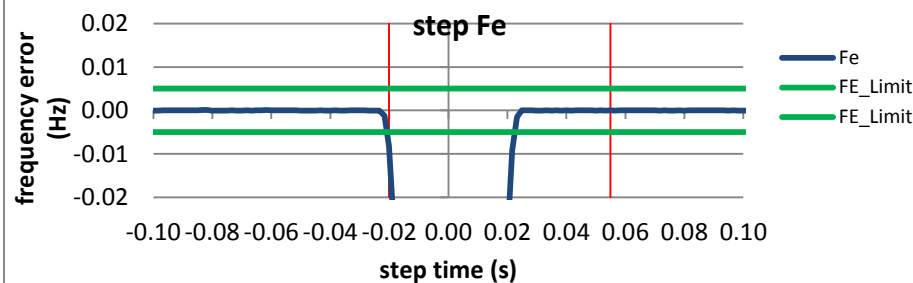


Figure 4587: Fs = 60 FPS, +10 degree phase step

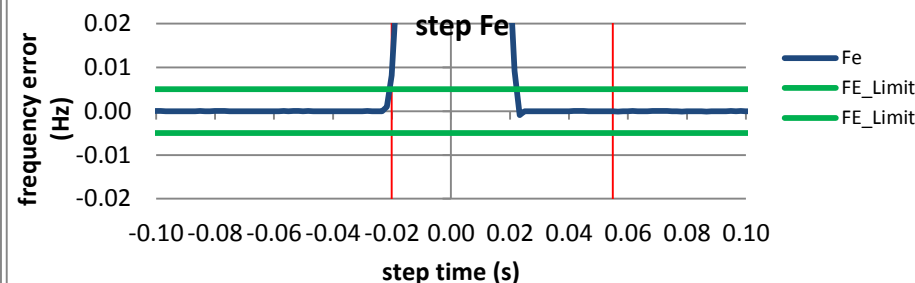


Figure 4588: Fs = 60 FPS, -10 degree phase step

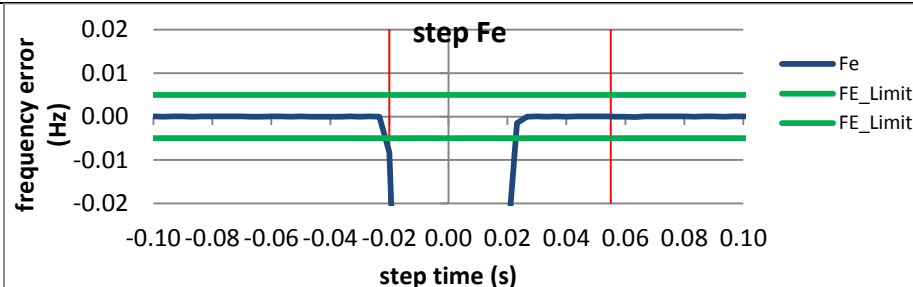


Figure 4589: Fs = 30 FPS, +10 degree phase step

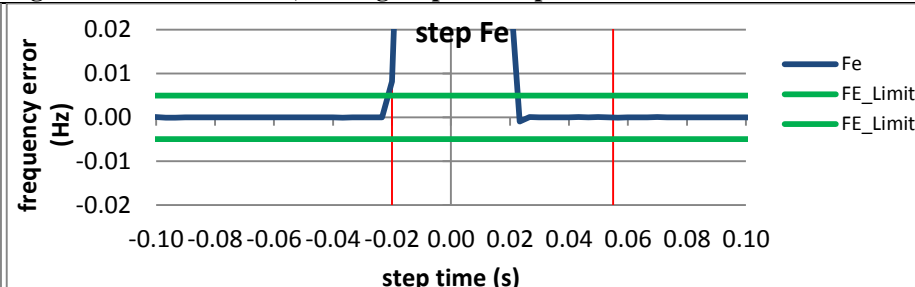


Figure 4590: Fs = 30 FPS, -10 degree phase step

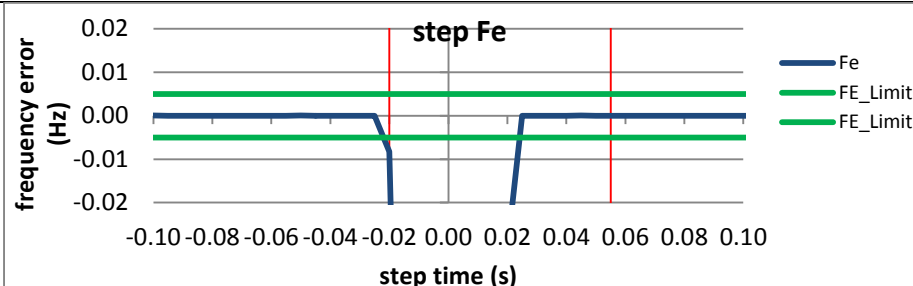


Figure 4591: Fs = 20 FPS, + 10 degree phase step

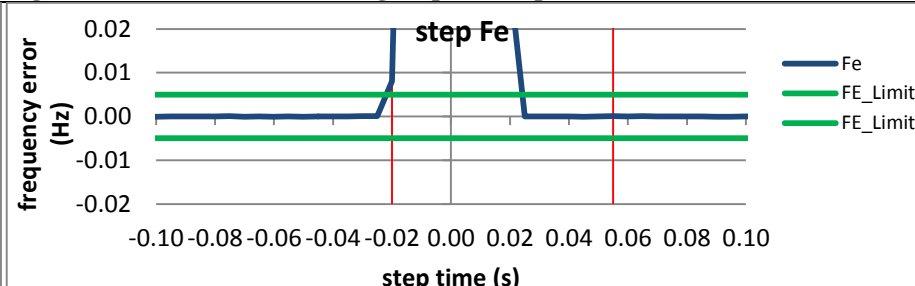
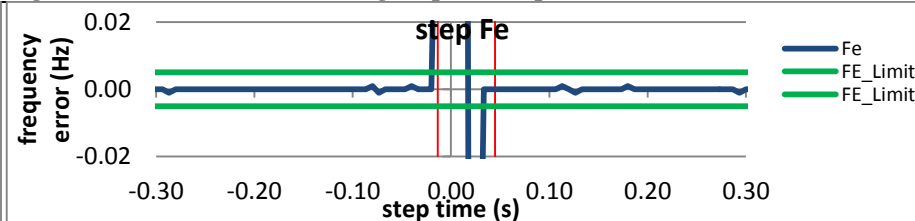
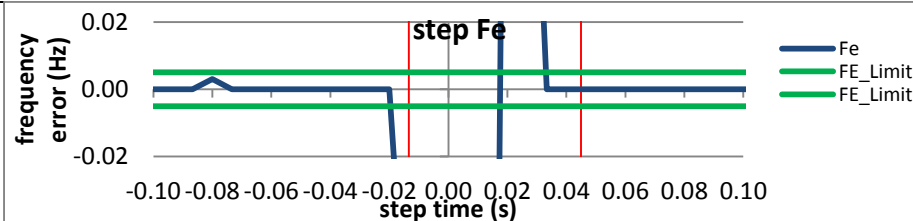
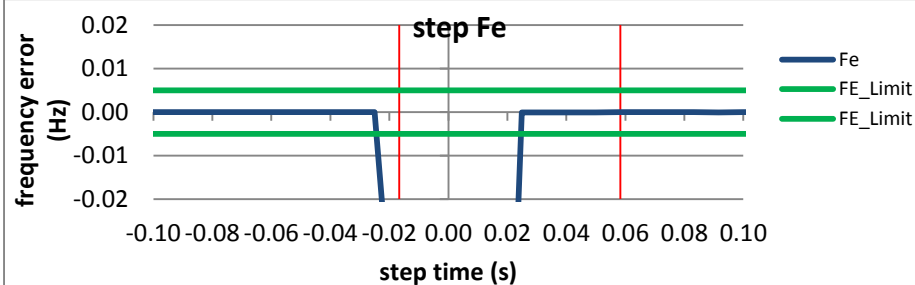


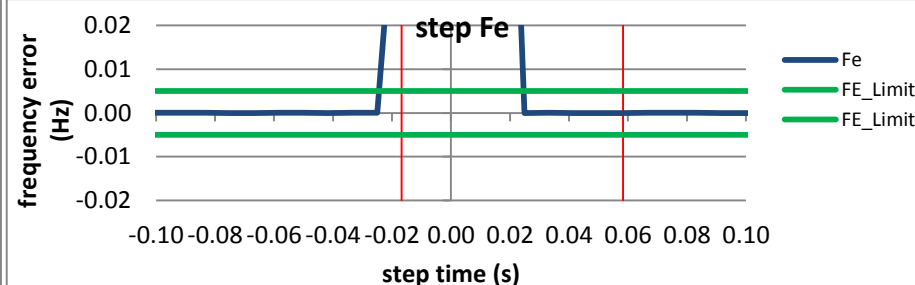
Figure 4592: Fs = 20 FPS, -10 degree phase step



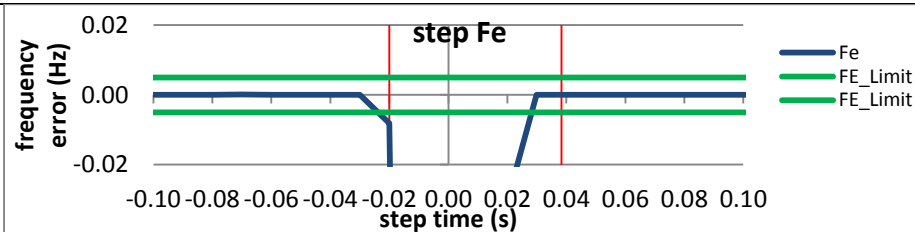
**Figure 4593:  $F_s = 15$  FPS, +10 degree phase step**



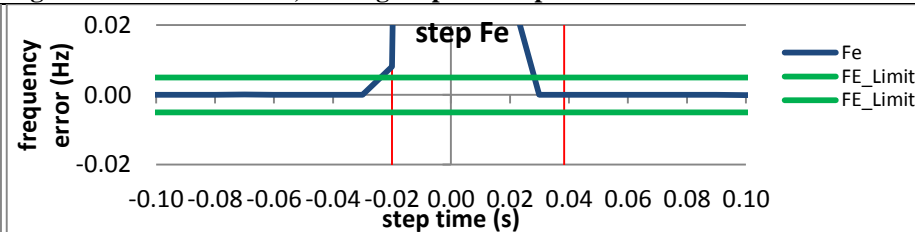
**Figure 4594:  $F_s = 15$  FPS, -10 degree phase step**



**Figure 4595:  $F_s = 12$  FPS, +10 degree phase step**



**Figure 4596:  $F_s = 12$  FPS, -10 degree phase step**



**Figure 4597:  $F_s = 10$  FPS, +10 degree phase step**



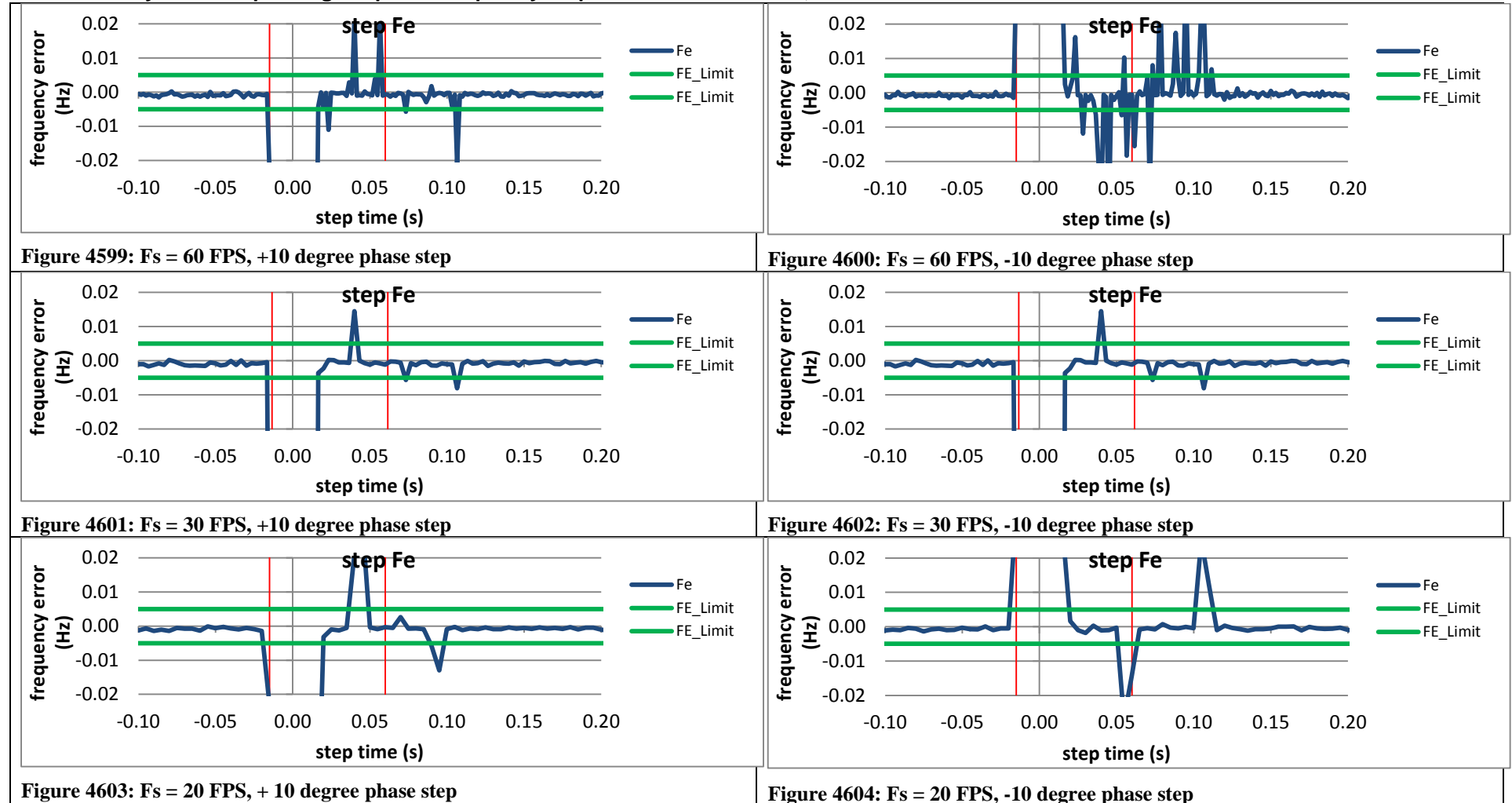
**Figure 4598:  $F_s = 10$  FPS, -10 degree phase step**

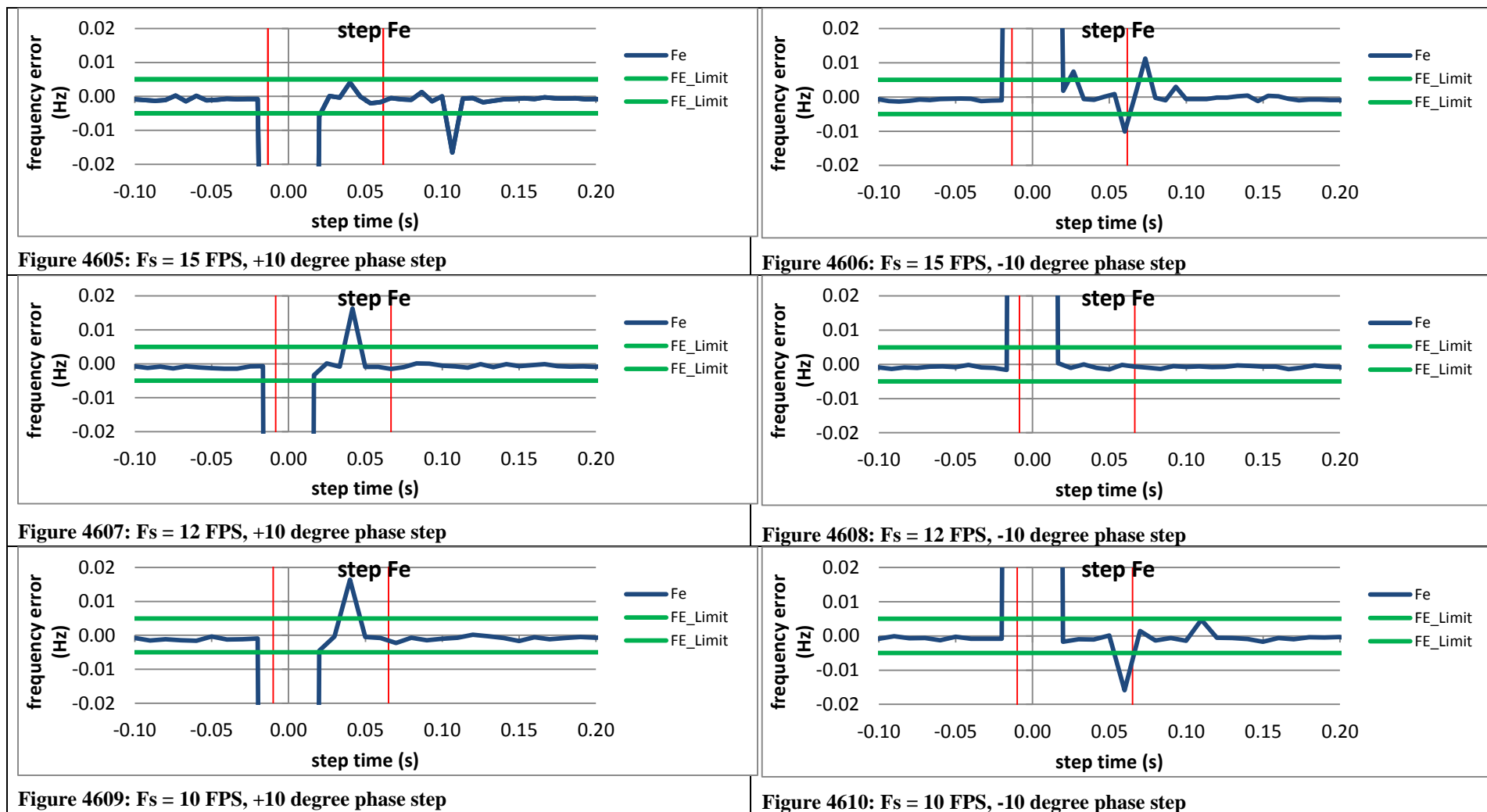


### 9.6.6 PMU E dynamic step change in phase frequency response time: $F_0 = 60$ Hz, P class

PMU E does not support P class

### 9.6.7 PMU F dynamic step change in phase frequency response time: $F_0 = 60$ Hz, P class

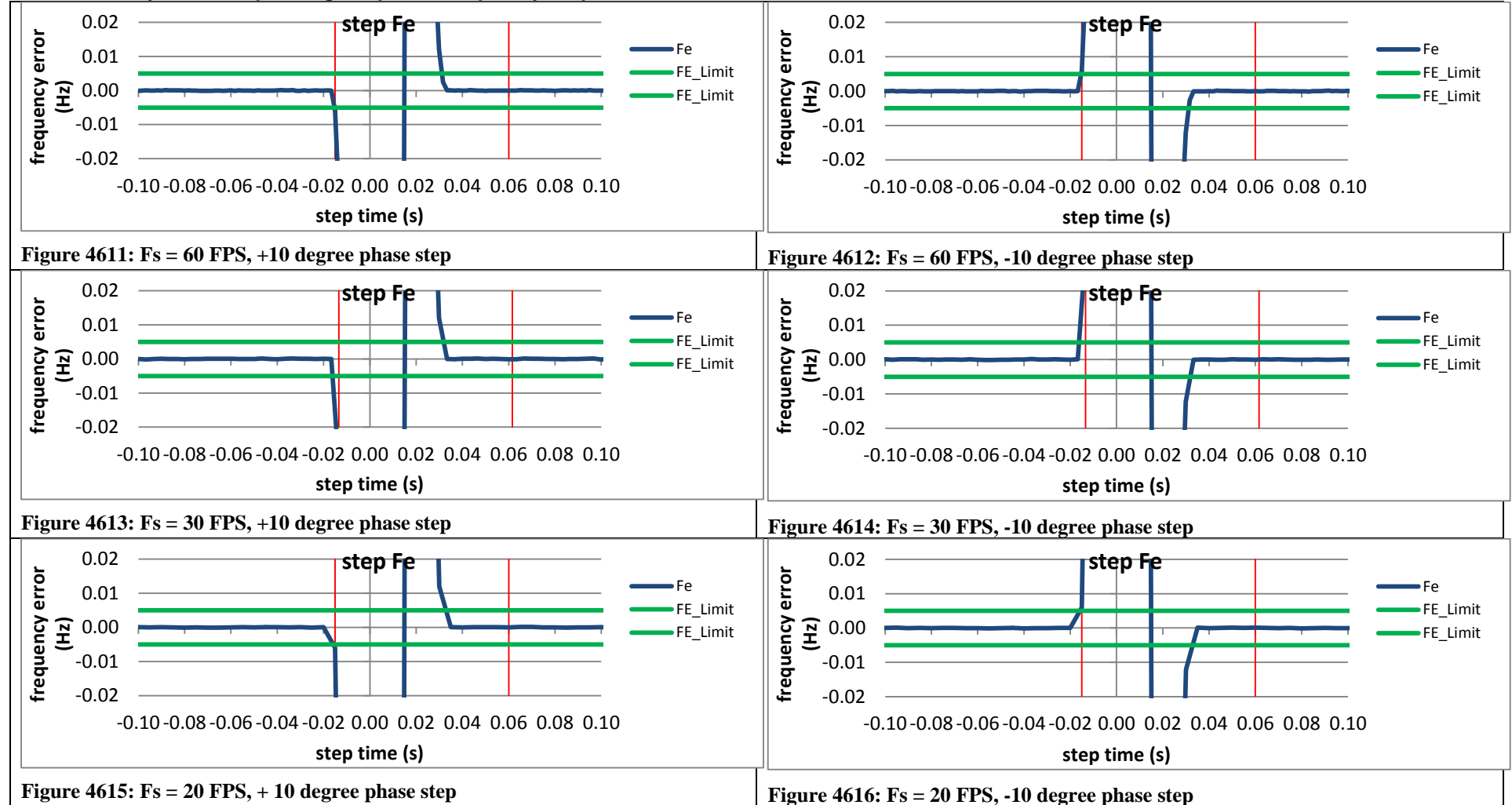




### 9.6.8 PMU G dynamic step change in phase frequency response time: $F_0 = 60$ Hz, P class

PMU G does not support P class.

### 9.6.9 PMU H dynamic step change in phase frequency response time: $F_0 = 60$ Hz, P class



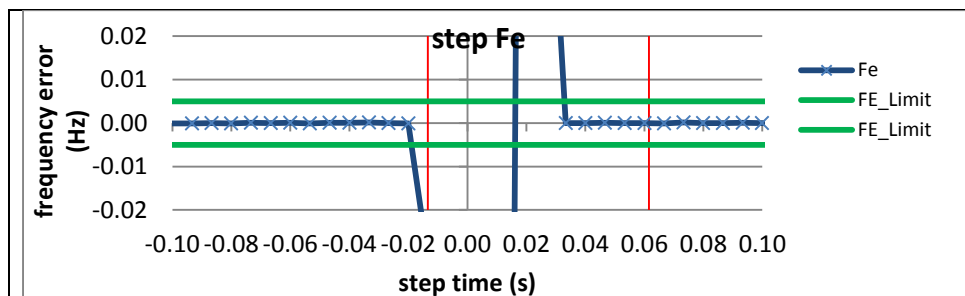


Figure 4617:  $F_s = 15$  FPS, +10 degree phase step

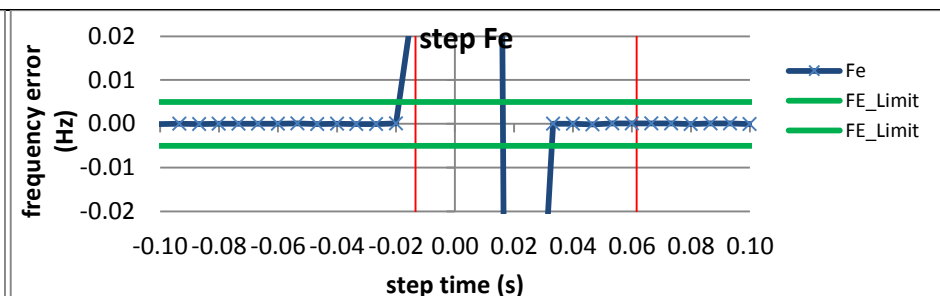


Figure 4618:  $F_s = 15$  FPS, -10 degree phase step

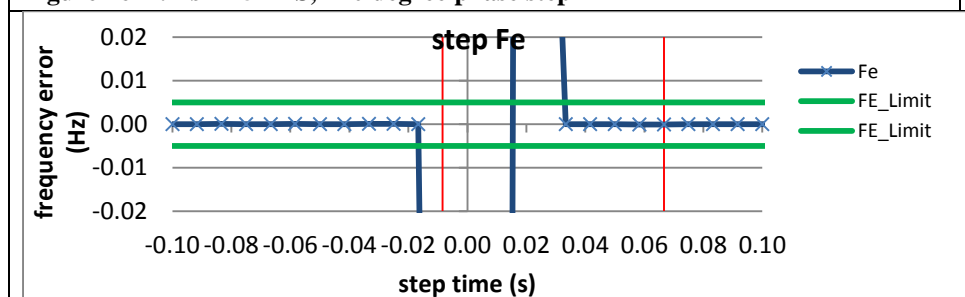


Figure 4619:  $F_s = 12$  FPS, +10 degree phase step

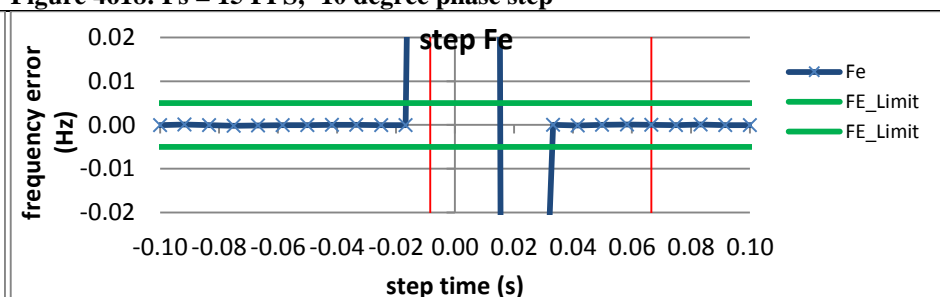


Figure 4620:  $F_s = 12$  FPS, -10 degree phase step

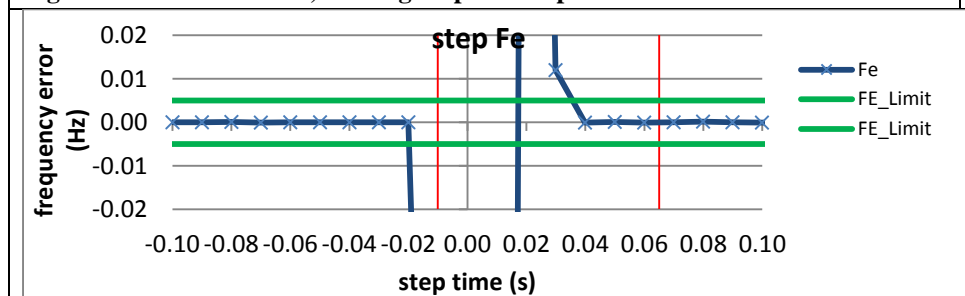


Figure 4621:  $F_s = 10$  FPS, +10 degree phase step

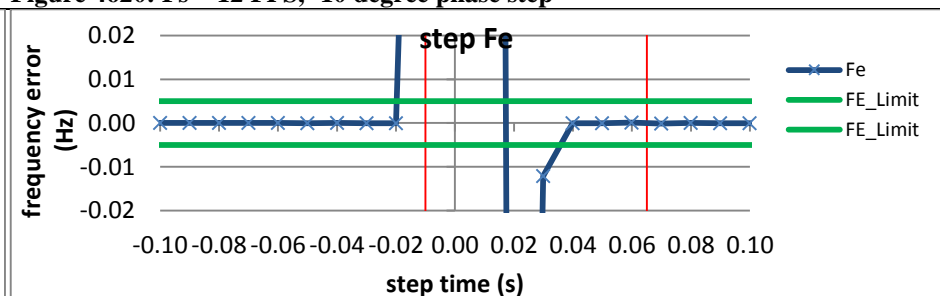


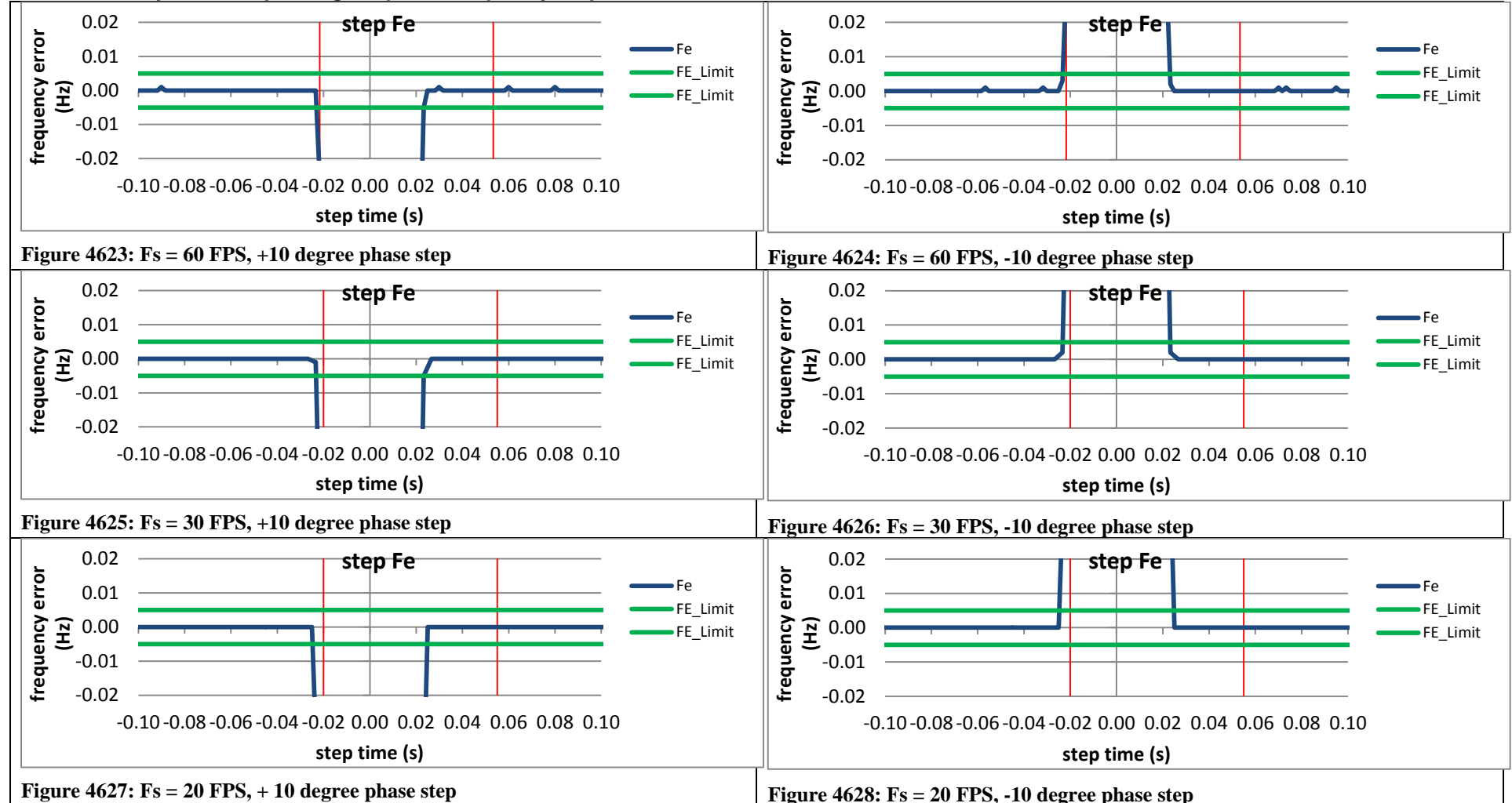
Figure 4622:  $F_s = 10$  FPS, -10 degree phase step

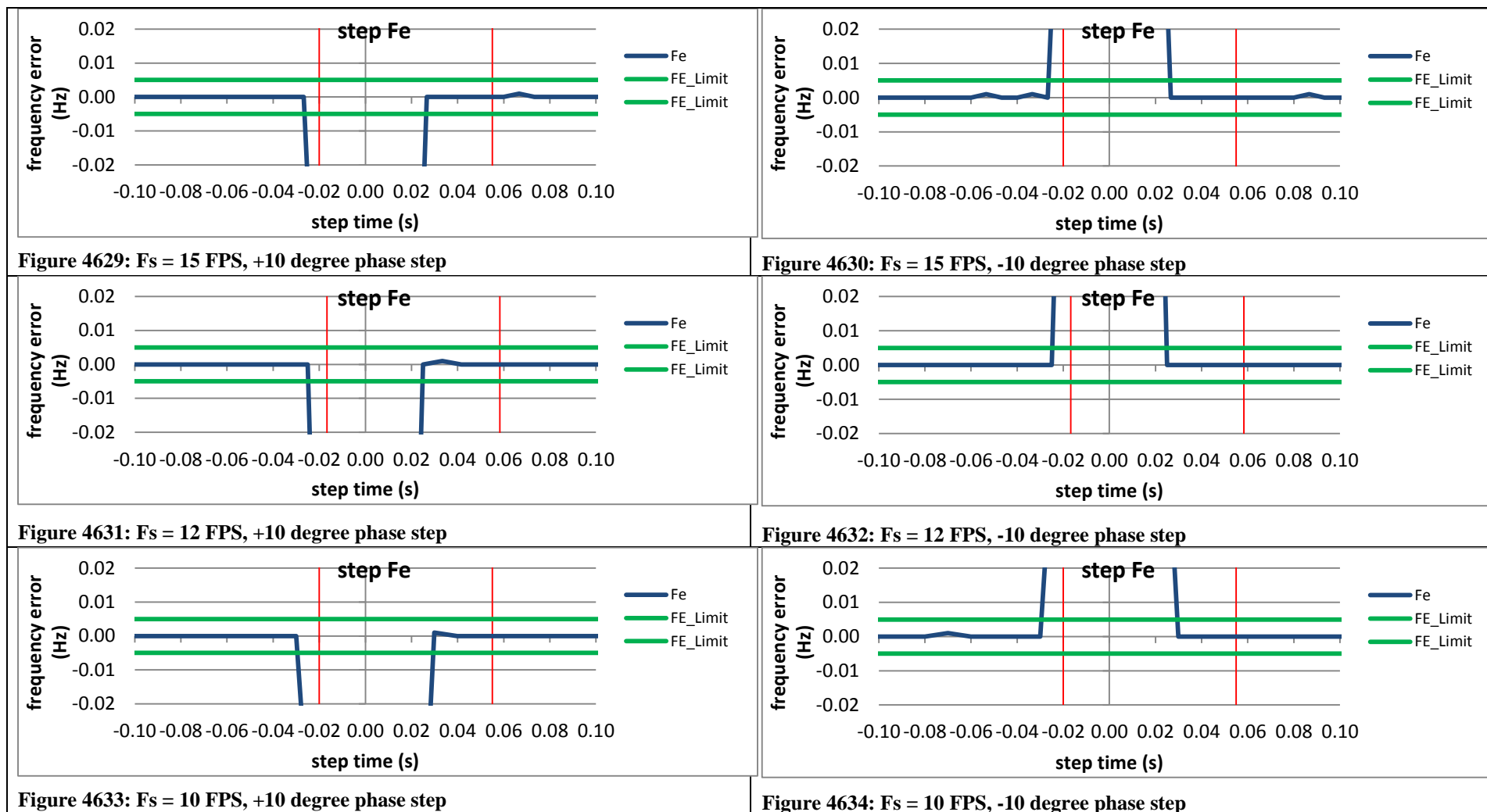


### 9.6.10 PMU I dynamic step change in phase frequency response time: $F_0 = 60$ Hz, P class

PMU I does not support P class

### 9.6.11 PMU J dynamic step change in phase frequency response time: $F_0 = 60$ Hz, P class



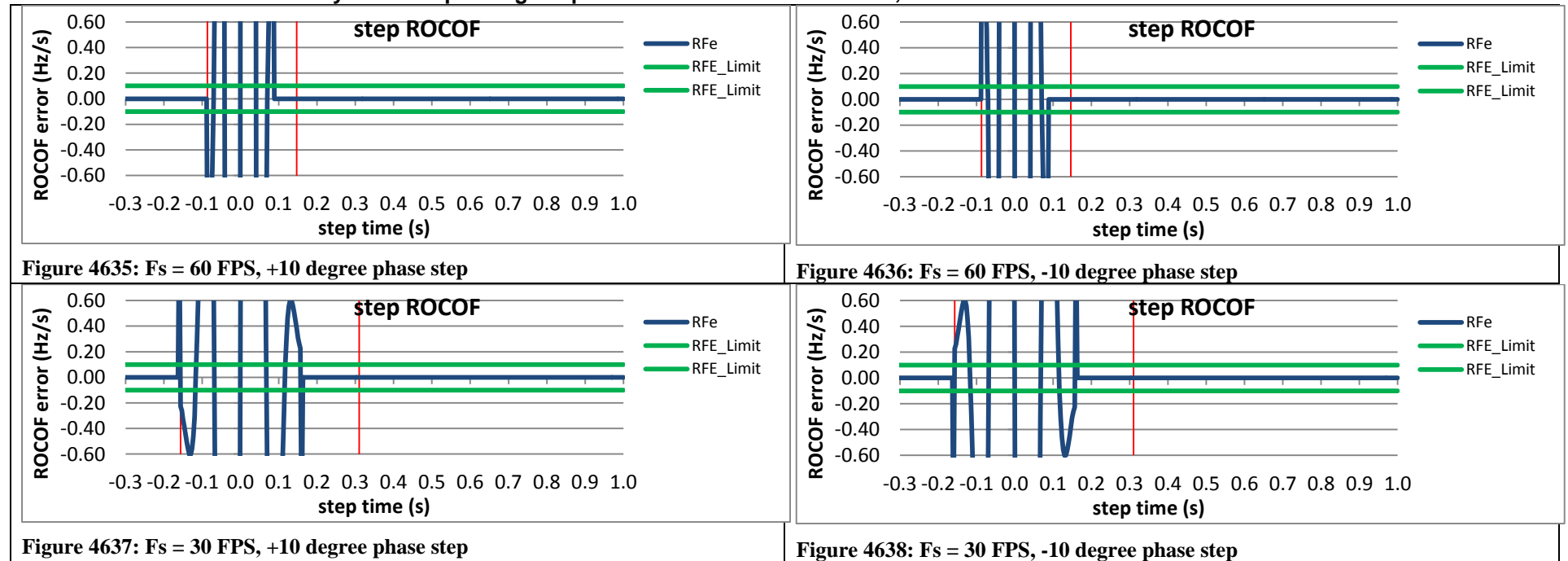


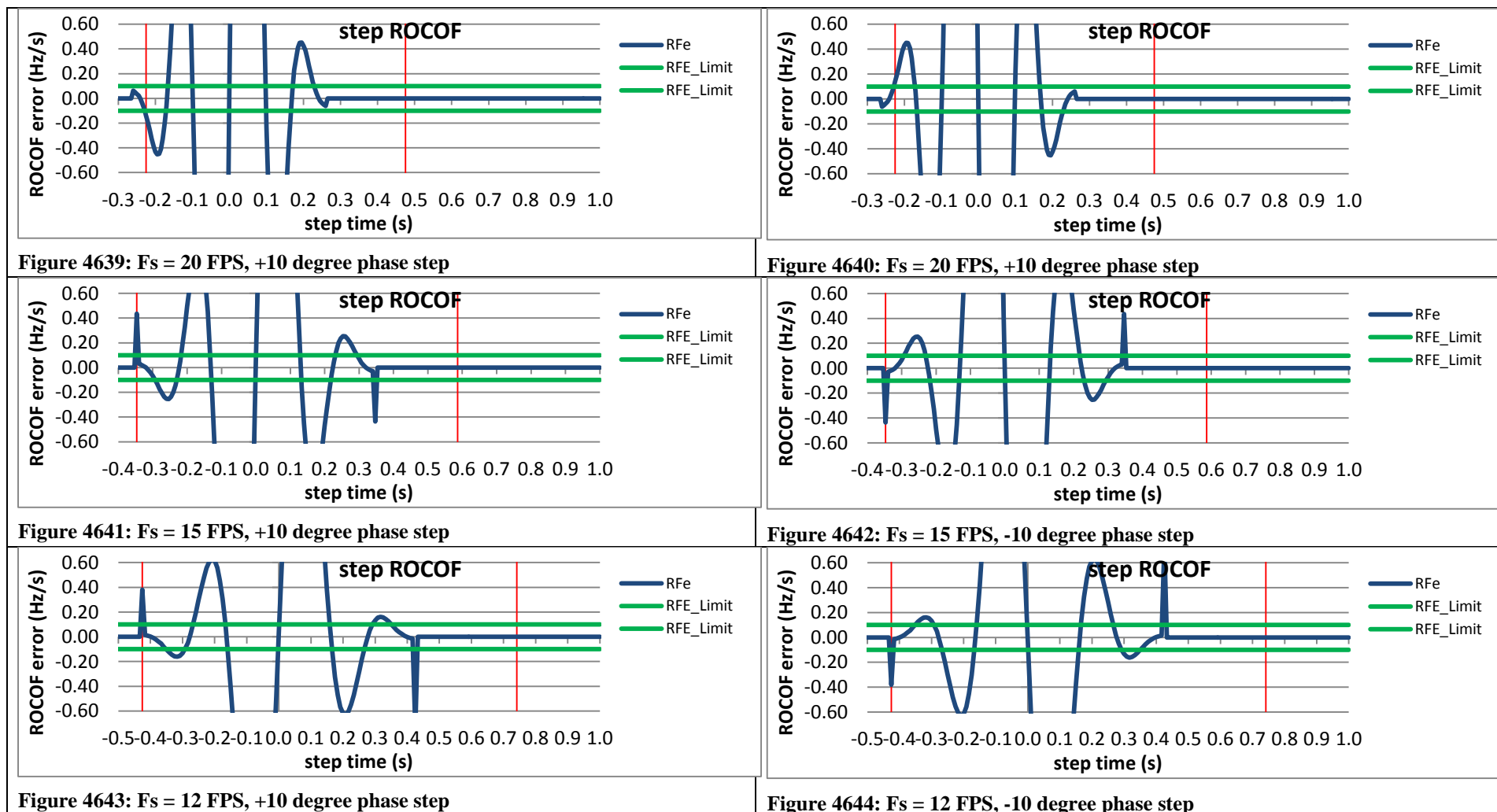
## 9.7 Dynamic step change in phase: ROCOF response time

Fs (FPS)	10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P
PMU A	-	F	-	F	-	F	-	F	-	F	-	F
PMU B	P	F	P	F	P	F	P	F	P	F	P	F
PMU C	P	F	P	F	P	F	P	F	P	F	P	F
PMU D	P	P	P	P	P	P	P	P	P	P	P	P
PMU E	P	-	-	-	P	-	P	-	P	-	P	-
PMU F	P	P	P	P	P	P	P	P	P	P	P	F
PMU G*	P	-	P	-	P	-	P	-	P	-	P	-
PMU H	P	P	P	P	P	P	P	P	P	P	P	P
PMU I	P	-	P	-	P	-	P	-	P	-	F	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P

\* PMU G always outputs ROCOF = 0

### 9.7.1 C37.118.1-2011 Annex C dynamic step change in phase ROCOF error: F0 = 60 Hz, M class





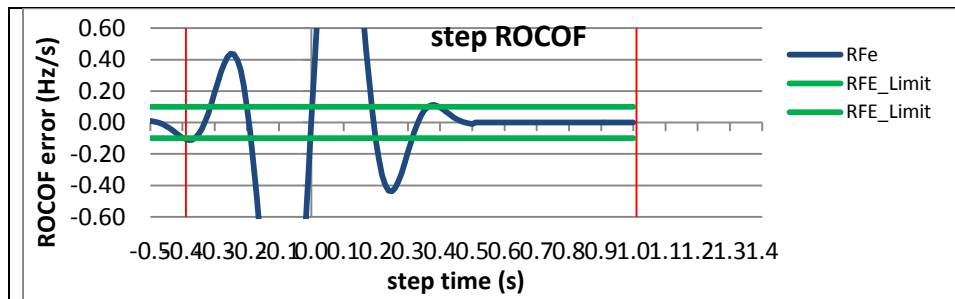


Figure 4645:  $F_s = 10$  FPS, +10 degree phase step

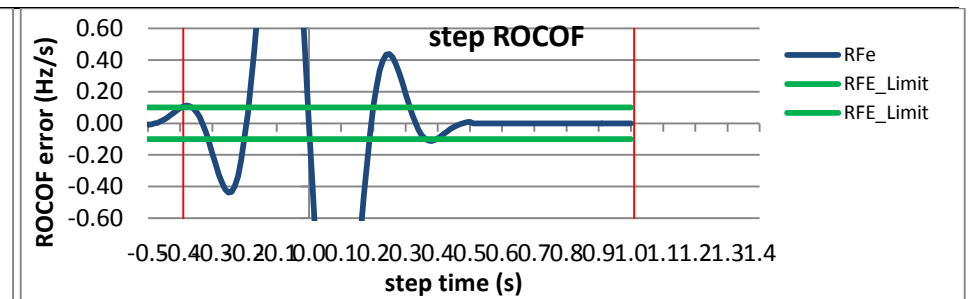
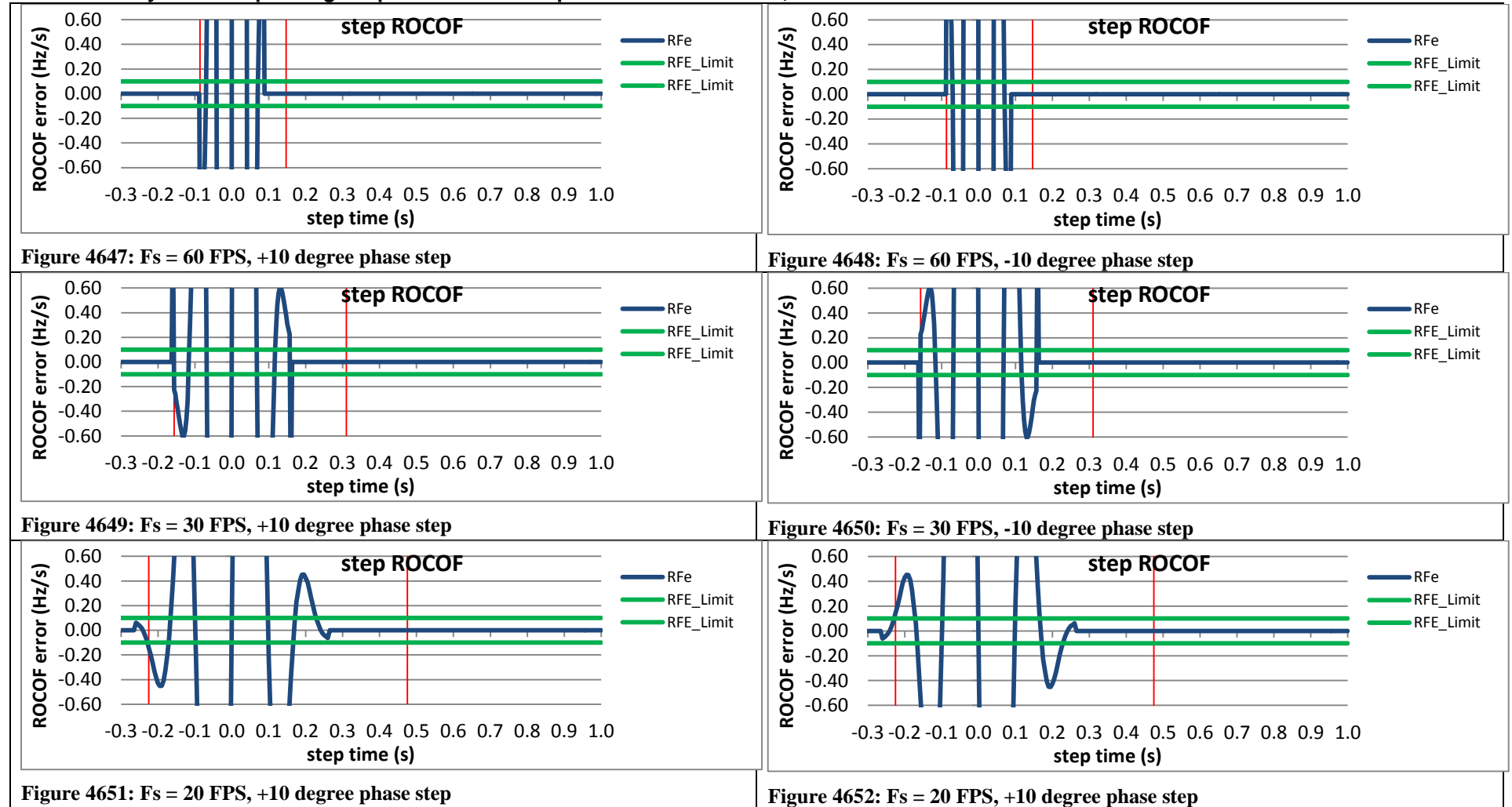


Figure 4646:  $F_s = 10$  FPS, -10 degree phase step

### 9.7.2 PMU A dynamic step change in phase ROCOF response time: $F_0 = 60$ Hz, M class



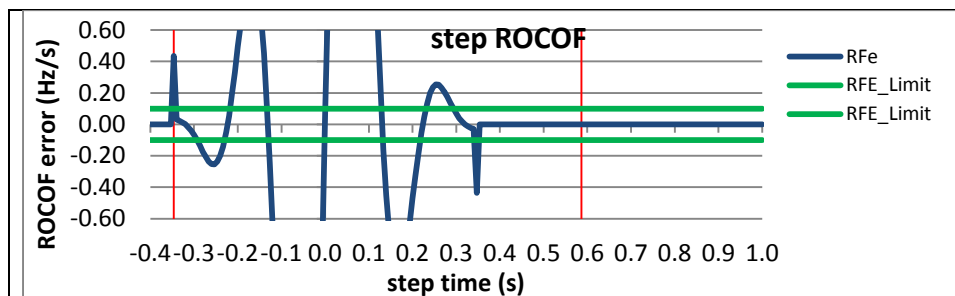


Figure 4653:  $F_s = 15$  FPS, +10 degree phase step

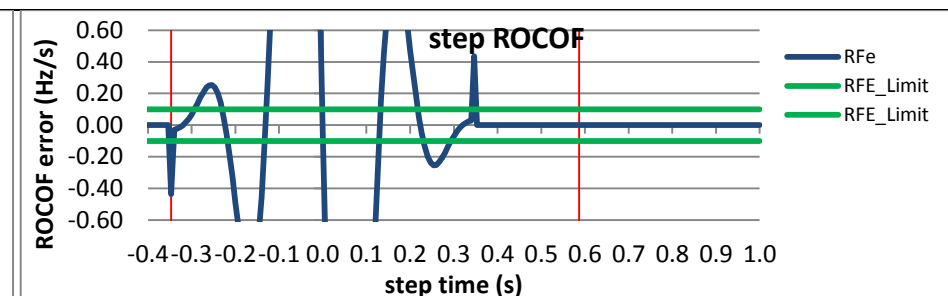


Figure 4654:  $F_s = 15$  FPS, -10 degree phase step

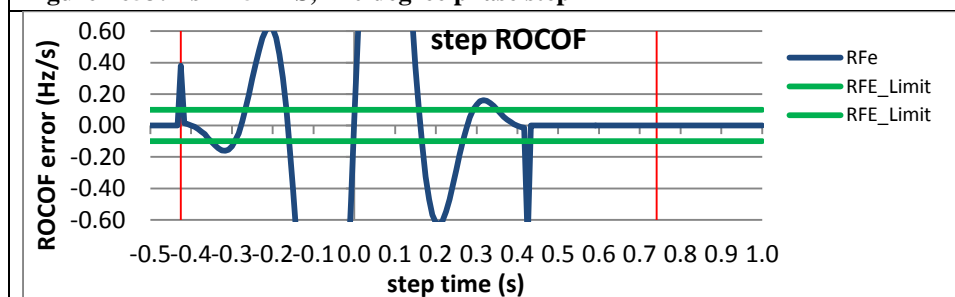


Figure 4655:  $F_s = 12$  FPS, +10 degree phase step

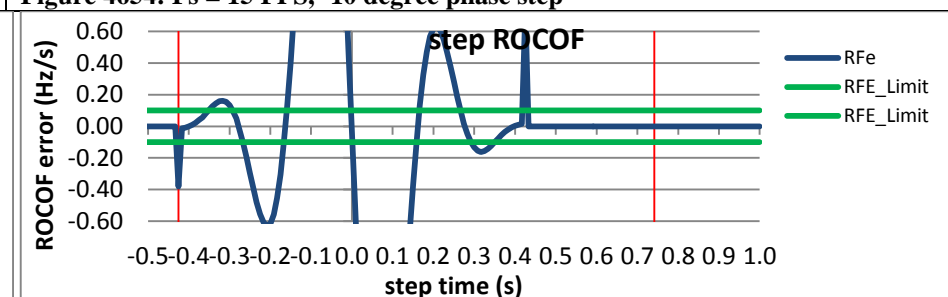


Figure 4656:  $F_s = 12$  FPS, -10 degree phase step

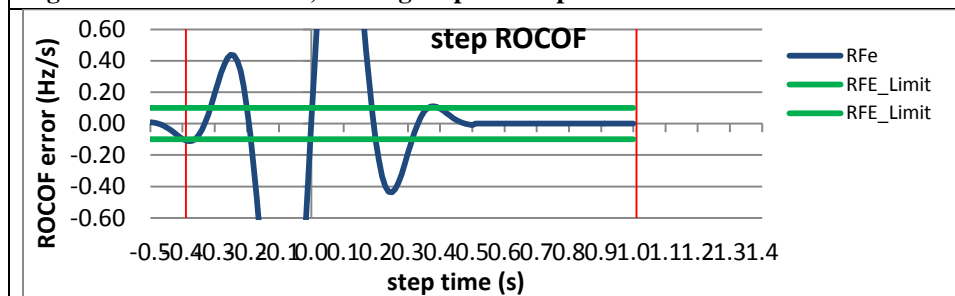


Figure 4657:  $F_s = 10$  FPS, +10 degree phase step

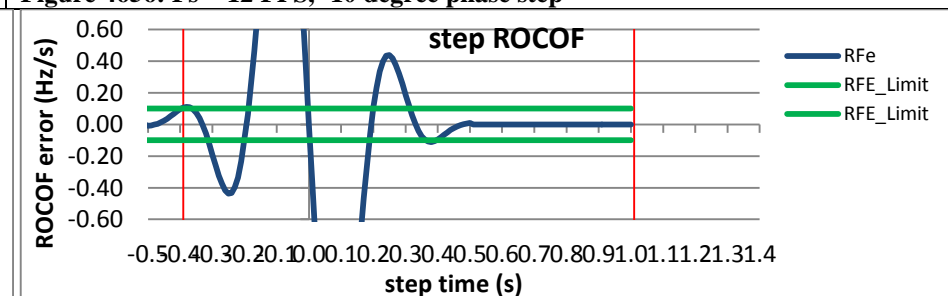
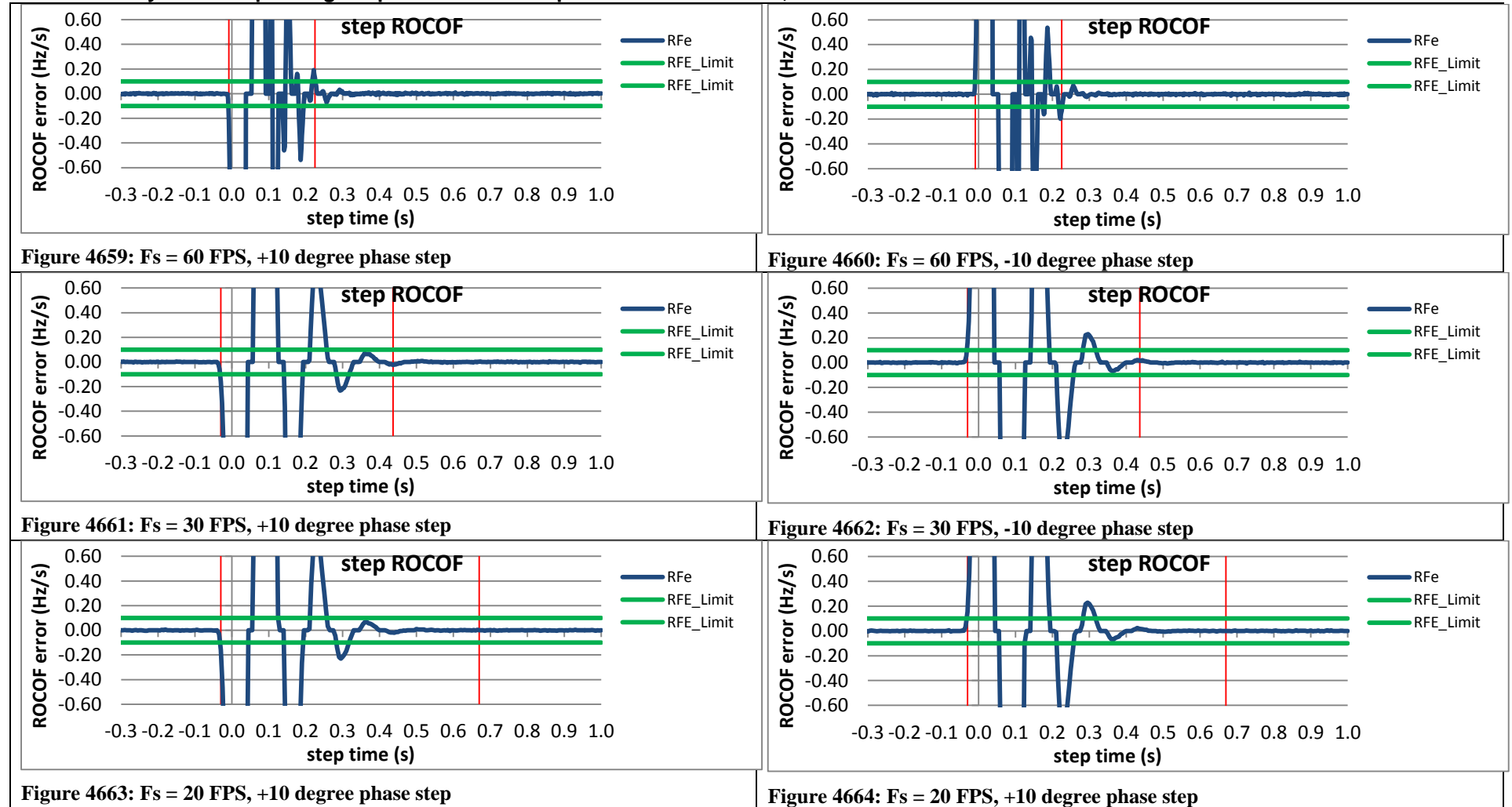
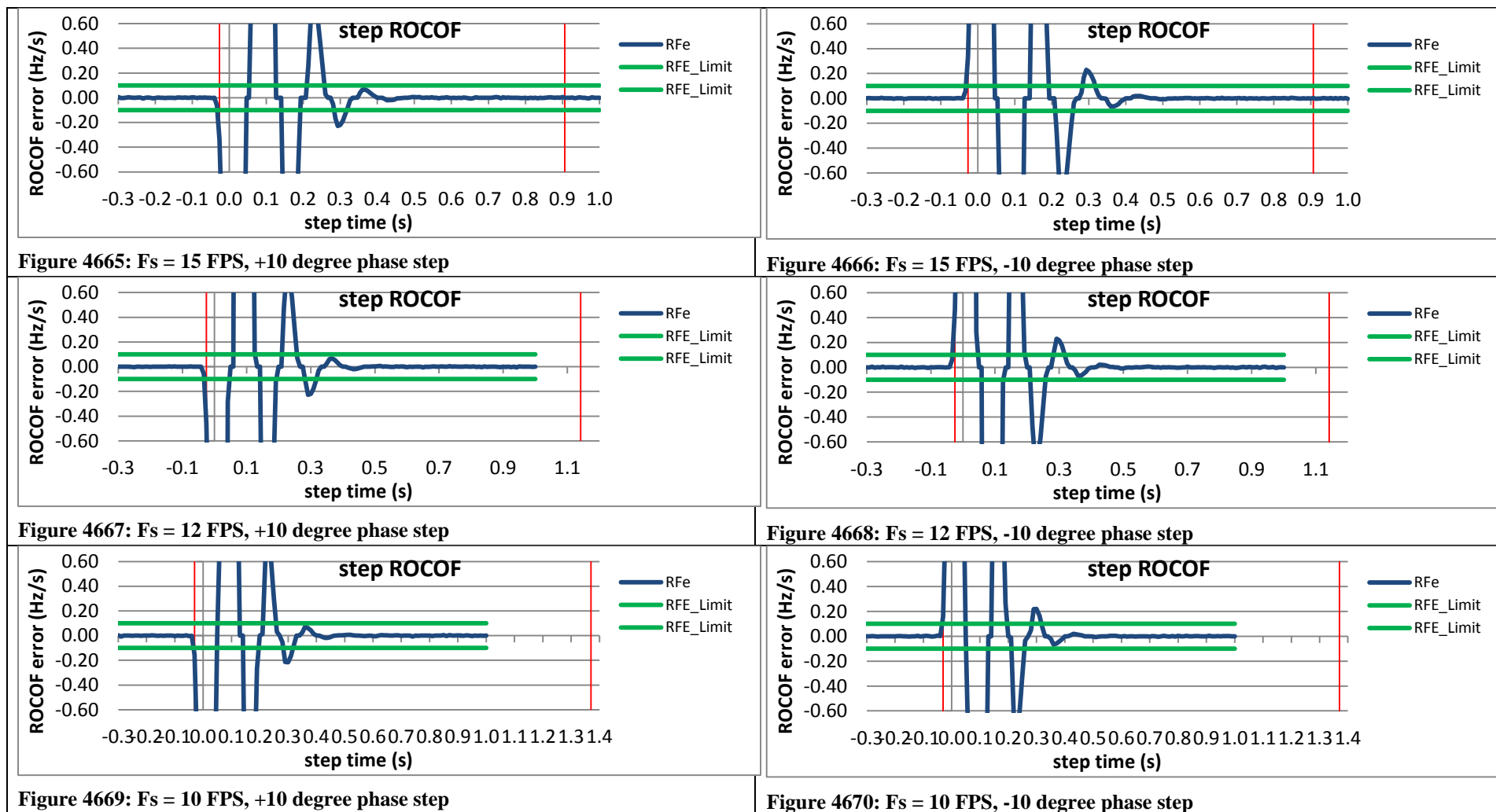


Figure 4658:  $F_s = 10$  FPS, -10 degree phase step

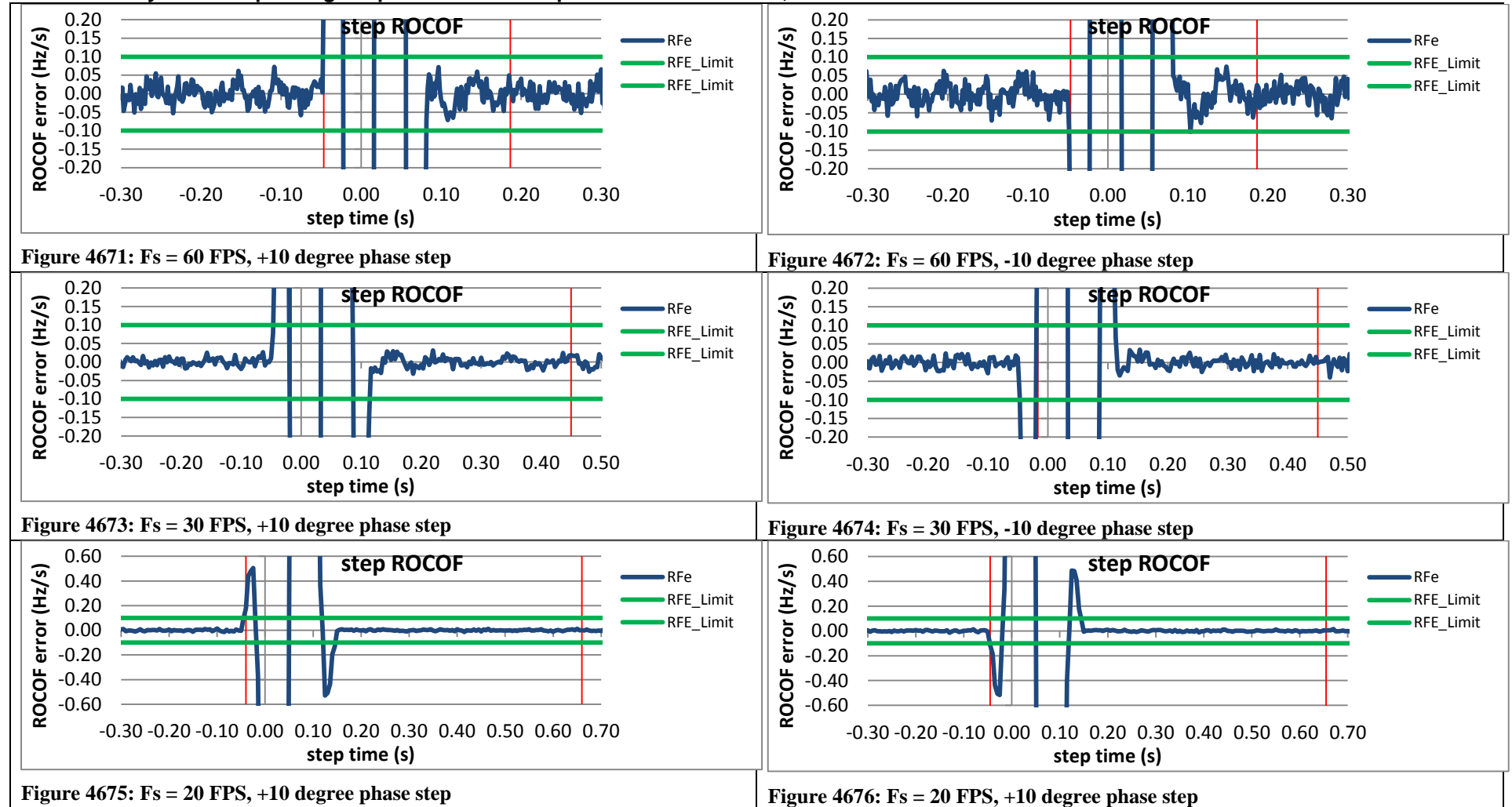
### 9.7.3 PMU B dynamic step change in phase ROCOF response time: $F_0 = 60$ Hz, M class







#### 9.7.4 PMU C dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class



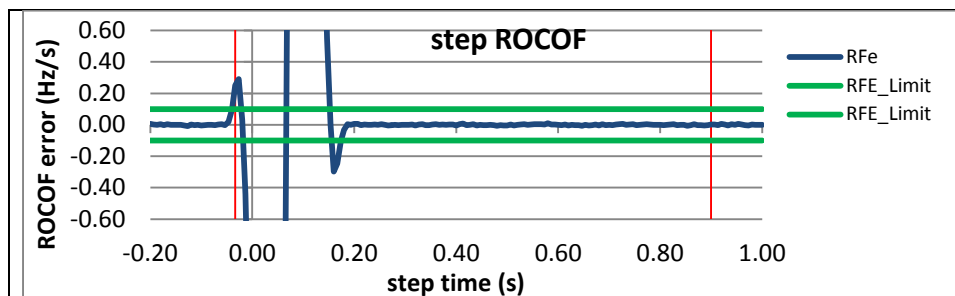


Figure 4677:  $F_s = 15$  FPS, +10 degree phase step

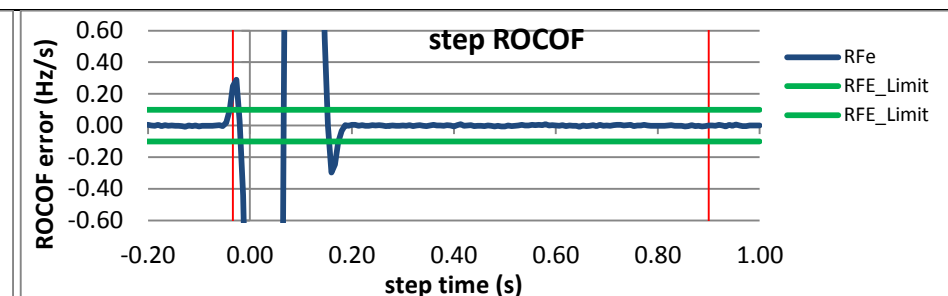


Figure 4678:  $F_s = 15$  FPS, -10 degree phase step

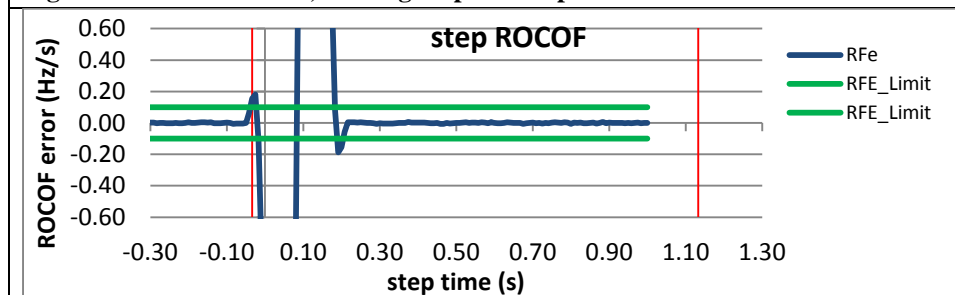


Figure 4679:  $F_s = 12$  FPS, +10 degree phase step

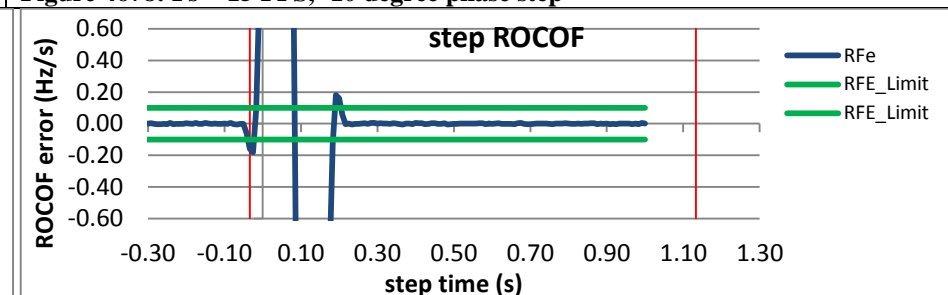


Figure 4680:  $F_s = 12$  FPS, -10 degree phase step

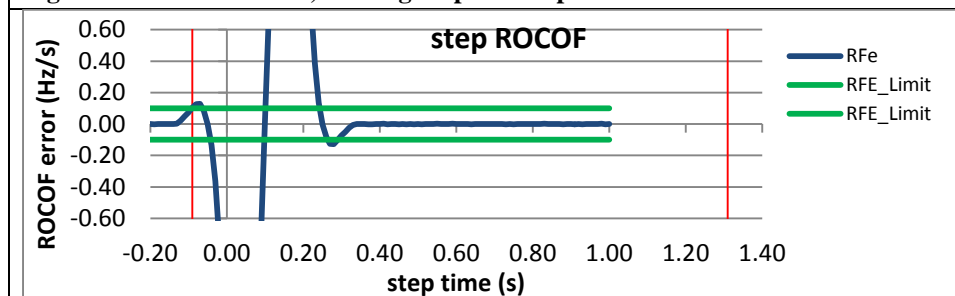


Figure 4681:  $F_s = 10$  FPS, +10 degree phase step

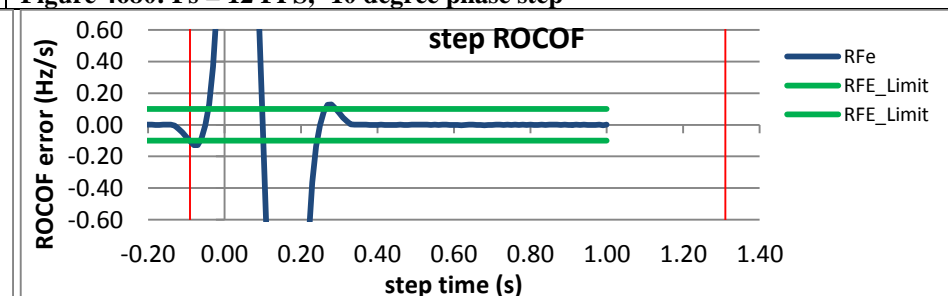
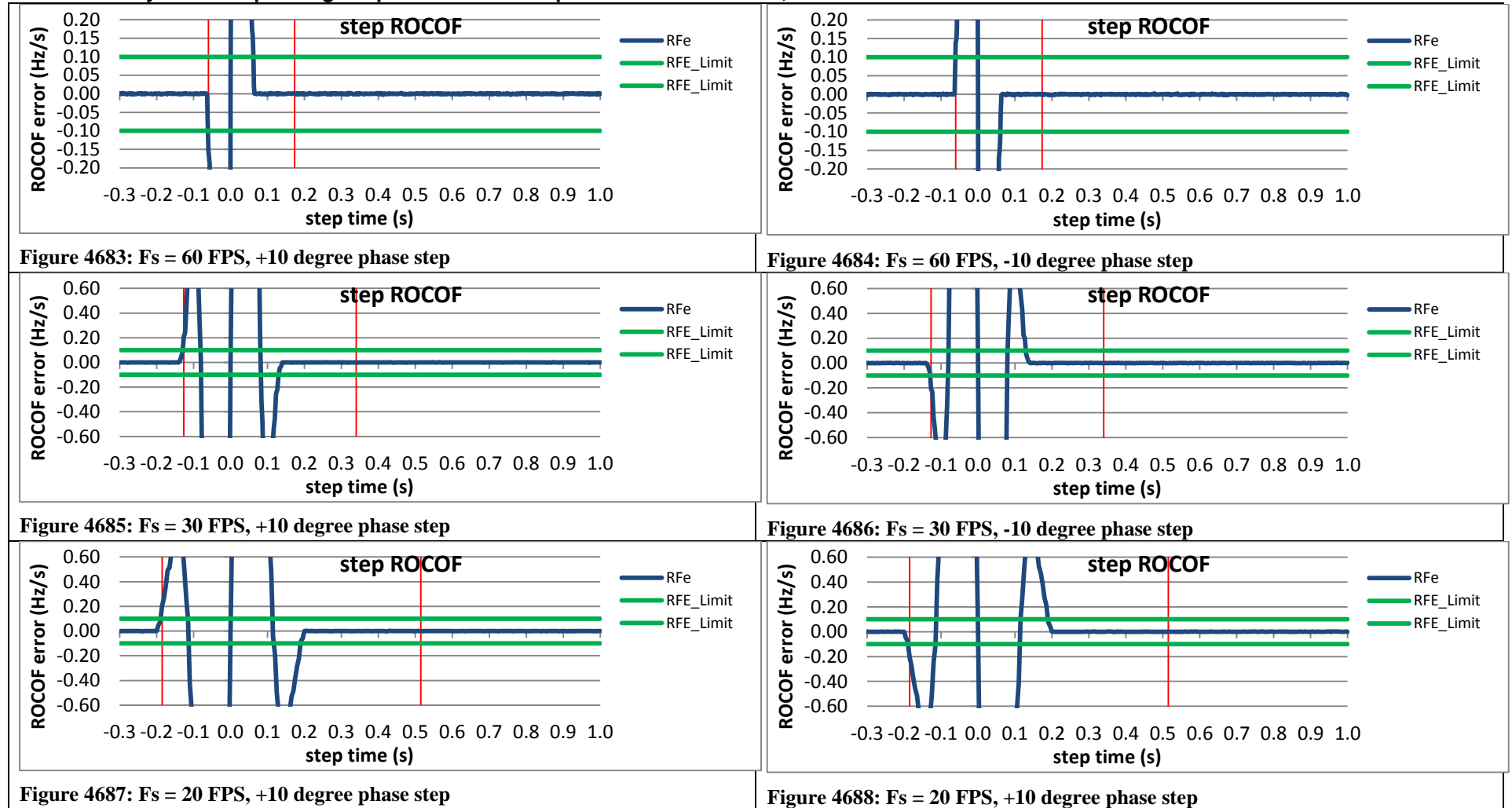
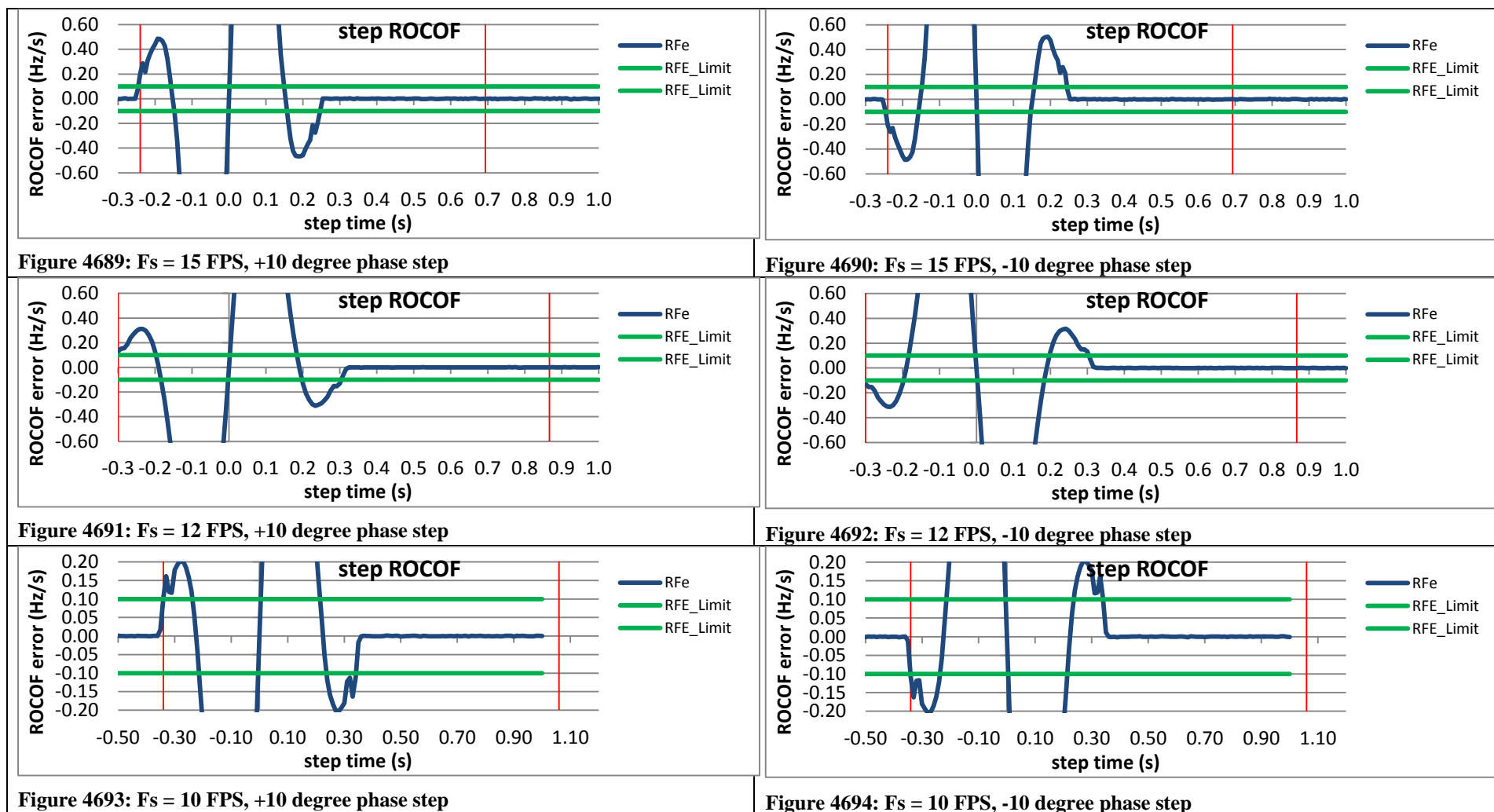


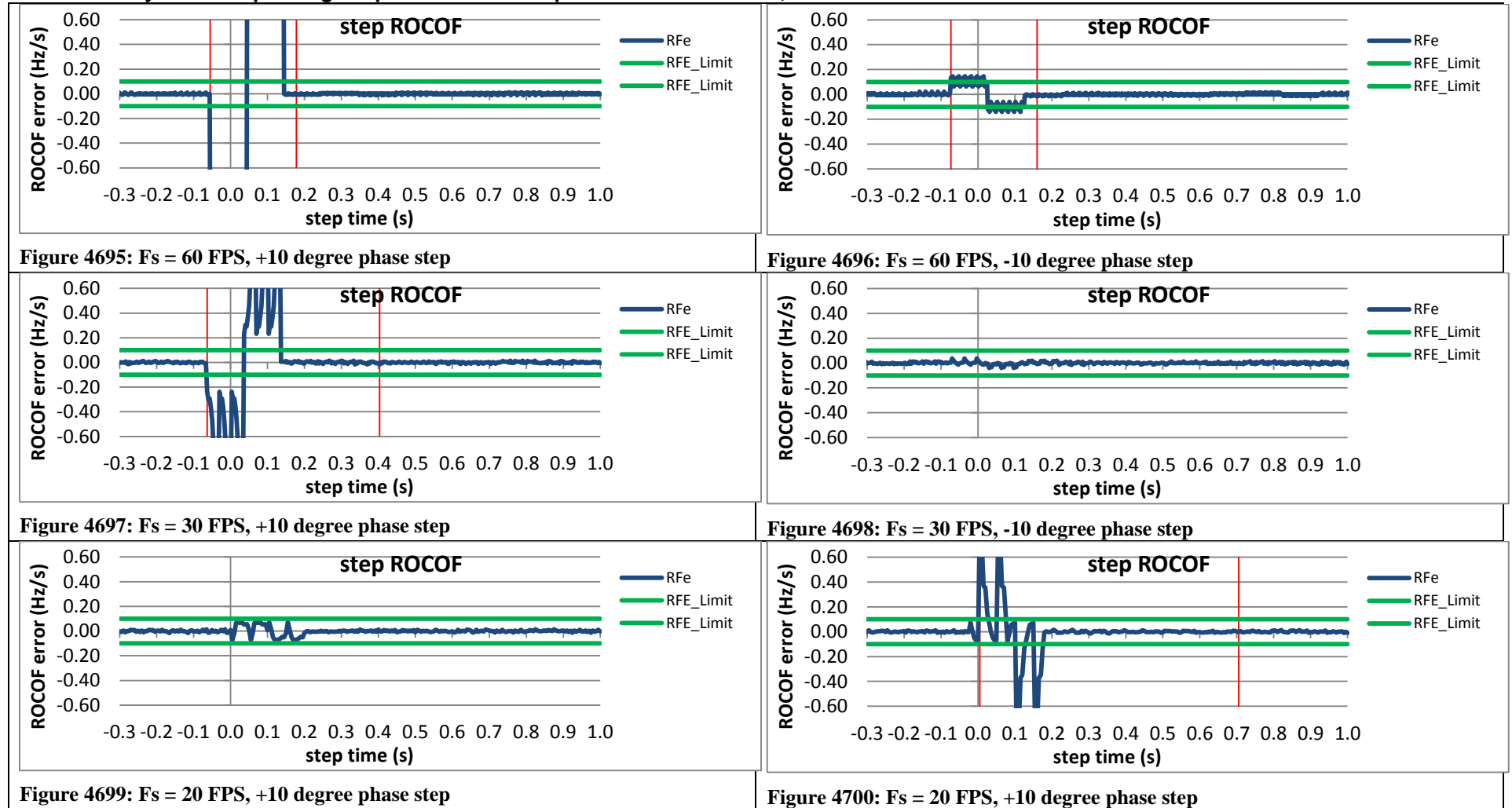
Figure 4682:  $F_s = 10$  FPS, -10 degree phase step

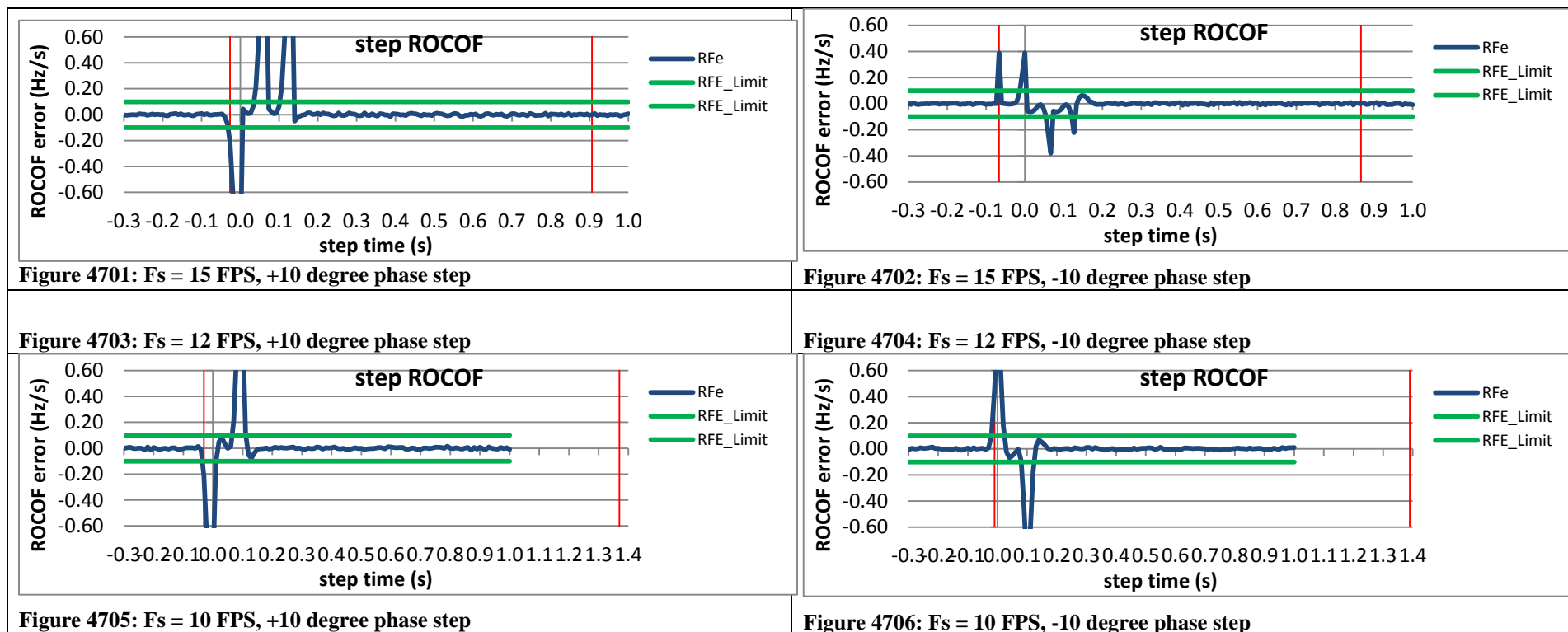
### 9.7.5 PMU D dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class



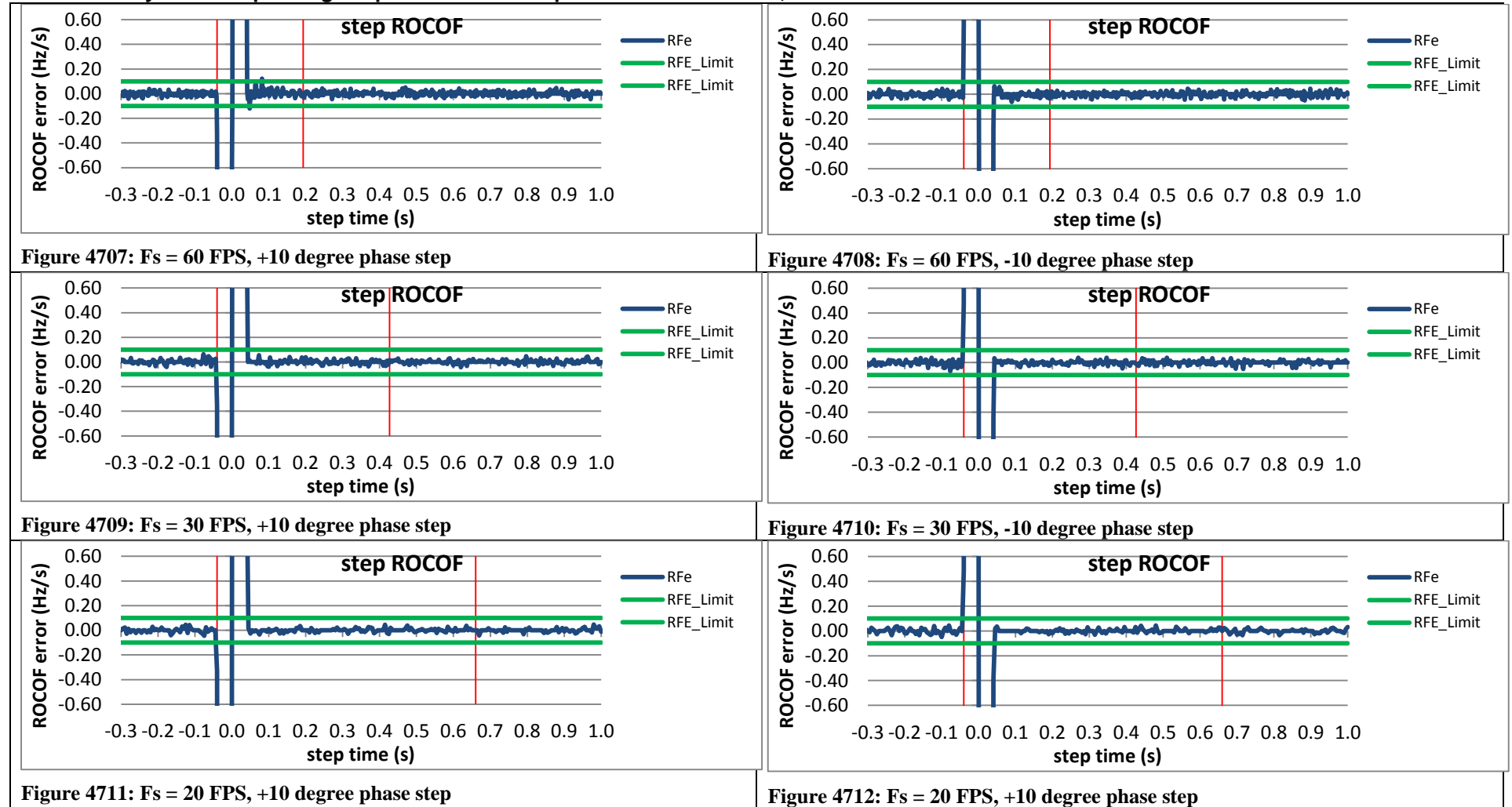


### 9.7.6 PMU E dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class





### 9.7.7 PMU F dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class





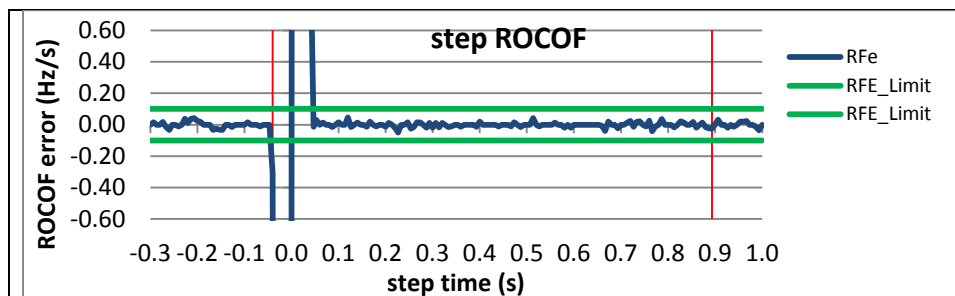


Figure 4713:  $F_s = 15$  FPS, +10 degree phase step

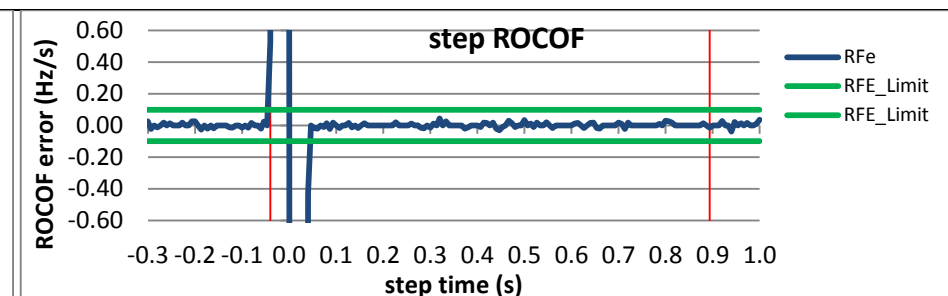


Figure 4714:  $F_s = 15$  FPS, -10 degree phase step

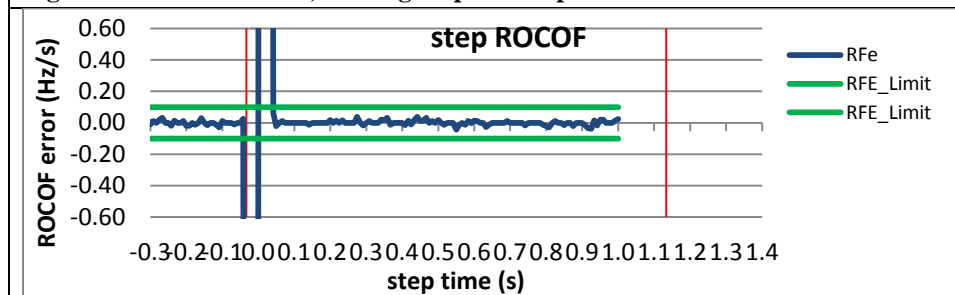


Figure 4715:  $F_s = 12$  FPS, +10 degree phase step

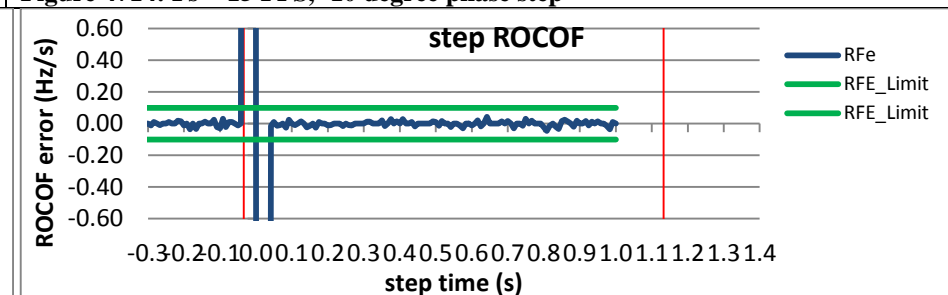


Figure 4716:  $F_s = 12$  FPS, -10 degree phase step

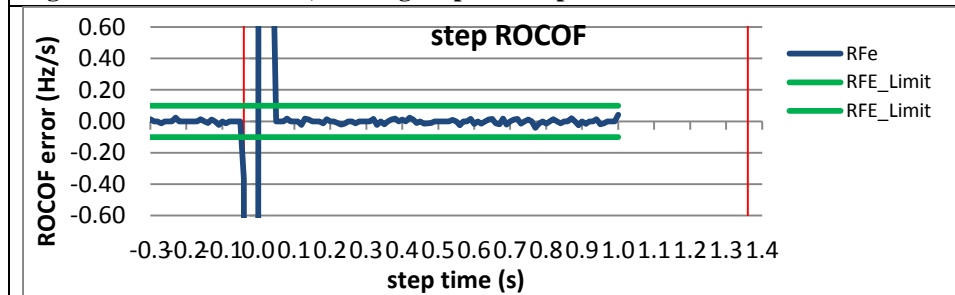


Figure 4717:  $F_s = 10$  FPS, +10 degree phase step

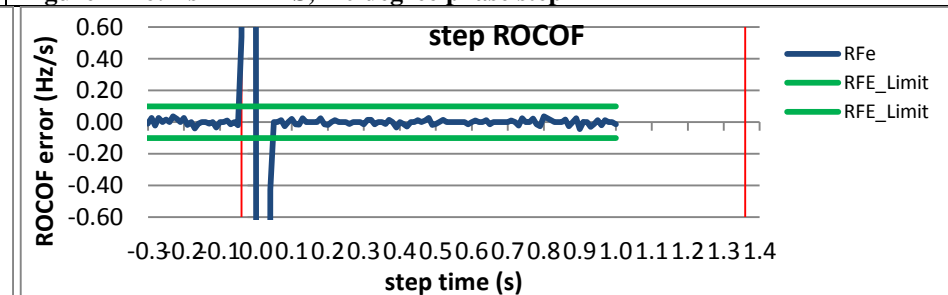


Figure 4718:  $F_s = 10$  FPS, -10 degree phase step

### 9.7.8 PMU G \* dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class

Figure 4719: Fs = 60 FPS is not supported by this PMU

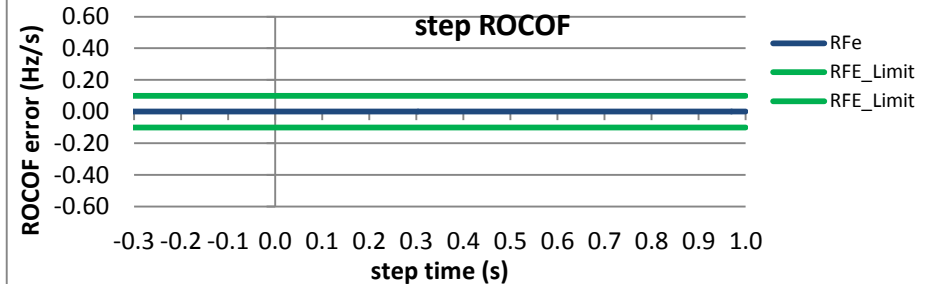
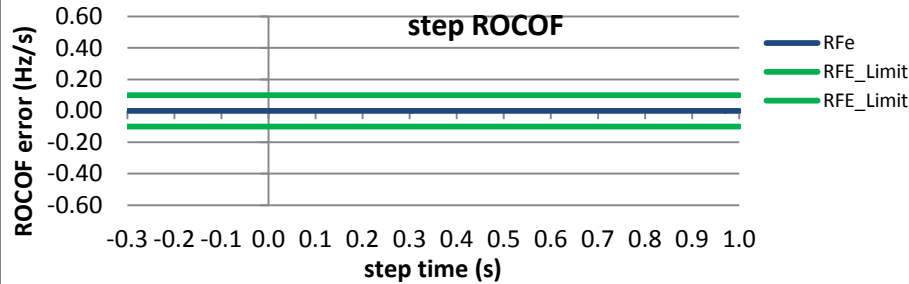


Figure 4720: Fs = 30 FPS, +10 degree phase step

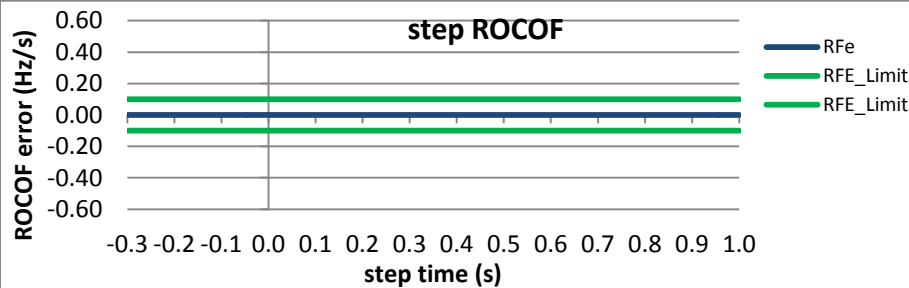


Figure 4721: Fs = 30 FPS, -10 degree phase step

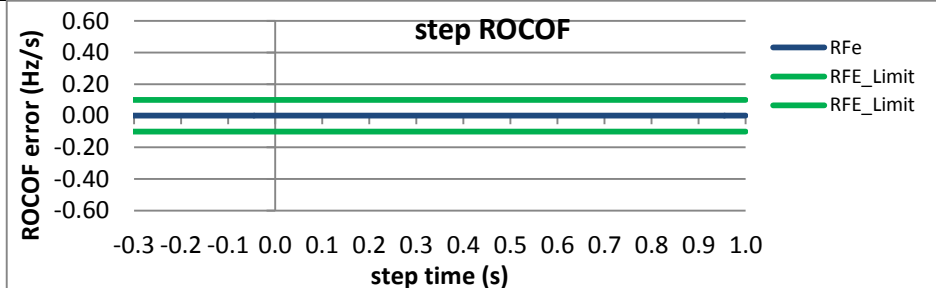


Figure 4722: Fs = 20 FPS, +10 degree phase step

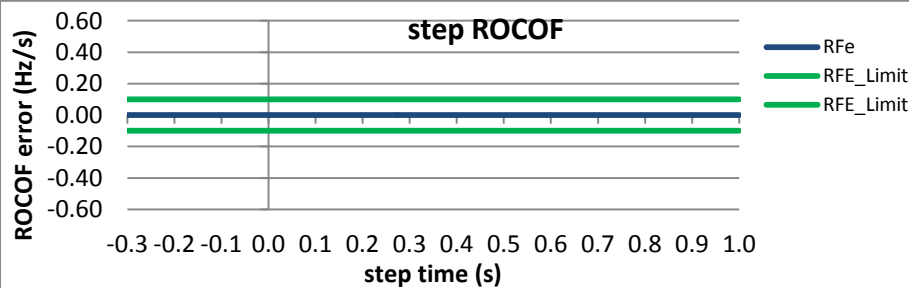


Figure 4723: Fs = 20 FPS, +10 degree phase step

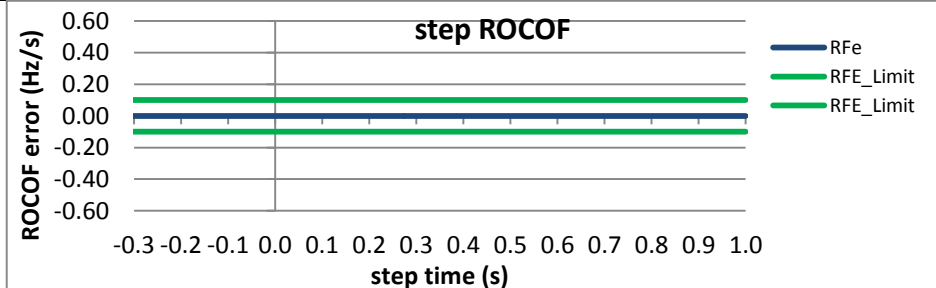
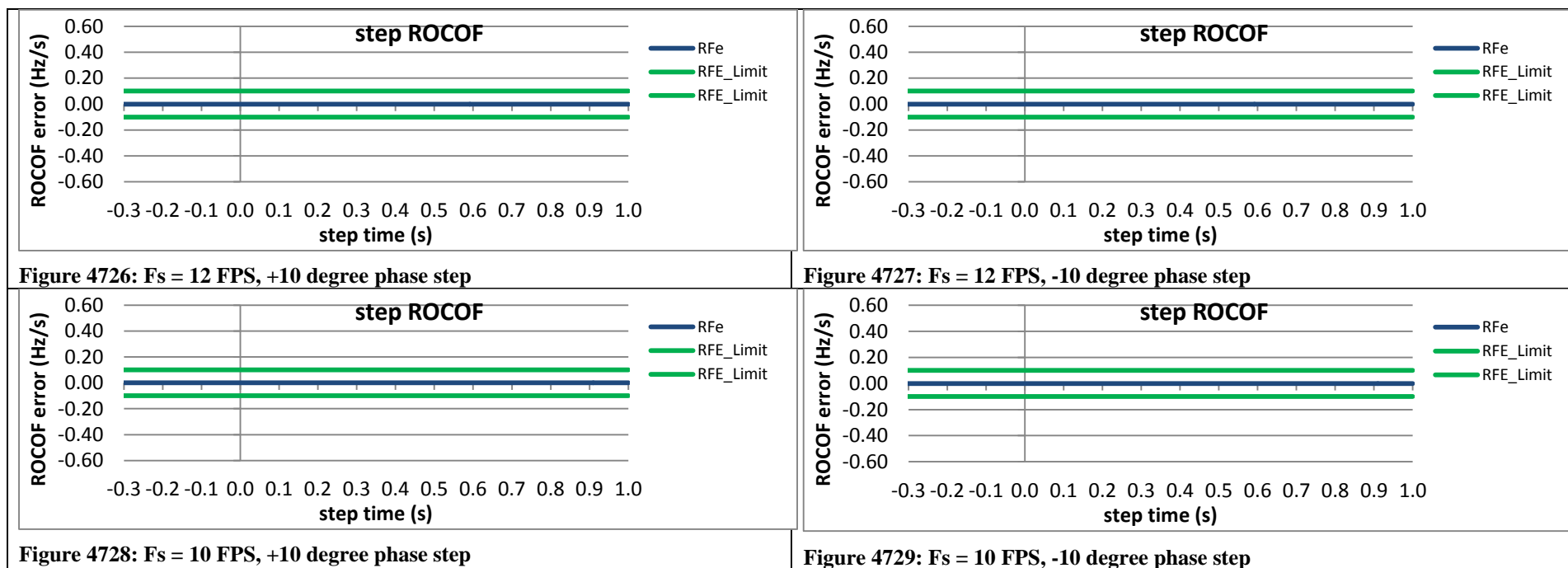


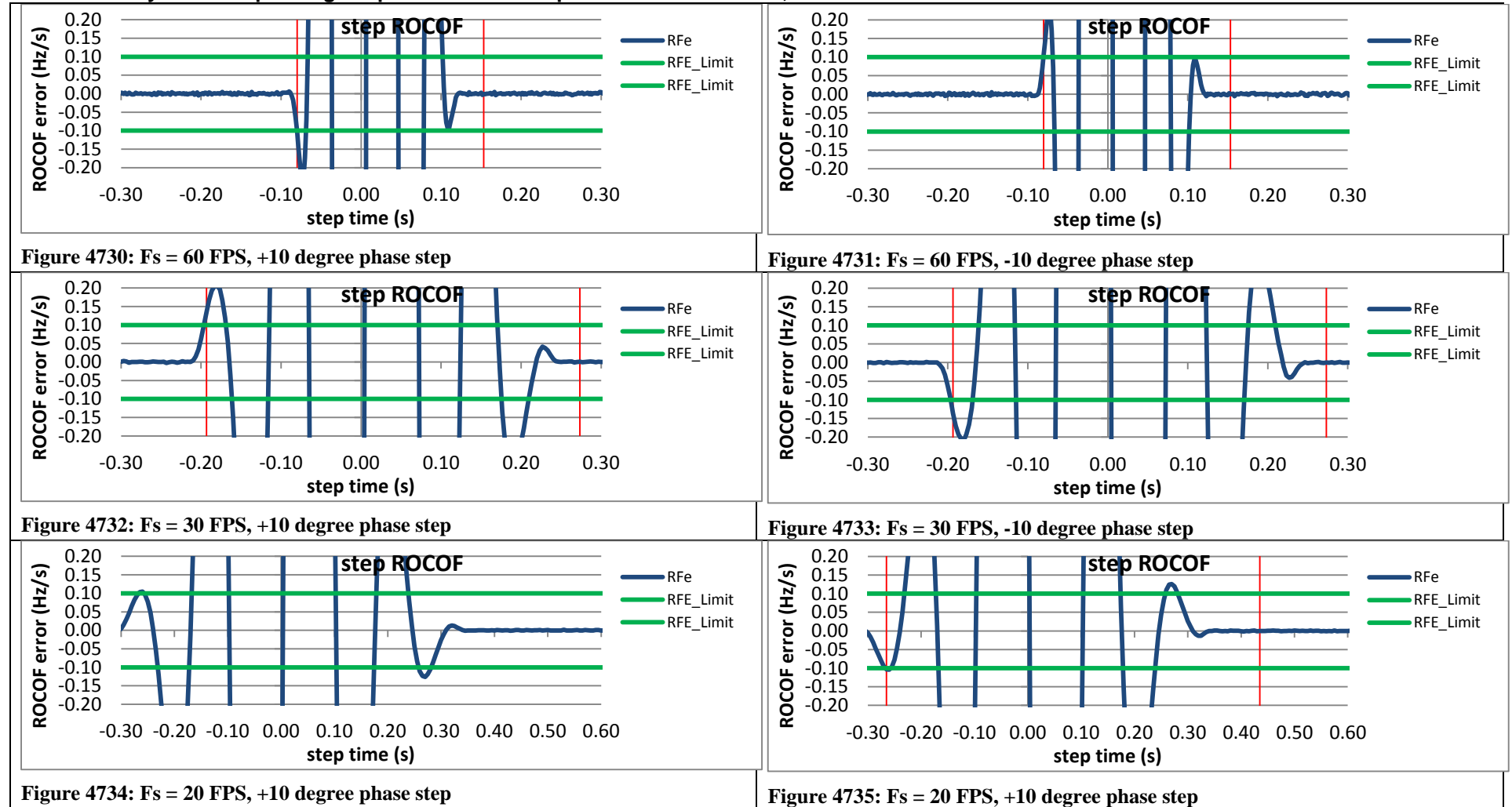
Figure 4724: Fs = 15 FPS, +10 degree phase step

Figure 4725: Fs = 15 FPS, -10 degree phase step



\* PMU G always outputs ROCOF = 0

### 9.7.9 PMU H dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class



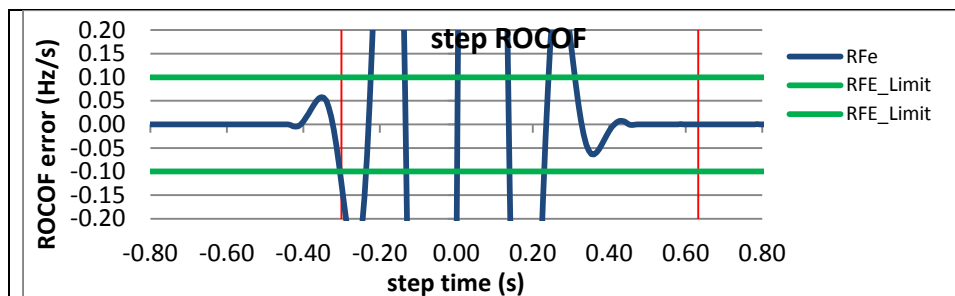


Figure 4736:  $F_s = 15$  FPS, +10 degree phase step

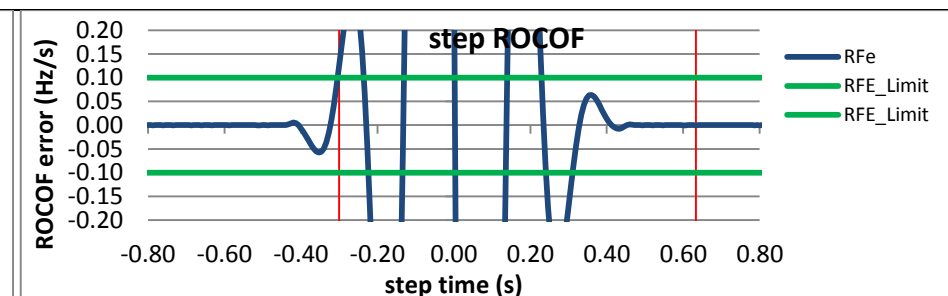


Figure 4737:  $F_s = 15$  FPS, -10 degree phase step

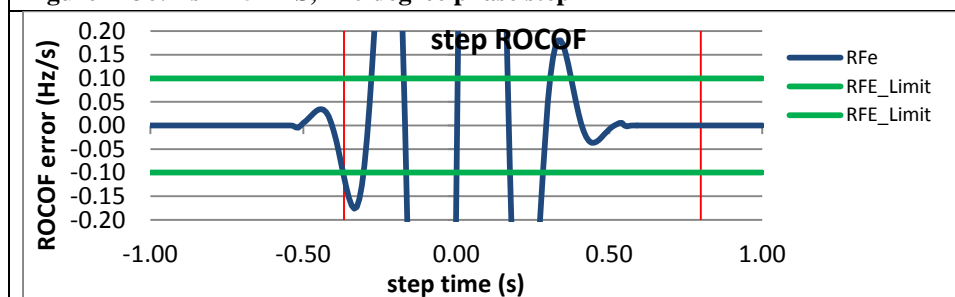


Figure 4738:  $F_s = 12$  FPS, +10 degree phase step

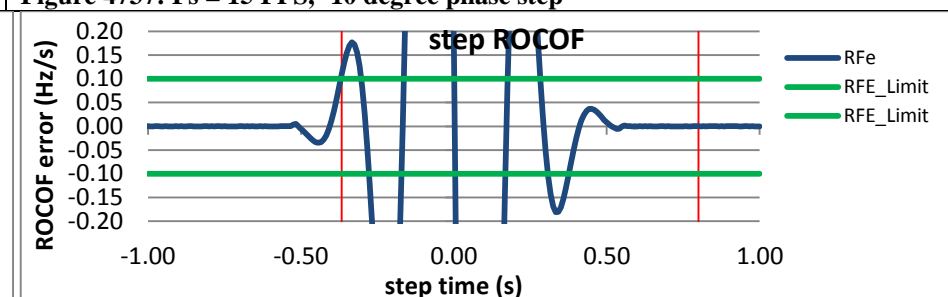


Figure 4739:  $F_s = 12$  FPS, -10 degree phase step

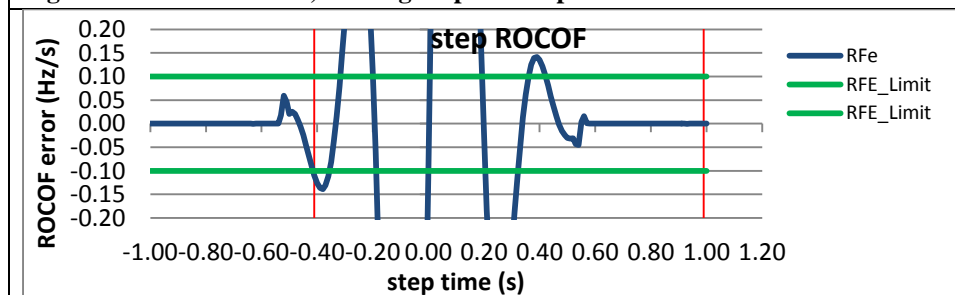


Figure 4740:  $F_s = 10$  FPS, +10 degree phase step

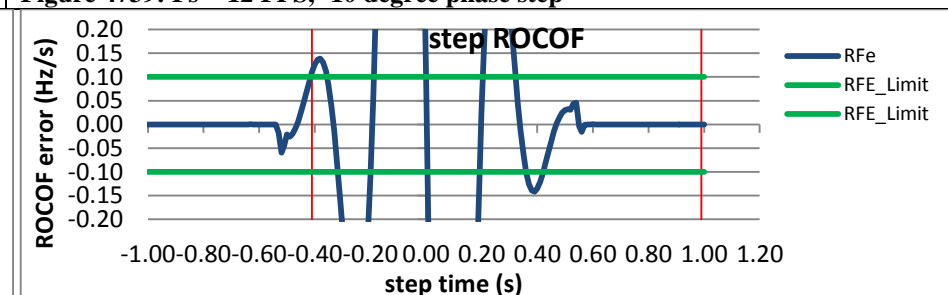
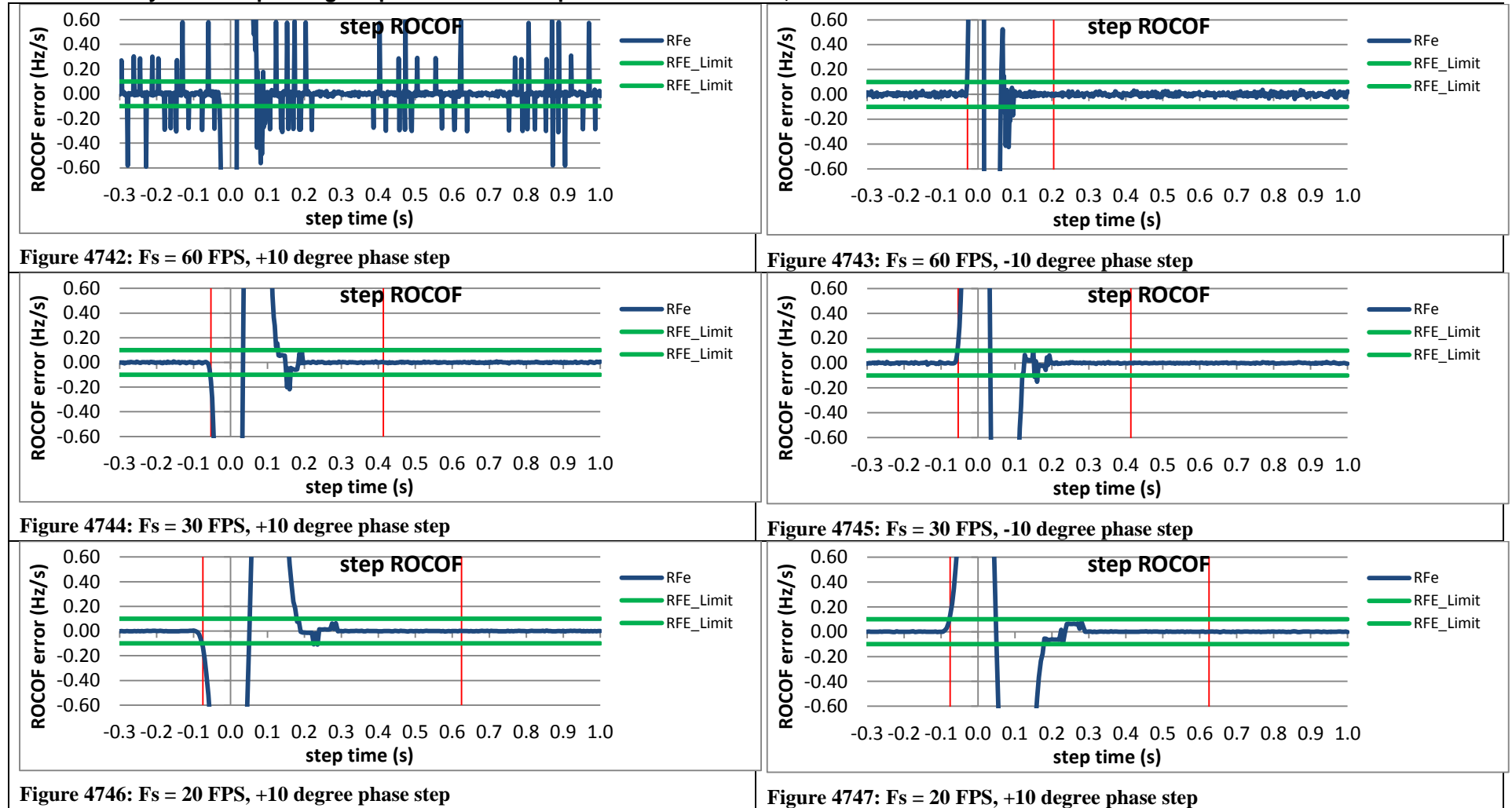


Figure 4741:  $F_s = 10$  FPS, -10 degree phase step

### 9.7.10 PMU I dynamic step change in phase ROCOF response time: $F_0 = 60$ Hz, M class



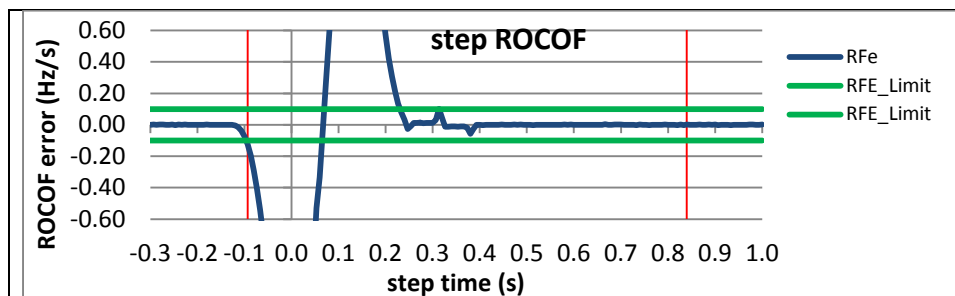


Figure 4748:  $F_s = 15$  FPS, +10 degree phase step

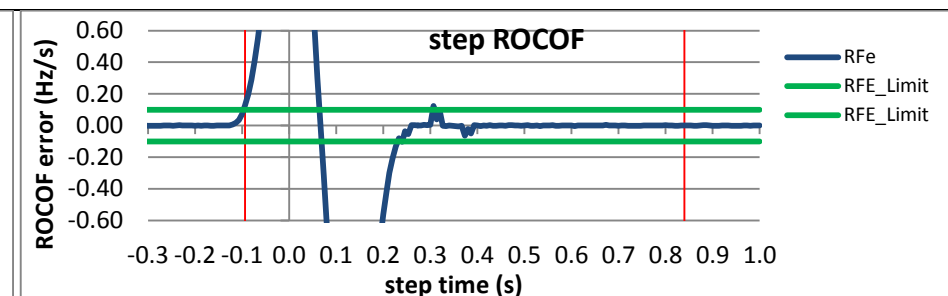


Figure 4749:  $F_s = 15$  FPS, -10 degree phase step

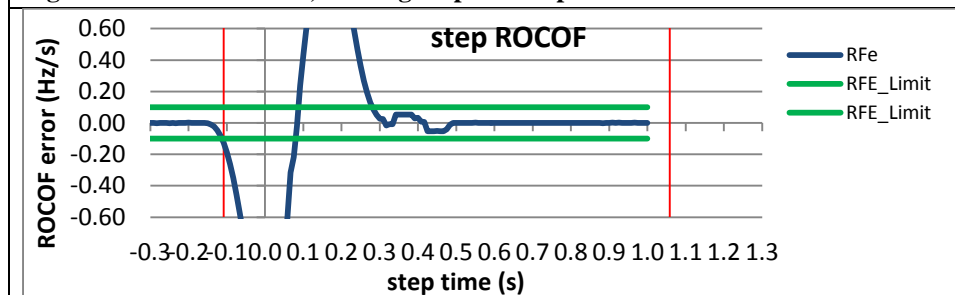


Figure 4750:  $F_s = 12$  FPS, +10 degree phase step

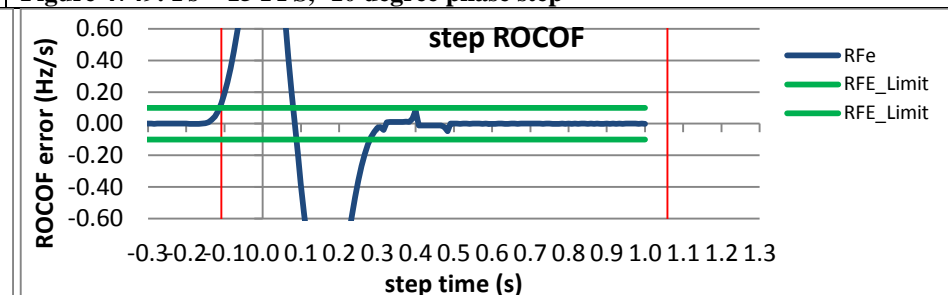


Figure 4751:  $F_s = 12$  FPS, -10 degree phase step

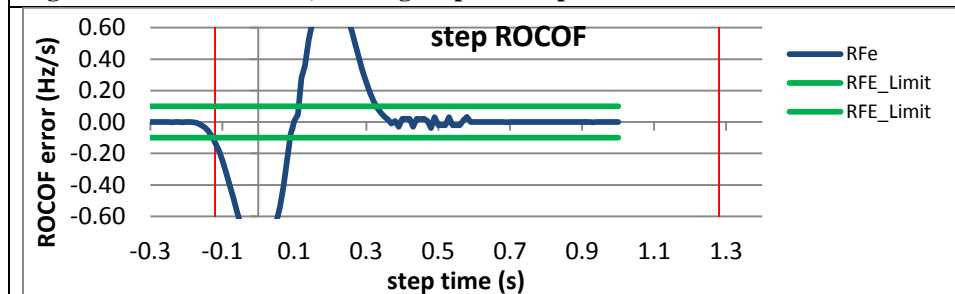


Figure 4752:  $F_s = 10$  FPS, +10 degree phase step

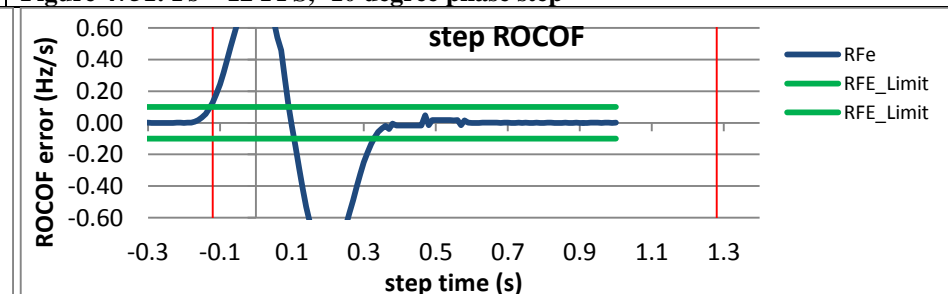
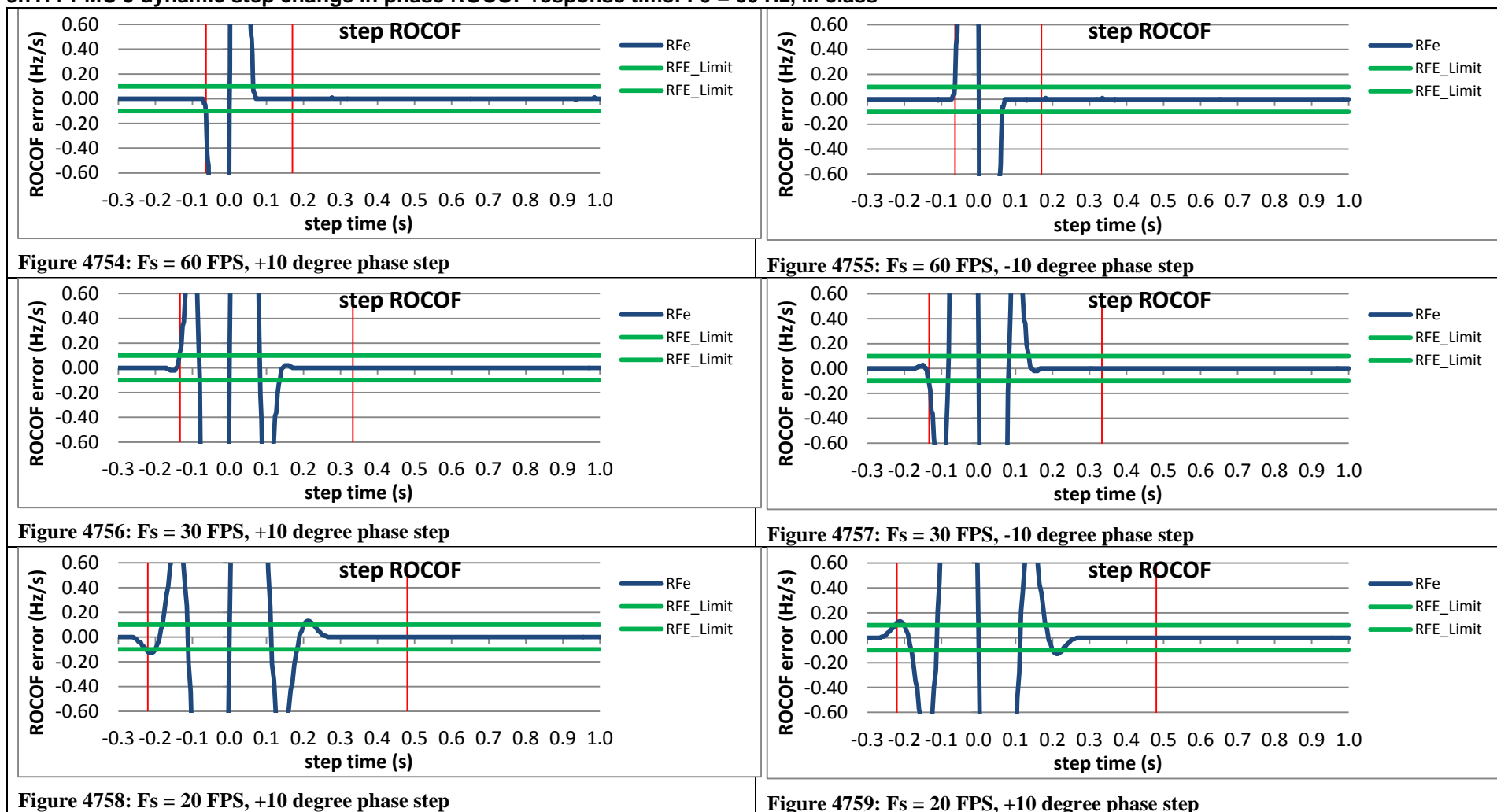


Figure 4753:  $F_s = 10$  FPS, -10 degree phase step

# 9.7.11 PMU J dynamic step change in phase ROCOF response time: F0 = 60 Hz, M class





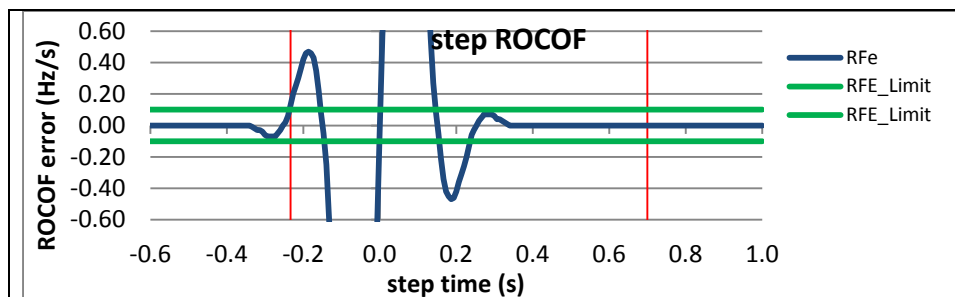


Figure 4760:  $F_s = 15$  FPS, +10 degree phase step

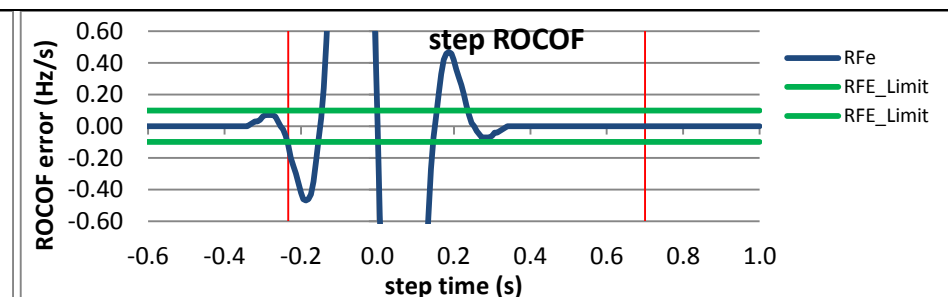


Figure 4761:  $F_s = 15$  FPS, -10 degree phase step

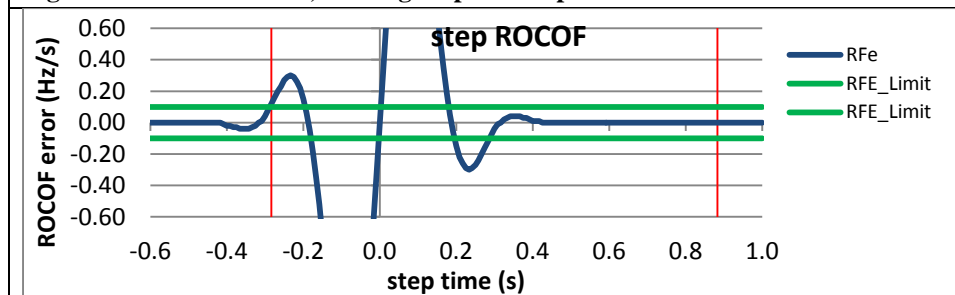


Figure 4762:  $F_s = 12$  FPS, +10 degree phase step

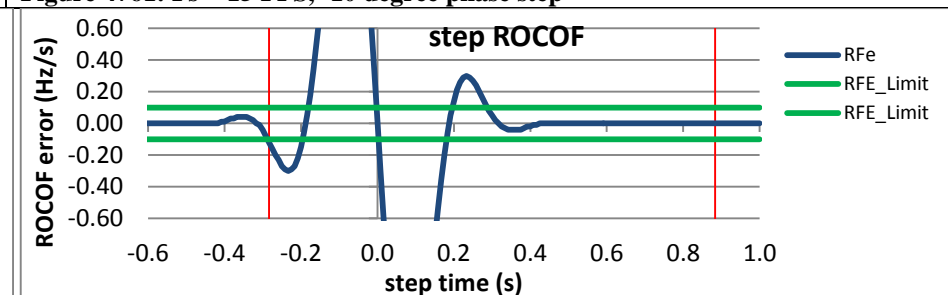


Figure 4763:  $F_s = 12$  FPS, -10 degree phase step

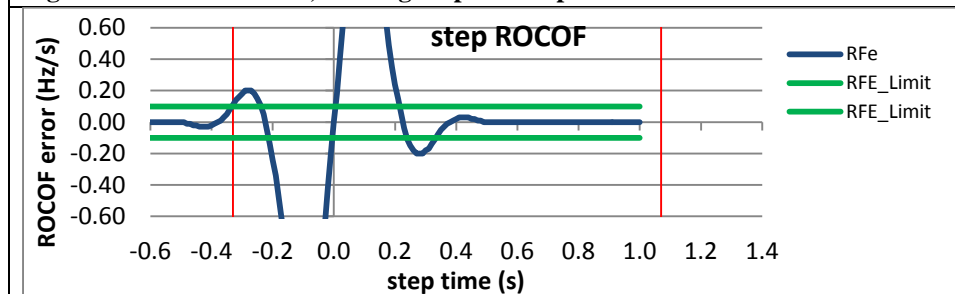


Figure 4764:  $F_s = 10$  FPS, +10 degree phase step

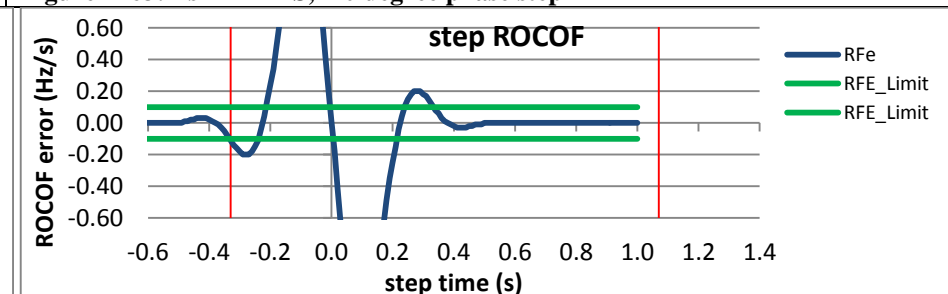
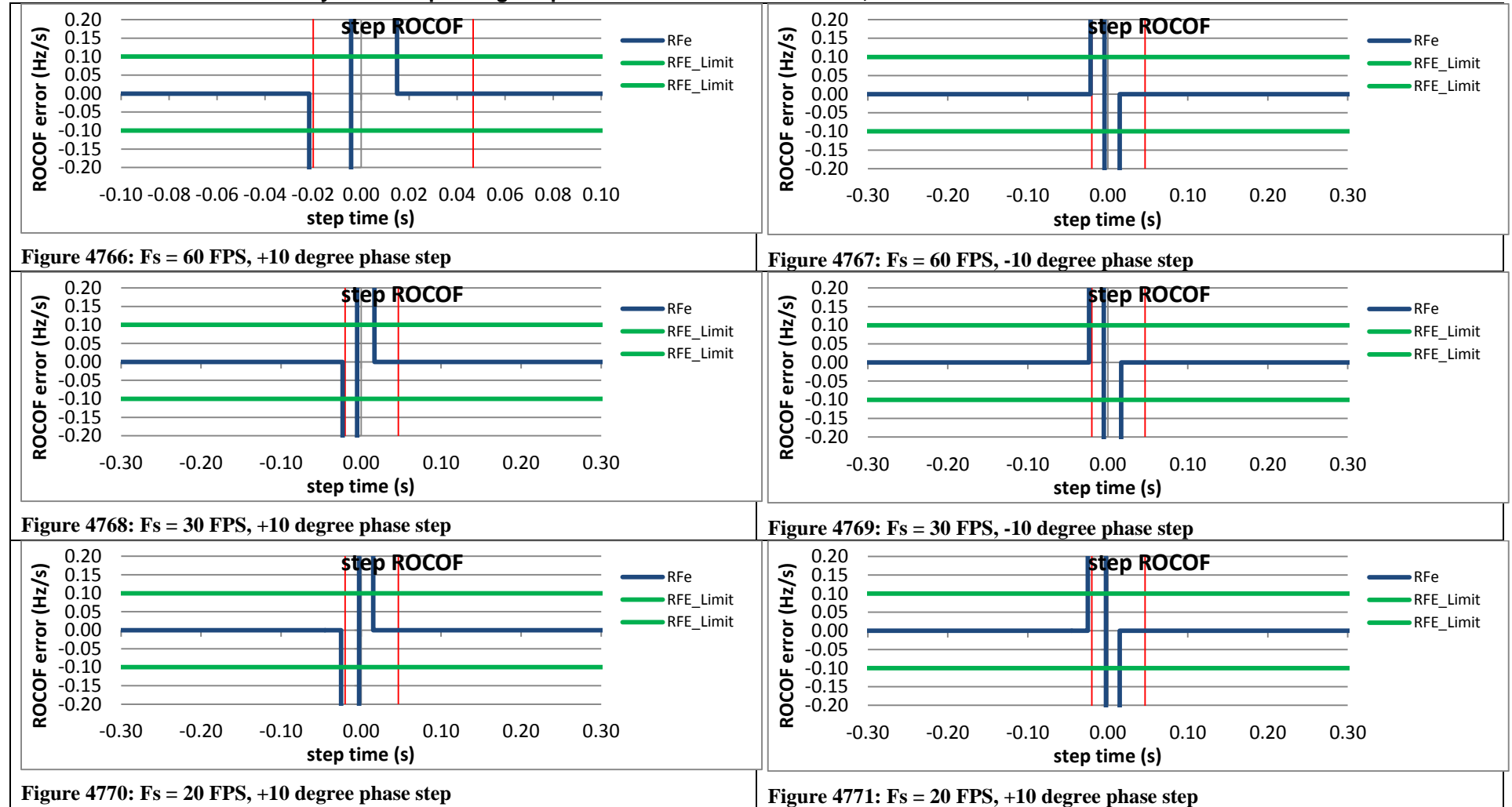


Figure 4765:  $F_s = 10$  FPS, -10 degree phase step

## 9.8 Dynamic step change in phase: ROCOF response time: P class

### 9.8.1 C37.118.1-2011 Annex C dynamic step change in phase ROCOF error: F0 = 60 Hz, P class



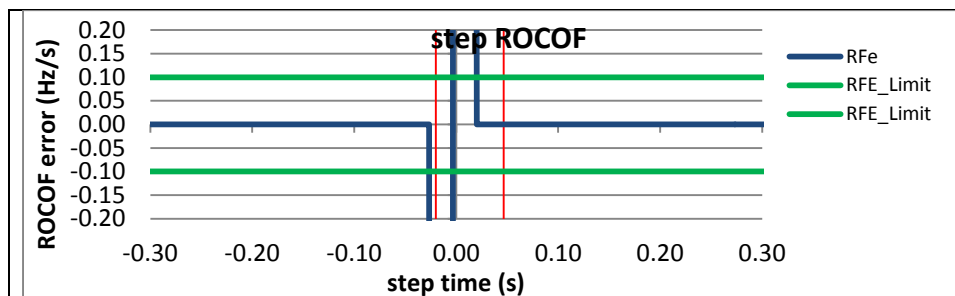


Figure 4772:  $F_s = 15$  FPS, +10 degree phase step

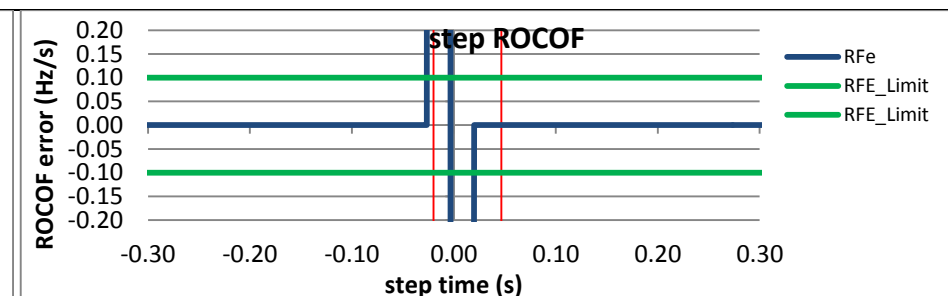


Figure 4773:  $F_s = 15$  FPS, -10 degree phase step

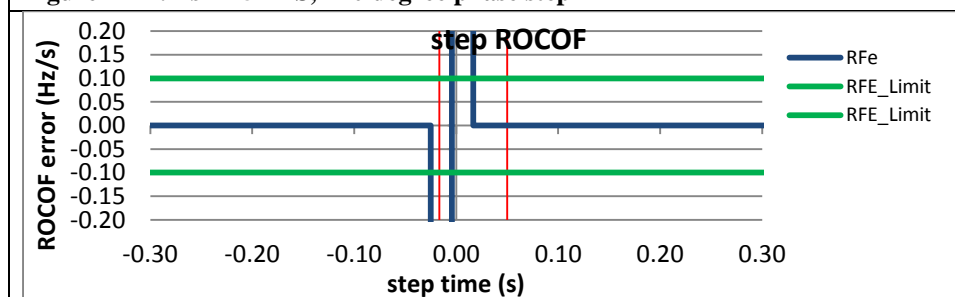


Figure 4774:  $F_s = 12$  FPS, +10 degree phase step

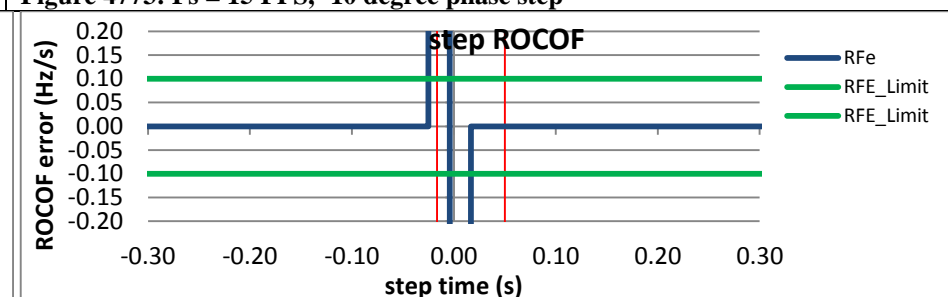


Figure 4775:  $F_s = 12$  FPS, -10 degree phase step

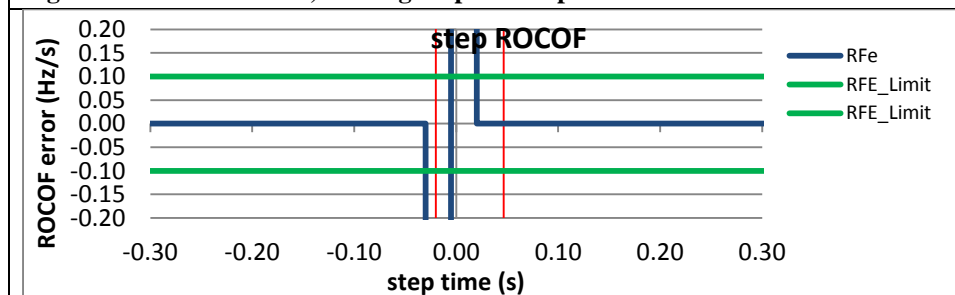


Figure 4776:  $F_s = 10$  FPS, +10 degree phase step

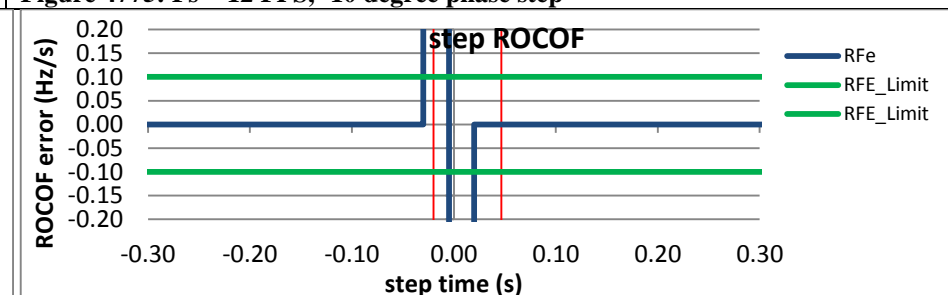
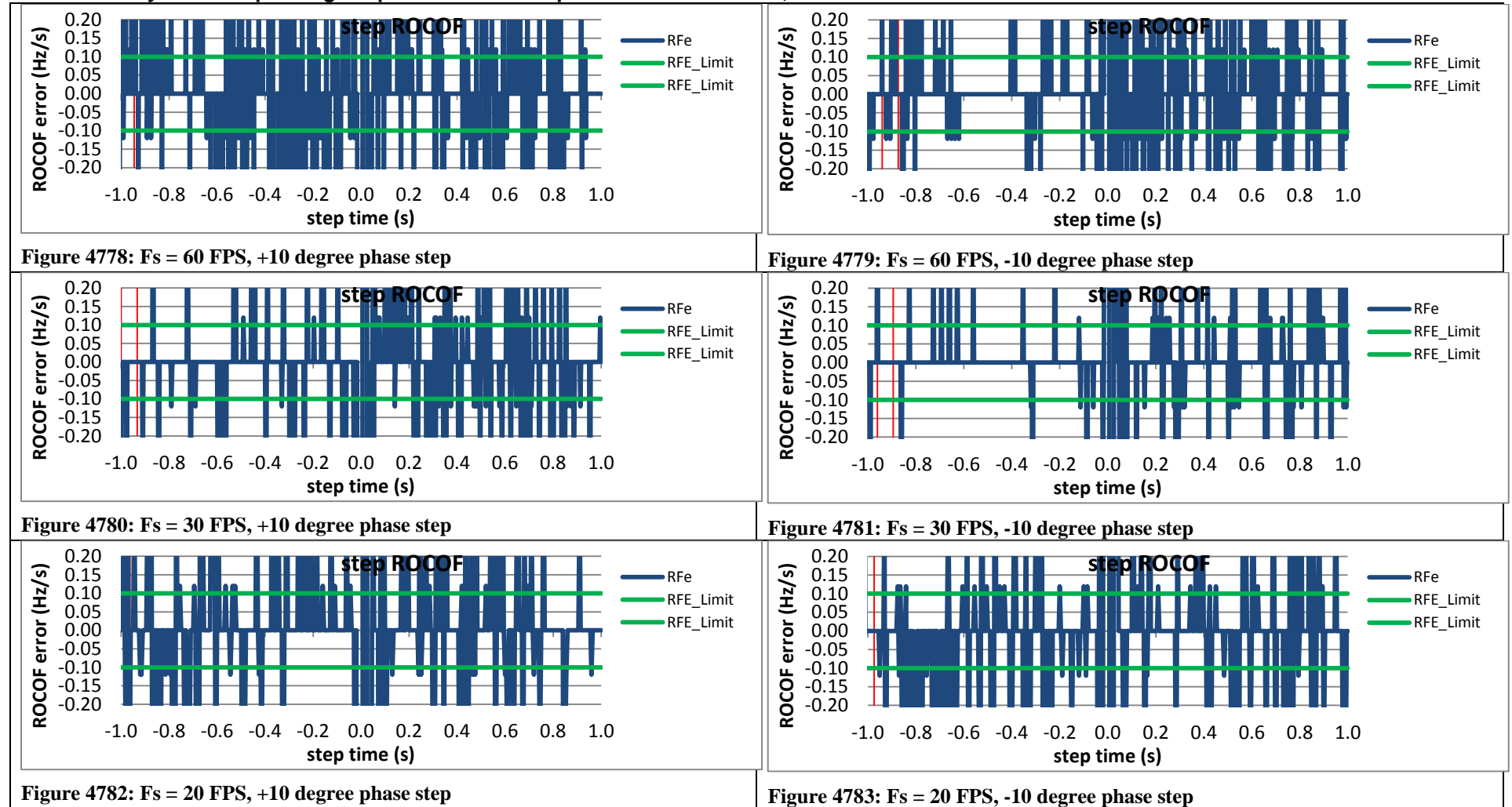
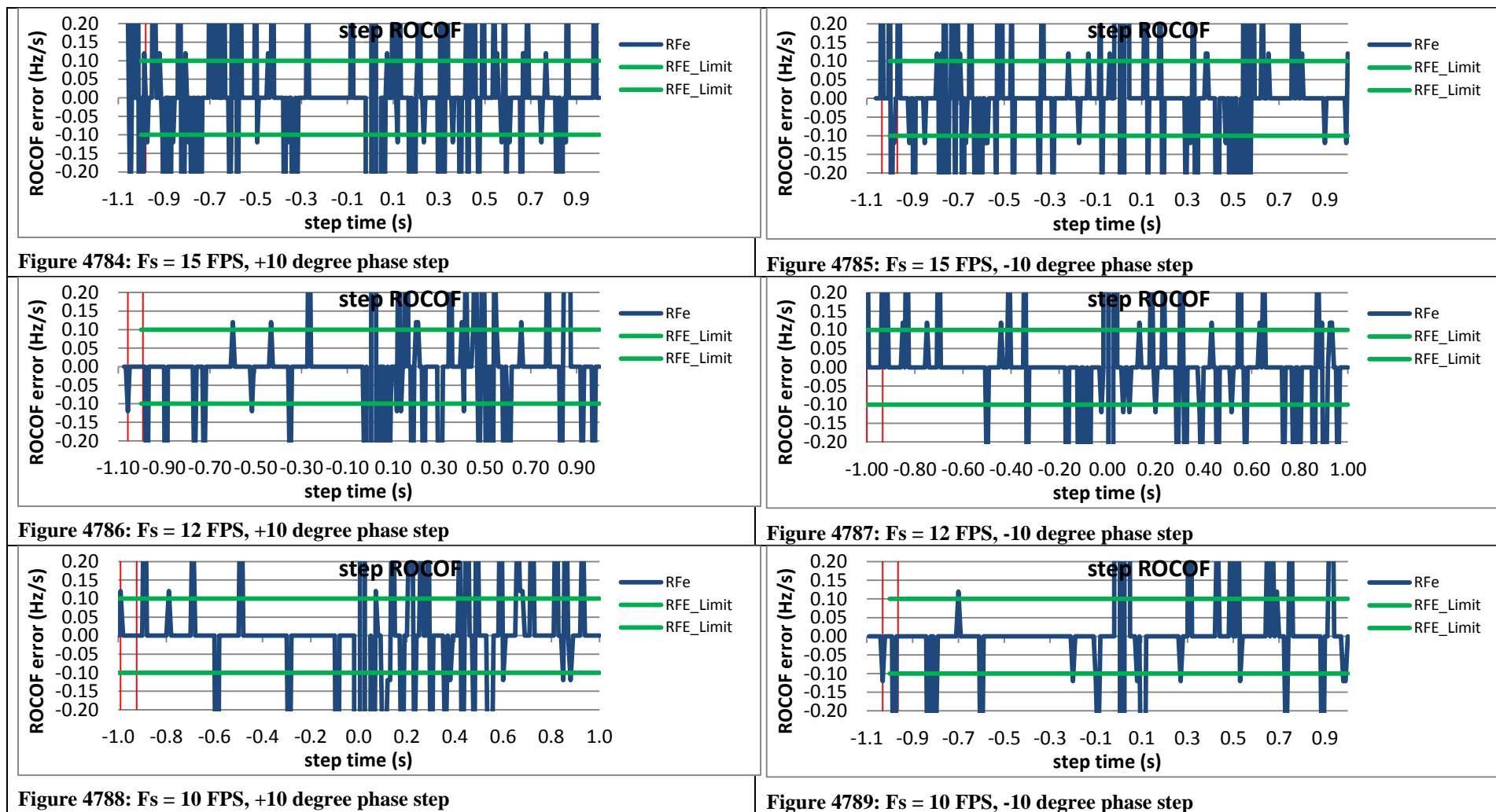


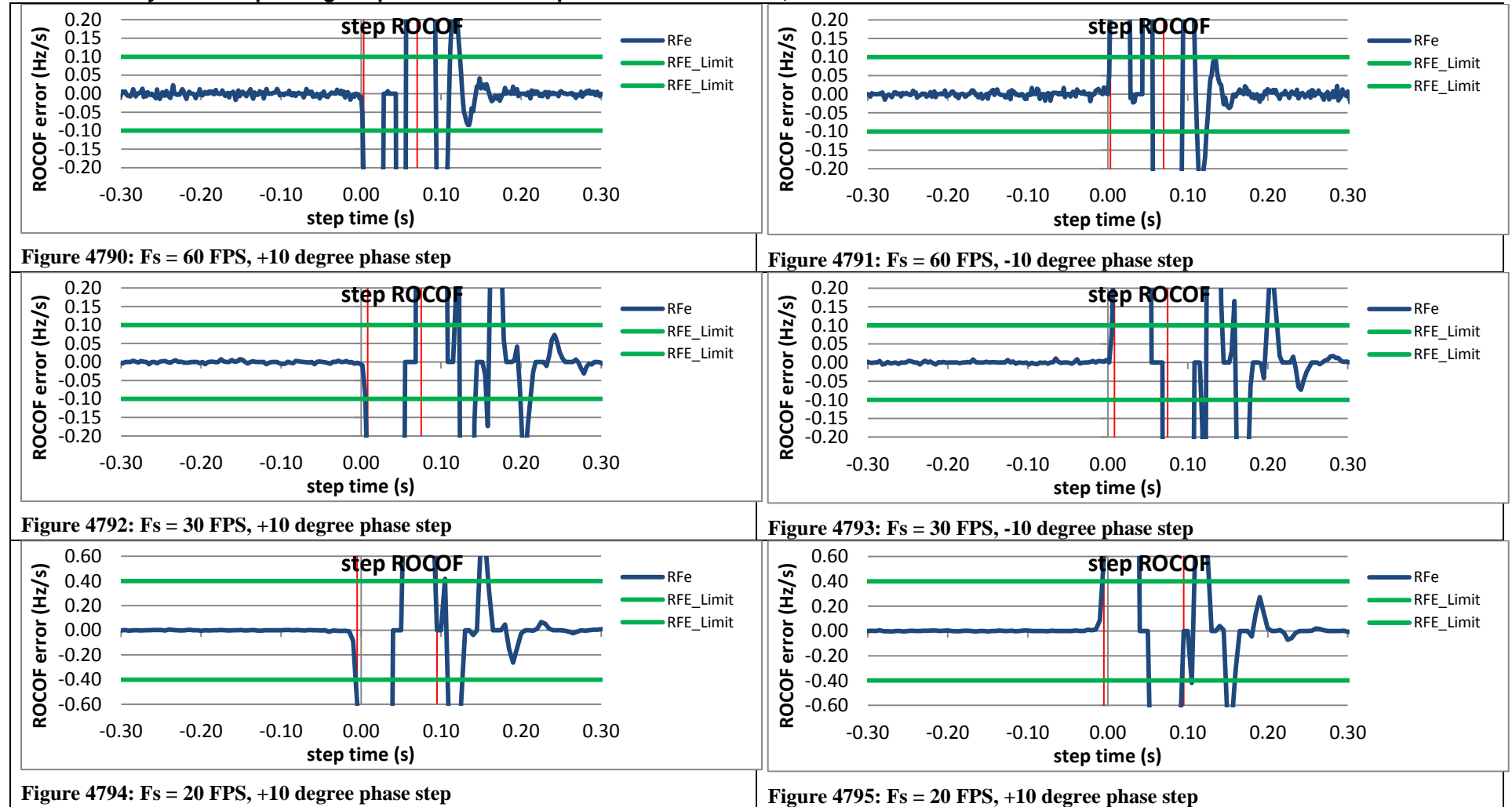
Figure 4777:  $F_s = 10$  FPS, -10 degree phase step

### 9.8.2 PMU A dynamic step change in phase ROCOF response time: $F_0 = 60$ Hz, P class





### 9.8.3 PMU B dynamic step change in phase ROCOF response time: $F_0 = 60$ Hz, P class



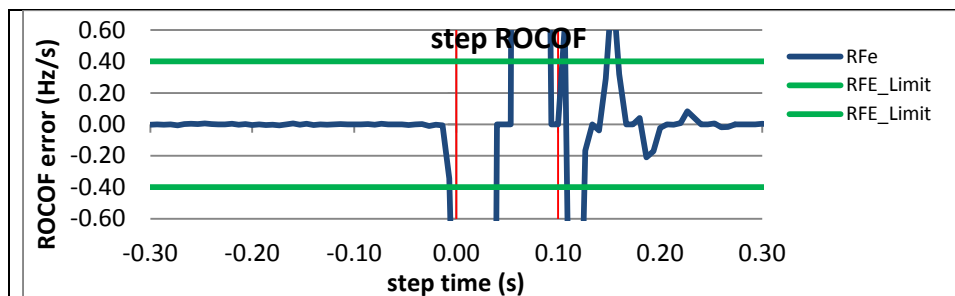


Figure 4796: Fs = 15 FPS, +10 degree phase step

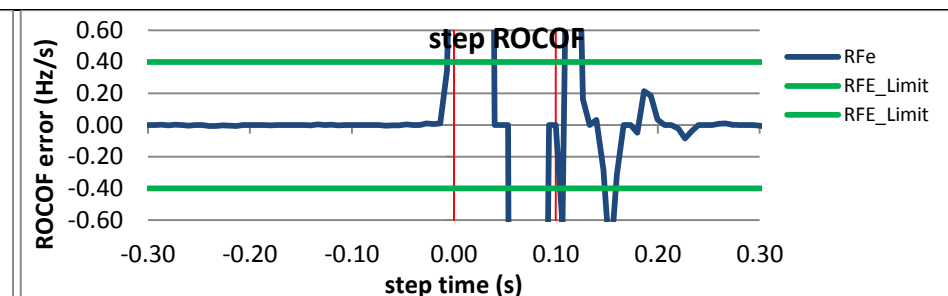


Figure 4797: Fs = 15 FPS, -10 degree phase step

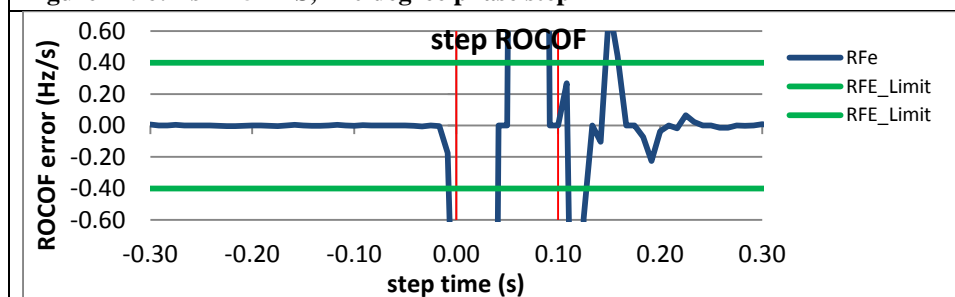


Figure 4798: Fs = 12 FPS, +10 degree phase step

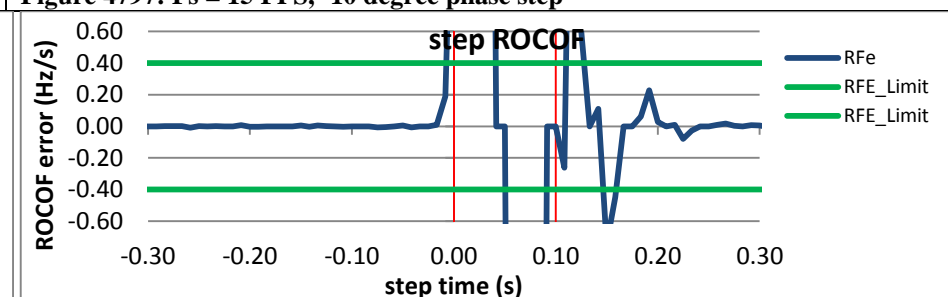


Figure 4799: Fs = 12 FPS, -10 degree phase step

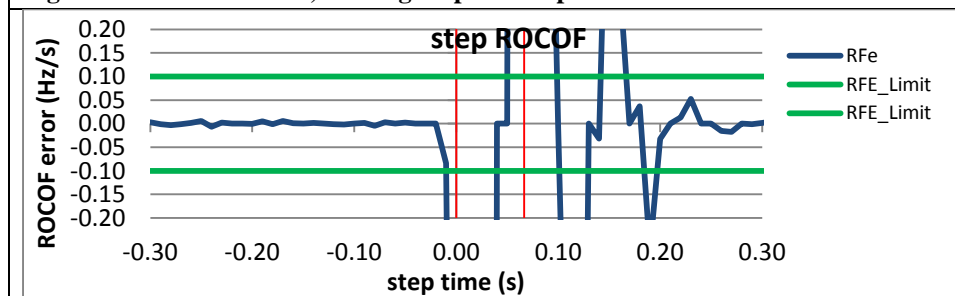


Figure 4800: Fs = 10 FPS, +10 degree phase step

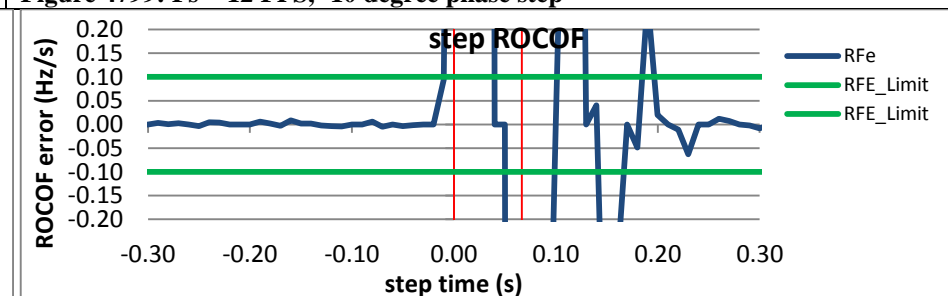
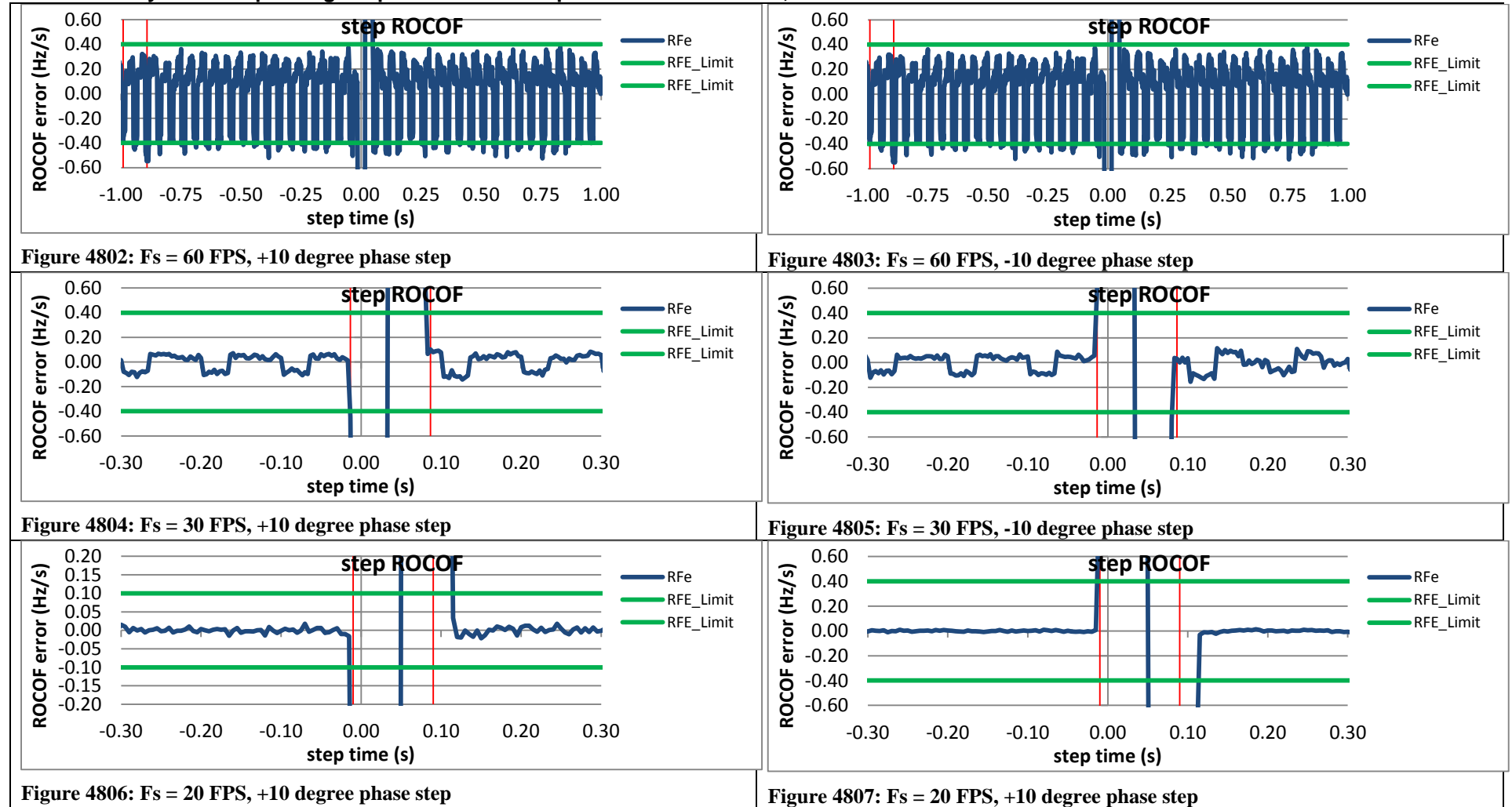


Figure 4801: Fs = 10 FPS, -10 degree phase step

#### 9.8.4 PMU C dynamic step change in phase ROCOF response time: $F_0 = 60$ Hz, P class





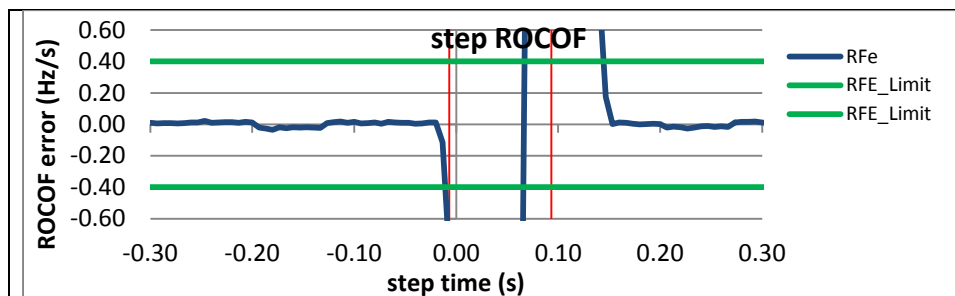


Figure 4808:  $F_s = 15$  FPS, +10 degree phase step

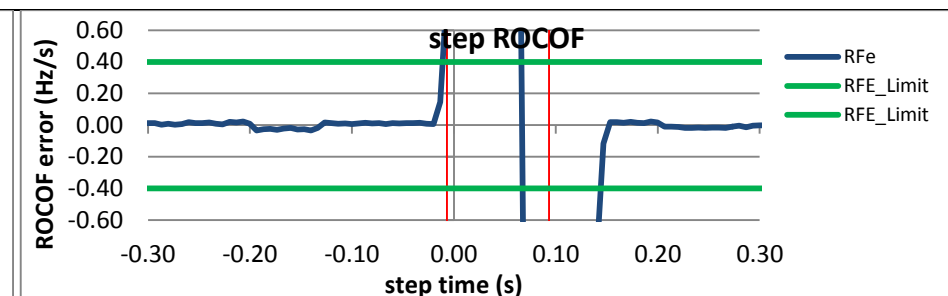


Figure 4809:  $F_s = 15$  FPS, -10 degree phase step

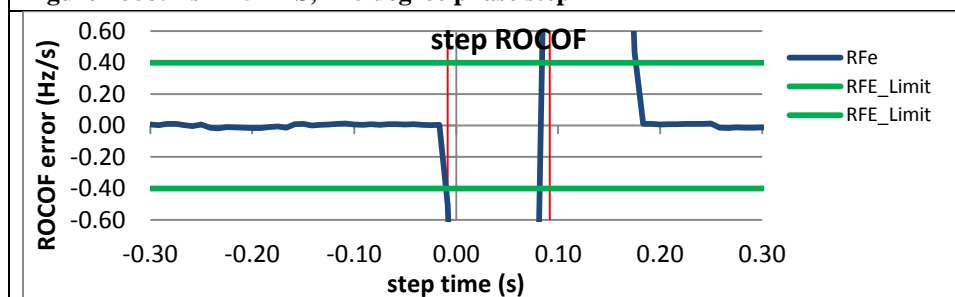


Figure 4810:  $F_s = 12$  FPS, +10 degree phase step

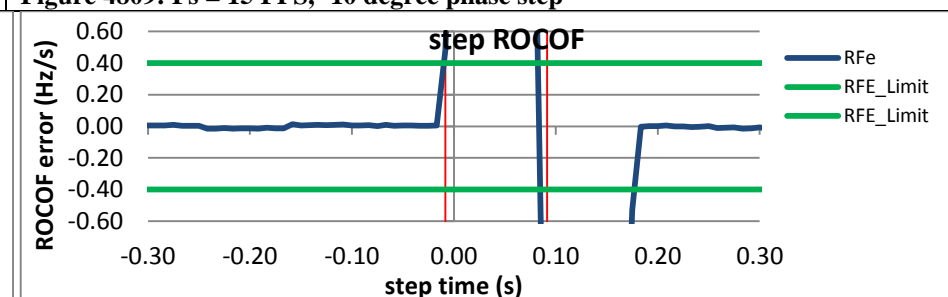


Figure 4811:  $F_s = 12$  FPS, -10 degree phase step

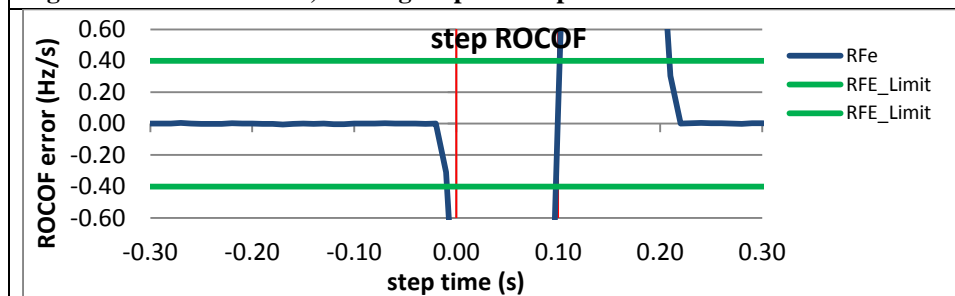


Figure 4812:  $F_s = 10$  FPS, +10 degree phase step

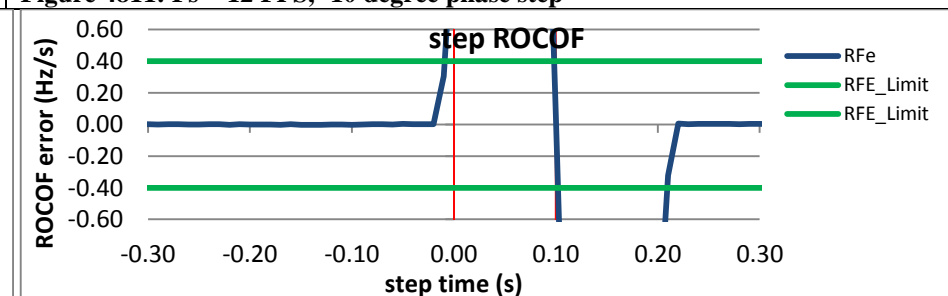
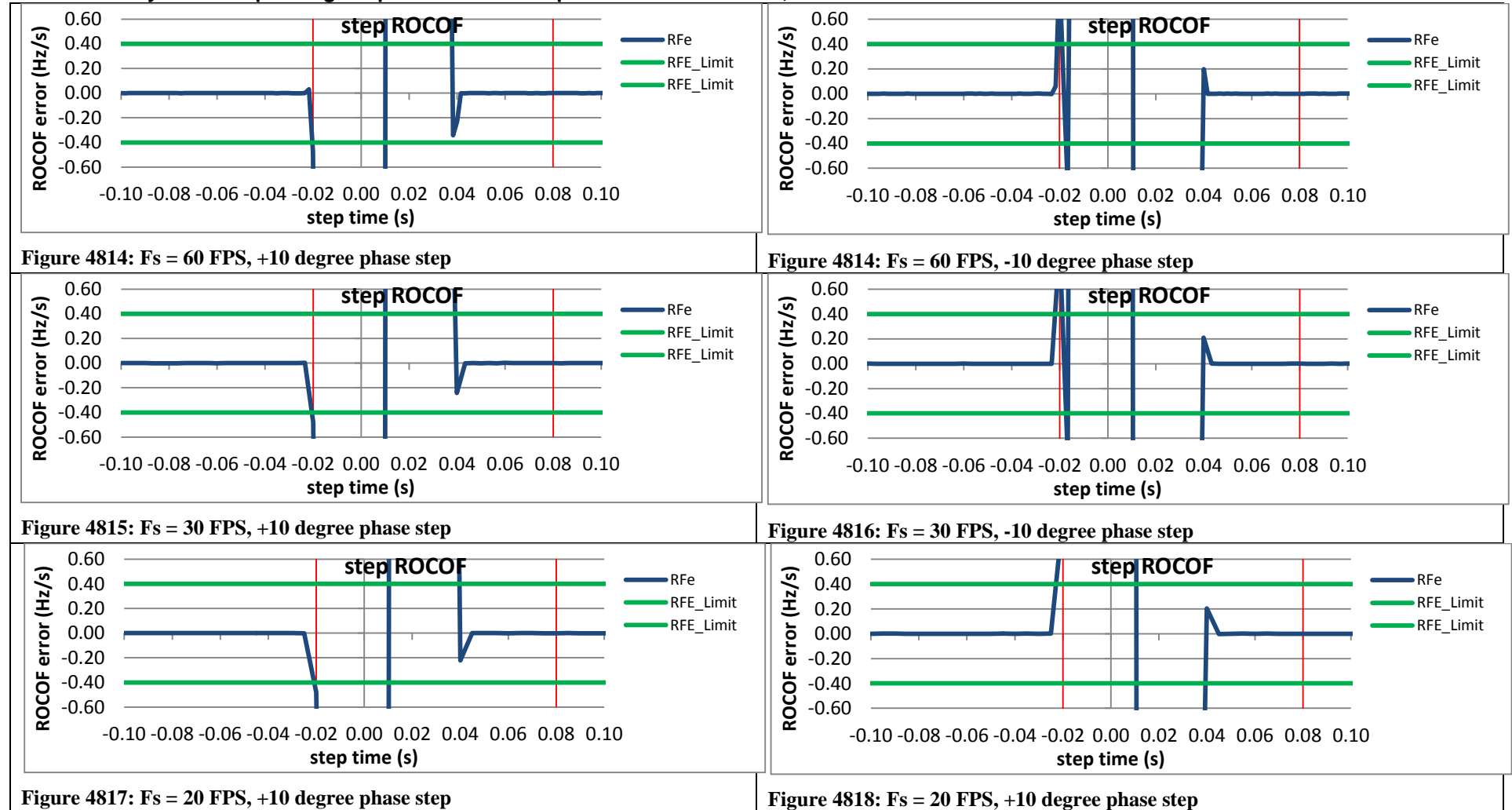


Figure 4813:  $F_s = 10$  FPS, -10 degree phase step

### 9.8.5 PMU D dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class



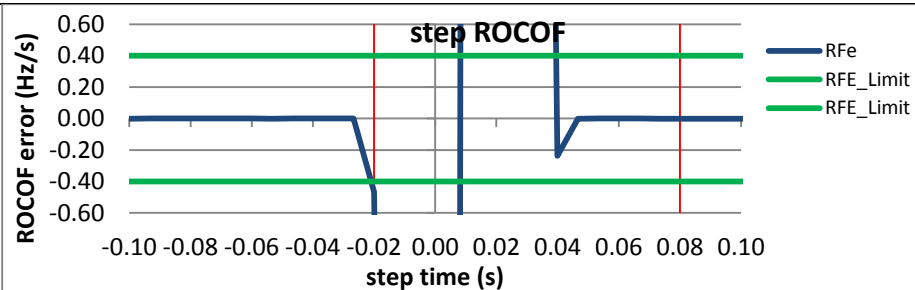


Figure 4819:  $F_s = 15$  FPS, +10 degree phase step

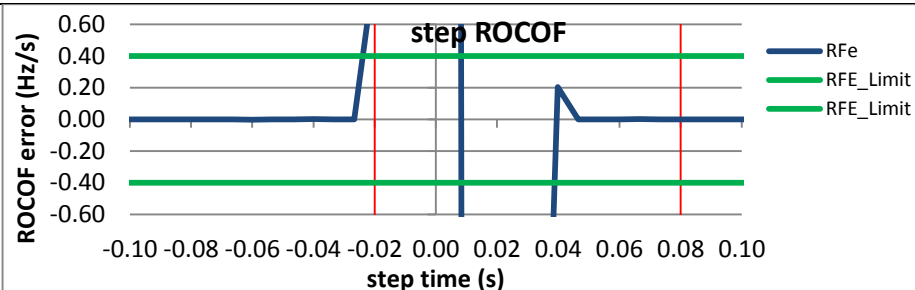


Figure 4820:  $F_s = 15$  FPS, -10 degree phase step

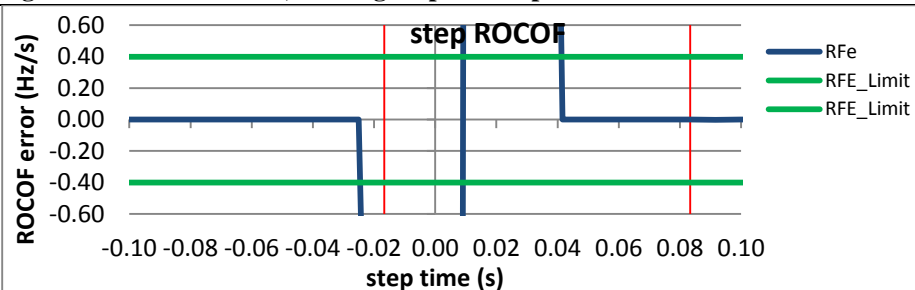


Figure 4821:  $F_s = 12$  FPS, +10 degree phase step

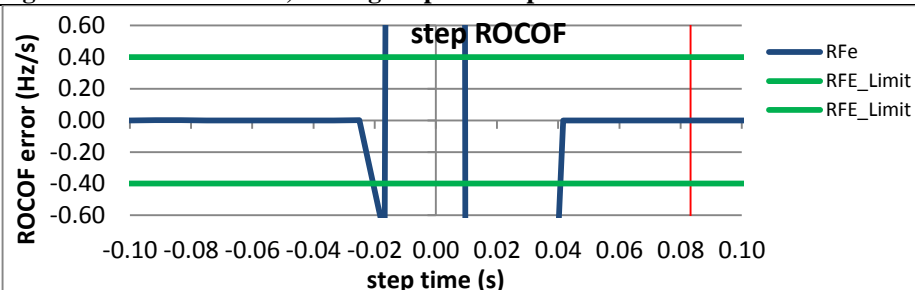


Figure 4822:  $F_s = 12$  FPS, -10 degree phase step

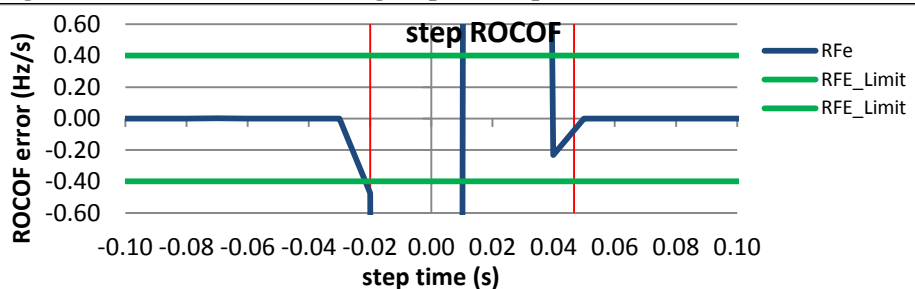


Figure 4823:  $F_s = 10$  FPS, +10 degree phase step

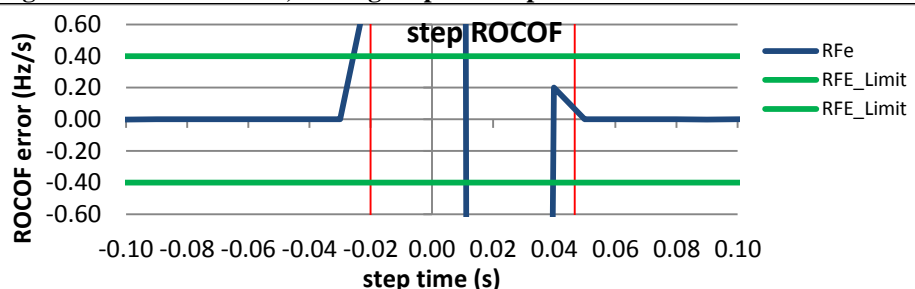
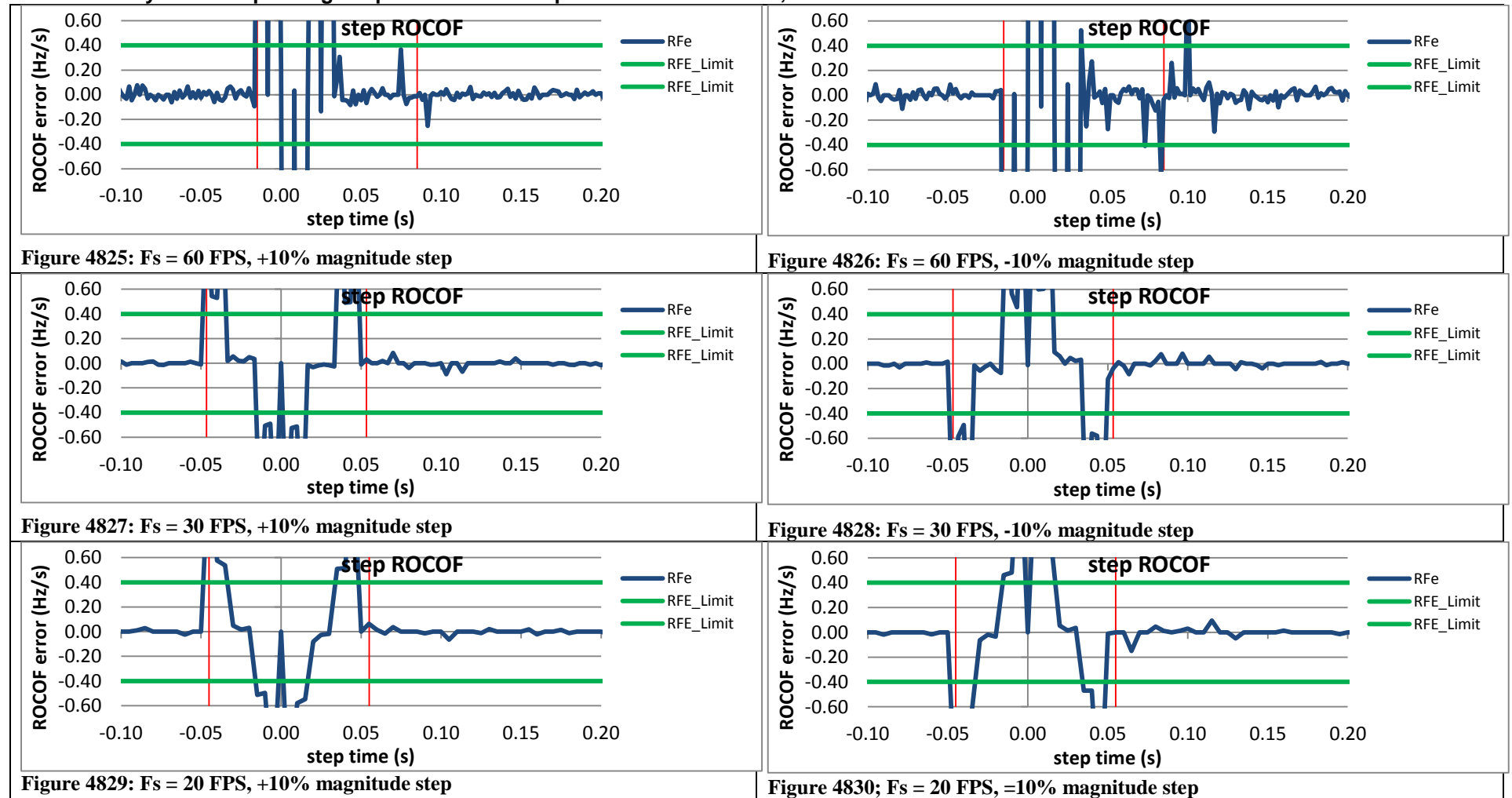


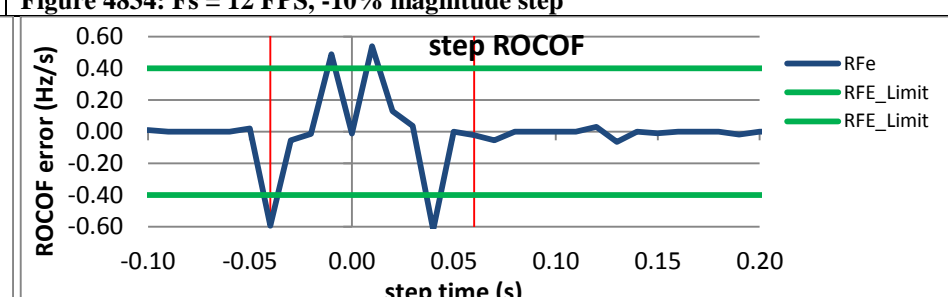
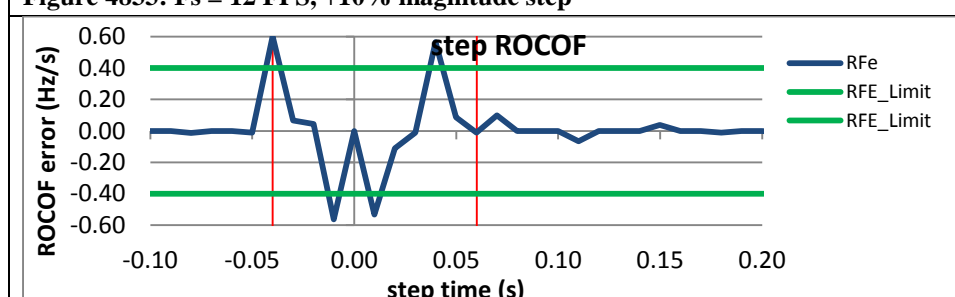
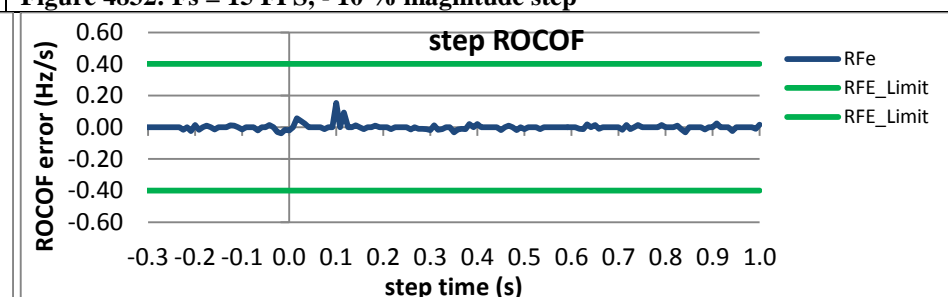
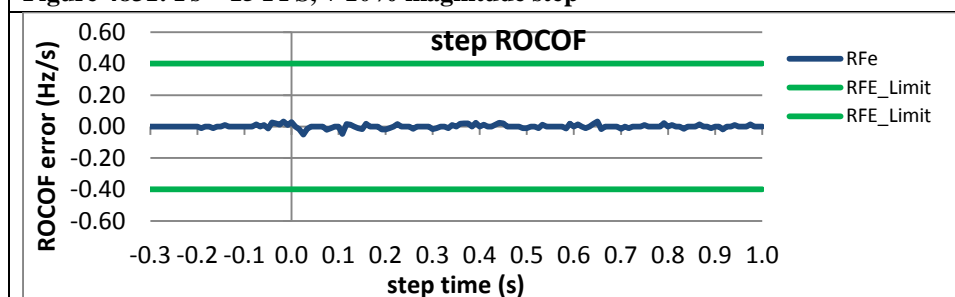
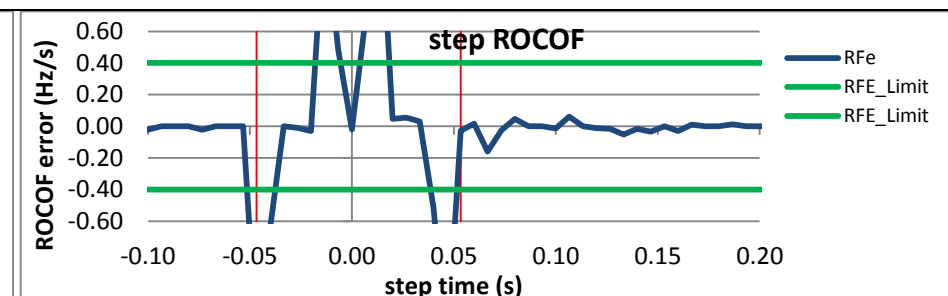
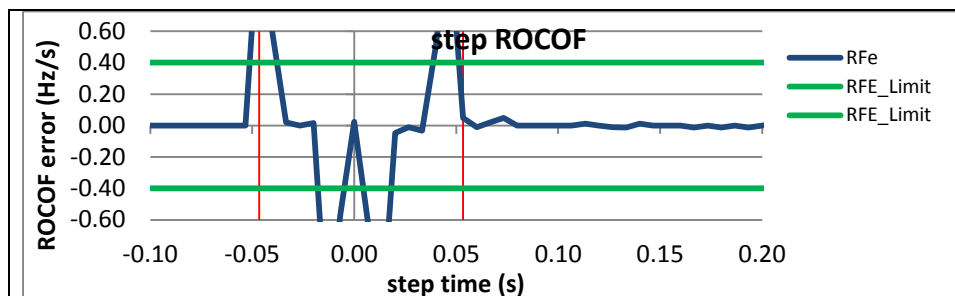
Figure 4824:  $F_s = 10$  FPS, -10 degree phase step

### 9.8.6 PMU E dynamic step change in phase ROCOF response time: $F_0 = 60$ Hz, P class

PMU E does not support P class.

### 9.8.7 PMU F dynamic step change in phase ROCOF response time: $F_0 = 60$ Hz, P class

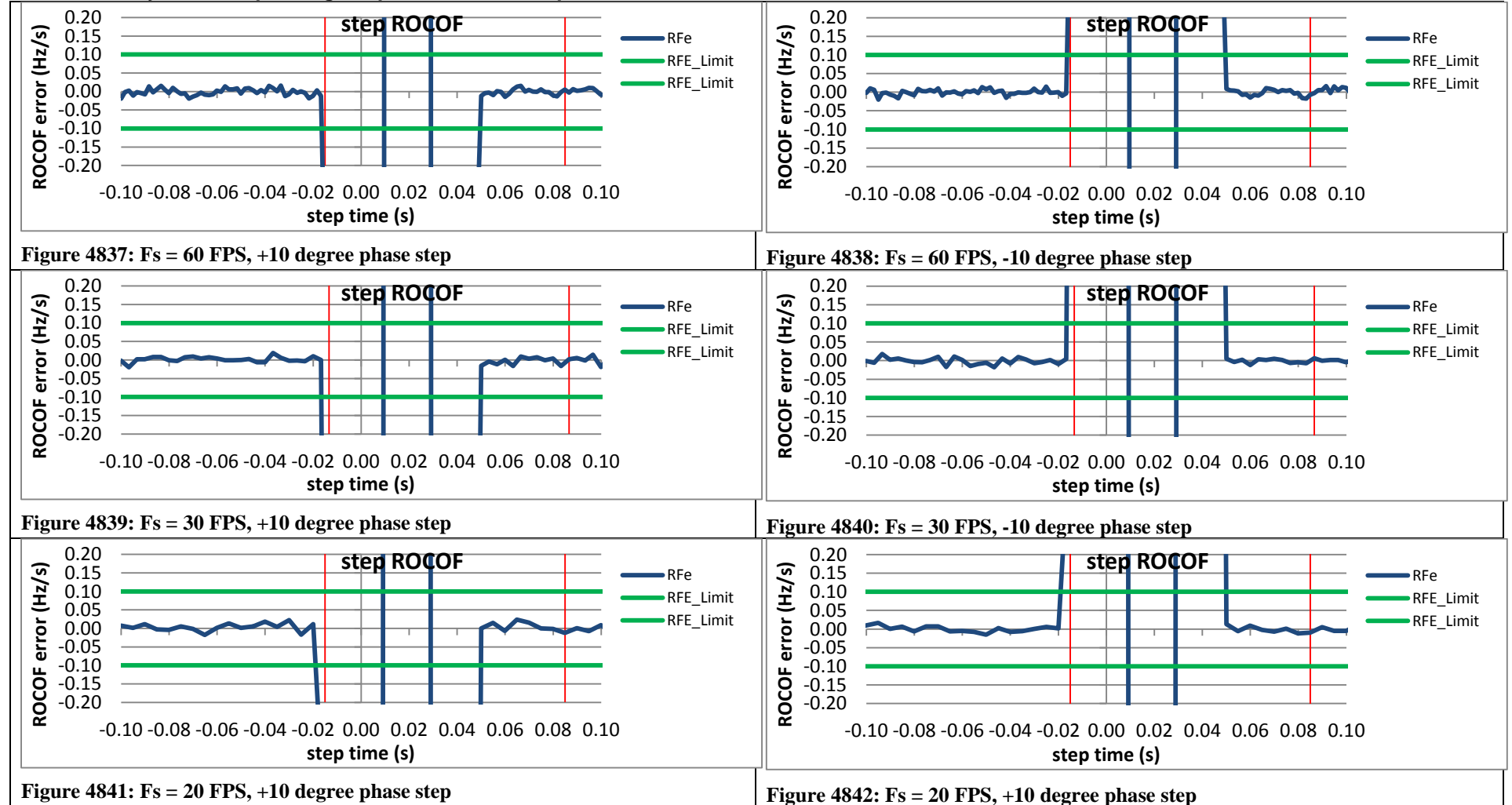




### 9.8.8 PMU G dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class

PMU G does not support P class.

### 9.8.9 PMU H dynamic step change in phase ROCOF response time: F0 = 60 Hz, P class



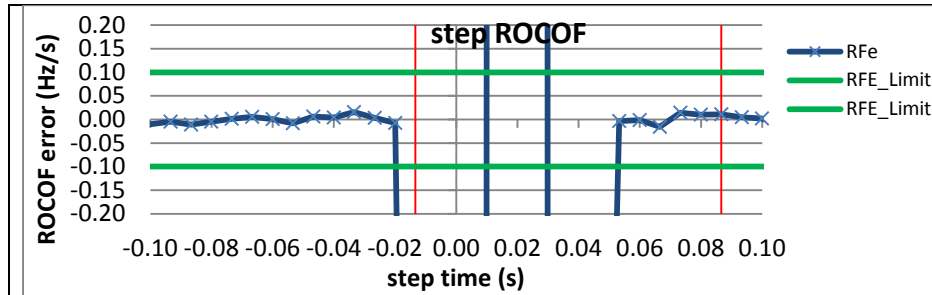


Figure 4843:  $F_s = 15$  FPS, +10 degree phase step

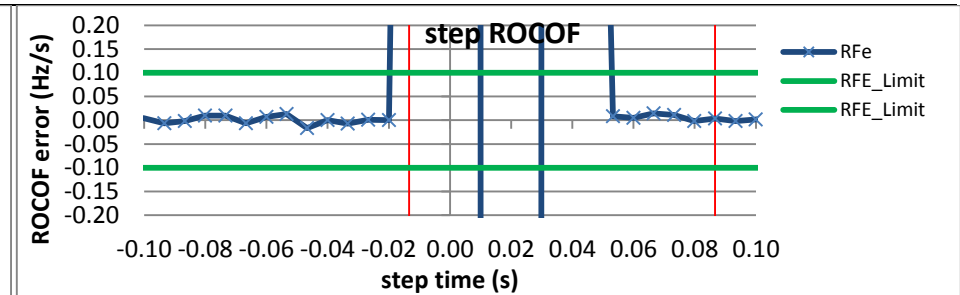


Figure 4844:  $F_s = 15$  FPS, -10 degree phase step

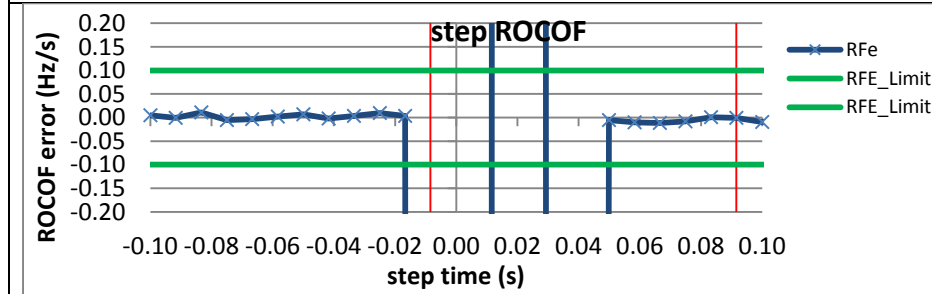


Figure 4845:  $F_s = 12$  FPS, +10 degree phase step

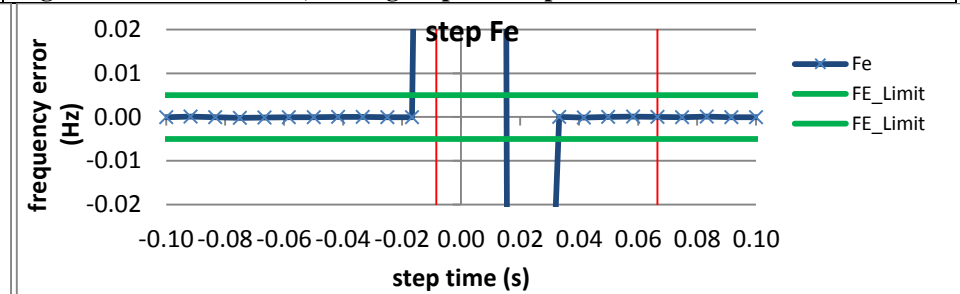


Figure 4846:  $F_s = 12$  FPS, -10 degree phase step

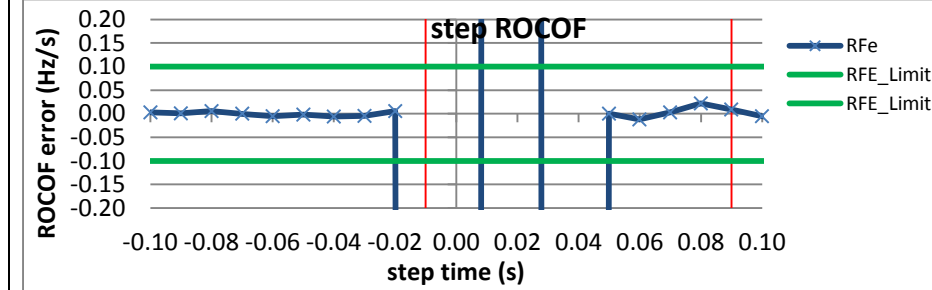


Figure 4847:  $F_s = 10$  FPS, +10 degree phase step

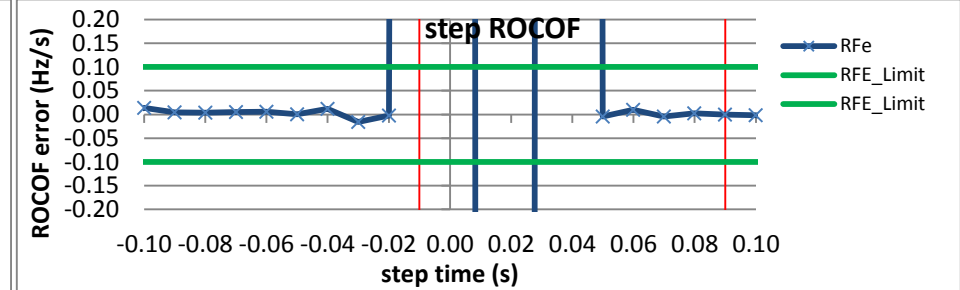
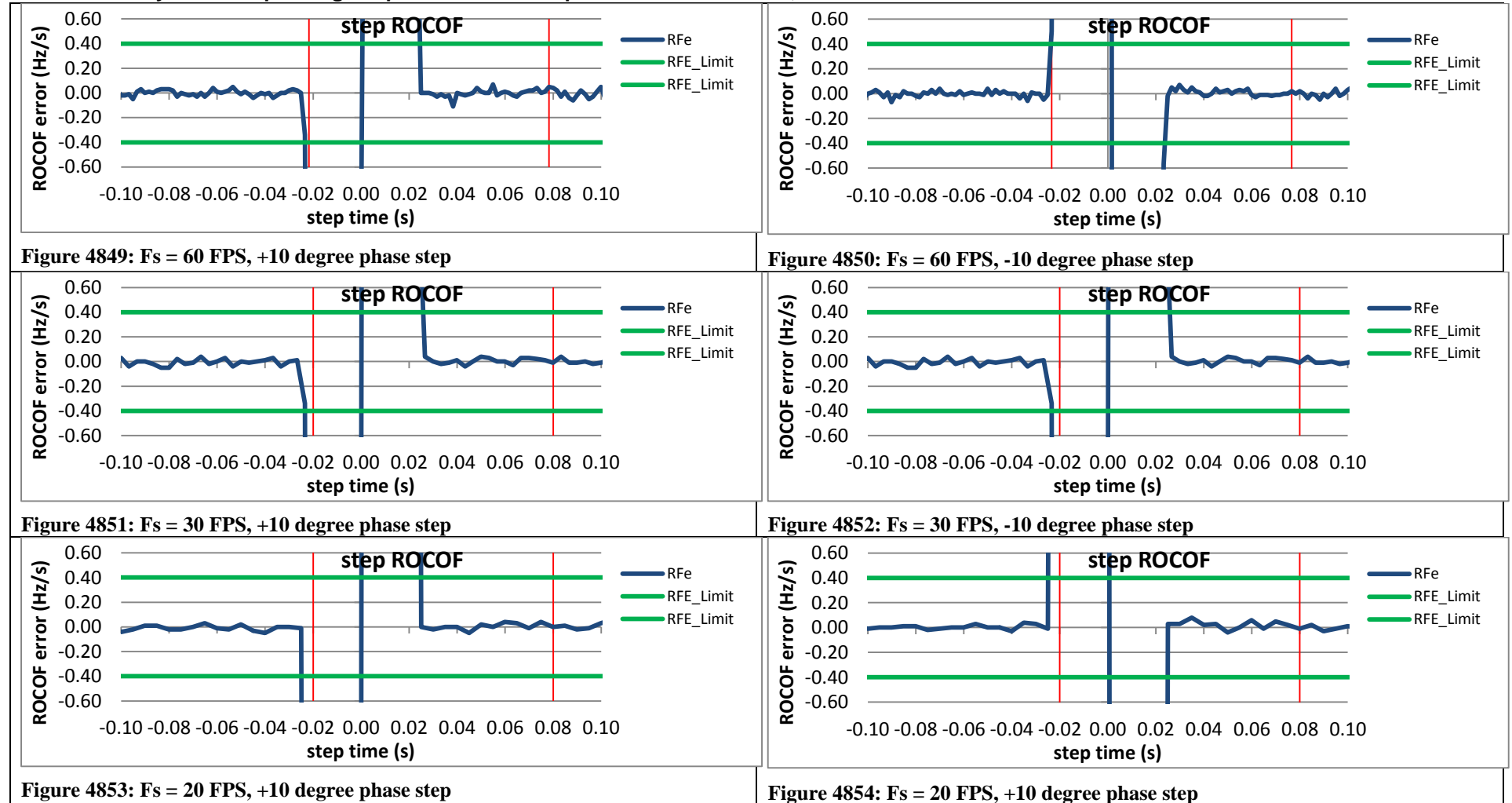


Figure 4848:  $F_s = 10$  FPS, -10 degree phase step

#### 9.8.10 PMU I dynamic step change in phase ROCOF response time: $F_0 = 60$ Hz, P class

PMU I does not support P class

### 9.8.11 PMU J dynamic step change in phase ROCOF response time: $F_0 = 60$ Hz, P class





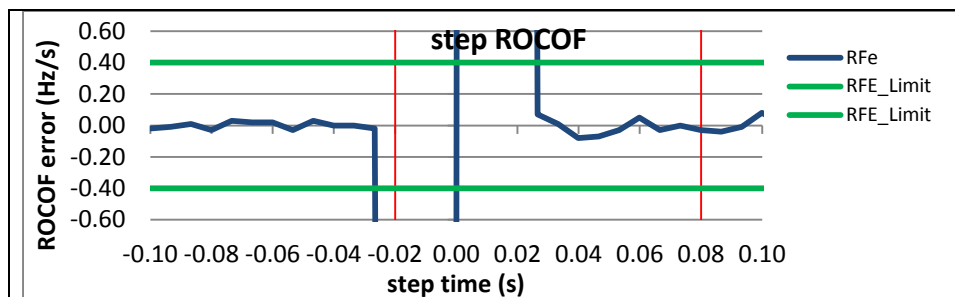


Figure 4855:  $F_s = 15$  FPS, +10 degree phase step

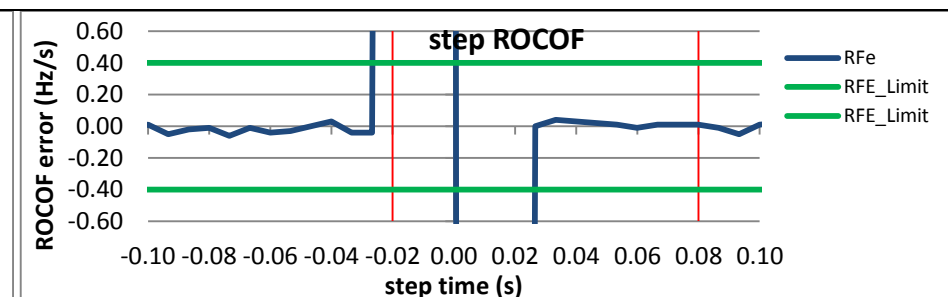


Figure 4856:  $F_s = 15$  FPS, -10 degree phase step

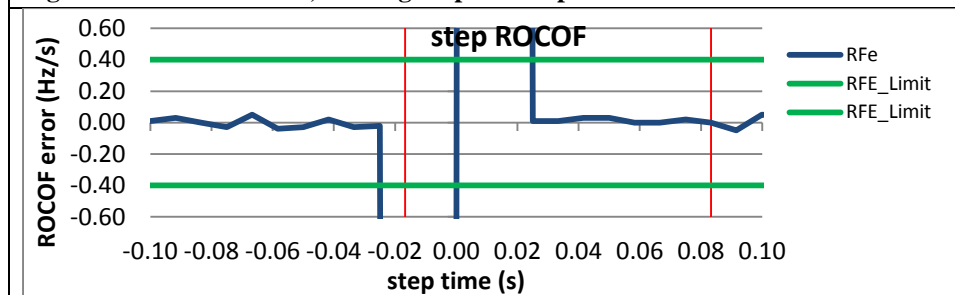


Figure 4857:  $F_s = 12$  FPS, +10 degree phase step

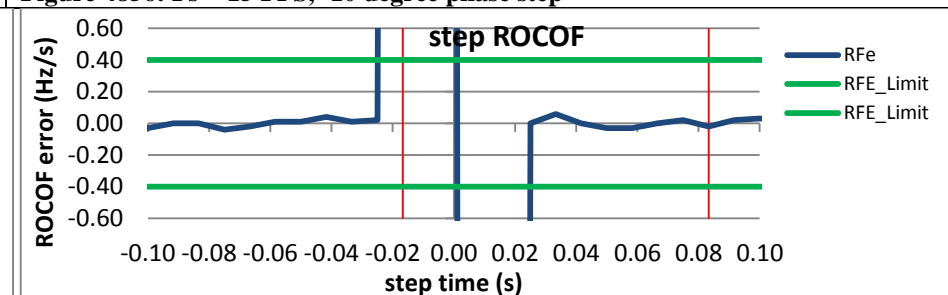


Figure 4858:  $F_s = 12$  FPS, -10 degree phase step

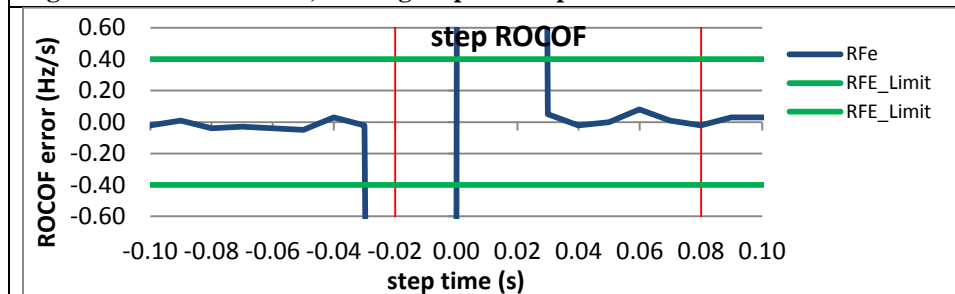


Figure 4859:  $F_s = 10$  FPS, +10 degree phase step

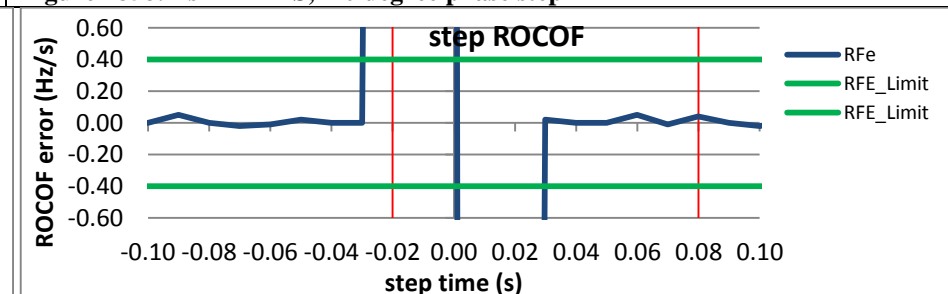


Figure 4860:  $F_s = 10$  FPS, -10 degree phase step

## 9.9 Dynamic step change in phase: phasor overshoot: M class

Fs (FPS)	10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P
PMU A	P	P		P	P	P	P		P		P	P
PMU B	F	F	F	F	F	F	F	F	F	F	F	F
PMU C	P	P	P	P	P	P	P	P	P	P	P	P
PMU D	P	P	P	P	P	P	P	P	P	P	P	P
PMU E	P	-	P	-	P	-	P	-	P	-	P	-
PMU F	P	P	P	P	P	P	P	P	P	P	P	P
PMU G	F	-	F	-	F	-	F	-	F	-	-	-
PMU H	P	P	P	P	P	P	P	P	P	P	P	P
PMU I	P	-	P	-	P	-	P	-	P	-	P	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P

## Dynamic step change in phase: phasor delay time M class

Fs (FPS)	10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P
PMU A	P	P	P	P	P	P	P	P	P	P	P	P
PMU B	P	P	P	P	P	P	P	P	P	P	P	P
PMU C	P	P	P	P	P	P	P	P	P	P	P	P
PMU D	P	P	P	P	P	P	P	P	P	P	P	P
PMU E	P	-	P	-	P	-	P	-	P	-	P	-
PMU F	P	P	P	P	P	P	P	P	P	P	P	P
PMU G	F	-	F	-	F	-	F	-	F	-	F	-
PMU H	P	P	P	P	P	P	P	P	P	P	P	P
PMU I	P	-	P	-	P	-	P	-	P	-	P	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P

### 9.9.1 C37.118.1-2011 Annex C dynamic step change in phase phasor overshoot: $F_0 = 60$ Hz, M class

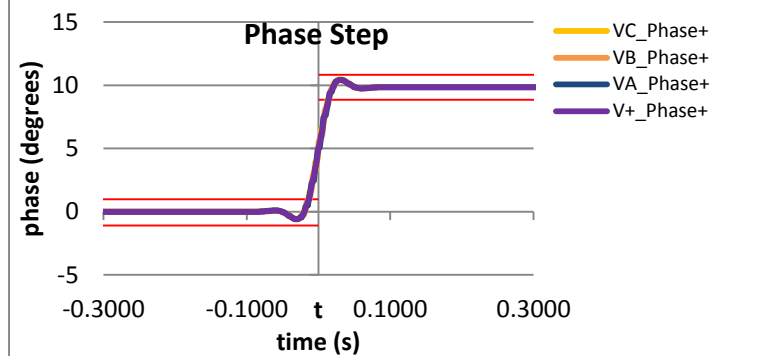


Figure 4861:  $F_s = 60$  FPS, +10 degree phase step

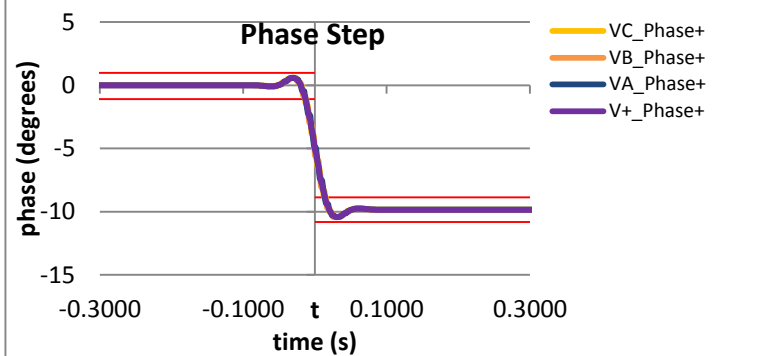


Figure 4862:  $F_s = 60$  FPS, -10 degree phase step

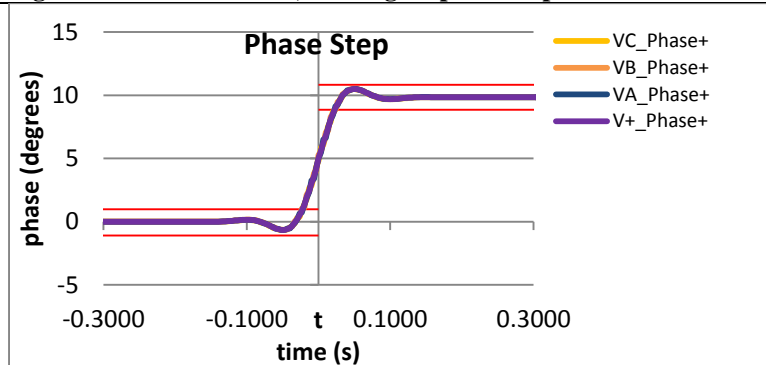


Figure 4863:  $F_s = 30$  FPS, +10 degree phase step

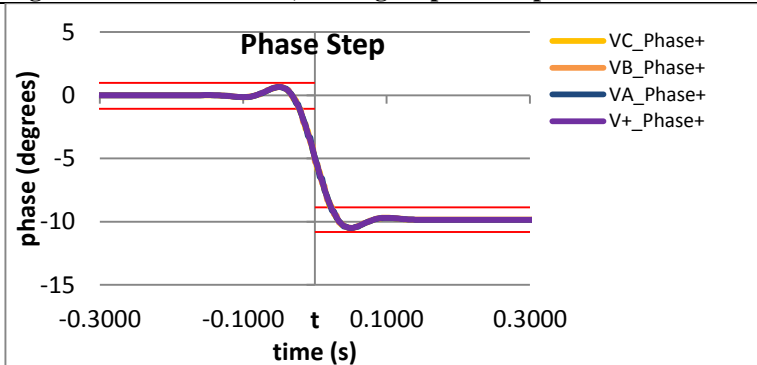


Figure 4864:  $F_s = 30$  FPS, -10 degree phase step

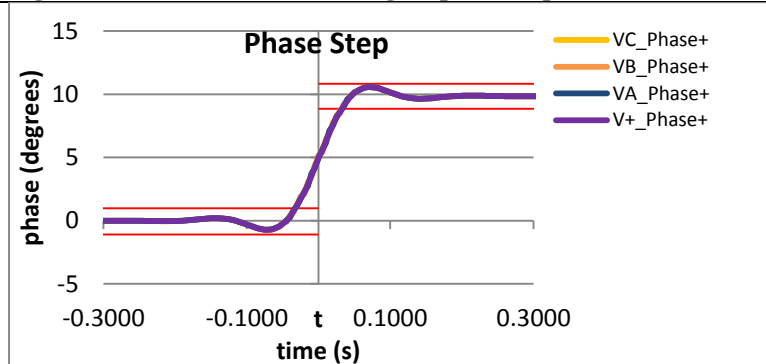


Figure 4865:  $F_s = 20$  FPS, +10 degree phase step

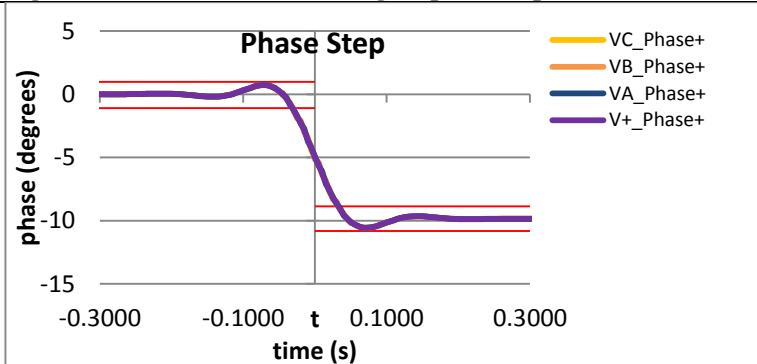


Figure 4866:  $F_s = 20$  FPS, -10 degree phase step

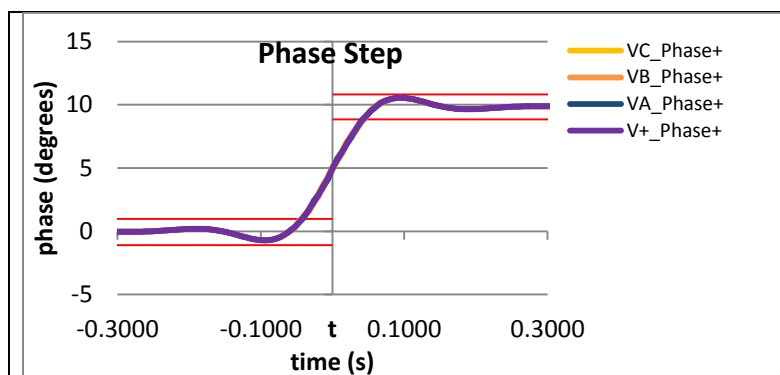


Figure 4867:  $F_s = 15$  FPS, +10 degree phase step

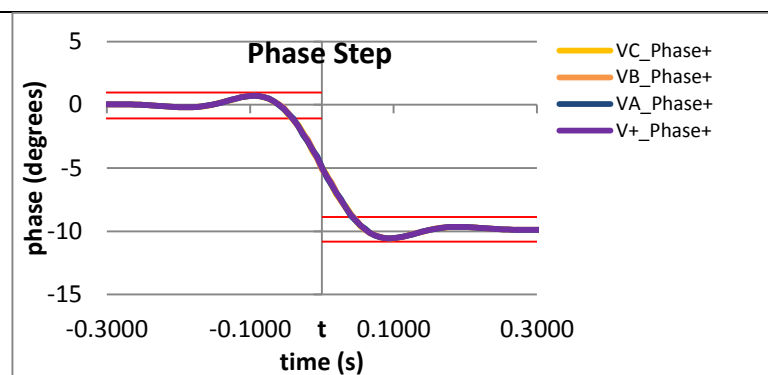


Figure 4868:  $F_s = 15$  FPS, -10 degree phase step

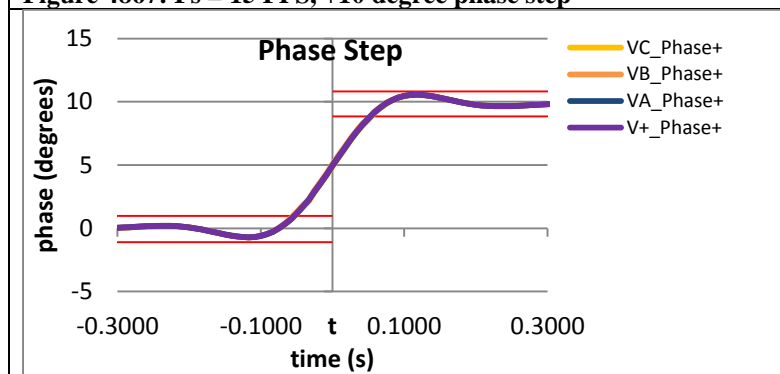


Figure 4869:  $F_s = 12$  FPS, +10 degree phase step

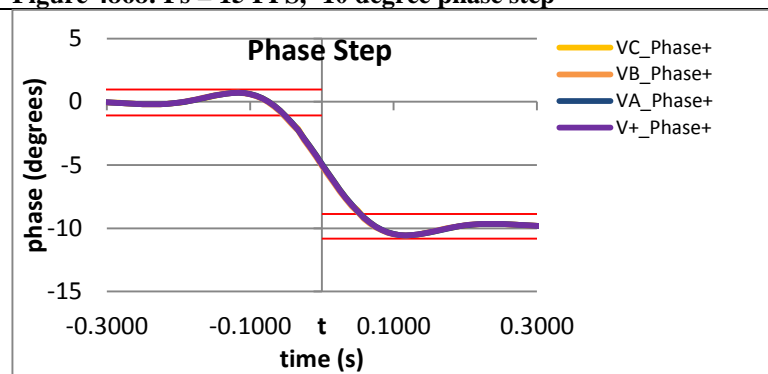


Figure 4870:  $F_s = 12$  FPS, -10 degree phase step

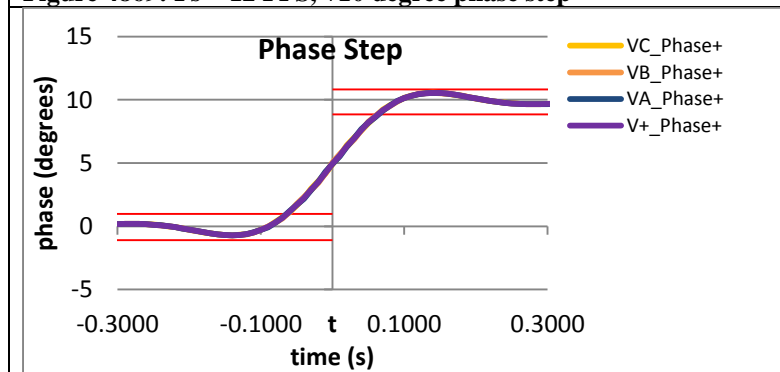


Figure 4871:  $F_s = 10$  FPS, +10 degree phase step

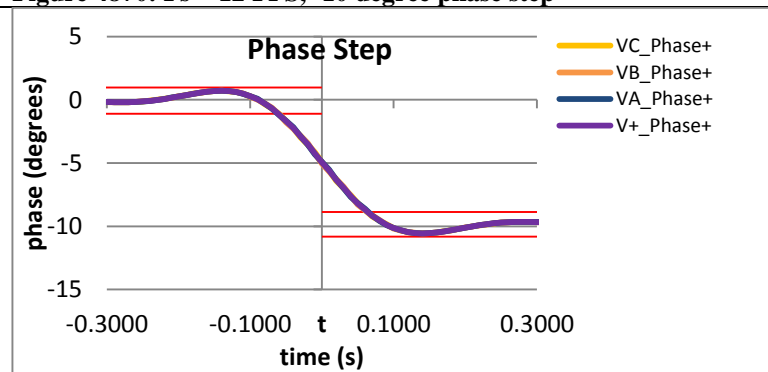


Figure 4872:  $F_s = 10$  FPS, -10 degree phase step

### 9.9.2 PMU A dynamic step change in phase phasor overshoot: $F_0 = 60$ Hz, M class

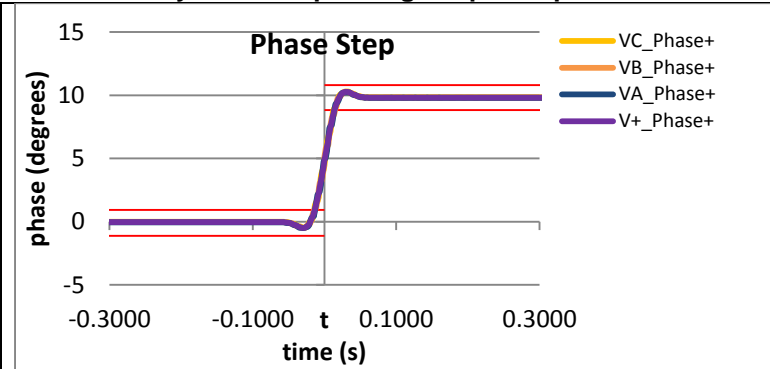


Figure 4873:  $F_s = 60$  FPS, +10 degree phase step

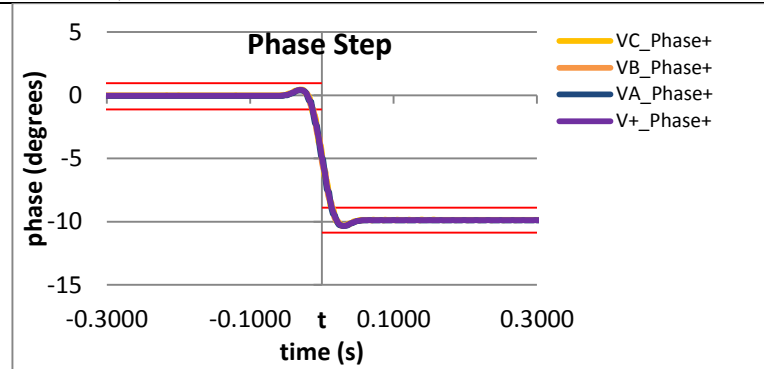


Figure 4874:  $F_s = 60$  FPS, -10 degree phase step

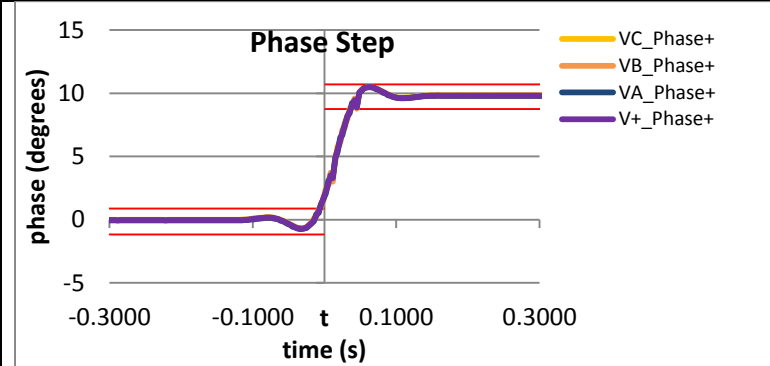


Figure 4875:  $F_s = 30$  FPS, +10 degree phase step

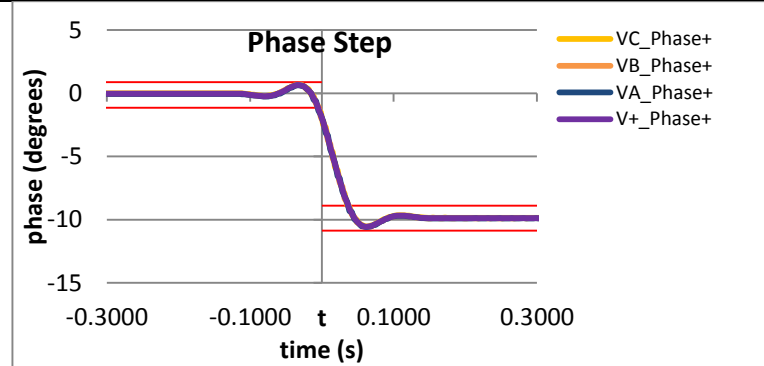


Figure 4876:  $F_s = 30$  FPS, -10 degree phase step

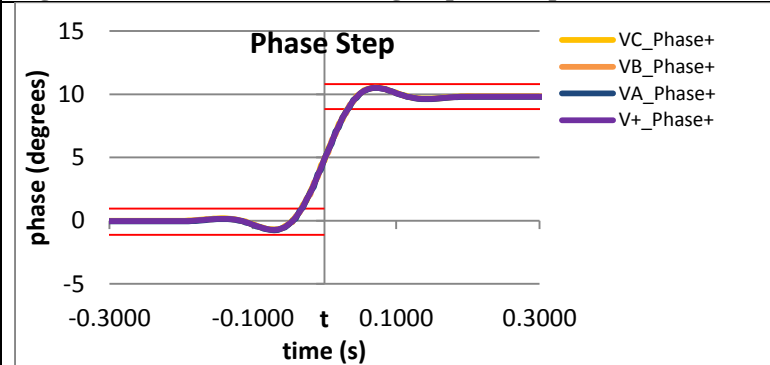


Figure 4877:  $F_s = 20$  FPS, +10 degree phase step

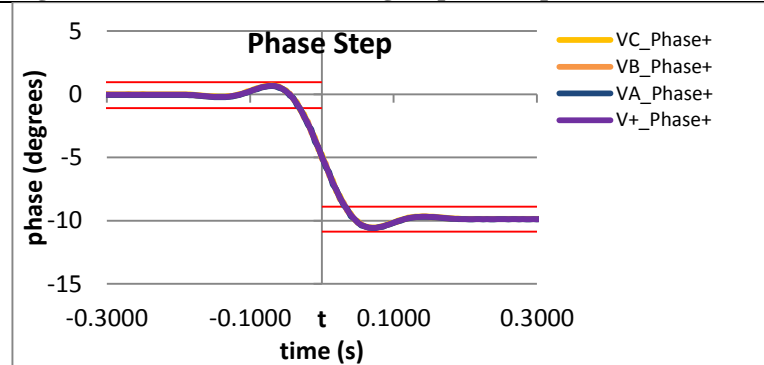


Figure 4878:  $F_s = 20$  FPS, -10 degree phase step

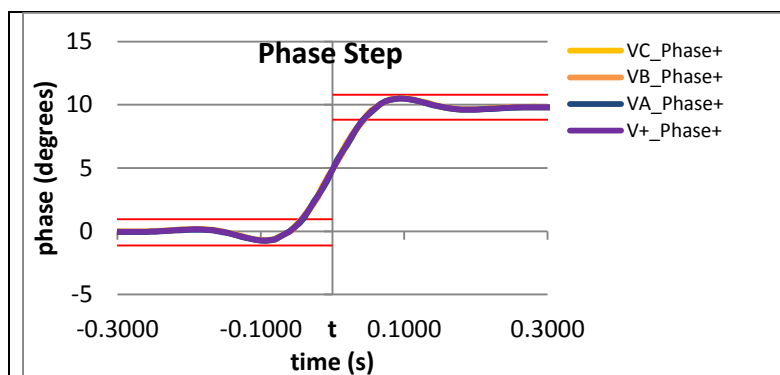


Figure 4879:  $F_s = 15$  FPS, +10 degree phase step

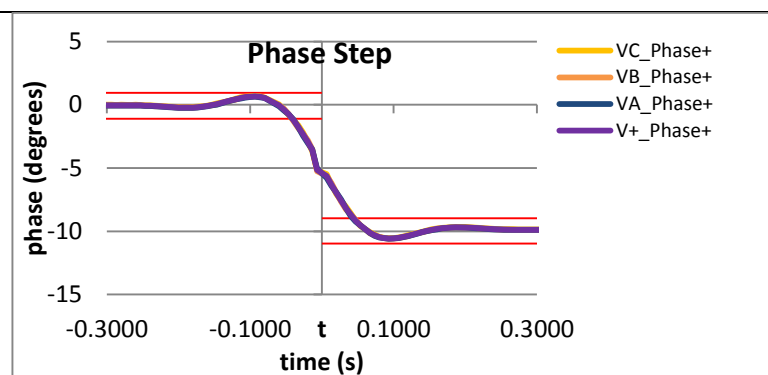


Figure 4880:  $F_s = 15$  FPS, -10 degree phase step

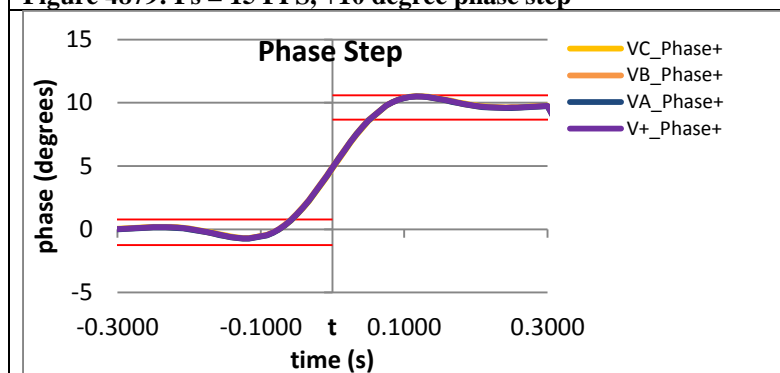


Figure 4881:  $F_s = 12$  FPS, +10 degree phase step

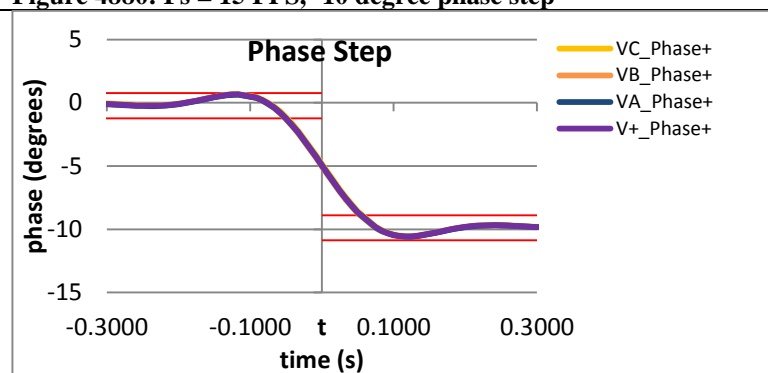


Figure 4882:  $F_s = 12$  FPS, -10 degree phase step

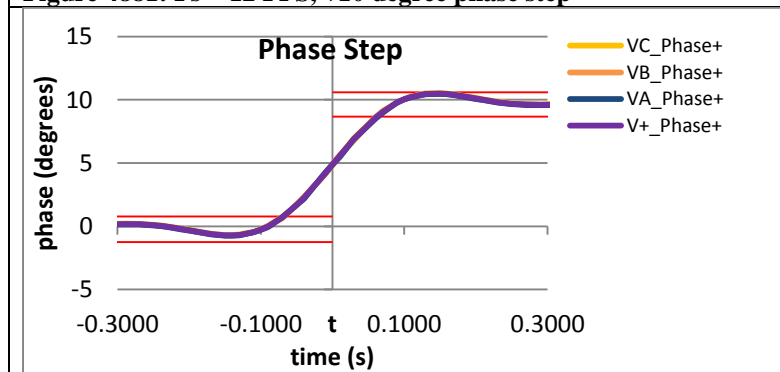


Figure 4883:  $F_s = 10$  FPS, +10 degree phase step

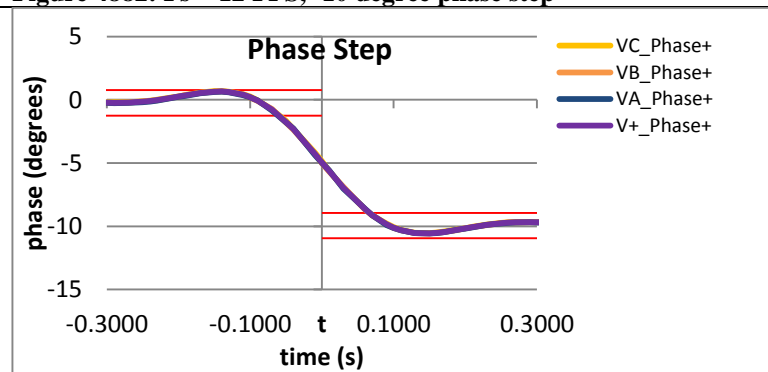


Figure 4884:  $F_s = 10$  FPS, -10 degree phase step

### 9.9.3 PMU B dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class

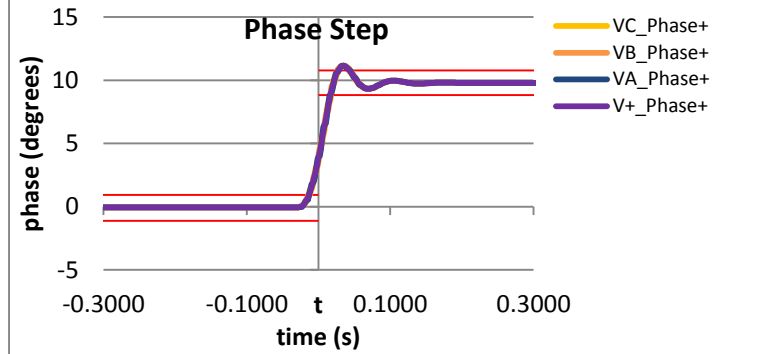


Figure 4885: Fs = 60 FPS, +10 degree phase step

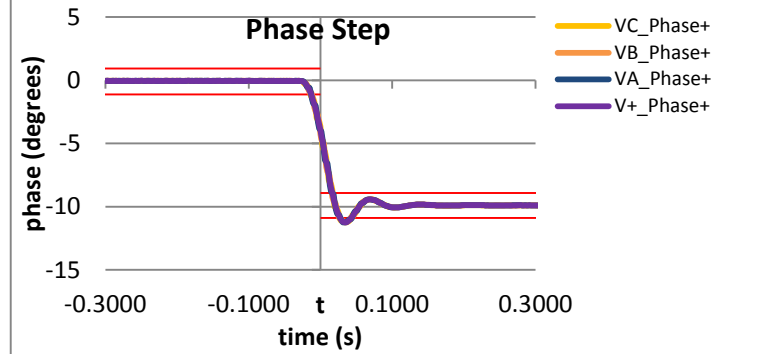


Figure 4886: Fs = 60 FPS, -10 degree phase step

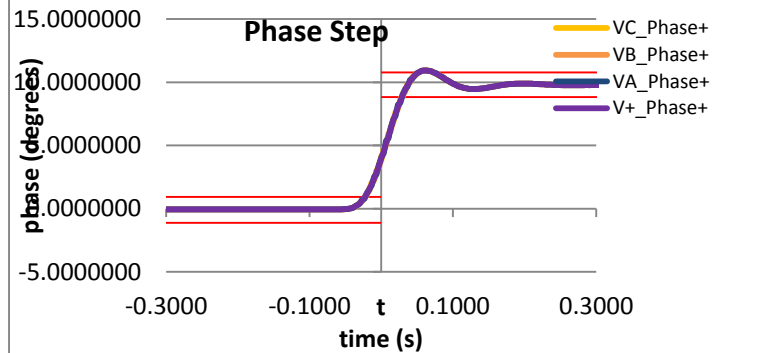


Figure 4887: Fs = 30 FPS, +10 degree phase step

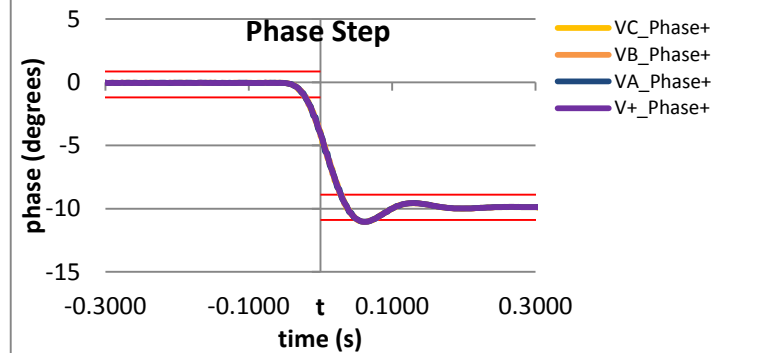


Figure 4888: Fs = 30 FPS, -10 degree phase step

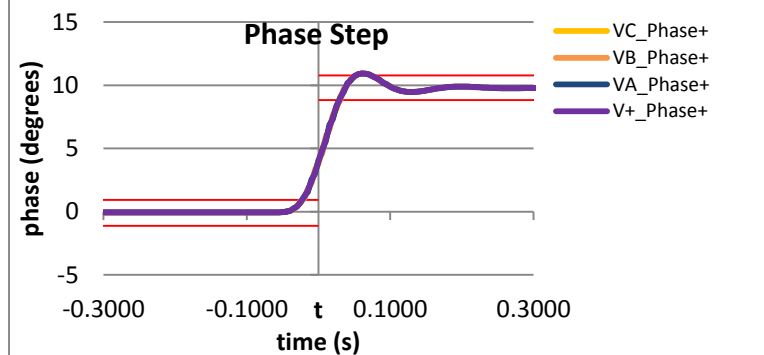


Figure 4889: Fs = 20 FPS, +10 degree phase step

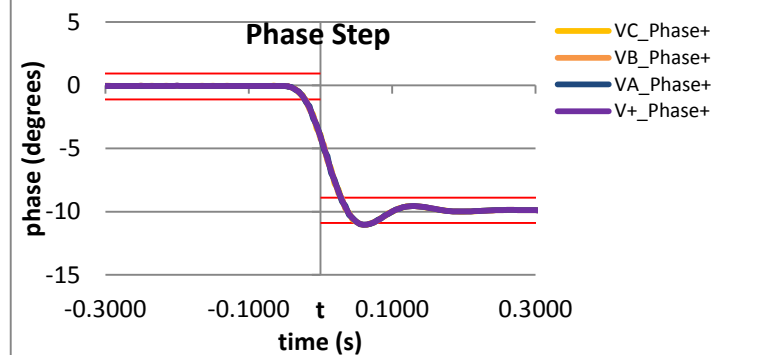


Figure 4890: Fs = 20 FPS, -10 degree phase step

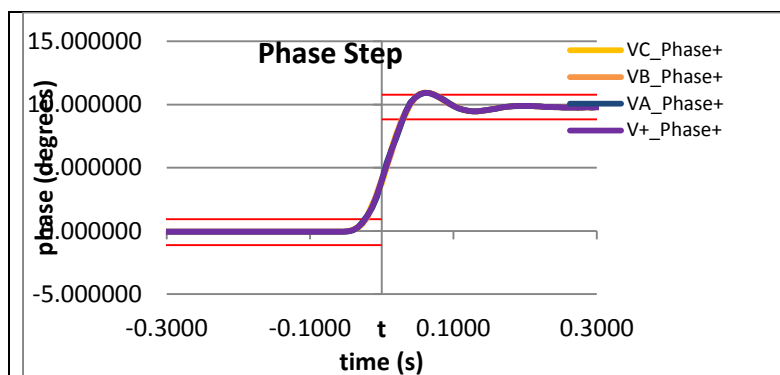


Figure 4891: Fs = 15 FPS, +10 degree phase step

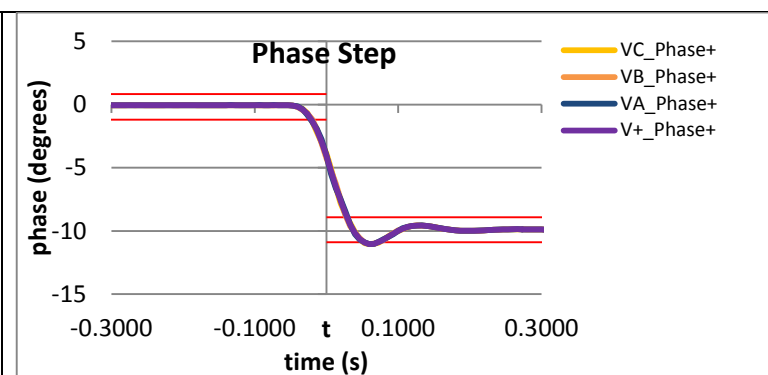


Figure 4892: Fs = 15 FPS, -10 degree phase step

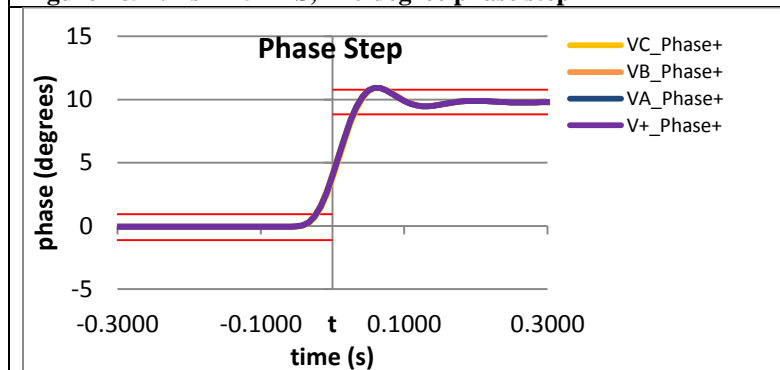


Figure 4893: Fs = 12 FPS, +10 degree phase step

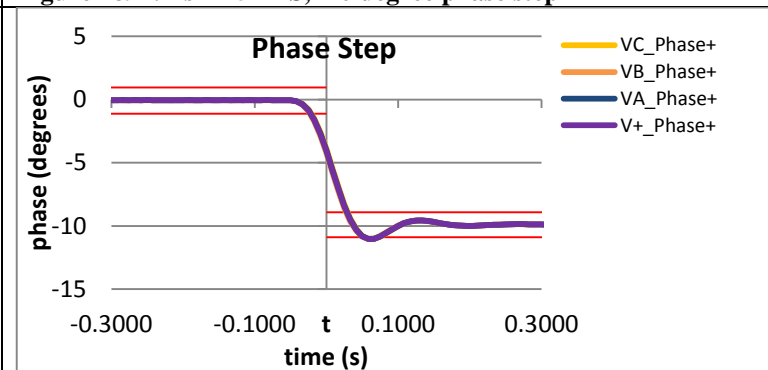


Figure 4894: Fs = 12 FPS, -10 degree phase step

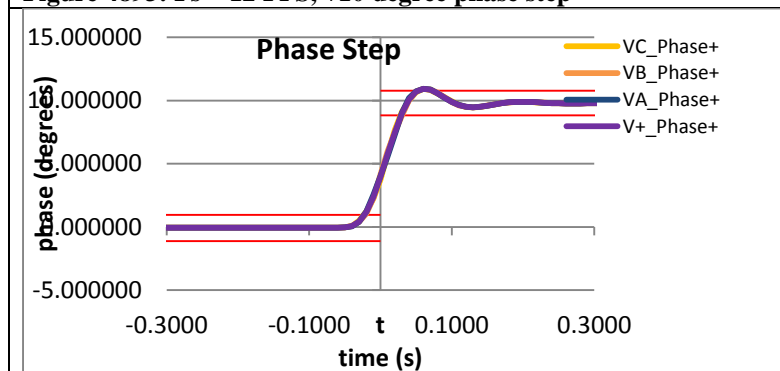


Figure 4895: Fs = 10 FPS, +10 degree phase step

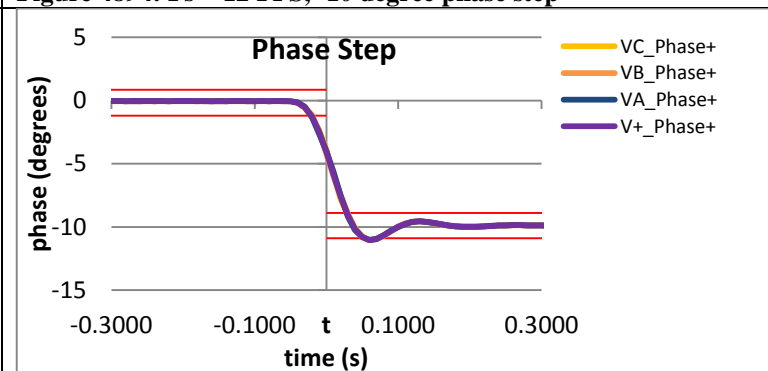
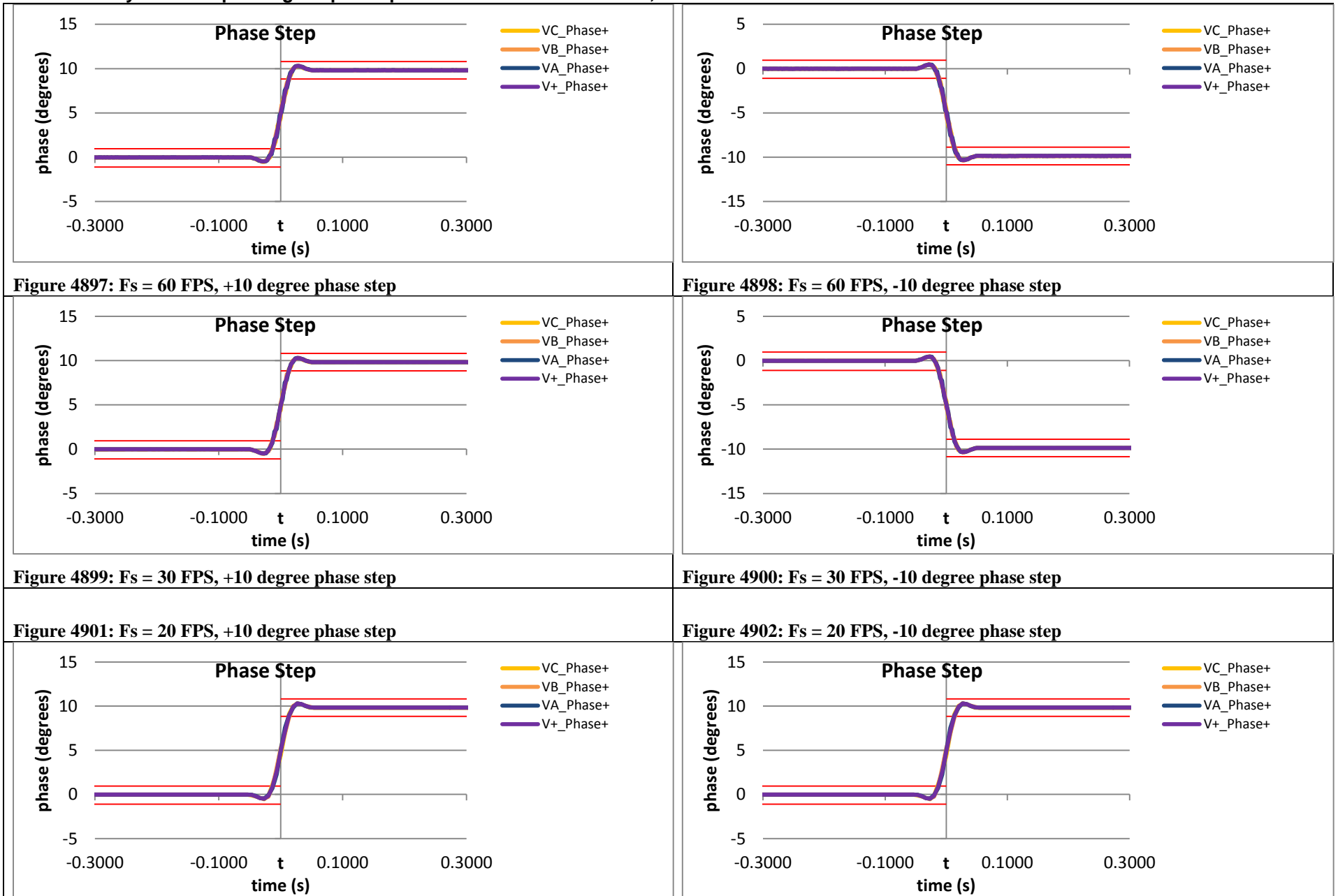


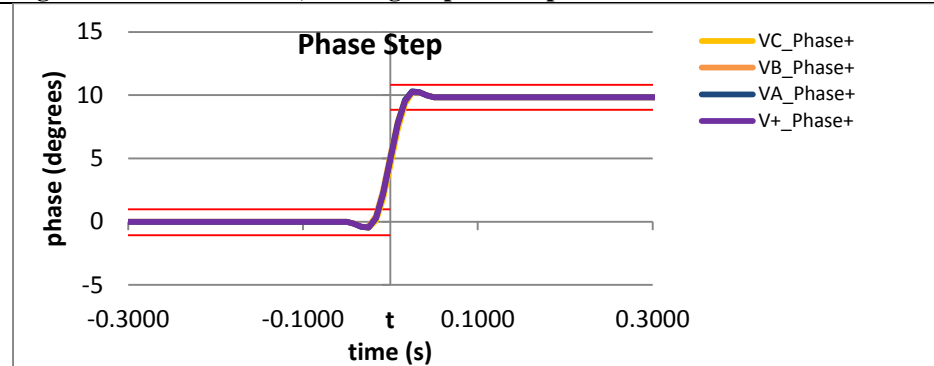
Figure 4896: Fs = 10 FPS, -10 degree phase step



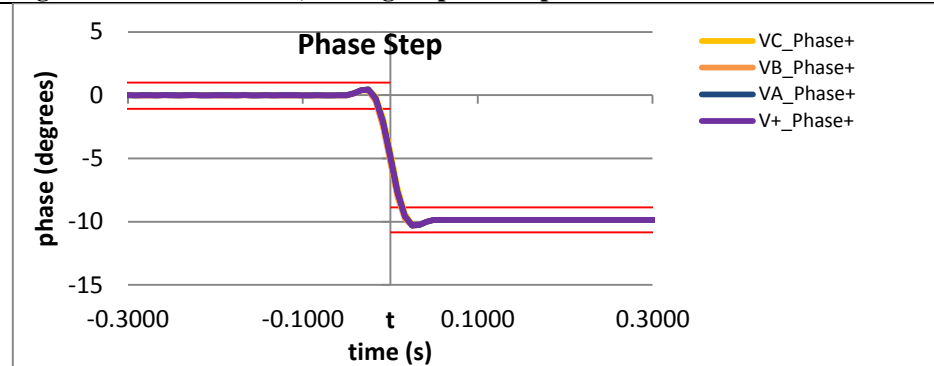
#### 9.9.4 PMU C dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class



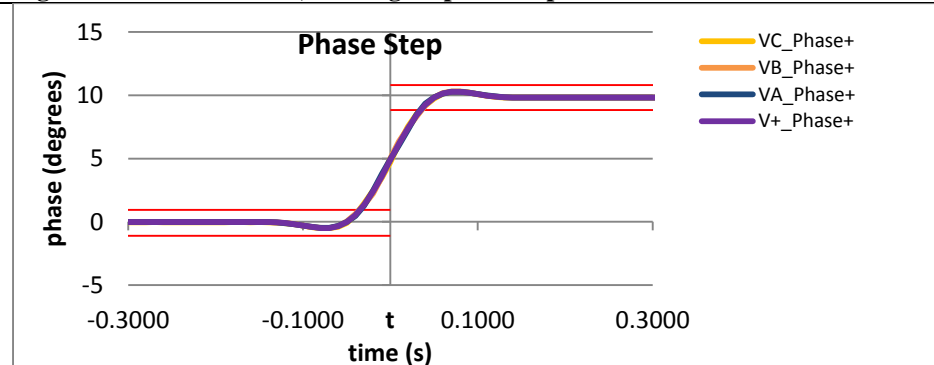
**Figure 4903:  $F_s = 15$  FPS, +10 degree phase step**



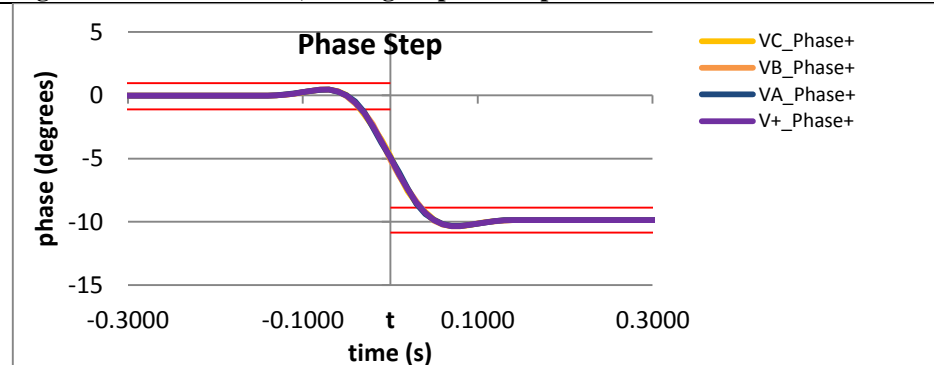
**Figure 4904:  $F_s = 15$  FPS, -10 degree phase step**



**Figure 4905:  $F_s = 12$  FPS, +10 degree phase step**



**Figure 4906:  $F_s = 12$  FPS, -10 degree phase step**



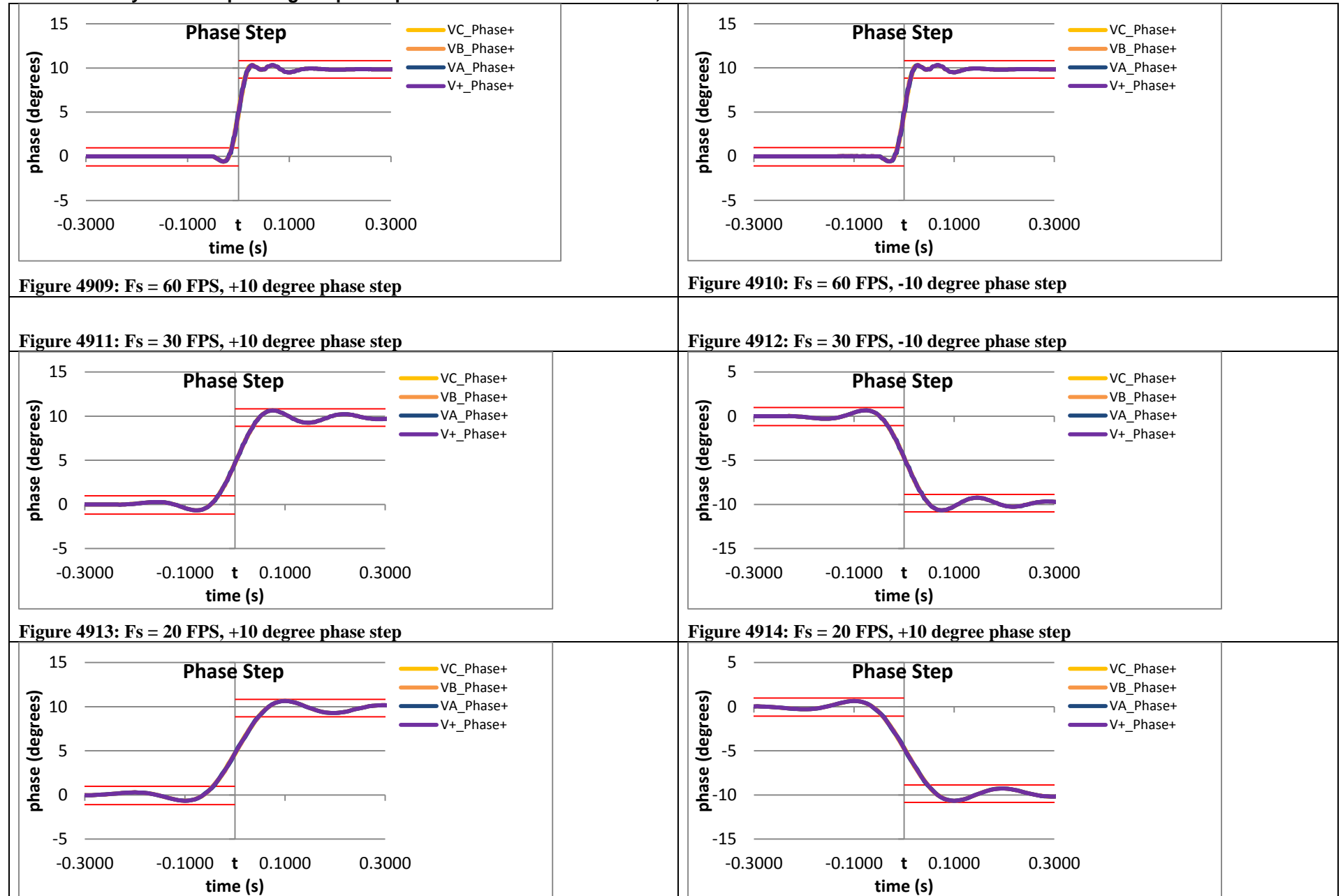
**Figure 4907:  $F_s = 10$  FPS, +10 degree phase step**



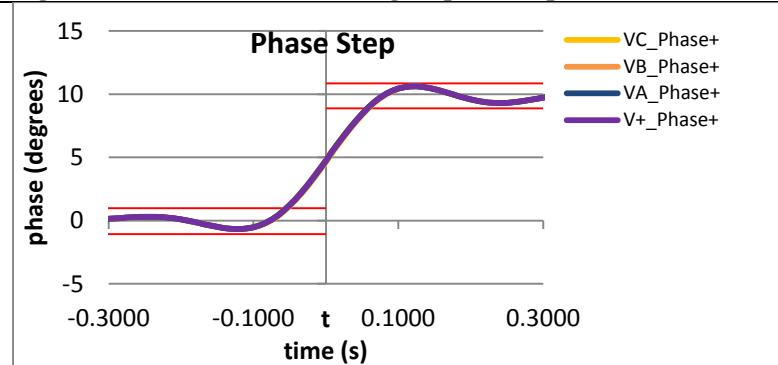
**Figure 4908:  $F_s = 10$  FPS, -10 degree phase step**



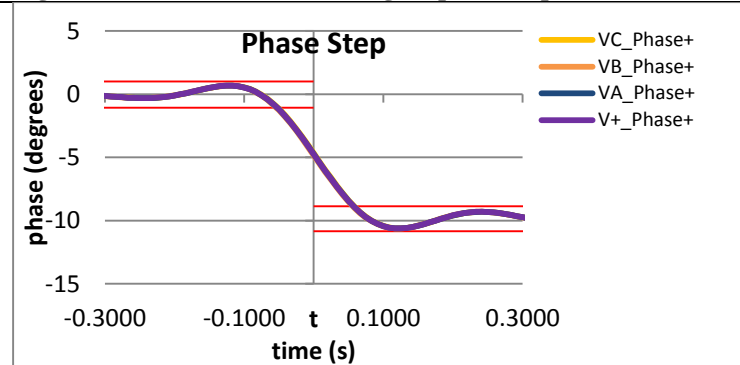
### 9.9.5 PMU D dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class



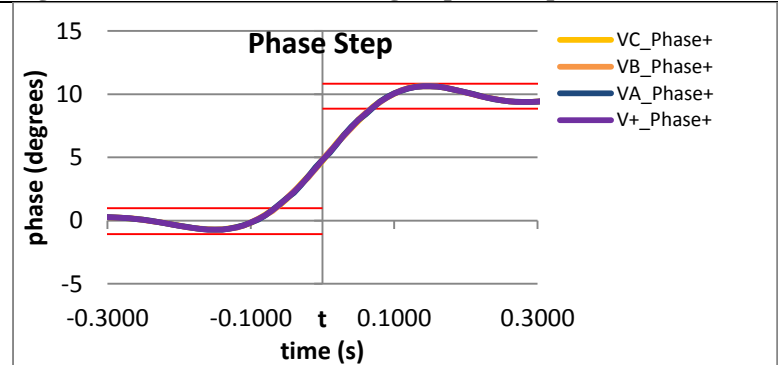
**Figure 4915: Fs = 15 FPS, +10 degree phase step**



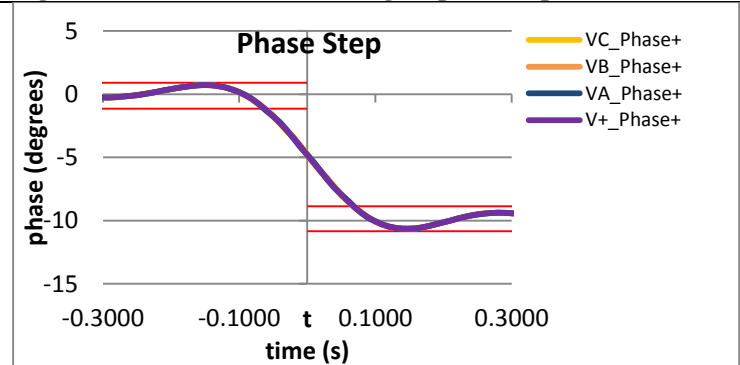
**Figure 4916: Fs = 15 FPS, -10 degree phase step**



**Figure 4917: Fs = 12 FPS, +10 degree phase step**



**Figure 4918: Fs = 12 FPS, -10 degree phase step**



**Figure 4919: Fs = 10 FPS, +10 degree phase step**



**Figure 4920: Fs = 10 FPS, -10 degree phase step**



### 9.9.6 PMU E dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class

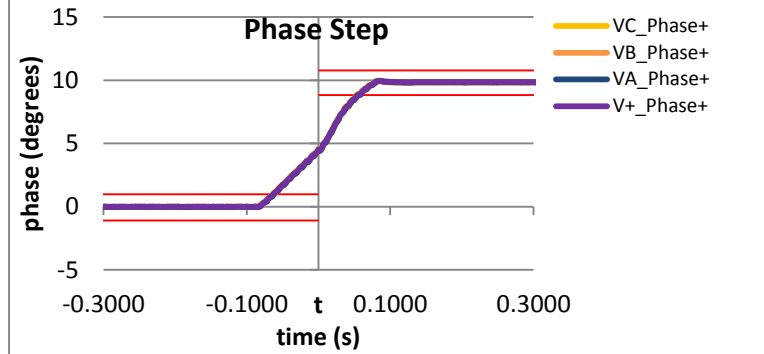


Figure 4921: Fs = 60 FPS, +10 degree phase step

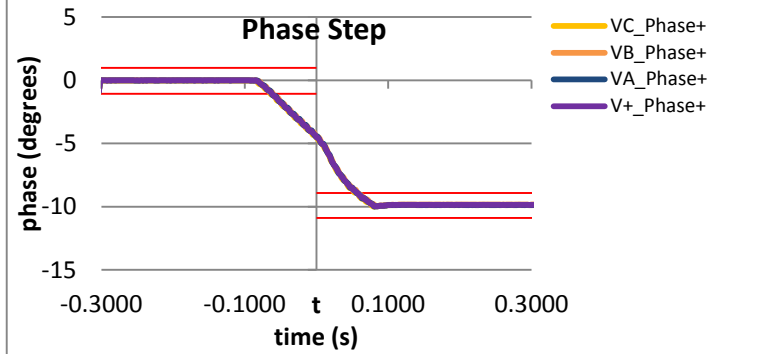


Figure 4922: Fs = 60 FPS, -10 degree phase step

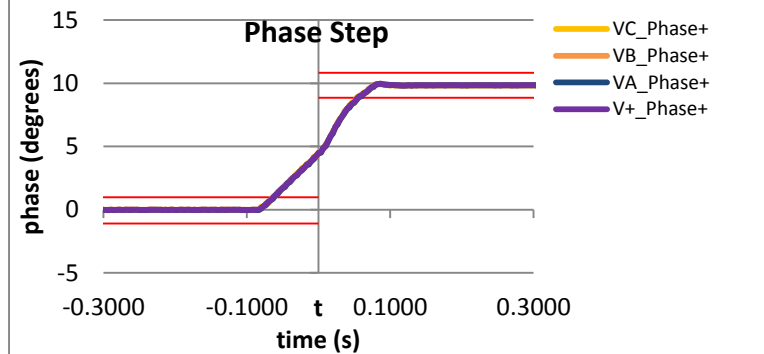


Figure 4923: Fs = 30 FPS, +10 degree phase step

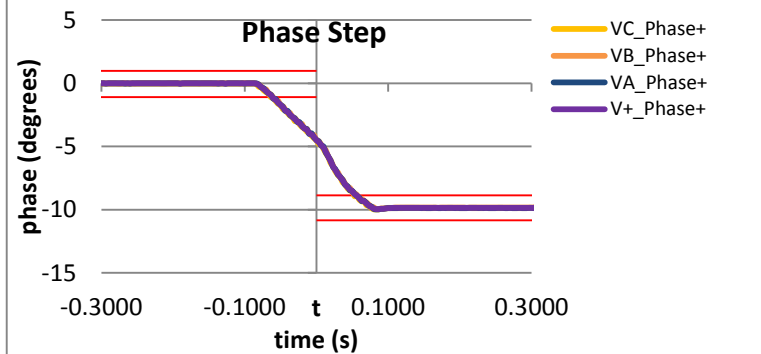


Figure 4924: Fs = 30 FPS, -10 degree phase step

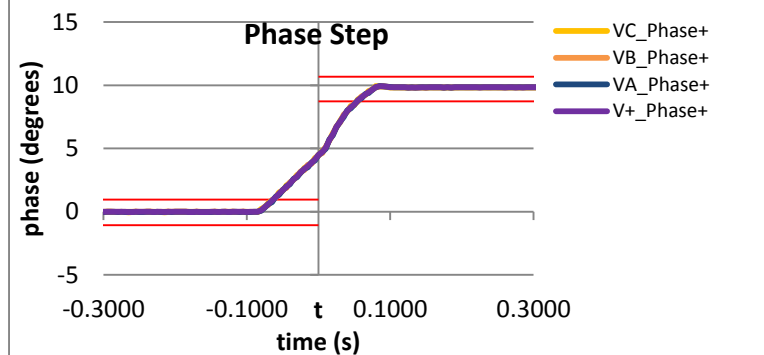


Figure 4925: Fs = 20 FPS, +10 degree phase step

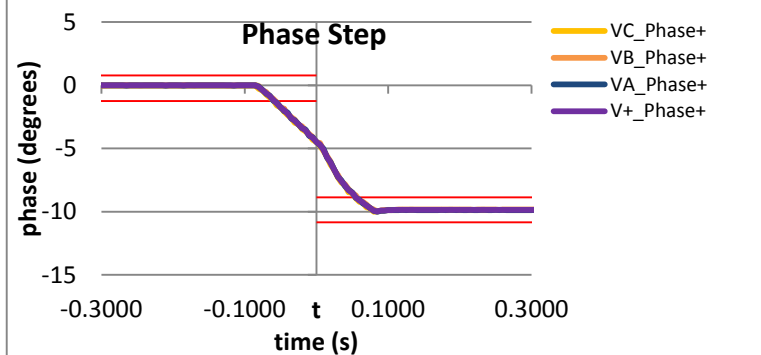


Figure 4926: Fs = 20 FPS, -10 degree phase step

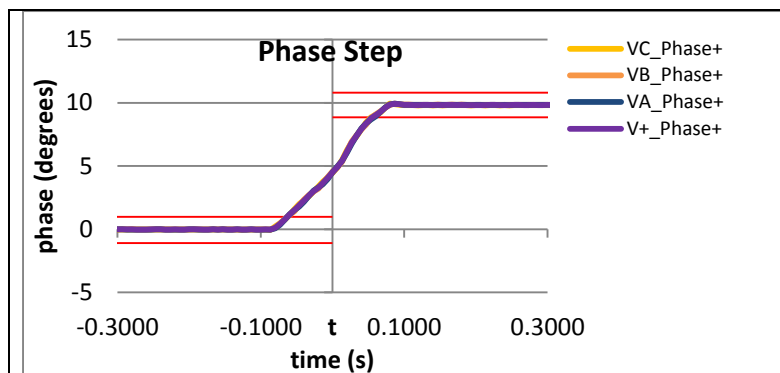


Figure 4927:  $F_s = 15$  FPS, +10 degree phase step

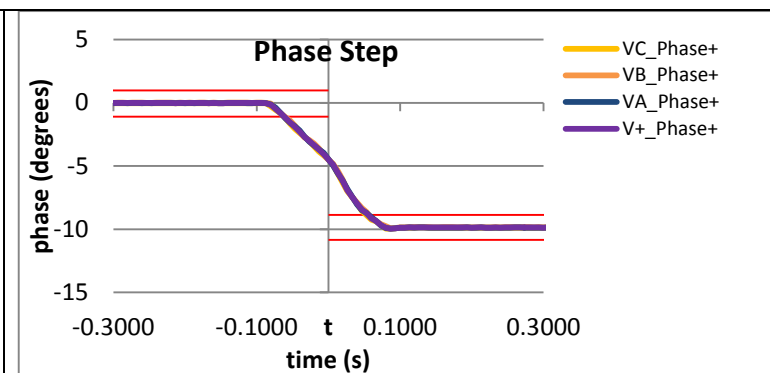


Figure 4928:  $F_s = 15$  FPS, -10 degree phase step

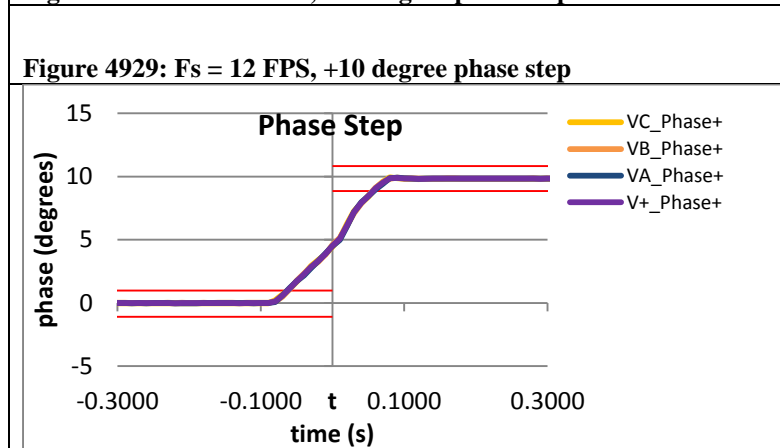


Figure 4929:  $F_s = 12$  FPS, +10 degree phase step

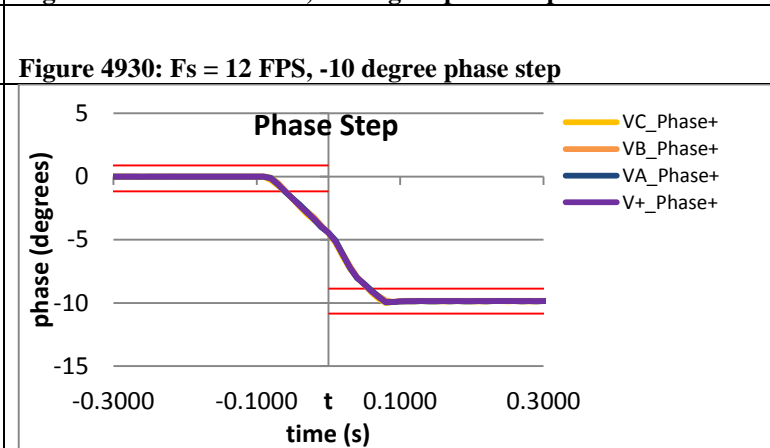


Figure 4930:  $F_s = 12$  FPS, -10 degree phase step

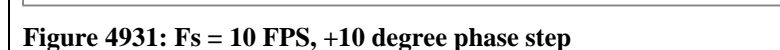


Figure 4931:  $F_s = 10$  FPS, +10 degree phase step



Figure 4932:  $F_s = 10$  FPS, -10 degree phase step

### 9.9.7 PMU F dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class

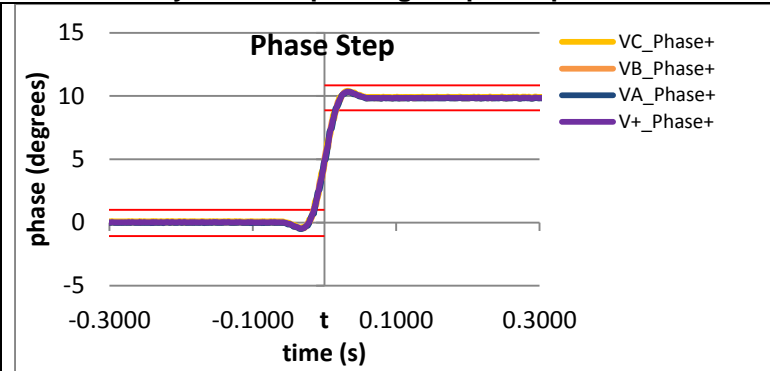


Figure 4933: Fs = 60 FPS, +10 degree phase step

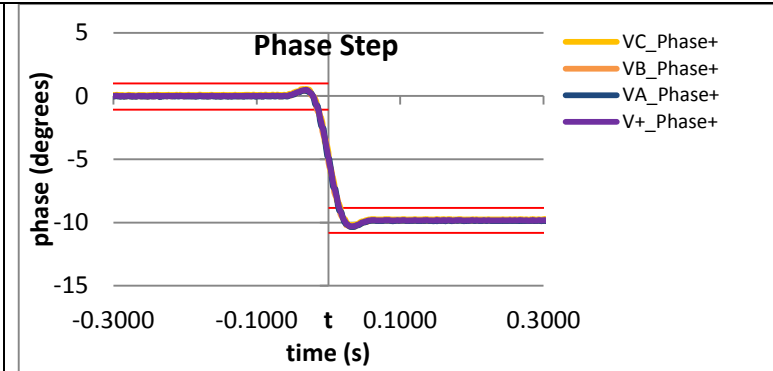


Figure 4934: Fs = 60 FPS, -10 degree phase step

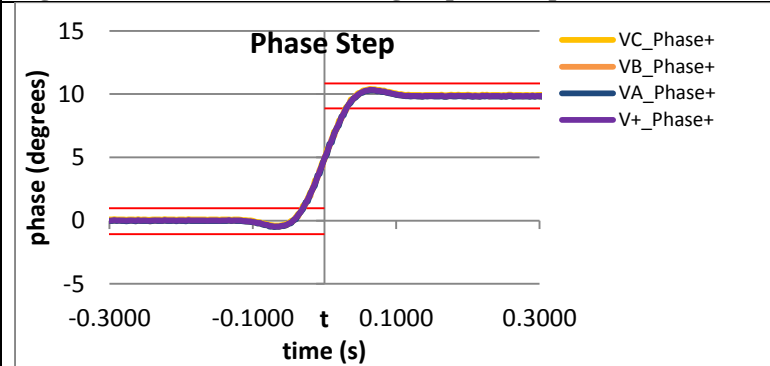


Figure 4935: Fs = 30 FPS, +10 degree phase step

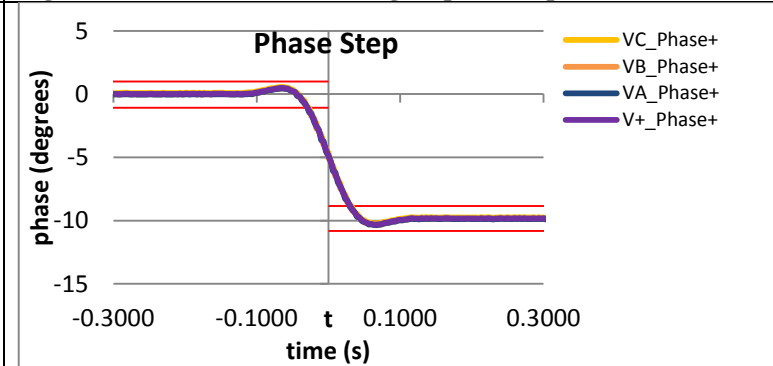


Figure 4936: Fs = 30 FPS, -10 degree phase step

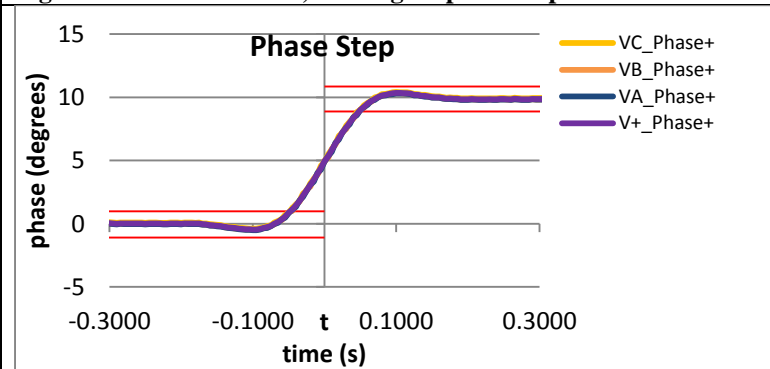


Figure 4937: Fs = 20 FPS, +10 degree phase step

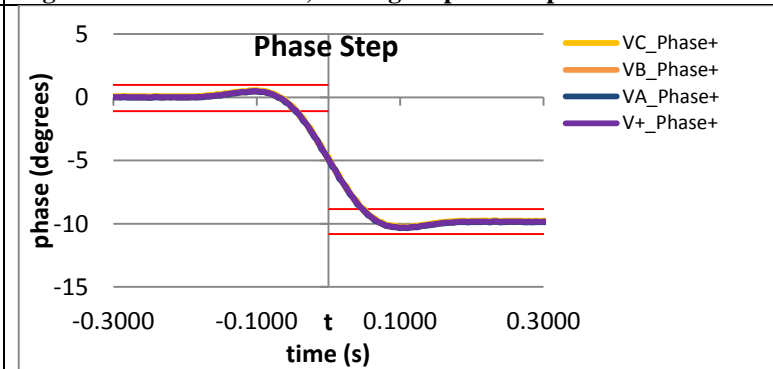


Figure 4938: Fs = 20 FPS, +10 degree phase step

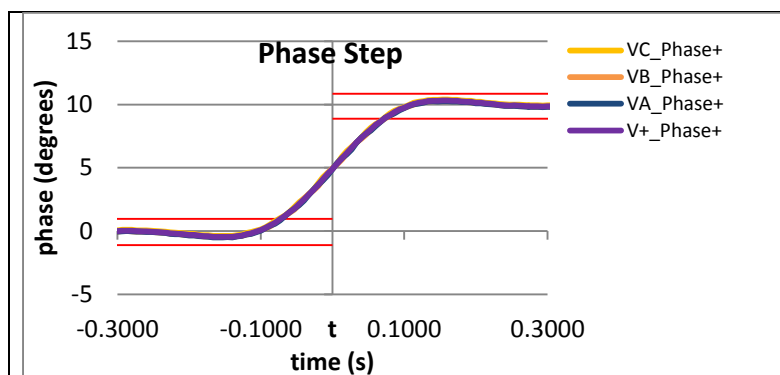


Figure 4939:  $F_s = 15$  FPS, +10 degree phase step

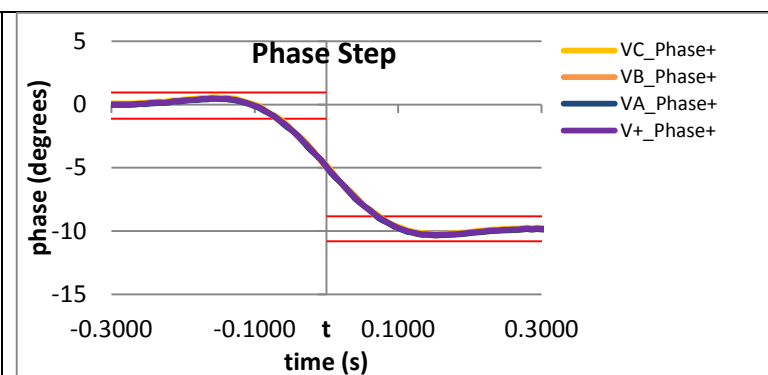


Figure 4940:  $F_s = 15$  FPS, -10 degree phase step

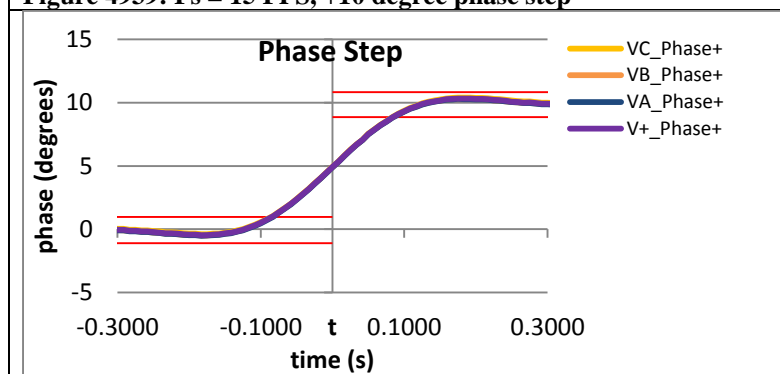


Figure 4941:  $F_s = 12$  FPS, +10 degree phase step

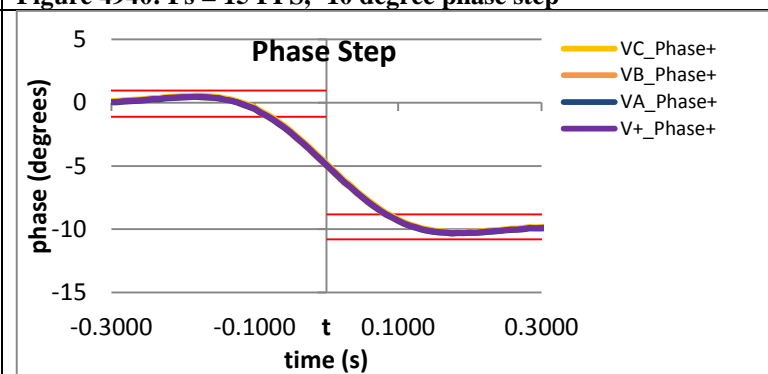


Figure 4942:  $F_s = 12$  FPS, -10 degree phase step

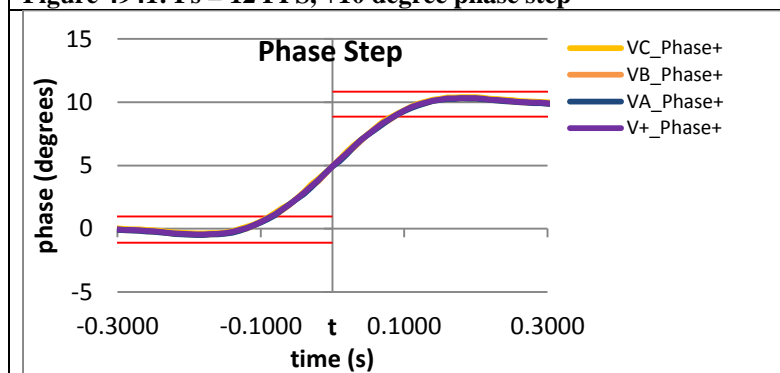


Figure 4943:  $F_s = 10$  FPS, +10 degree phase step

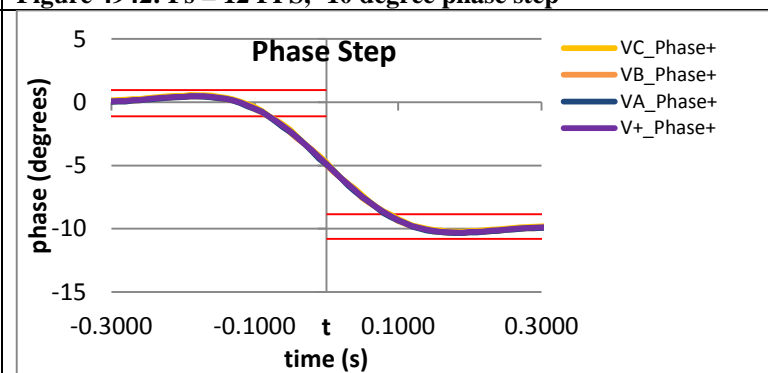
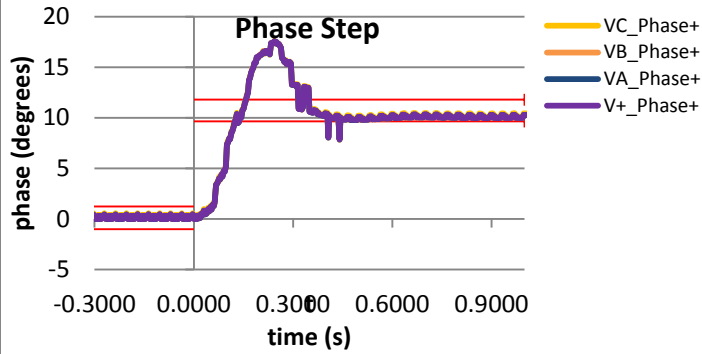


Figure 4944:  $F_s = 10$  FPS, -10 degree phase step

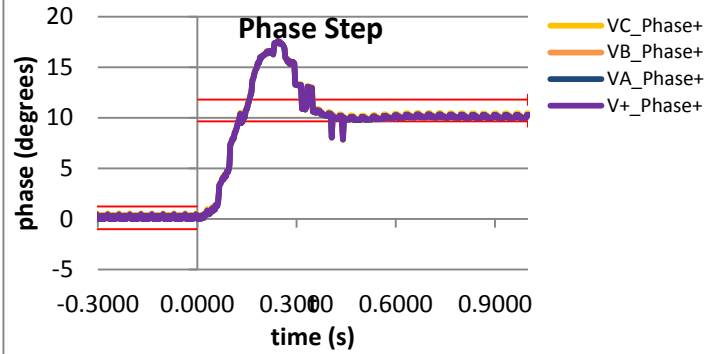


### 9.9.8 PMU G dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class

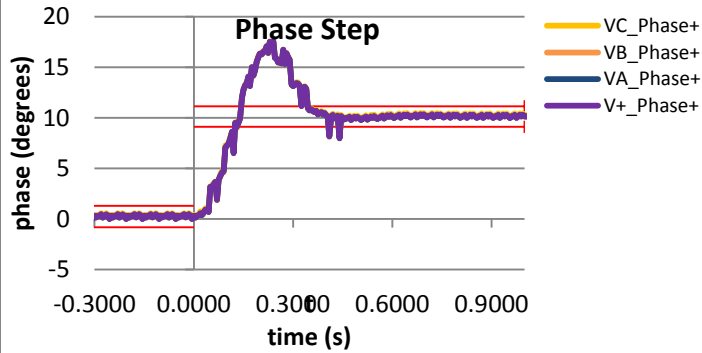
**Figure 4945: Fs = 60 FPS is not supported by this PMU**



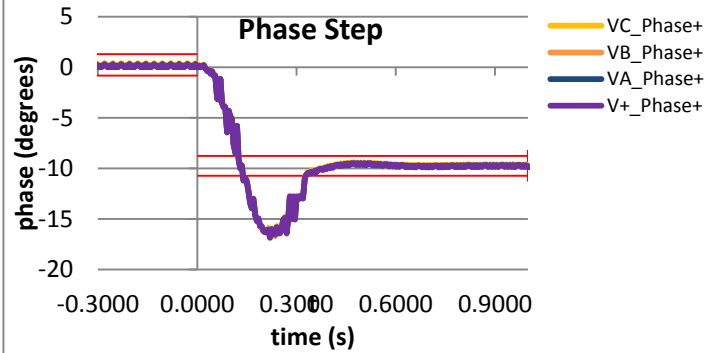
**Figure 4946: Fs = 60 FPS is not supported by this PMU**



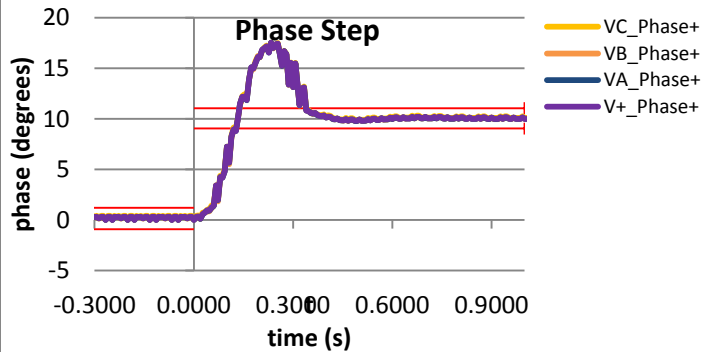
**Figure 4947: Fs = 30 FPS, +10 degree phase step**



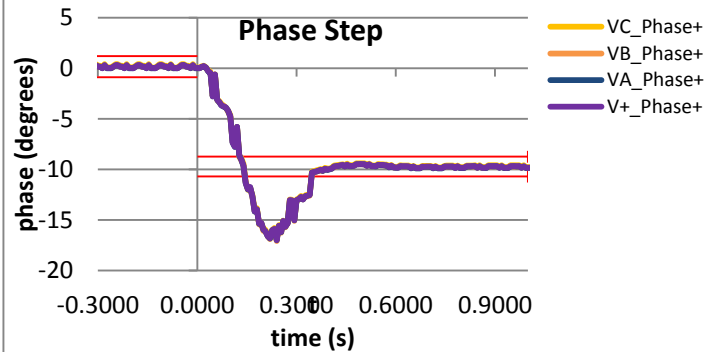
**Figure 4948: Fs = 30 FPS, -10 degree phase step**



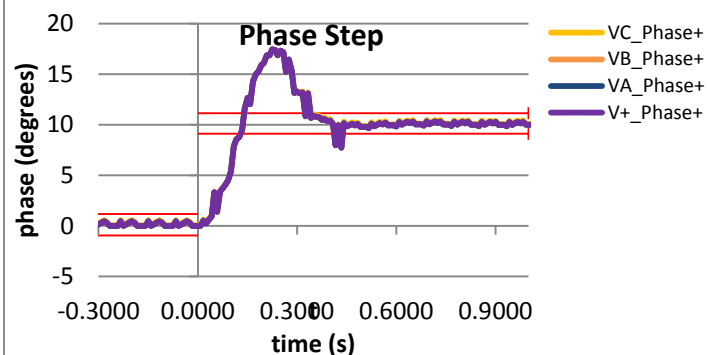
**Figure 4949: Fs = 20 FPS, +10 degree phase step**



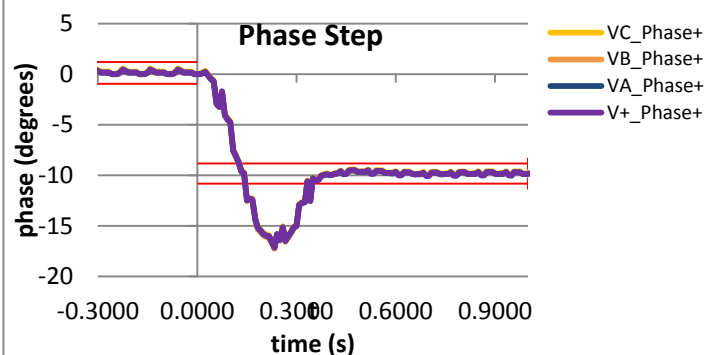
**Figure 4950: Fs = 20 FPS, +10 degree phase step**



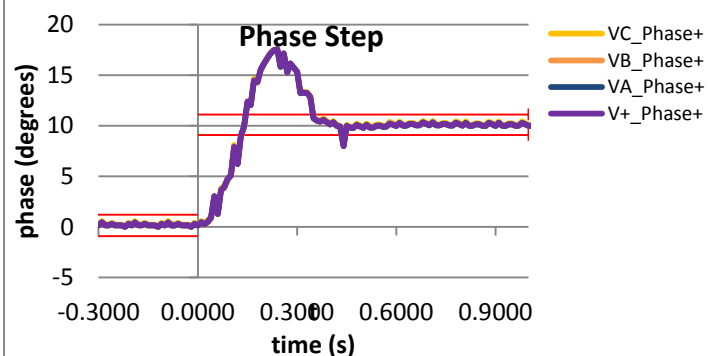
**Figure 4951:  $F_s = 15$  FPS, +10 degree phase step**



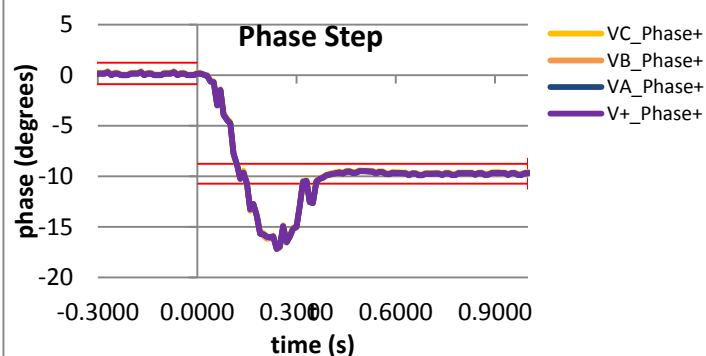
**Figure 4952:  $F_s = 15$  FPS, -10 degree phase step**



**Figure 4953:  $F_s = 12$  FPS, +10 degree phase step**



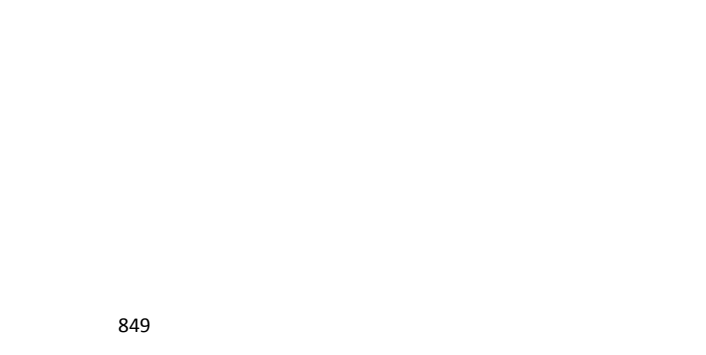
**Figure 4954:  $F_s = 12$  FPS, -10 degree phase step**



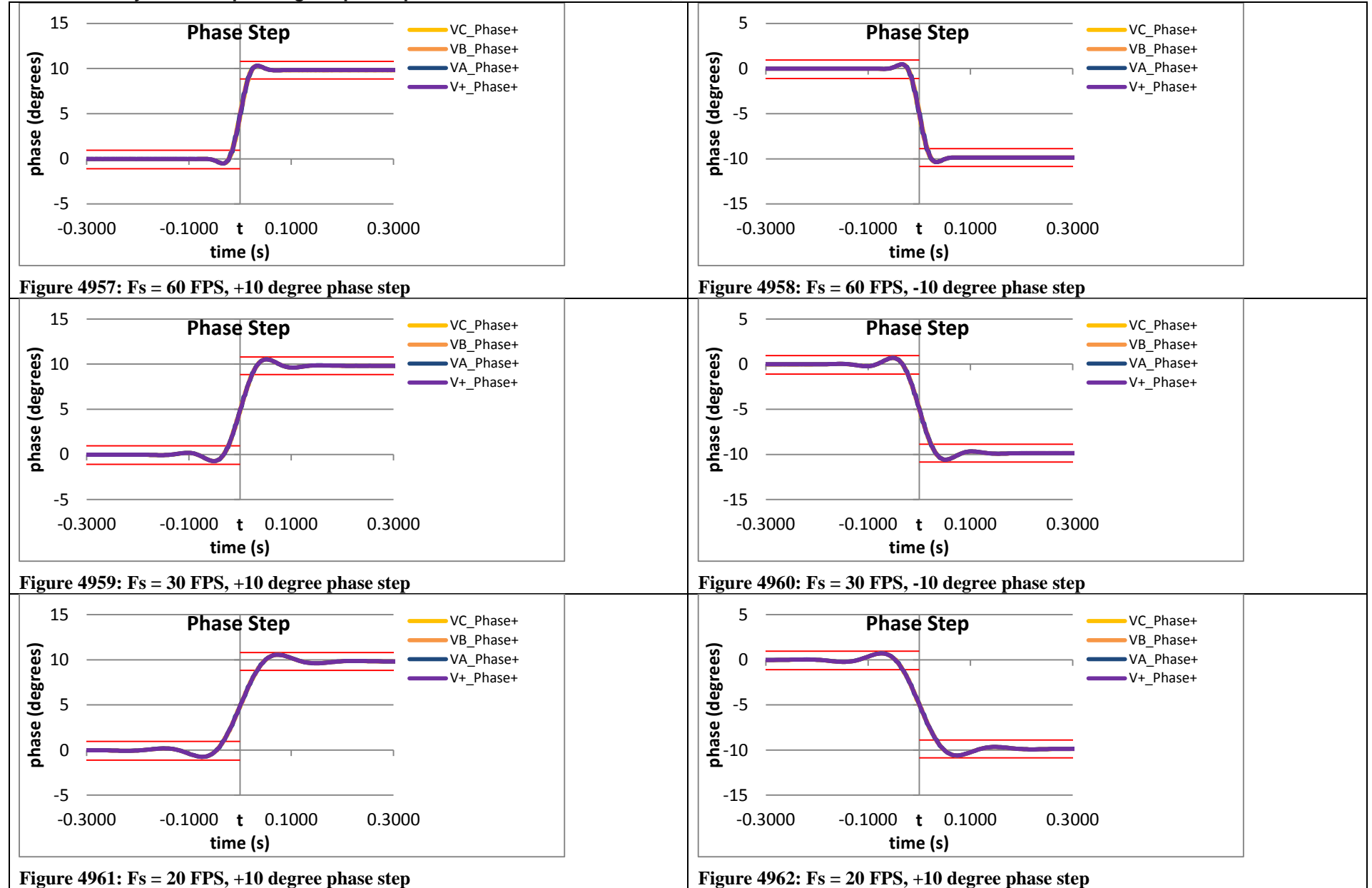
**Figure 4955:  $F_s = 10$  FPS, +10 degree phase step**



**Figure 4956:  $F_s = 10$  FPS, -10 degree phase step**



### 9.9.9 PMU H dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class



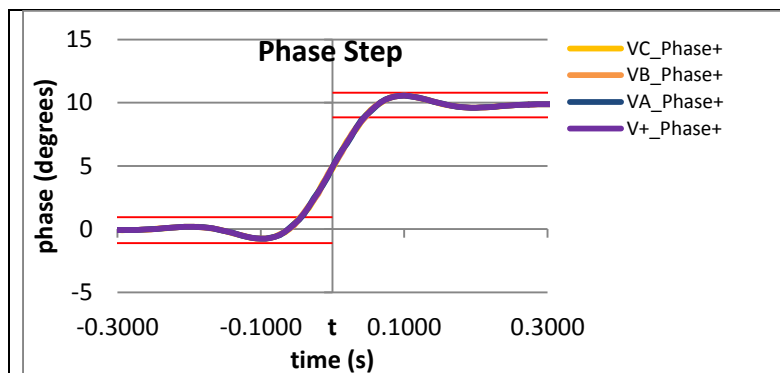


Figure 4963:  $F_s = 15$  FPS, +10 degree phase step

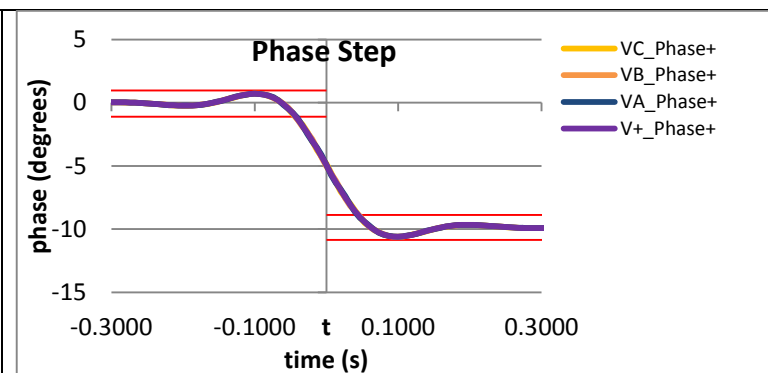


Figure 4964:  $F_s = 15$  FPS, -10 degree phase step

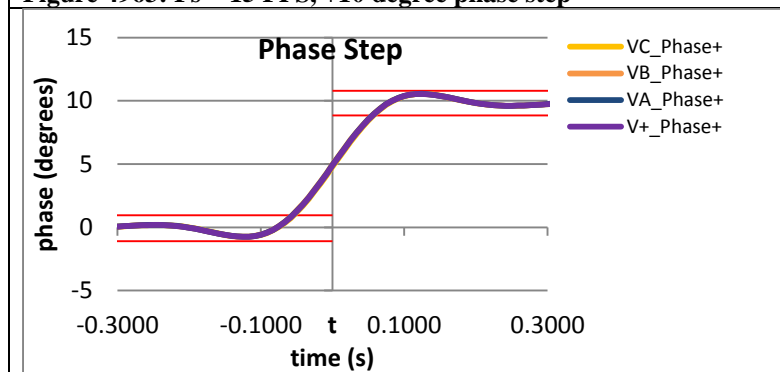


Figure 4965:  $F_s = 12$  FPS, +10 degree phase step

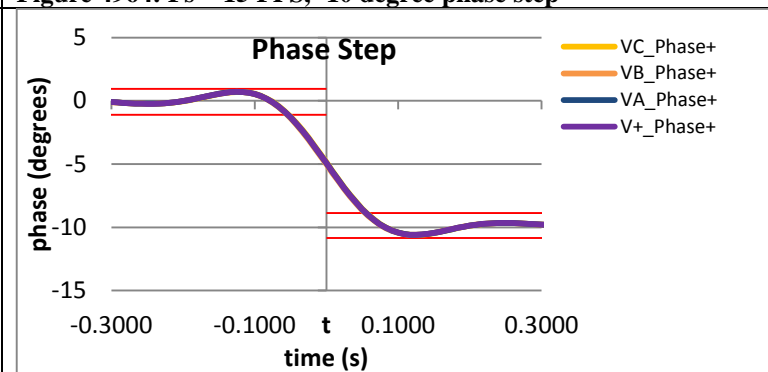


Figure 4966:  $F_s = 12$  FPS, -10 degree phase step

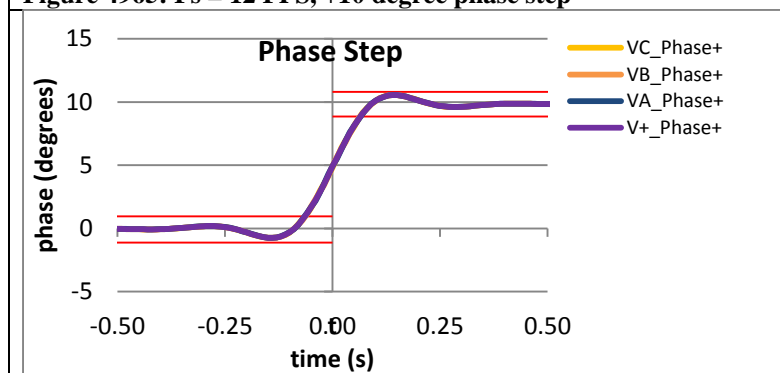


Figure 4967:  $F_s = 10$  FPS, +10 degree phase step

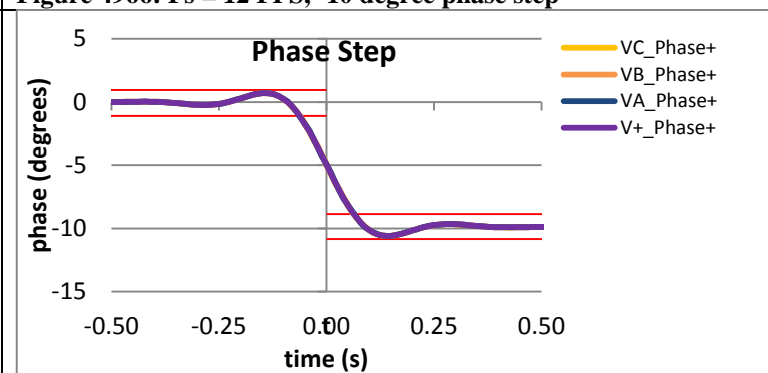
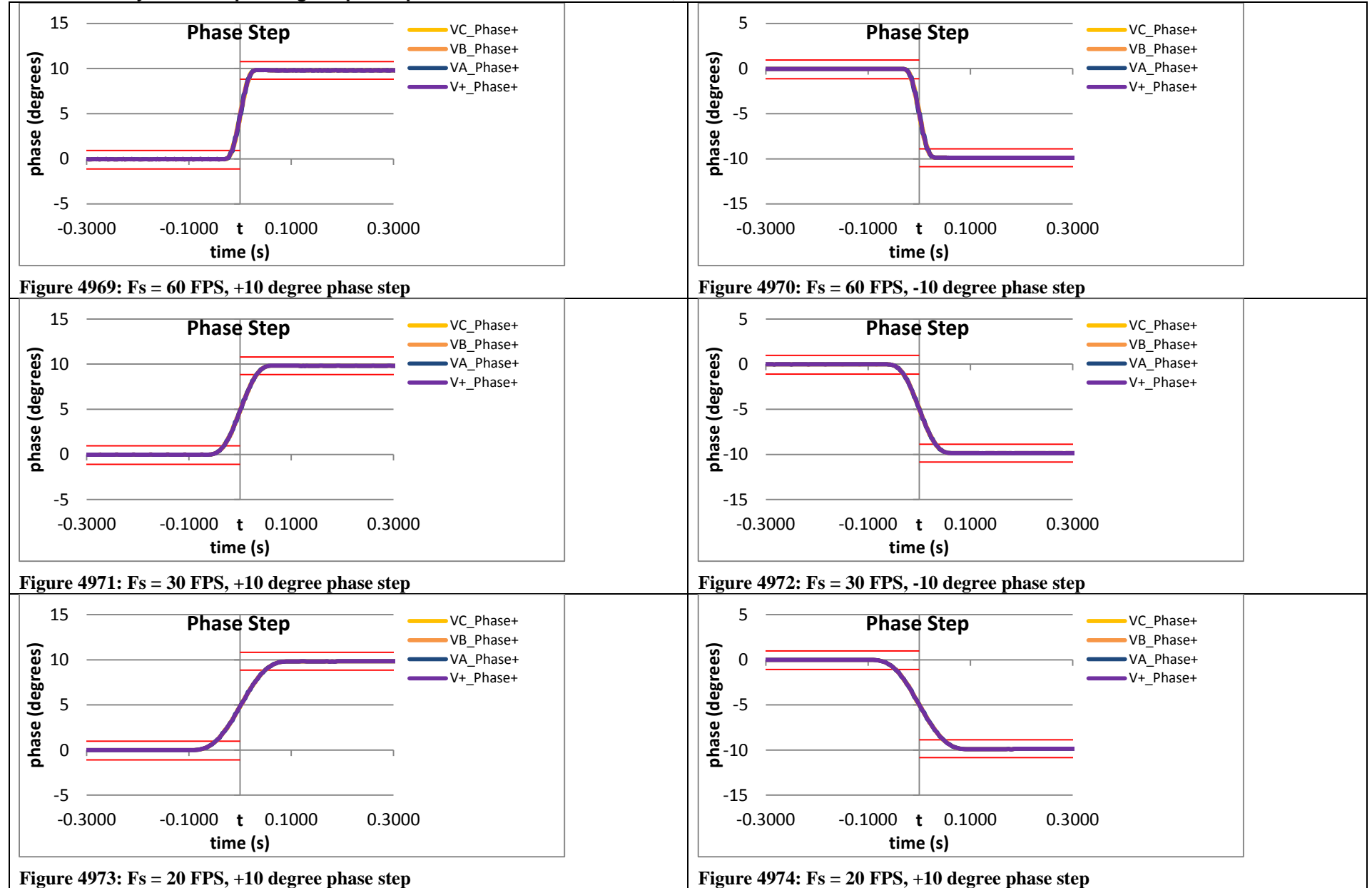


Figure 4968:  $F_s = 10$  FPS, -10 degree phase step

### 9.9.10 PMU I dynamic step change in phase phasor overshoot: F0 = 60 Hz, M class



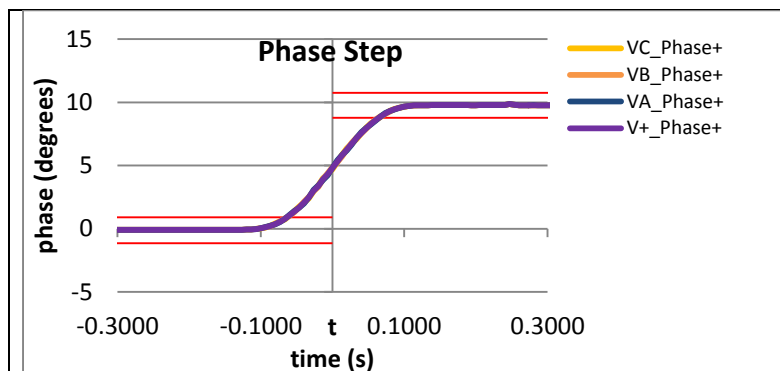


Figure 4975:  $F_s = 15$  FPS, +10 degree phase step

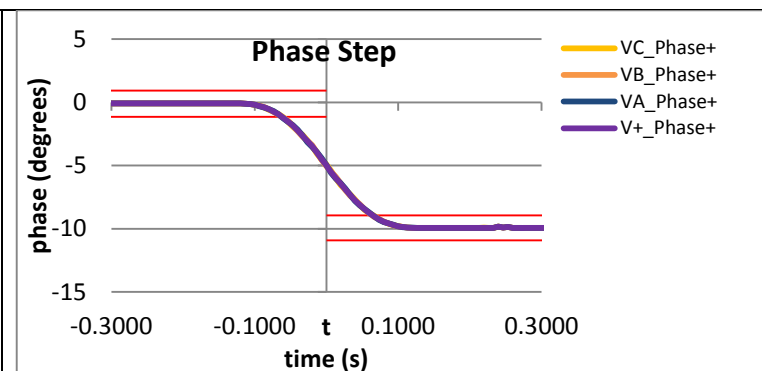


Figure 4976:  $F_s = 15$  FPS, -10 degree phase step

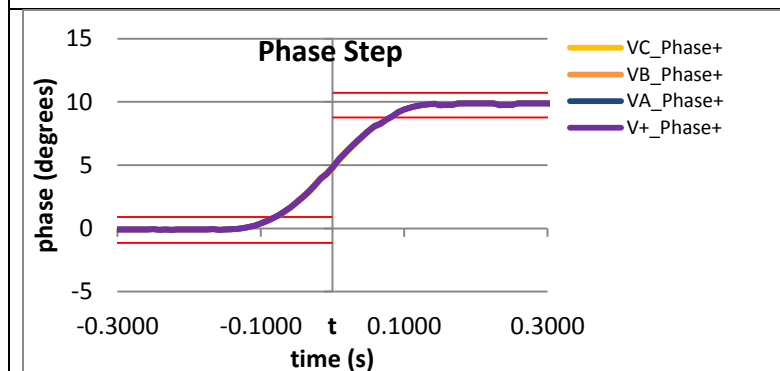


Figure 4977:  $F_s = 12$  FPS, +10 degree phase step

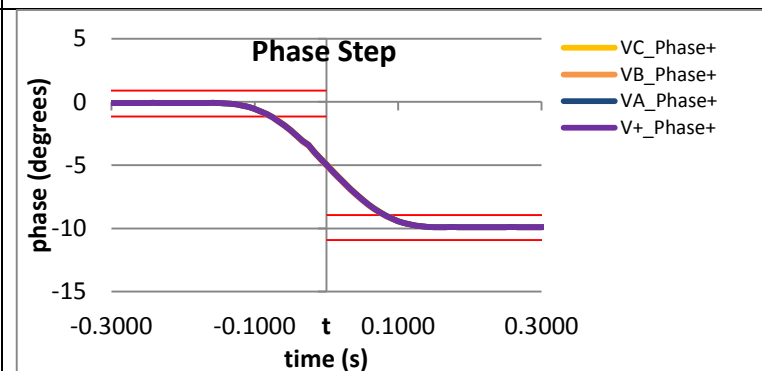


Figure 4978:  $F_s = 12$  FPS, -10 degree phase step

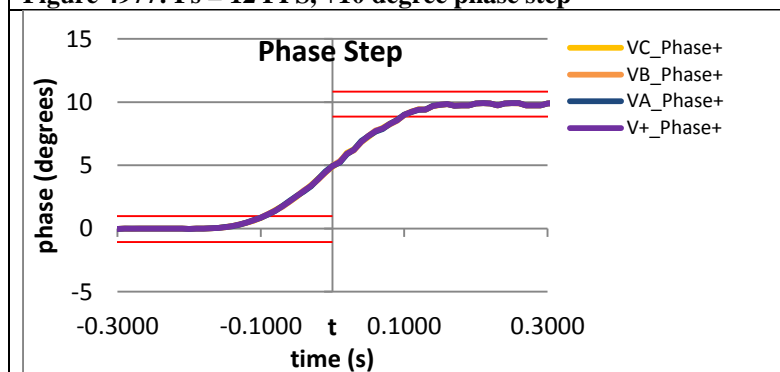


Figure 4979:  $F_s = 10$  FPS, +10 degree phase step

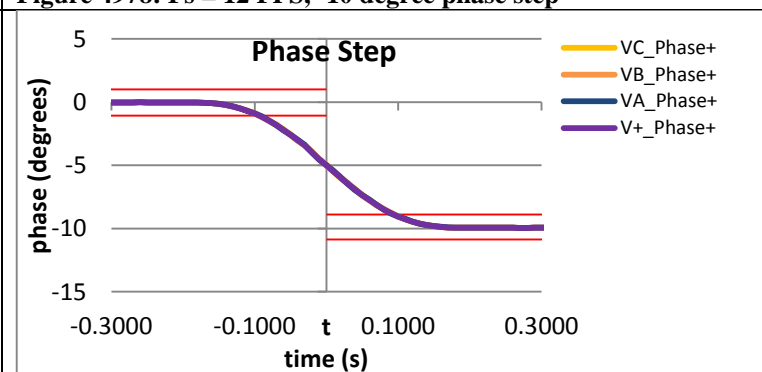
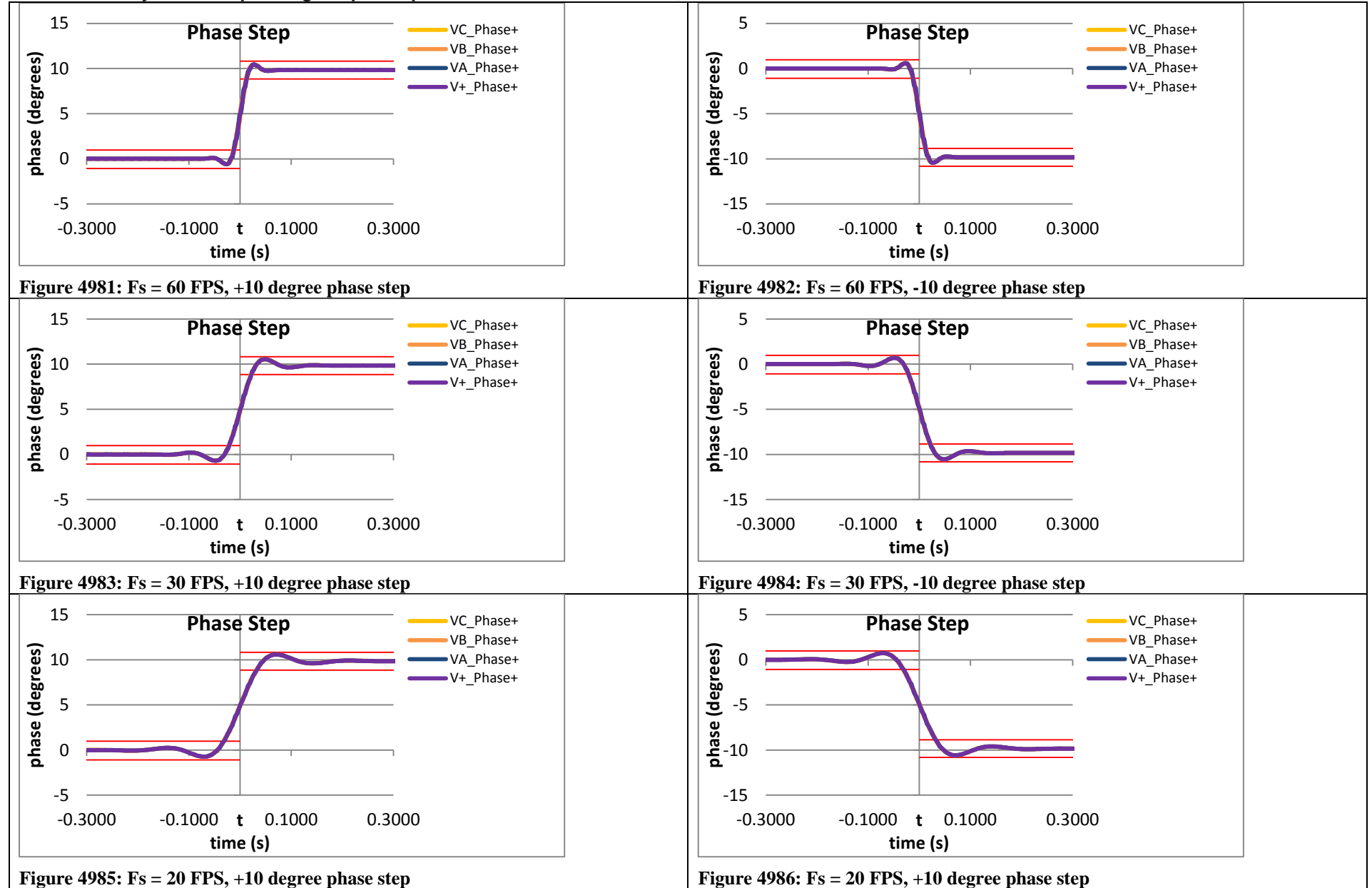


Figure 4980:  $F_s = 10$  FPS, -10 degree phase step

### 9.9.11 PMU J dynamic step change in phase phasor overshoot: $F_0 = 60$ Hz, M class



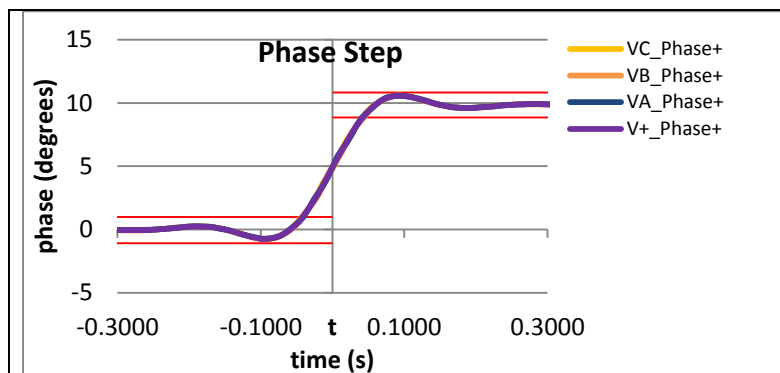


Figure 4987:  $F_s = 15$  FPS, +10 degree phase step

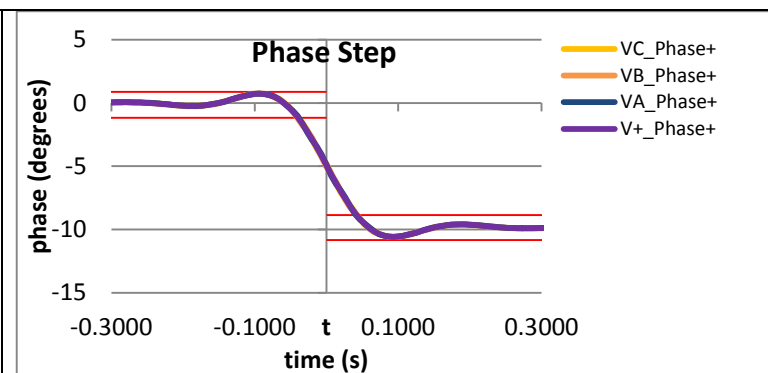


Figure 4988:  $F_s = 15$  FPS, -10 degree phase step

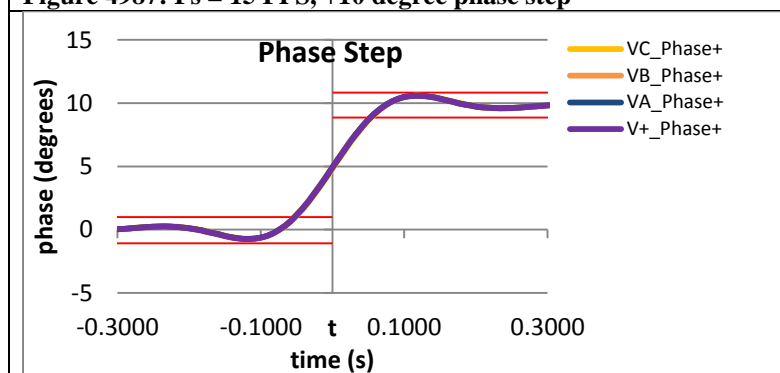


Figure 4989:  $F_s = 12$  FPS, +10 degree phase step

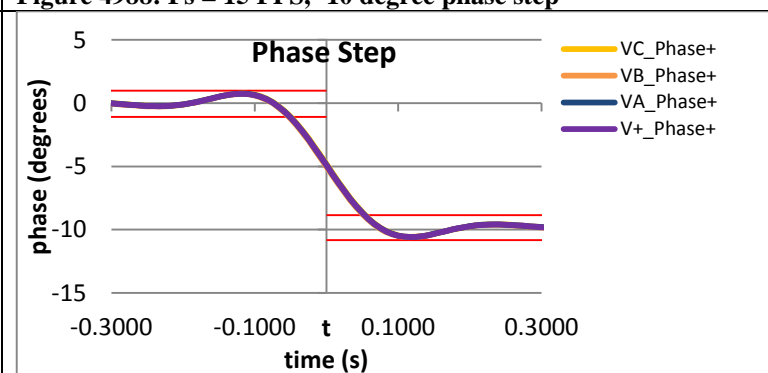


Figure 4990:  $F_s = 12$  FPS, -10 degree phase step

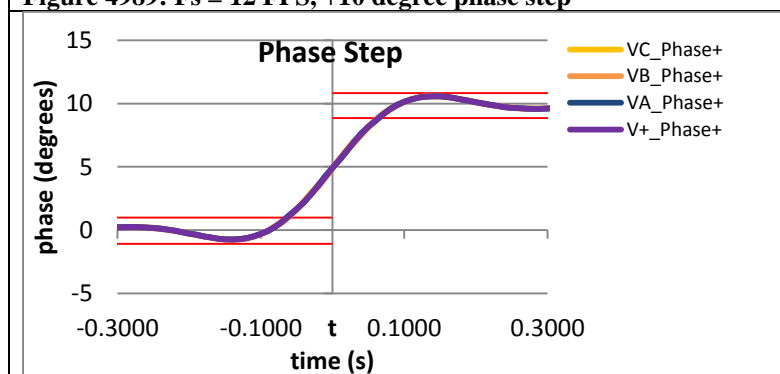


Figure 4991:  $F_s = 10$  FPS, +10 degree phase step

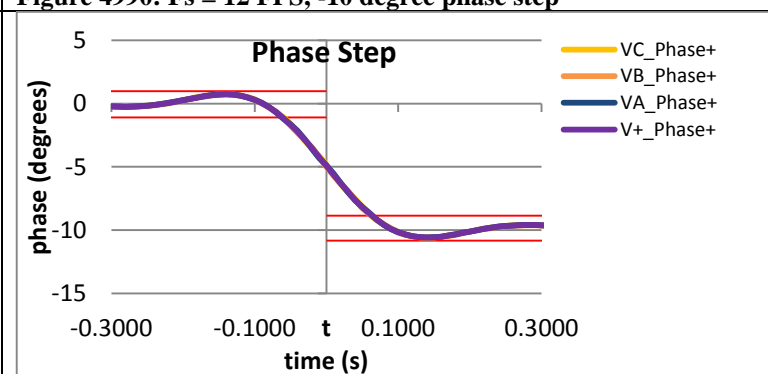


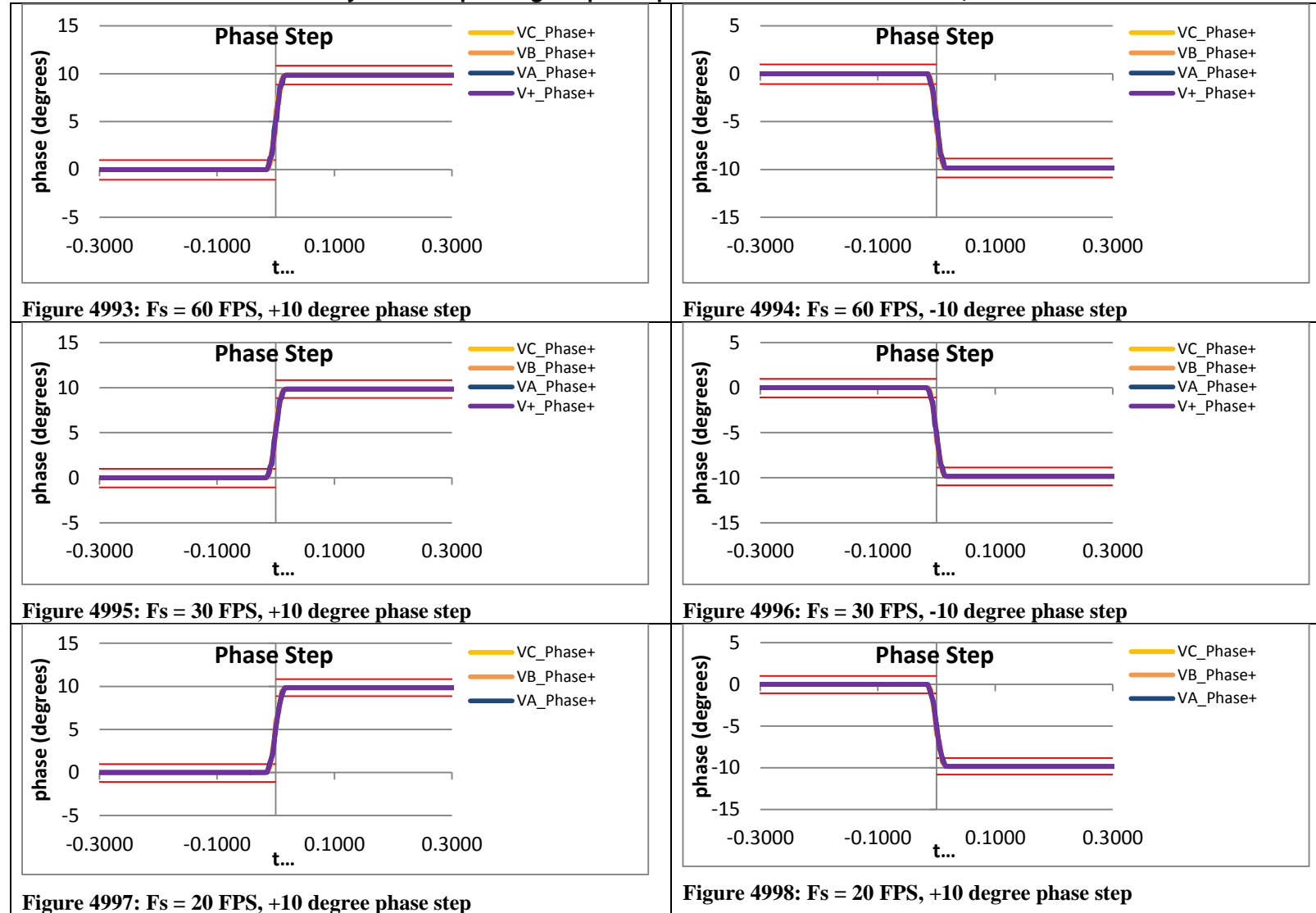
Figure 4992:  $F_s = 10$  FPS, -10 degree phase step



## 9.10 Dynamic step change in phase: phasor overshoot: P class

### Dynamic step change in phase: phasor delay time P class

#### 9.10.1 C37.118.1-2011 Annex C dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class



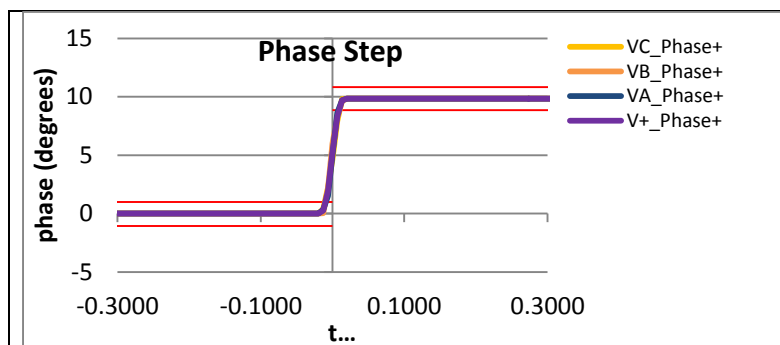


Figure 4999: Fs = 15 FPS, +10 degree phase step

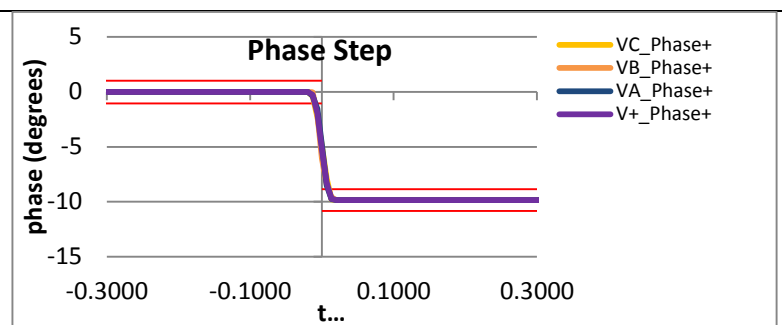


Figure 5000: Fs = 15 FPS, -10 degree phase step

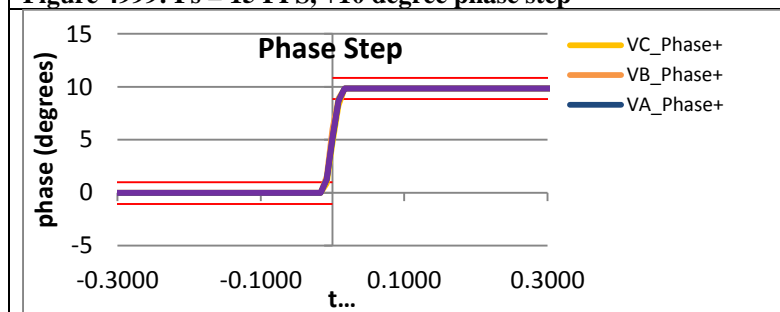


Figure 5001: Fs = 12 FPS, +10 degree phase step

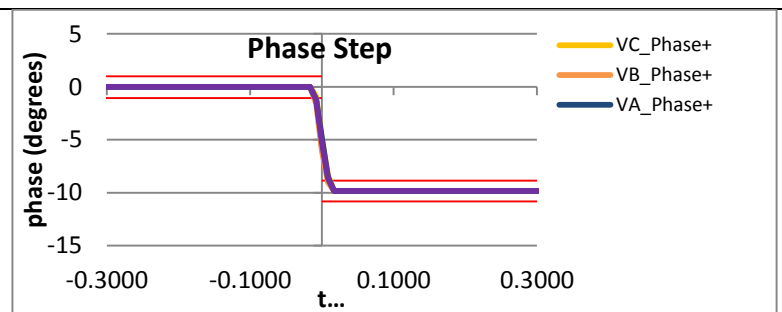


Figure 5002: Fs = 12 FPS, -10 degree phase step

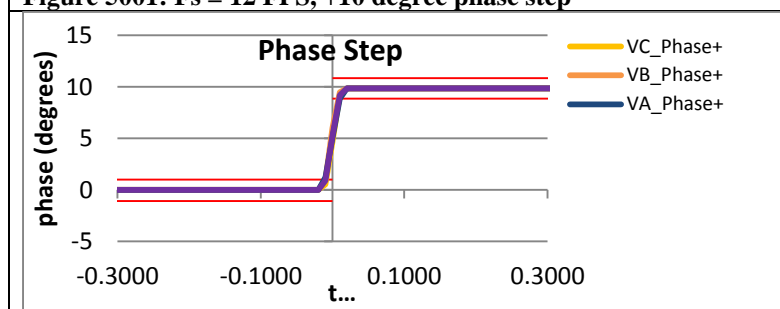


Figure 5003: Fs = 10 FPS, +10 degree phase step

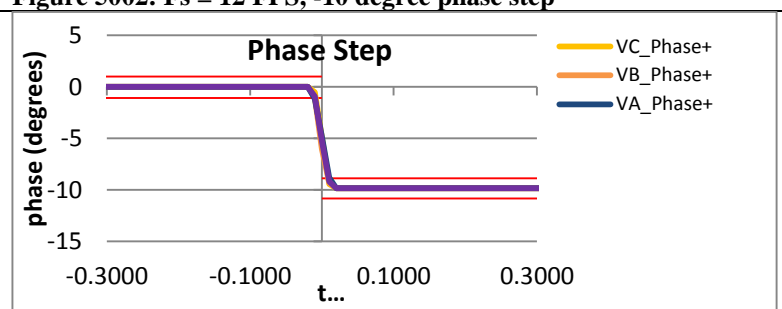
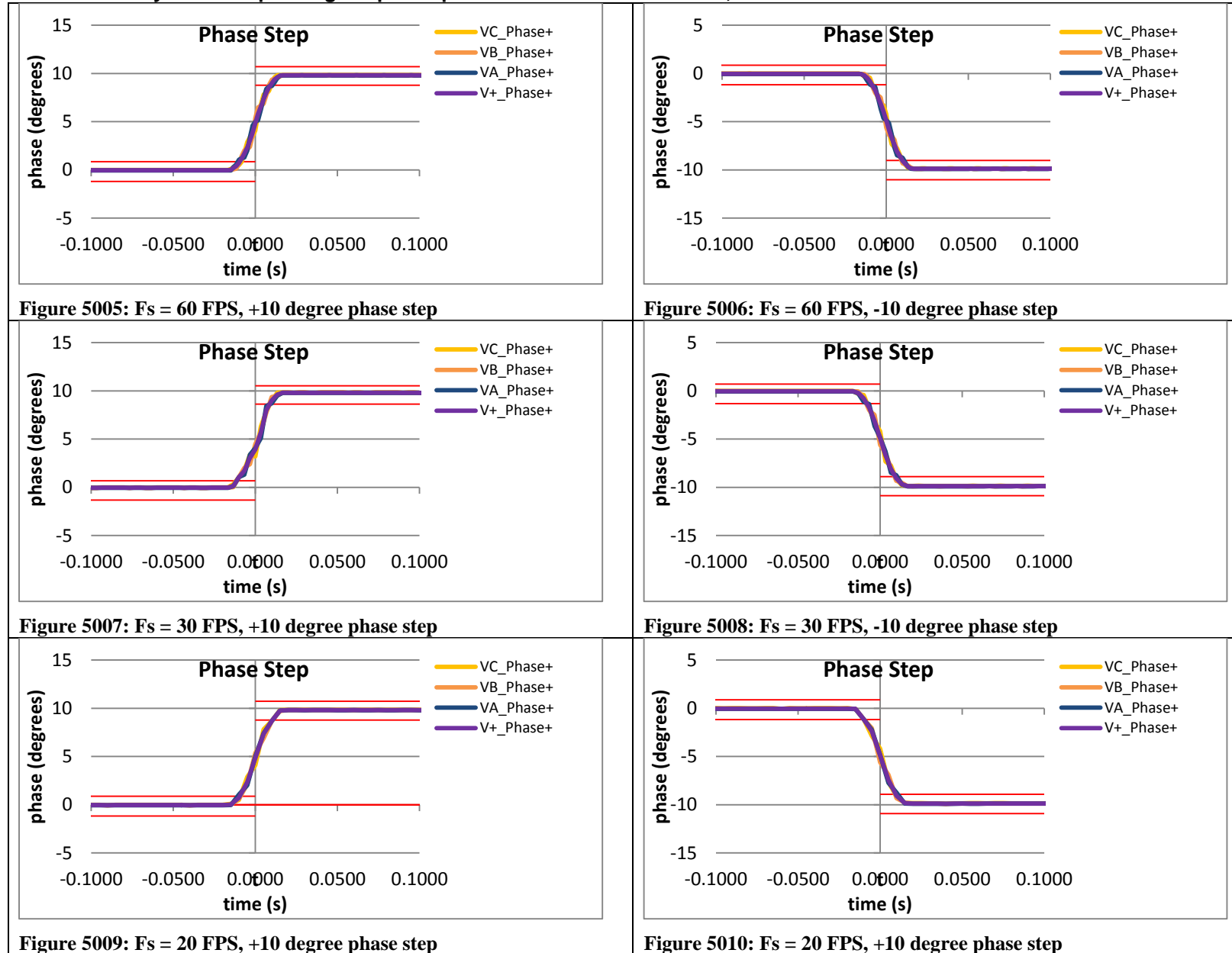


Figure 5004: Fs = 10 FPS, -10 degree phase step

### 9.10.2 PMU A dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class



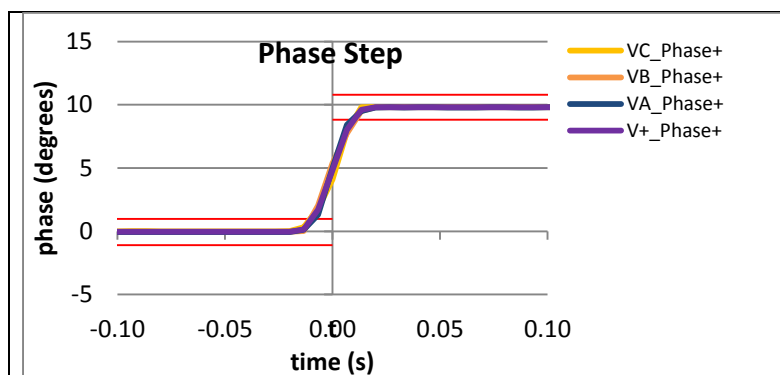


Figure 5011:  $F_s = 15$  FPS, +10 degree phase step

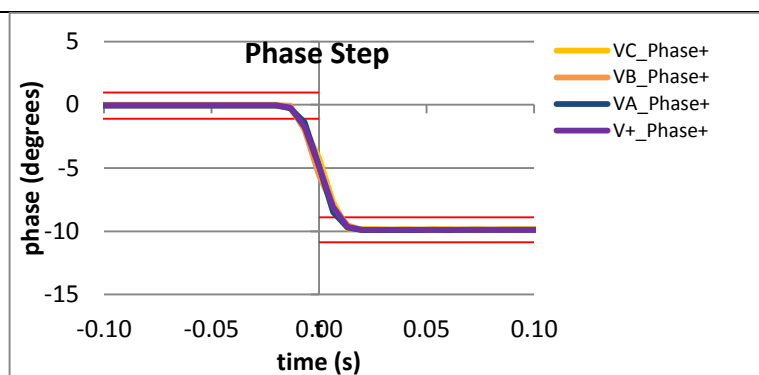


Figure 5012:  $F_s = 15$  FPS, -10 degree phase step

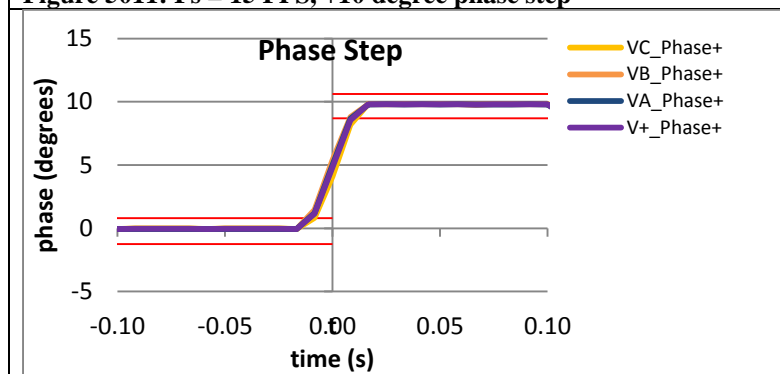


Figure 5013:  $F_s = 12$  FPS, +10 degree phase step

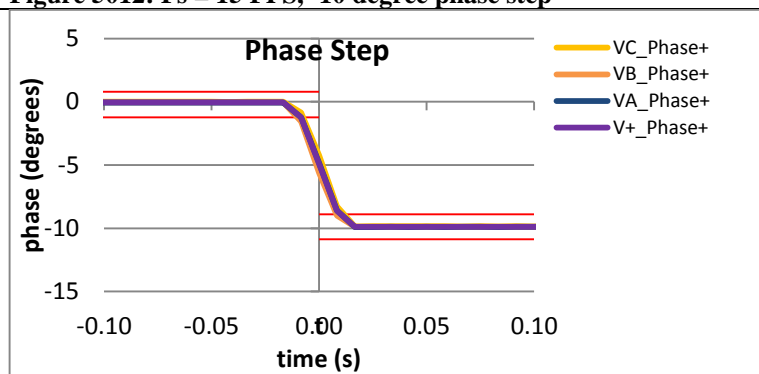


Figure 5014:  $F_s = 12$  FPS, -10 degree phase step

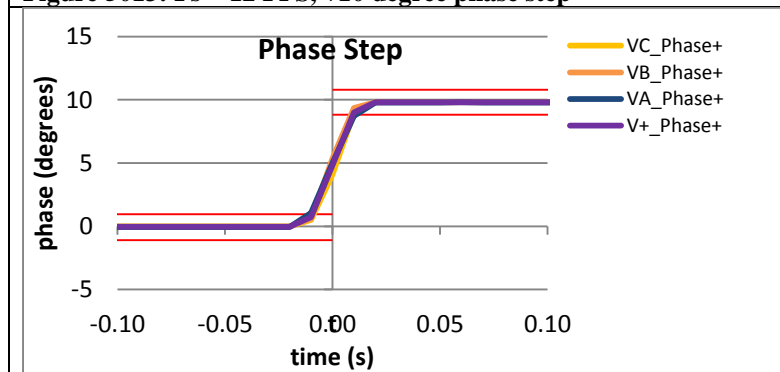


Figure 5015:  $F_s = 10$  FPS, +10 degree phase step

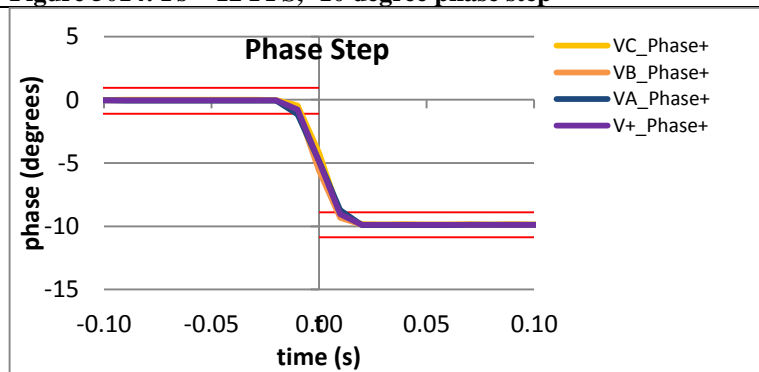
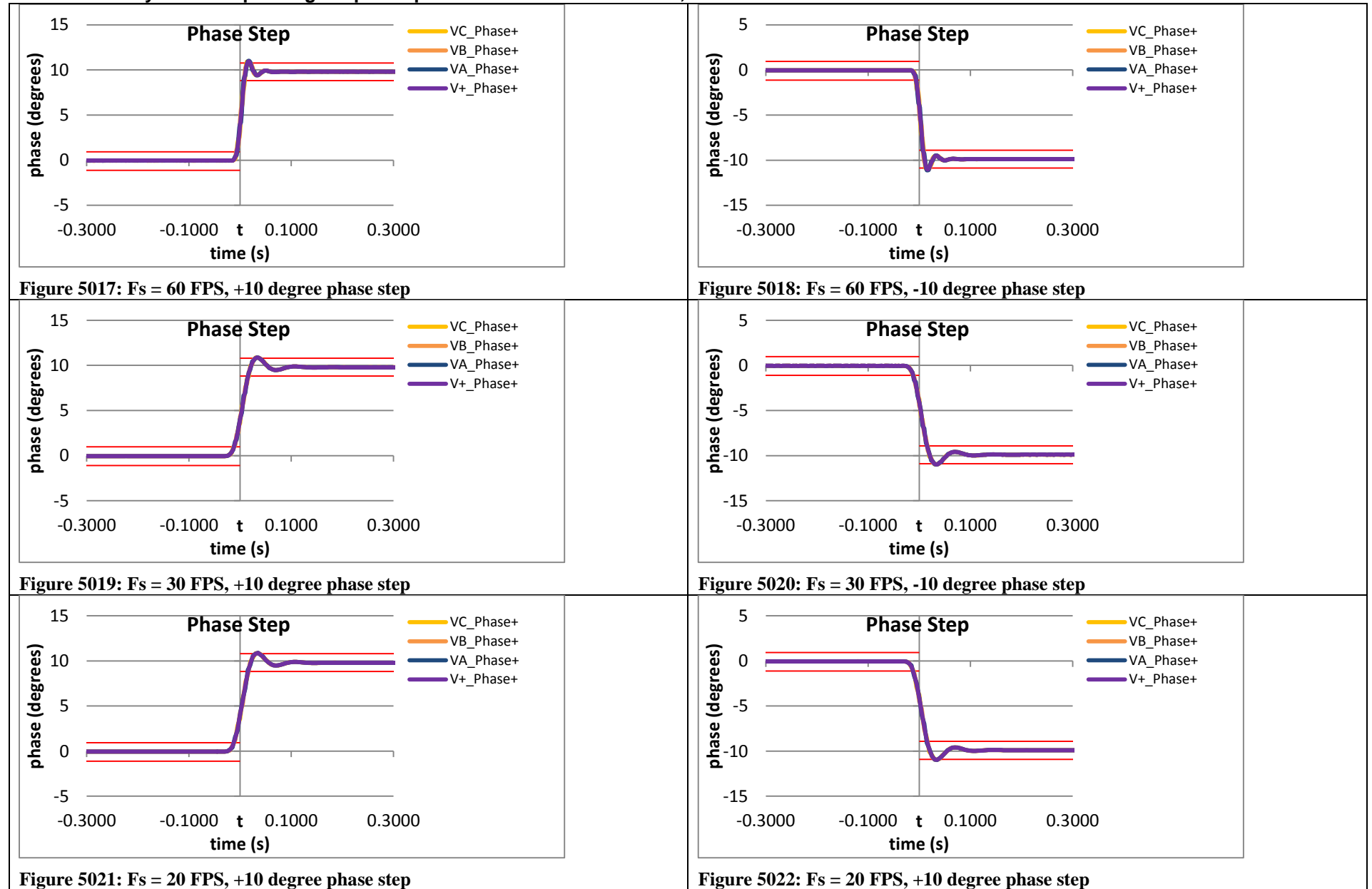


Figure 5016:  $F_s = 10$  FPS, -10 degree phase step

### 9.10.3 PMU B dynamic step change in phase phasor overshoot: $F_0 = 60$ Hz, P class



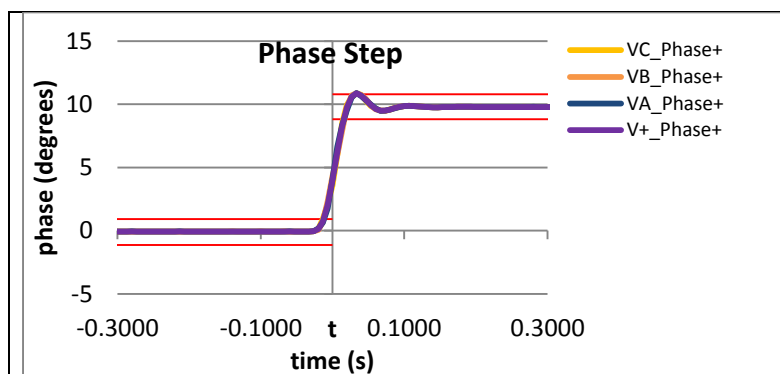


Figure 5023: Fs = 15 FPS, +10 degree phase step

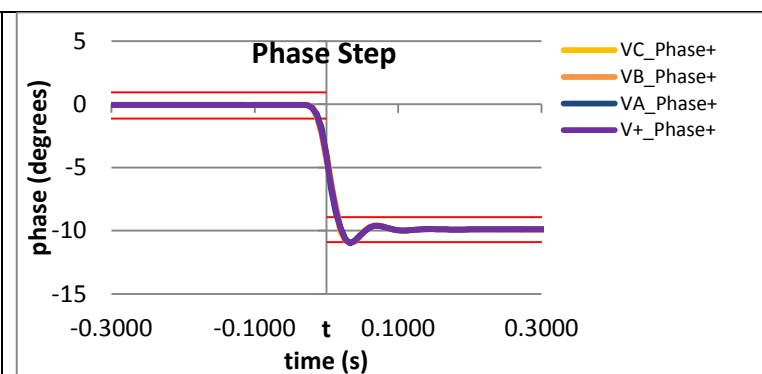


Figure 5024: Fs = 15 FPS, -10 degree phase step

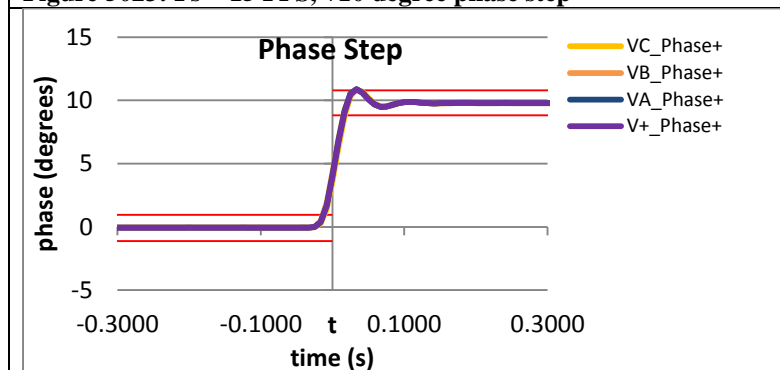


Figure 5025: Fs = 12 FPS, +10 degree phase step

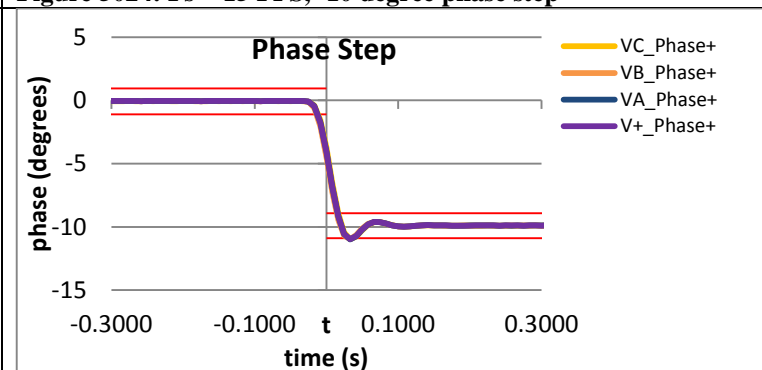


Figure 5026: Fs = 12 FPS, -10 degree phase step

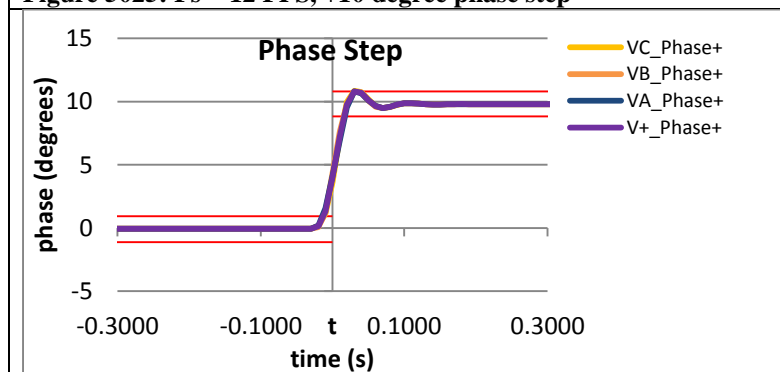


Figure 5027: Fs = 10 FPS, +10 degree phase step

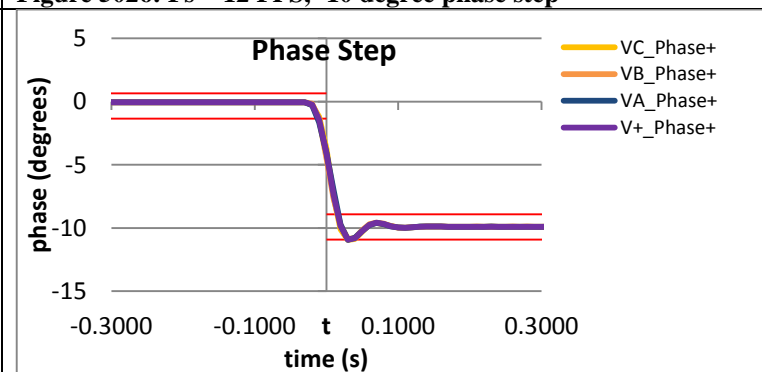


Figure 5028: Fs = 10 FPS, -10 degree phase step

#### 9.10.4 PMU C dynamic step change in phase phasor overshoot: $F_0 = 60$ Hz, P class

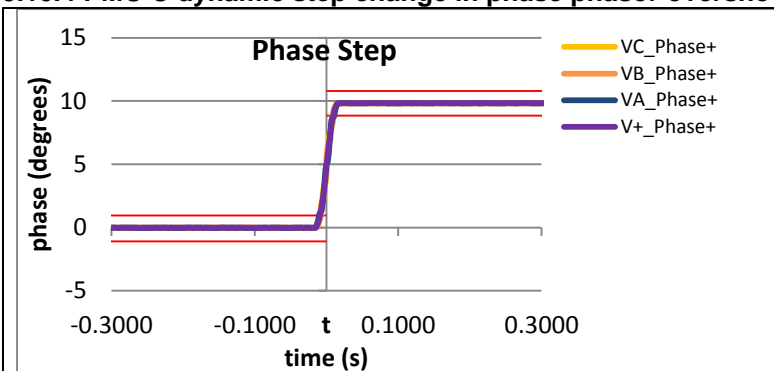


Figure 5029:  $F_s = 60$  FPS, +10 degree phase step

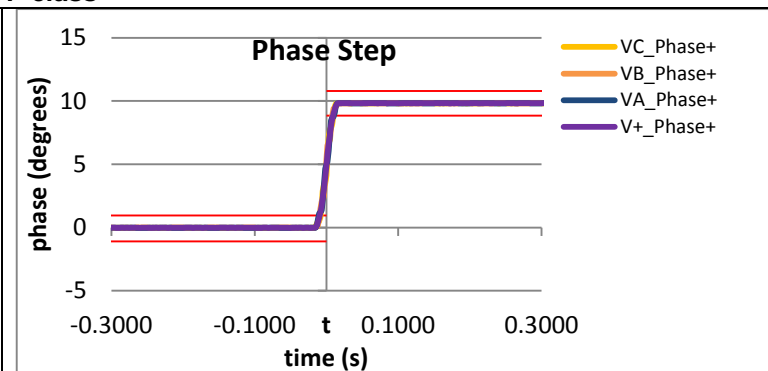


Figure 5030:  $F_s = 60$  FPS, -10 degree phase step

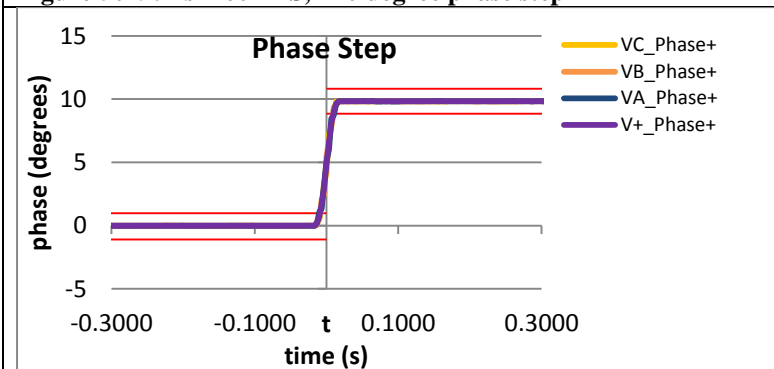


Figure 5031:  $F_s = 30$  FPS, +10 degree phase step

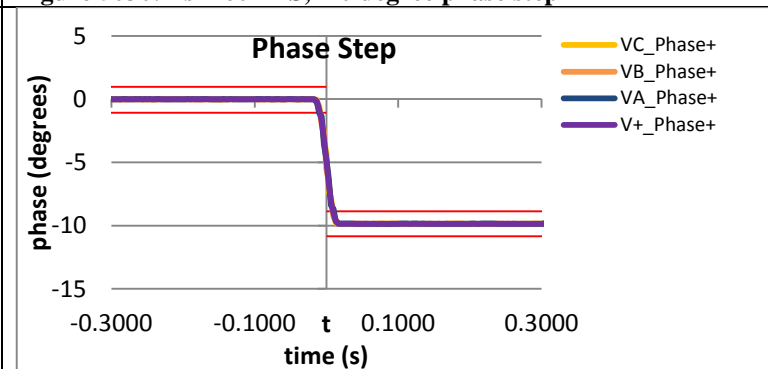


Figure 5032:  $F_s = 30$  FPS, -10 degree phase step

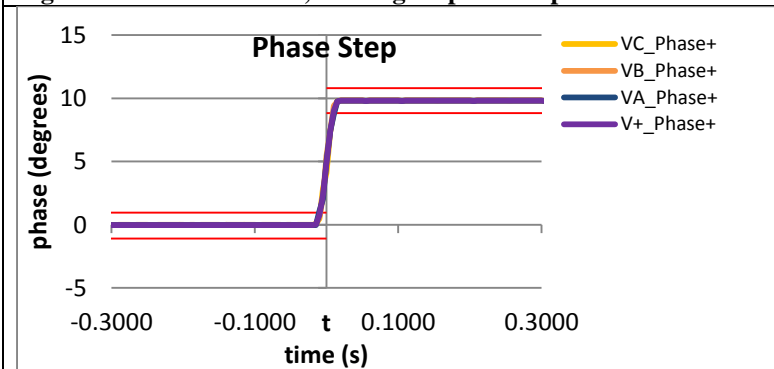


Figure 5033:  $F_s = 20$  FPS, +10 degree phase step

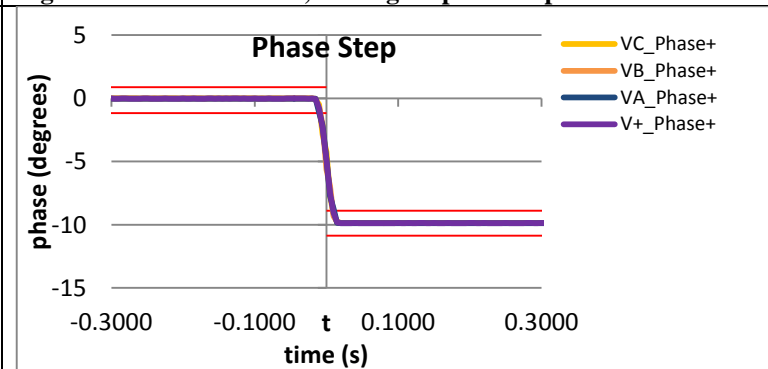


Figure 5034:  $F_s = 20$  FPS, +10 degree phase step

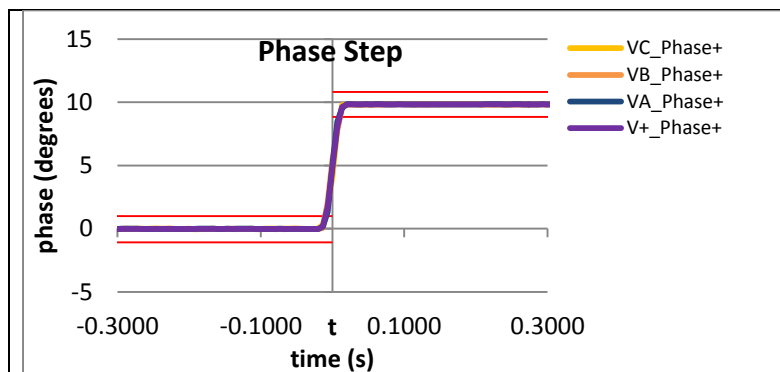


Figure 5035: Fs = 15 FPS, +10 degree phase step

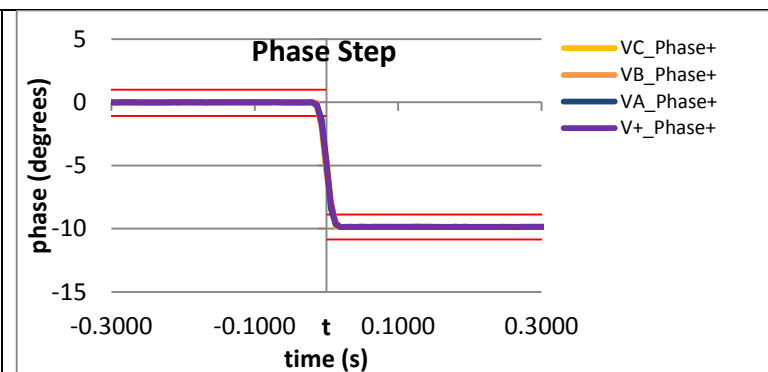


Figure 5036: Fs = 15 FPS, -10 degree phase step

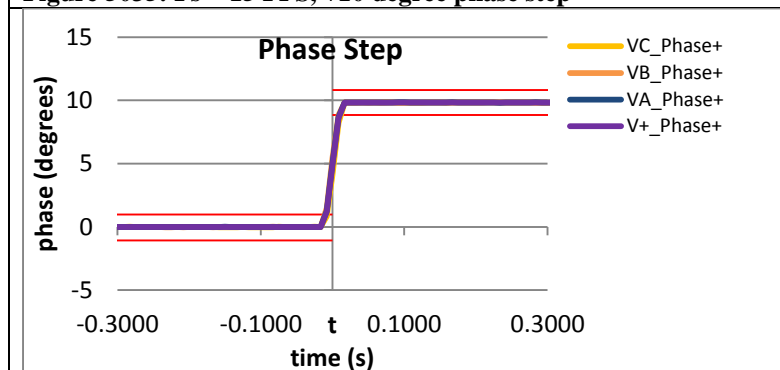


Figure 5037: Fs = 12 FPS, +10 degree phase step

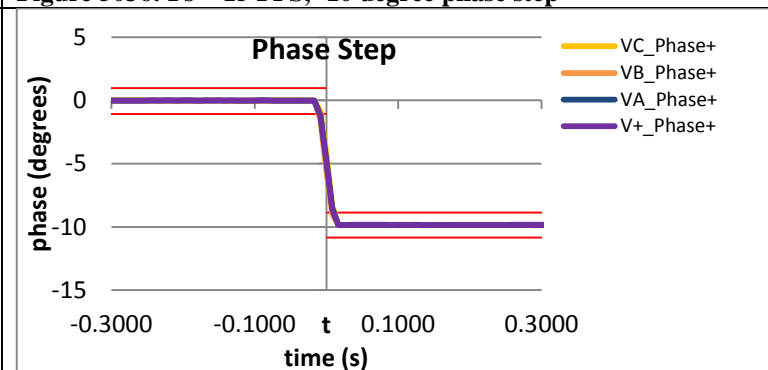


Figure 5038: Fs = 12 FPS, -10 degree phase step

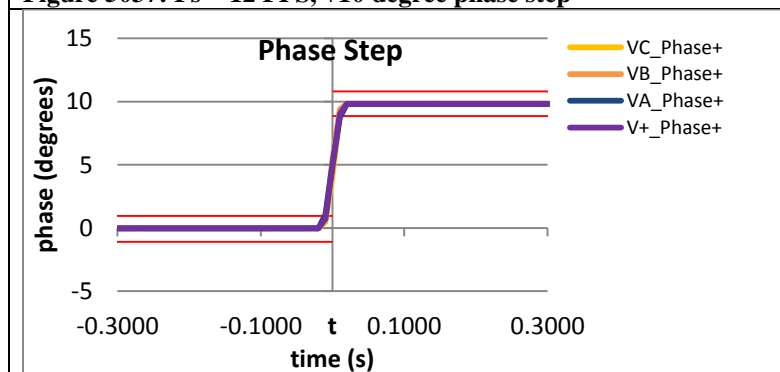


Figure 5039: Fs = 10 FPS, +10 degree phase step

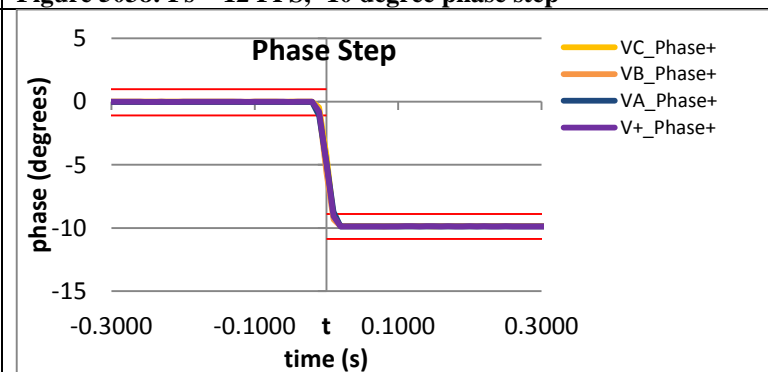
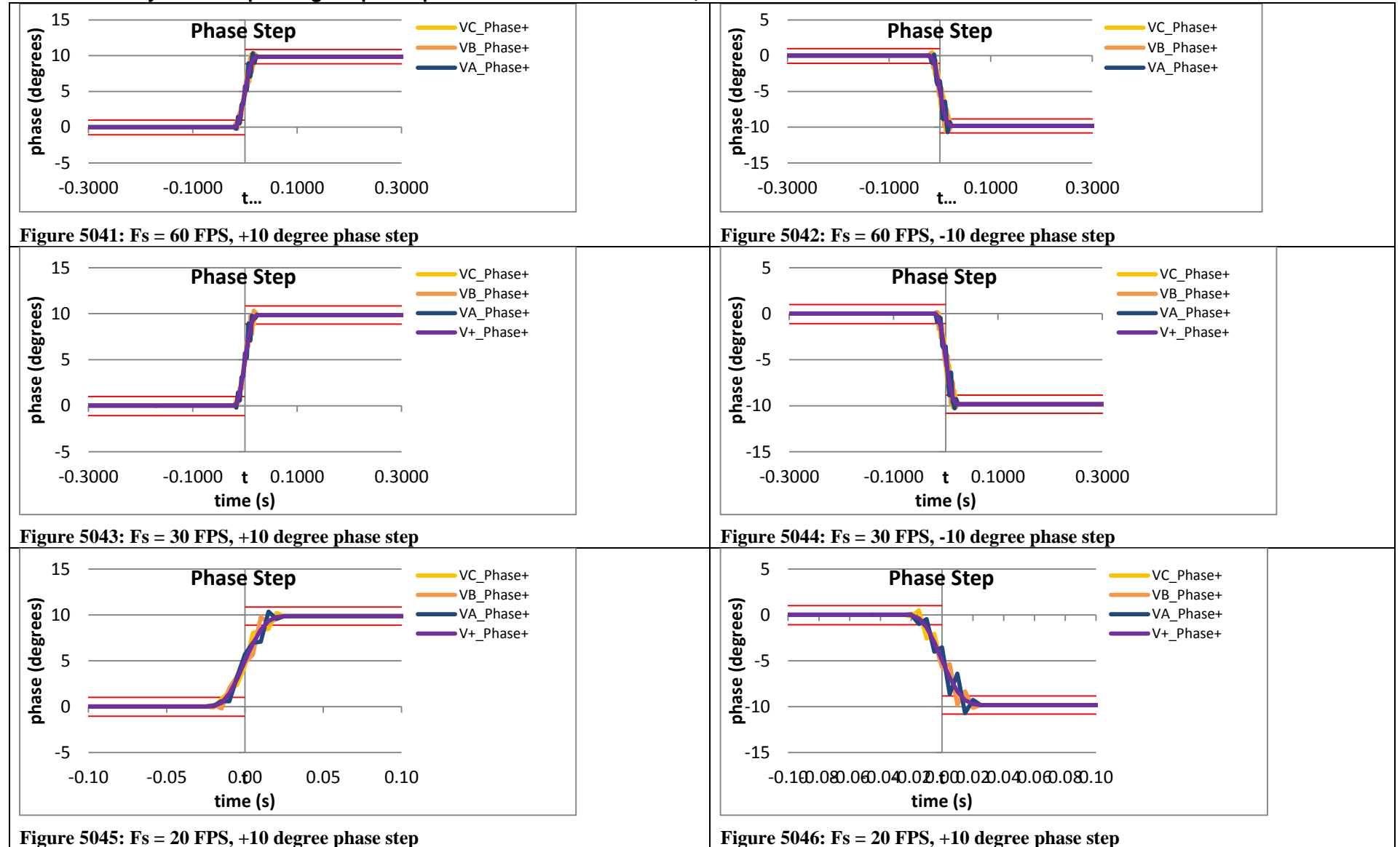


Figure 5040: Fs = 10 FPS, -10 degree phase step



### 9.10.5 PMU D dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class



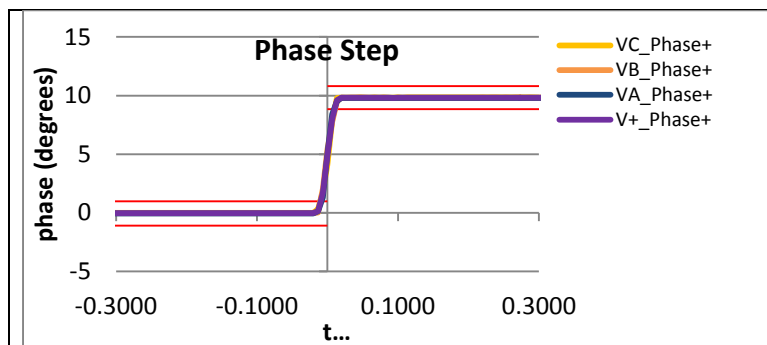


Figure 5047:  $F_s = 15$  FPS, +10 degree phase step

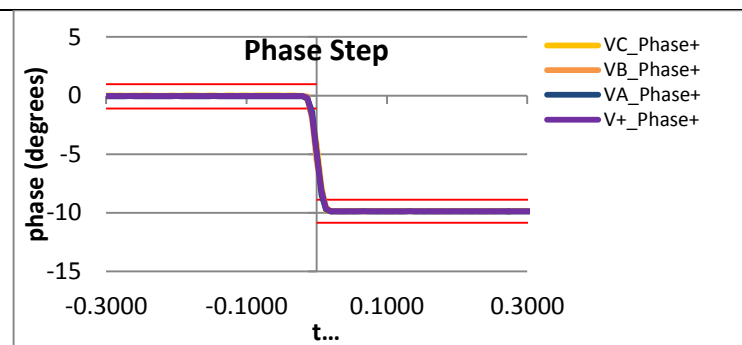


Figure 5048:  $F_s = 15$  FPS, -10 degree phase step

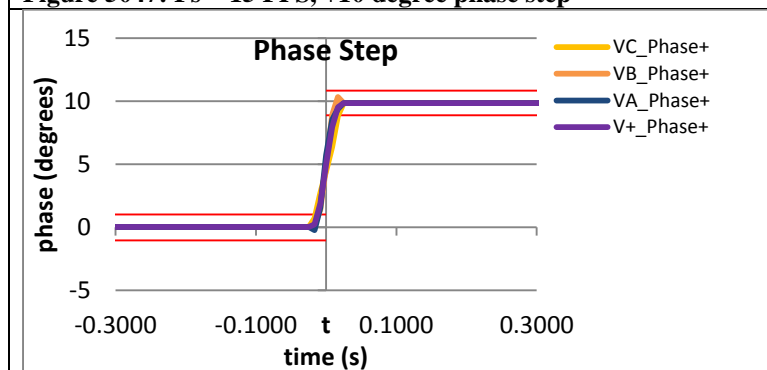


Figure 5049:  $F_s = 12$  FPS, +10 degree phase step

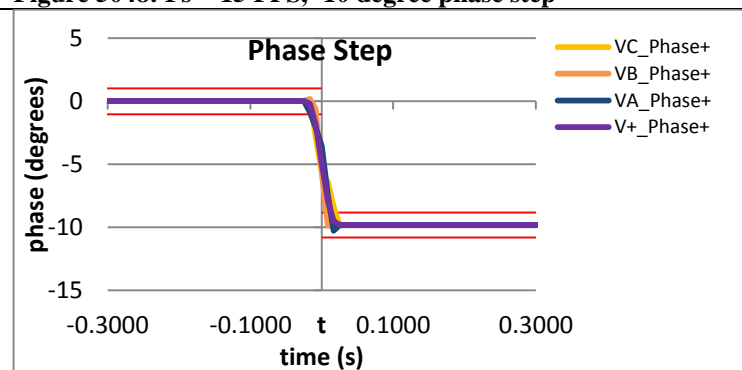


Figure 5050:  $F_s = 12$  FPS, -10 degree phase step

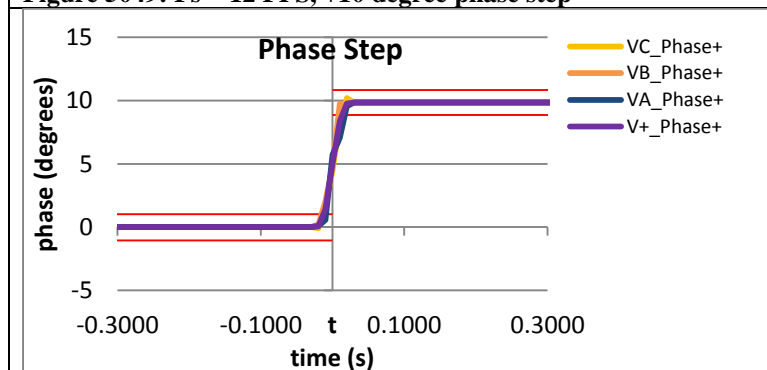


Figure 5051:  $F_s = 10$  FPS, +10 degree phase step

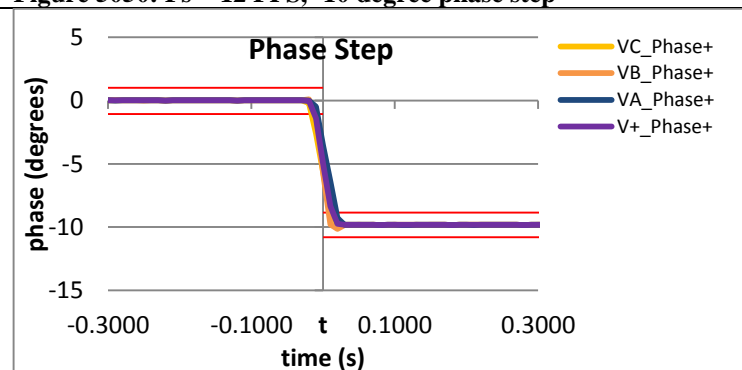
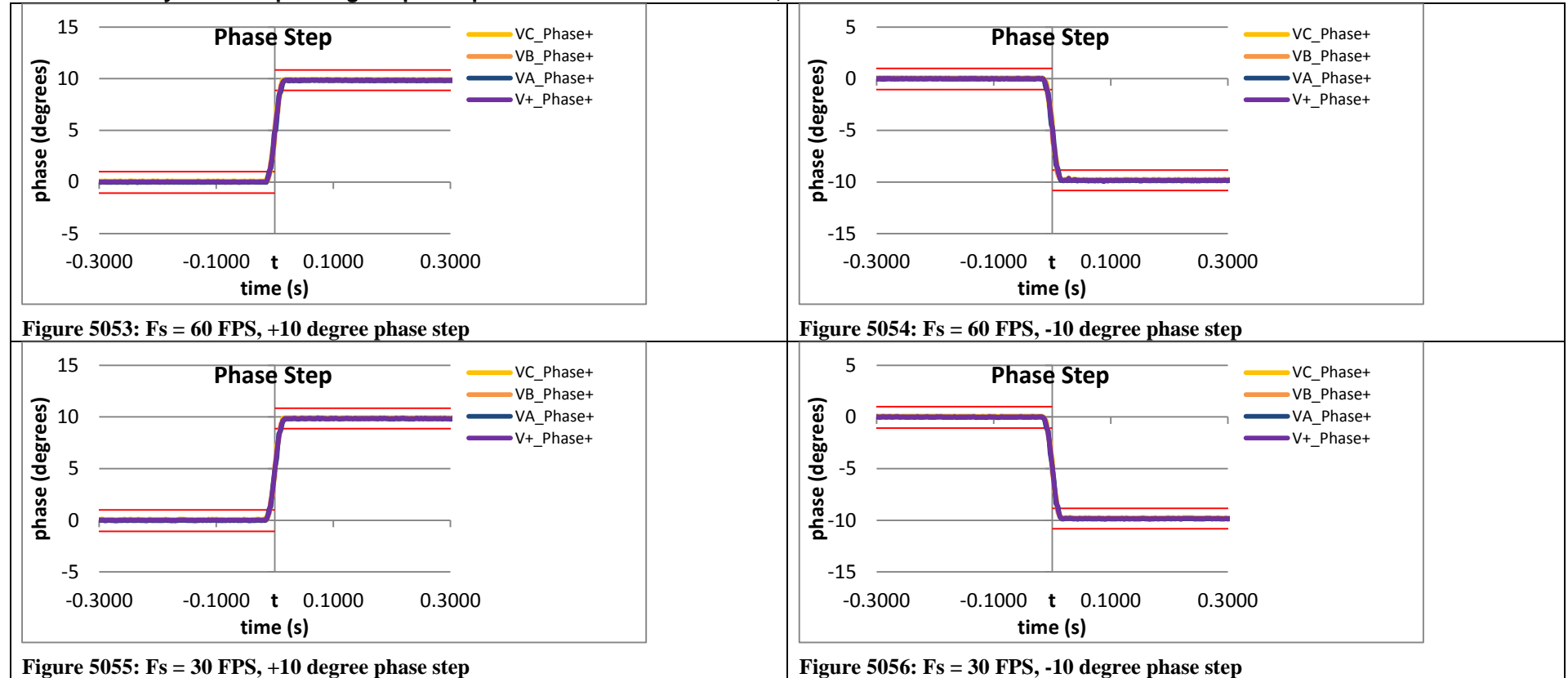


Figure 5052:  $F_s = 10$  FPS, -10 degree phase step

#### 9.10.6 PMU E dynamic step change in phase phasor overshoot: $F_0 = 60$ Hz, P class

PMU E does not support P class.

#### 9.10.7 PMU F dynamic step change in phase phasor overshoot: $F_0 = 60$ Hz, P class



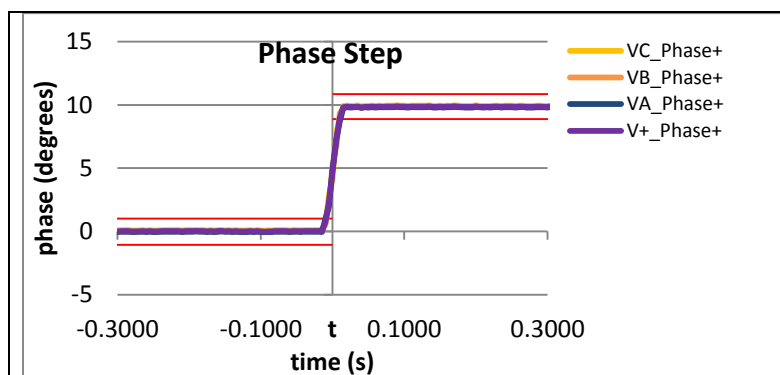


Figure 5057:  $F_s = 20$  FPS, +10 degree phase step

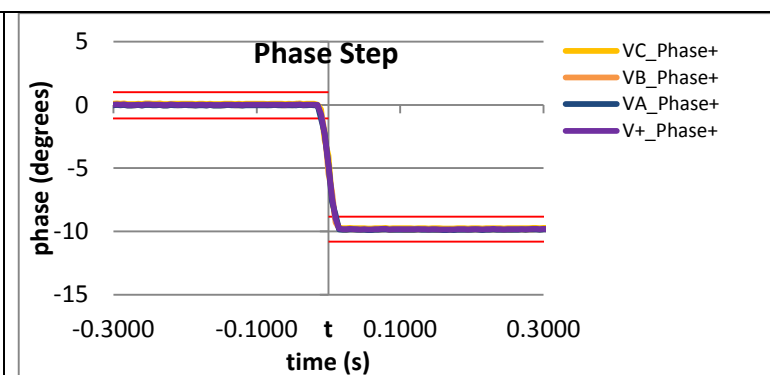


Figure 5058:  $F_s = 20$  FPS, +10 degree phase step

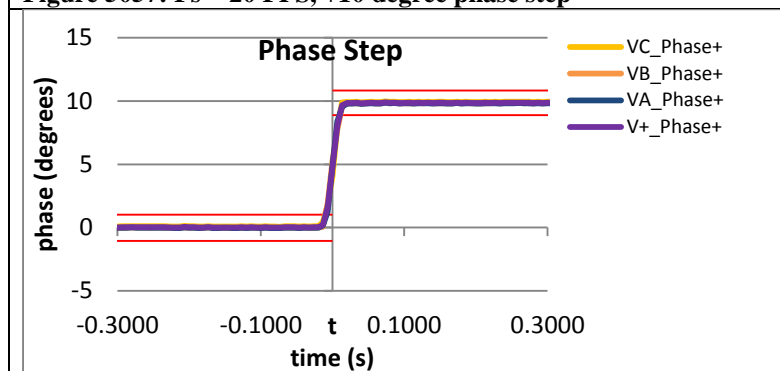


Figure 5059:  $F_s = 15$  FPS, +10 degree phase step

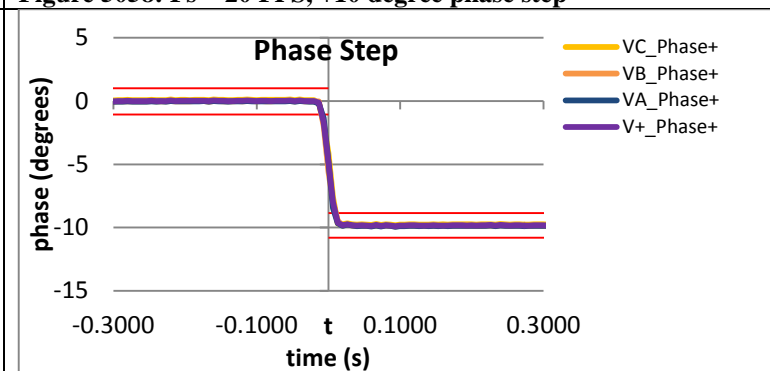


Figure 5060:  $F_s = 15$  FPS, -10 degree phase step

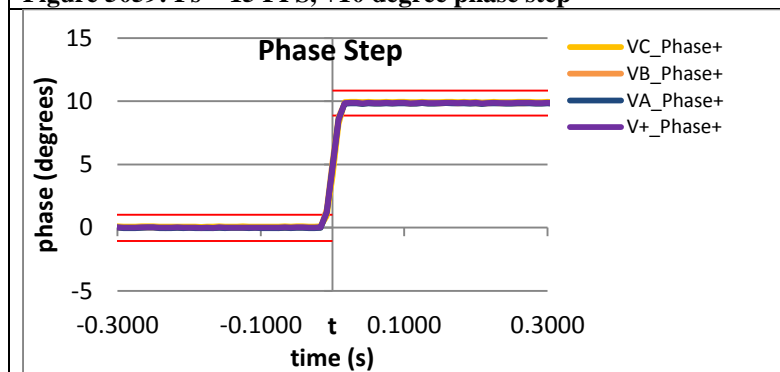


Figure 5061:  $F_s = 12$  FPS, +10 degree phase step

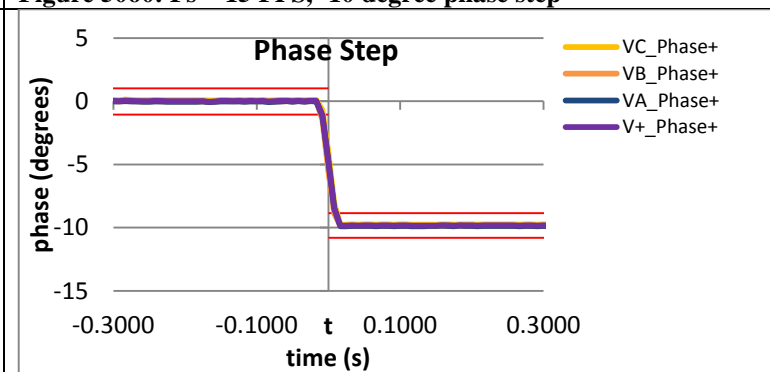


Figure 5062:  $F_s = 12$  FPS, -10 degree phase step

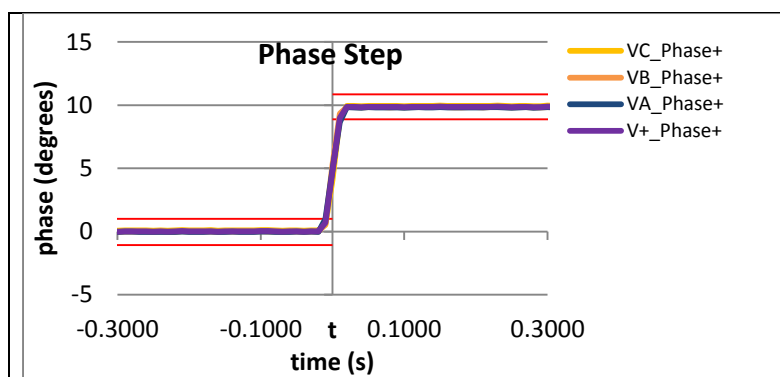


Figure 5063:  $F_s = 10$  FPS, +10 degree phase step

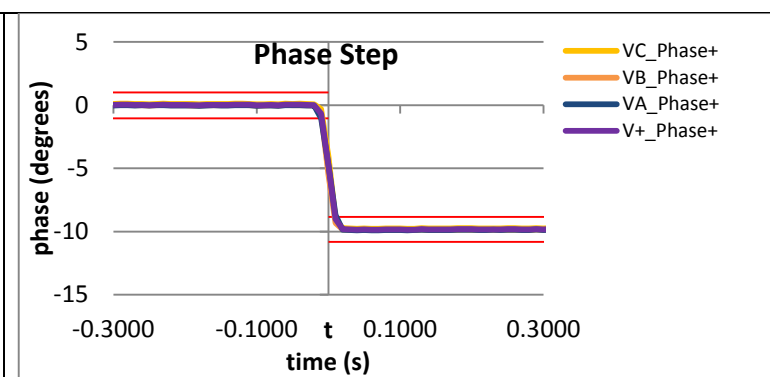
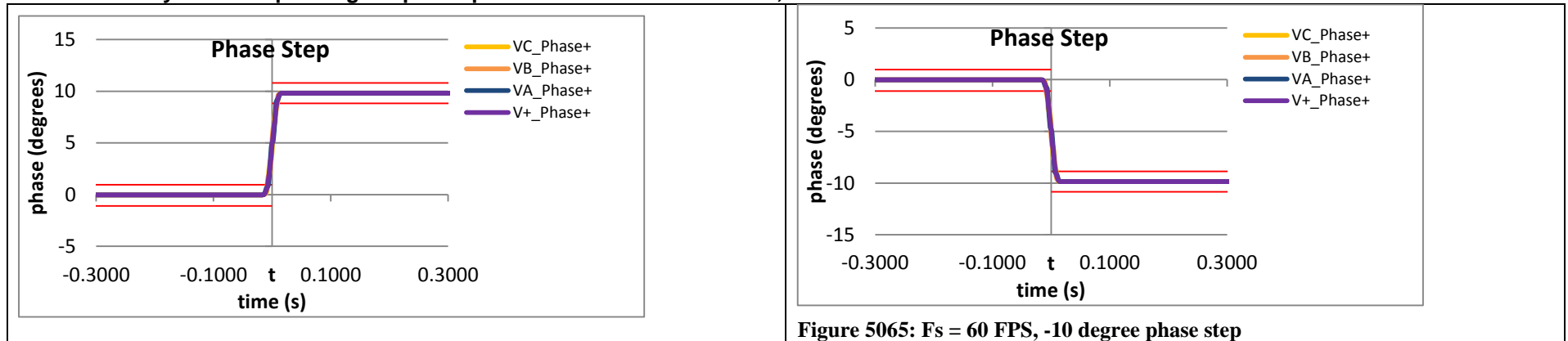


Figure 5064:  $F_s = 10$  FPS, -10 degree phase step

#### 9.10.8 PMU G \* dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class

PMU G does not support P class.

#### 9.10.9 PMU H dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class



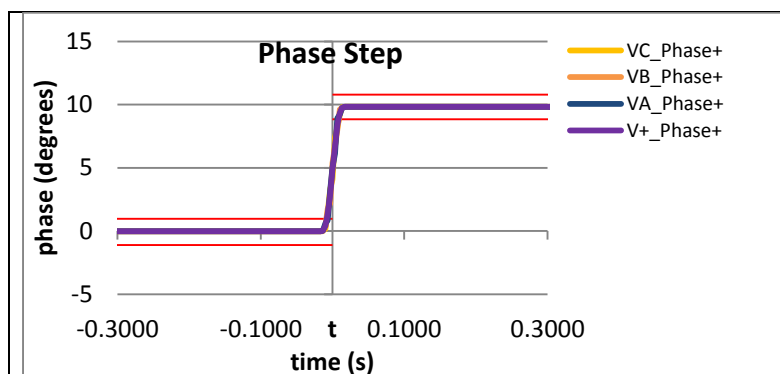


Figure 5066: Fs = 30 FPS, +10 degree phase step

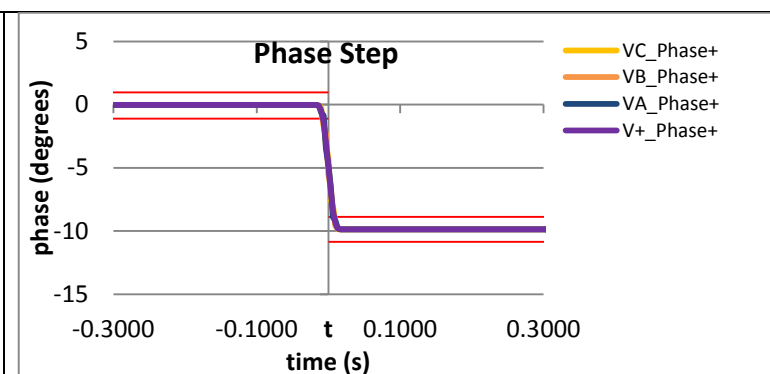


Figure 5067: Fs = 30 FPS, -10 degree phase step

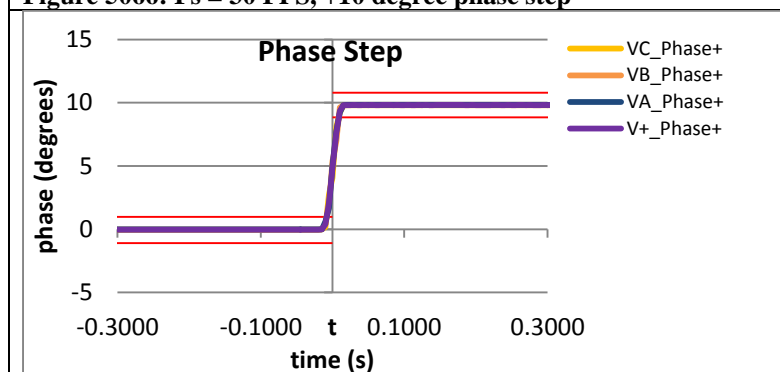


Figure 5068: Fs = 20 FPS, +10 degree phase step

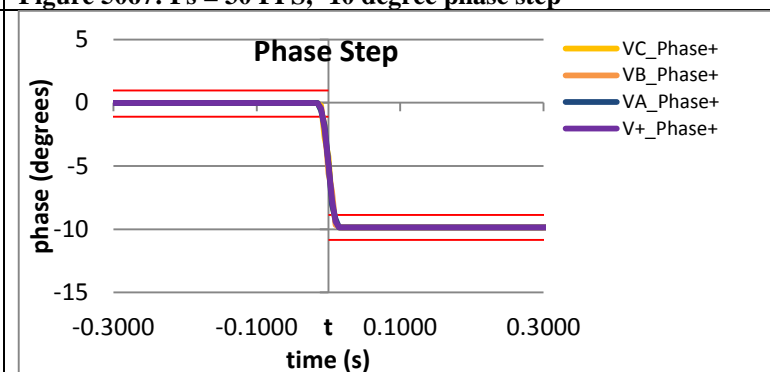


Figure 5069: Fs = 20 FPS, +10 degree phase step

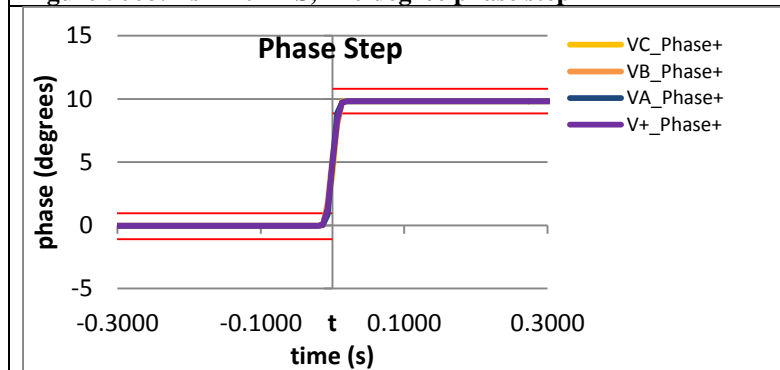


Figure 5070: Fs = 15 FPS, +10 degree phase step

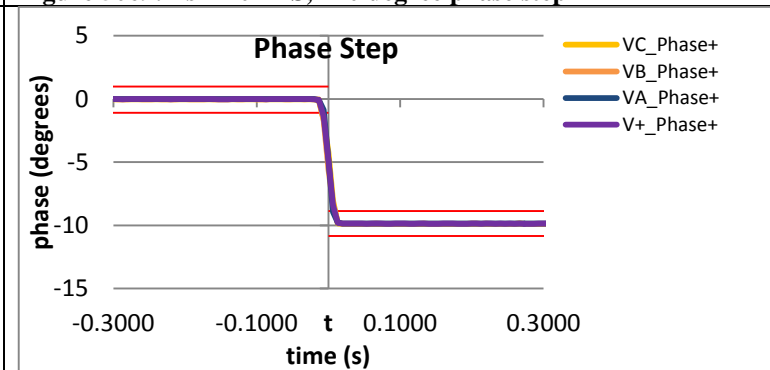


Figure 5071: Fs = 15 FPS, -10 degree phase step

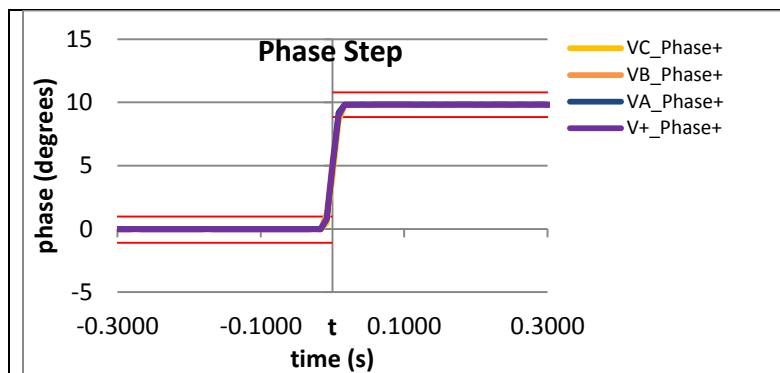


Figure 5072: Fs = 12 FPS, +10 degree phase step

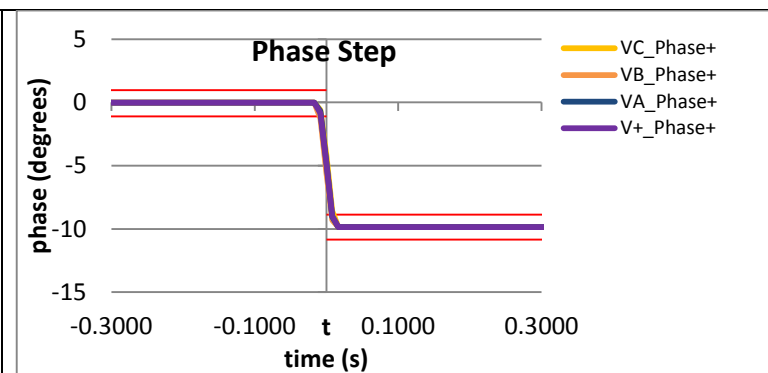


Figure 5073: Fs = 12 FPS, -10 degree phase step

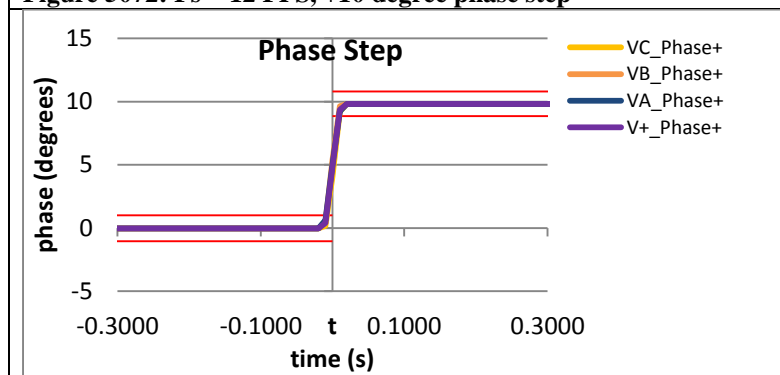


Figure 5074: Fs = 10 FPS, +10 degree phase step

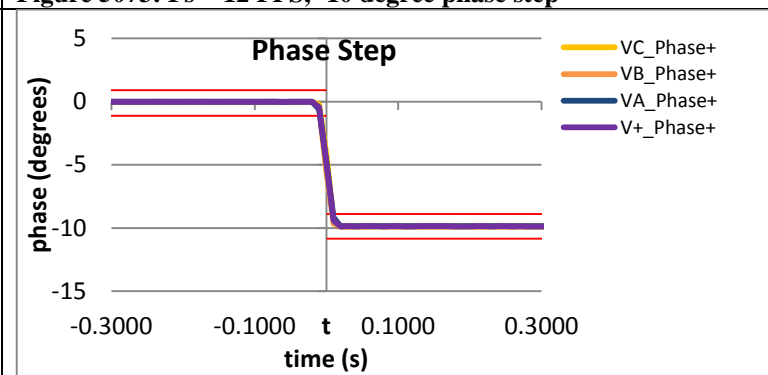


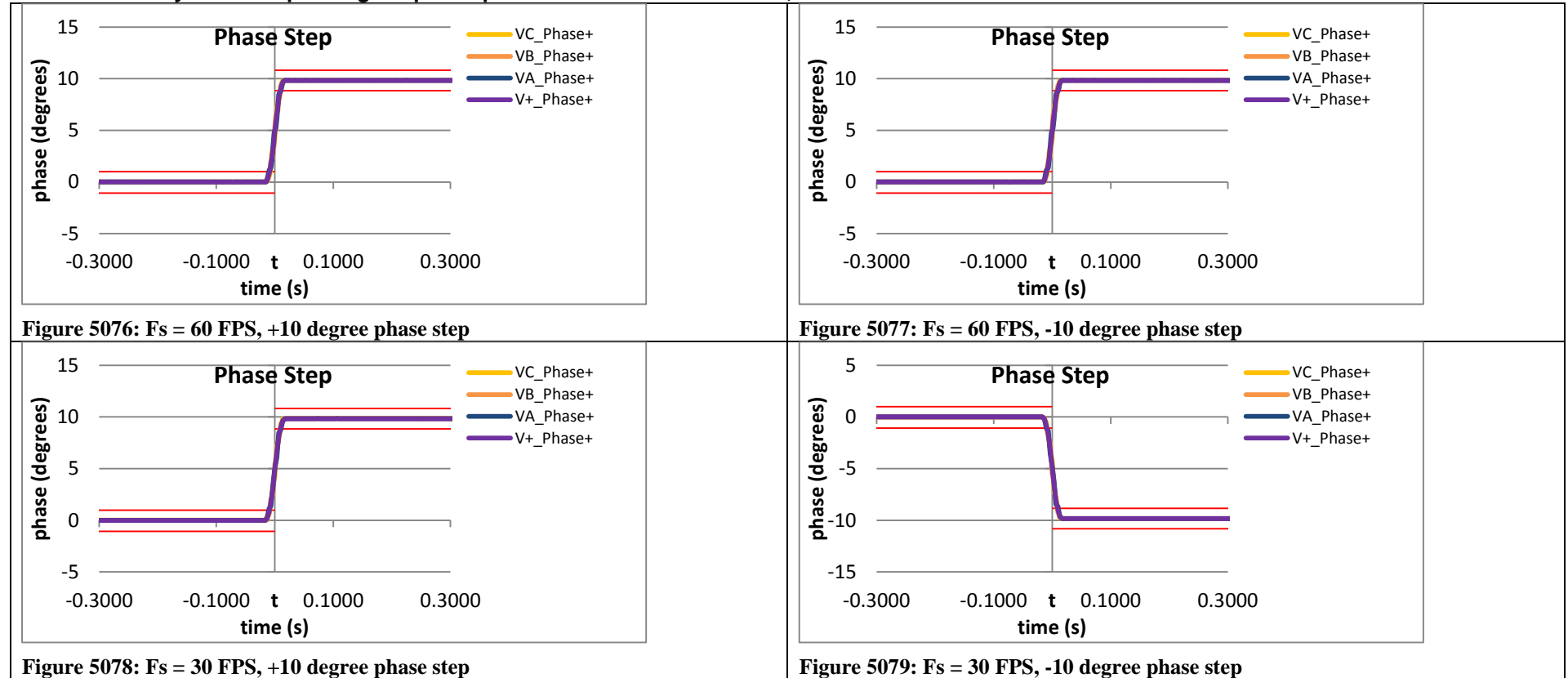
Figure 5075: Fs = 10 FPS, -10 degree phase step



#### 9.10.10 PMU I dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class

PMU I does not support P class

#### 9.10.11 PMU J dynamic step change in phase phasor overshoot: F0 = 60 Hz, P class



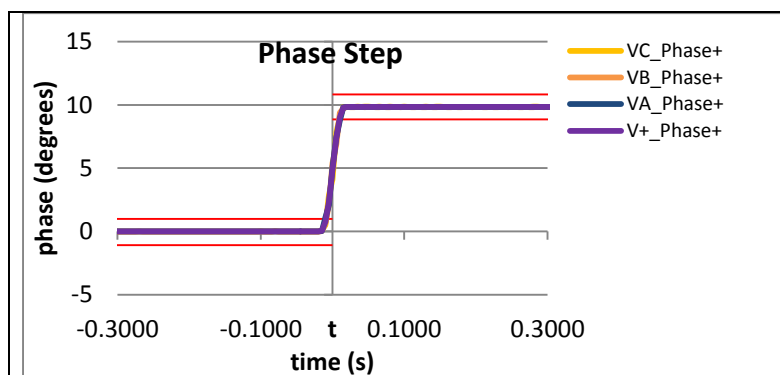


Figure 5080:  $F_s = 20$  FPS, +10 degree phase step

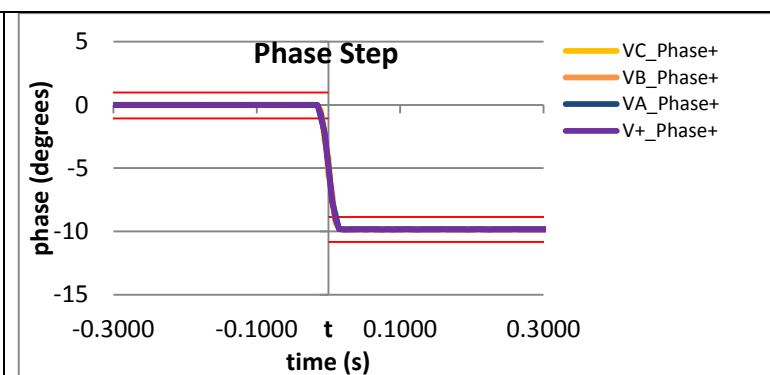


Figure 5081:  $F_s = 20$  FPS, +10 degree phase step

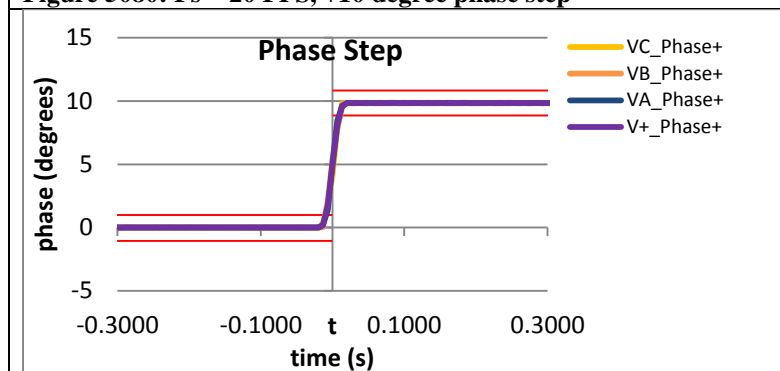


Figure 5082:  $F_s = 15$  FPS, +10 degree phase step

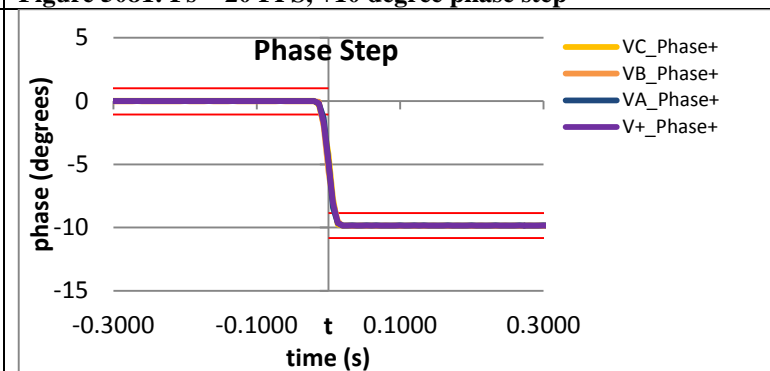


Figure 5083:  $F_s = 15$  FPS, -10 degree phase step

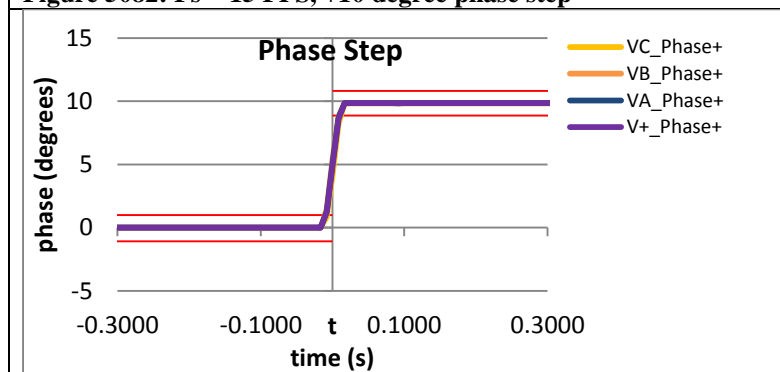


Figure 5084:  $F_s = 12$  FPS, +10 degree phase step

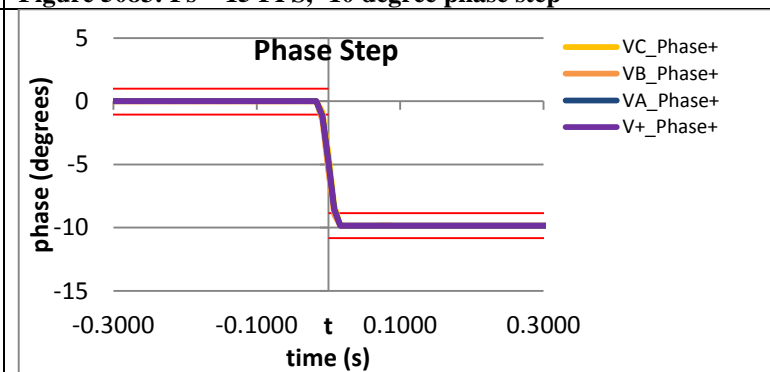


Figure 5085:  $F_s = 12$  FPS, -10 degree phase step

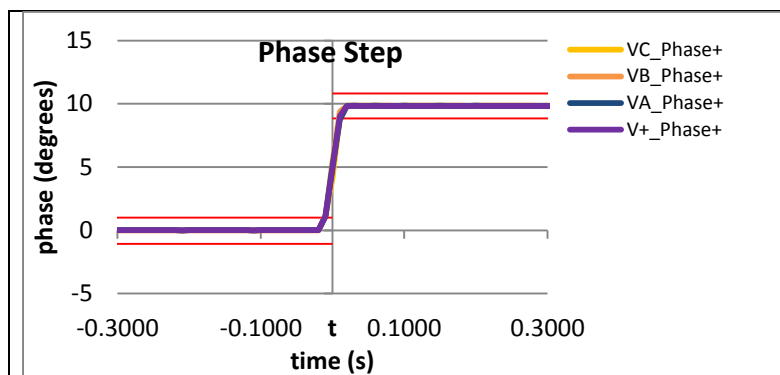


Figure 5086:  $F_s = 10$  FPS, +10 degree phase step

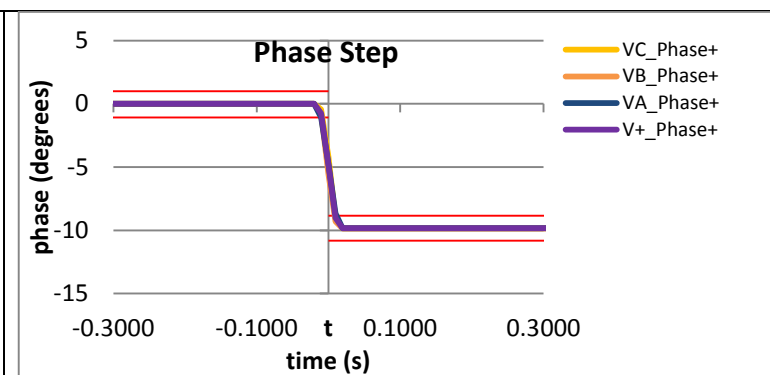


Figure 5087:  $F_s = 10$  FPS, -10 degree phase step

## 10. Dynamic step change in magnitude

10. Dynamic step change in magnitude.....	875
10.1 Dynamic step change in magnitude: phasor response time .....	876
10.2 Dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class .....	877
10.2.1 C37.118.1a Annex C dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class .....	877
10.2.2 PMU A dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class .....	879
10.2.3 PMU B dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class .....	881
10.2.4 PMU C dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class .....	883
10.2.5 PMU D dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class .....	885
10.2.6 PMU E dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class .....	887
10.2.7 PMU F dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class .....	889
10.2.8 PMU G dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class .....	891
10.2.9 PMU H dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class .....	893
10.2.10 PMU I dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class .....	895
10.2.11 PMU J dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class .....	897
10.3 Dynamic step change in magnitude current response time: F0 = 60 Hz, M class .....	899
10.3.1 C37.118.1-2011 Annex C dynamic step change in magnitude current response time: F0 = 60 Hz, M class .....	899
10.3.2 PMU A dynamic step change in magnitude current response time: F0 = 60 Hz, M class .....	902
10.3.3 PMU B dynamic step change in magnitude current response time: F0 = 60 Hz, M class .....	904
10.3.4 PMU C dynamic step change in magnitude current response time: F0 = 60 Hz, M class .....	906
10.3.5 PMU D dynamic step change in magnitude current response time: F0 = 60 Hz, M class .....	908
10.3.6 PMU E dynamic step change in magnitude current response time: F0 = 60 Hz, M class .....	910
10.3.7 PMU F dynamic step change in magnitude current response time: F0 = 60 Hz, M class .....	912
10.3.8 PMU G dynamic step change in magnitude current response time: F0 = 60 Hz, M class .....	914
10.3.9 PMU H dynamic step change in magnitude current response time: F0 = 60 Hz, M class .....	916
10.3.10 PMU I dynamic step change in magnitude current response time: F0 = 60 Hz, M class .....	918
10.3.11 PMU J dynamic step change in magnitude current response time: F0 = 60 Hz, M class .....	920
10.4 Dynamic step change in magnitude voltage response time: F0 = 60 Hz, P Class .....	922
10.4.1 C37.118.1a Annex C dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class .....	922
10.4.2 PMU A dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class .....	924
10.4.3 PMU B dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class .....	926
10.4.4 PMU C dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class .....	928
10.4.5 PMU D dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class .....	930
10.4.6 PMU E dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class .....	932
10.4.7 PMU F dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class .....	932
10.4.8 PMU G dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class .....	934

10.4.9 PMU H dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class .....	934
10.4.10 PMU I dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class .....	936
10.4.11 PMU J dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class .....	936
10.5 Dynamic step change in magnitude current response time: F0 = 60 Hz, P class .....	938
10.5.1 C37.118.1-2011 Annex C dynamic step change in magnitude current response time: F0 = 60 Hz, P class.....	938
10.5.2 PMU A dynamic step change in magnitude current response time: F0 = 60 Hz, P class .....	940
10.5.3 PMU B dynamic step change in magnitude current response time: F0 = 60 Hz, P class .....	942
10.5.4 PMU C dynamic step change in magnitude current response time: F0 = 60 Hz, P class .....	944
10.5.5 PMU D dynamic step change in magnitude current response time: F0 = 60 Hz, P class .....	946
10.5.6 PMU E dynamic step change in magnitude current response time: F0 = 60 Hz, P class .....	948
10.5.7 PMU F dynamic step change in magnitude current response time: F0 = 60 Hz, P class .....	948
10.5.8 PMU G dynamic step change in magnitude current response time: F0 = 60 Hz, P class .....	950
10.5.9 PMU H dynamic step change in magnitude current response time: F0 = 60 Hz, P class .....	950
10.5.10 PMU I dynamic step change in magnitude current response time: F0 = 60 Hz, P class .....	952
10.5.11 PMU J dynamic step change in magnitude current response time: F0 = 60 Hz, P class .....	952
10.6 Dynamic step change in magnitude: frequency response time .....	954
10.6.1 C37.118.1-2011 Annex C dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class .....	955
10.6.2 PMU A dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class .....	957
10.6.3 PMU B dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class .....	959
10.6.4 PMU C dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class .....	961
10.6.5 PMU D dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class .....	963
10.6.6 PMU E dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class.....	965
10.6.7 PMU F dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class .....	967
10.6.8 PMU G dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class .....	969
10.6.9 PMU H dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class .....	971
10.6.10 PMU I dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class.....	973
10.6.11 PMU J dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class .....	975
10.7 Dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class .....	977
10.7.1 C37.118.1-2011 Annex C dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class .....	977
10.7.2 PMU A dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class.....	979
10.7.3 PMU B dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class.....	981
10.7.4 PMU C dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class.....	983
10.7.5 PMU D dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class.....	985
10.7.6 PMU E dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class .....	987
10.7.7 PMU F dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class .....	987
10.7.8 PMU G dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class .....	989
10.7.9 PMU H dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class .....	989
10.7.10 PMU I dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class .....	991
10.7.11 PMU J dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class.....	991

10.8 Dynamic step change in magnitude: ROCOF response time .....	993
10.9 Dynamic step change in magnitude ROCOF error: F0 = 60 Hz, M class .....	993
10.9.1 C37.118.1-2011 Annex C dynamic step change in magnitude ROCOF error: F0 = 60 Hz, M class.....	993
10.9.2 PMU A dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class .....	995
10.9.3 PMU B dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class .....	998
10.9.4 PMU C dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class .....	1000
10.9.5 PMU D dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class .....	1002
10.9.6 PMU E dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class.....	1004
10.9.7 PMU F dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class.....	1006
10.9.8 PMU G * dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class .....	1008
10.9.9 PMU H dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class .....	1010
10.9.10 PMU I dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class.....	1012
10.9.11 PMU J dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class .....	1014
10.10 Dynamic step change in magnitude ROCOF error: F0 = 60 Hz, P class .....	1016
10.10.1 C37.118.1-2011 Annex C dynamic step change in magnitude ROCOF error: F0 = 60 Hz, P class .....	1016
10.10.2 PMU A dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class.....	1018
10.10.3 PMU B dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class.....	1020
10.10.4 PMU C dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class.....	1022
10.10.5 PMU D dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class .....	1024
10.10.6 PMU E dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class .....	1026
10.10.7 PMU F dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class .....	1026
10.10.8 PMU G * dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class.....	1028
10.10.9 PMU H dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class .....	1028
10.10.10 PMU I dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class.....	1030
10.10.11 PMU J dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class.....	1030
10.11 Dynamic step change in magnitude: phasor overshoot.....	1032
10.12 Dynamic step change in magnitude: phasor delay time .....	1032
10.12.1 C37.118.1-2011 Annex C dynamic step change in magnitude overshoot: F0 = 60 Hz, M class.....	1033
10.12.2 PMU A dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, M class .....	1036
10.12.3 PMU B dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, M class .....	1038
10.12.4 PMU C dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, M class .....	1040
10.12.5 PMU D dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, M class .....	1042
10.12.6 PMU E dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, M class .....	1045
10.12.7 PMU F dynamic step change in magnitude overshoot: F0 = 60 Hz, M class .....	1047
10.12.8 PMU G dynamic step change in magnitude overshoot: F0 = 60 Hz, M class .....	1049
10.12.9 PMU H dynamic step change in magnitude overshoot: F0 = 60 Hz, M class .....	1051
10.12.10 PMU I dynamic step change in magnitude overshoot: F0 = 60 Hz, M class .....	1053
10.12.11 PMU J dynamic step change in magnitude overshoot: F0 = 60 Hz, M class .....	1055

10.13 Dynamic step change in magnitude overshoot: F0 = 60 Hz, P class .....	1057
10.13.1 C37.118.1-2011 Annex C dynamic step change in magnitude overshoot: F0 = 60 Hz, P class .....	1057
10.13.2 PMU A dynamic step change in magnitude overshoot: F0 = 60 Hz, P class .....	1059
10.13.3 PMU B dynamic step change in magnitude overshoot: F0 = 60 Hz, P class .....	1061
10.13.4 PMU C dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class .....	1063
10.13.5 PMU D dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class .....	1065
10.13.6 PMU E dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class .....	1067
10.13.7 PMU F dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class .....	1067
10.13.8 PMU G dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class .....	1069
10.13.9 PMU H dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class .....	1069
10.13.10 PMU I dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class .....	1071

Performance during step changes in magnitude is determined by applying  $\pm 10\%$  step changes of magnitude. Response time and delay time of the phasors, frequency, and ROCOF measurements are compared to the limits. Overshoot of the phasors are compared to the limits.

A recommended practice for measuring a PMU's response to step changes in input is to run a series of  $n$  step sub-tests where the occurrence of the step is displaced in time relative to the PMU report-time. During each ( $n^{\text{th}}$ ) iteration of 10 sub-tests, the step occurs  $1/10^{\text{th}}$  of a reporting period further from the time of the report than the previous iteration of the subtest. The results are combined to trace an equivalent time sampled response curve. During each sub-test, the influence quantity (amplitude or phase) is stepped, the response data are gathered, and the magnitude is returned to its previous value in preparation for the next sub-test in the series. At the end of the series of sub-tests, the TVE, FE, RFE results and the PMU reported magnitude data from all sub-tests are indexed and overlaid to create smooth curves approximating the step response of the PMU. From the curves, delay time, response time, and overshoot/undershoot shall be calculated

The test plan for step change in phase and magnitude is as follows:

For the first test, let  $n = 0$ .

- a) Begin with three-phase balanced input at nominal amplitude and frequency. Hold steady state for at least 1 second plus one response time period.
- b) At the beginning of a reporting cycle plus  $n / (10 \times F_s)$  (i.e.,  $n \times \text{reporting period}/10$ ) step the magnitude by  $+10\%$  of the nominal magnitude and hold steady state for at least 1 second plus one response time period.
- c) Gather the PMU data, return the influence quantity to nominal and wait for the PMU to settle.
- d) Increment  $n$  by one ( $n = n + 1$ ), then repeat step c) through step d) until  $n = 10 - 1$ .
- e) Index and overlay the PMU data to obtain a smooth response curve.
- f) Repeat the tests for negative magnitude step.

IEEE Std. C37.118.1a-2014 sets the M class response time limit for M class phasors at  $7/F_s$  and for frequency and ROCOF at the greater of  $14/F_s$  or  $14/F_0$ .

IEEE Std. C37.118.1a-2014 sets the P class response time limit for phasors at  $2/F_0$  and the delay time limit at  $1/(4F_s)$ .

IEEE Std. C37.118.1a-2014 sets the P class response time limit for frequency at  $4.5/F_0$  and for ROCOF at  $6/F_0$ .

IEEE Std C37.118.1-2011 sets the M class phasor delay time at  $1/(4F_s)$  and the max overshoot at  $10\%$  of the step magnitude.

IEEE Std C37.118.1-2011 sets the P class phasor delay time at  $1/(4F_s)$  and the max overshoot at  $5\%$  of the step magnitude.

The response time plots in this section show the limit of TVE, Fe, or RFe as a green horizontal line. A red vertical line appears at the response time limits. note that the limits are not interpolated, the first horizontal red line appears at the first report which is above the TVE, FE or RFE limit and the second red line is at the response time limit away from the first.

The overshoot plots in this section show red horizontal lines at the overshoot/undershoot limits around the magnitude before and after the step.



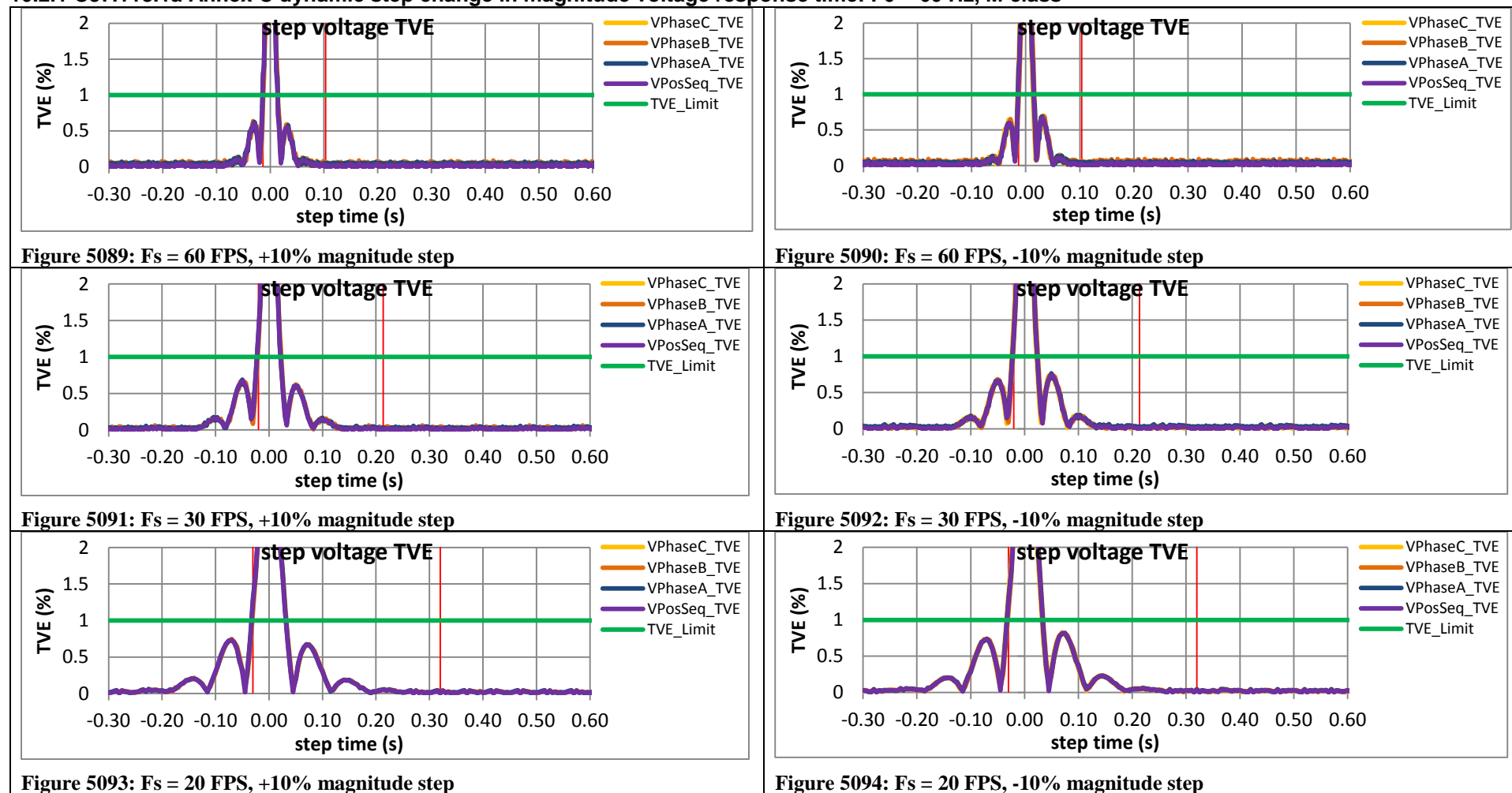
### 10.1 Dynamic step change in magnitude: phasor response time

Fs (FPS)	10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P
PMU A	P	P	P	P	P	P	P	P	P	P	P	P
PMU B	P	F	P	F	P	F	P	F	P	F	P	F
PMU C	P	P	P	P	P	P	P	P	P	P	P	P
PMU D	P	I	P	I	P	I	P	I	P	I	P	I
PMU E	P	-	-	-	P	-	P	-	P	-	F	-
PMU F	P	P	P	P	P	P	P	P	P	P	P	P
PMU G	P	-	P	-	P	-	F	-	F	-	-	-
PMU H	P	P	P	P	P	P	P	P	P	P	P	P
PMU I	P	-	P	-	P	-	P	-	P	-	P	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P

P = Pass, F = Fail, I = indeterminate

## 10.2 Dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class

### 10.2.1 C37.118.1a Annex C dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class



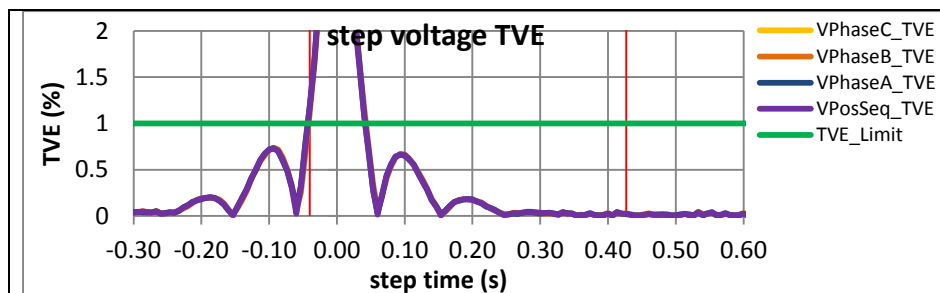


Figure 5095: Fs = 15 FPS, +10% magnitude step

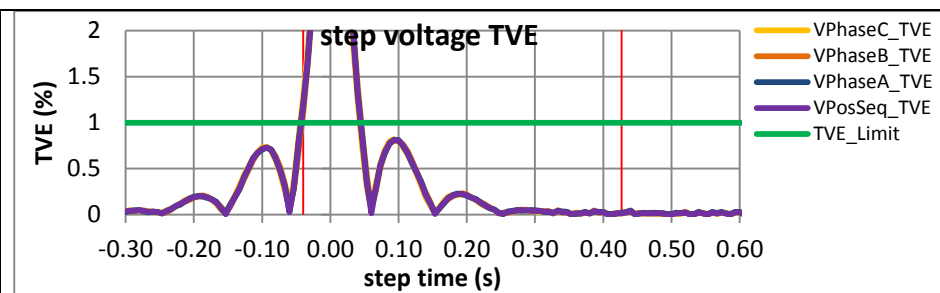


Figure 5096: Fs = 15 FPS, -10% magnitude step

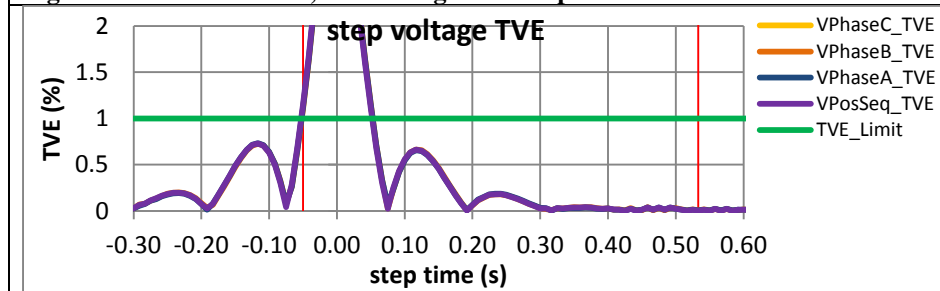


Figure 5097: Fs = 12 FPS, +10% magnitude step

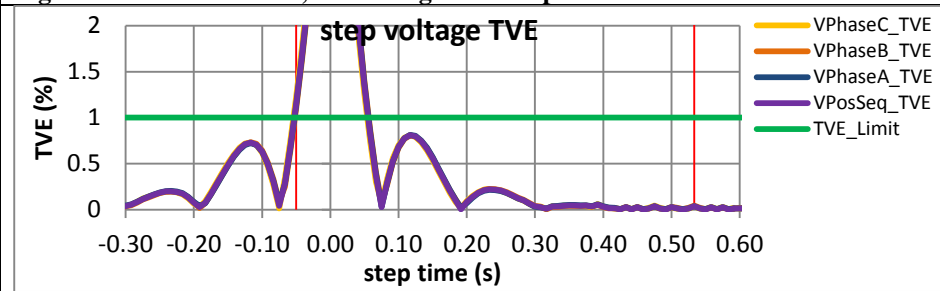


Figure 5098: Fs = 12 FPS, -10% magnitude step

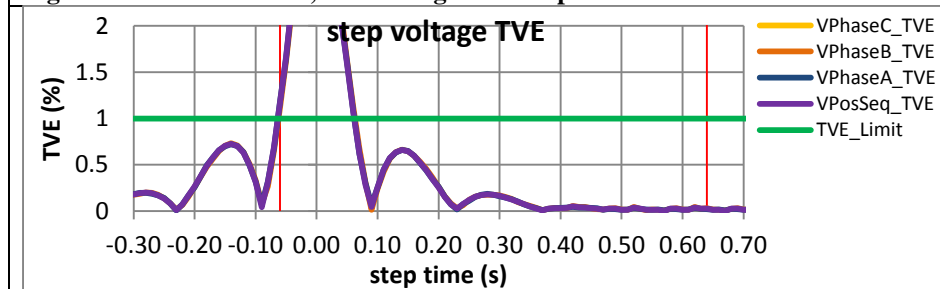


Figure 5099: Fs = 10 FPS, +10% magnitude step

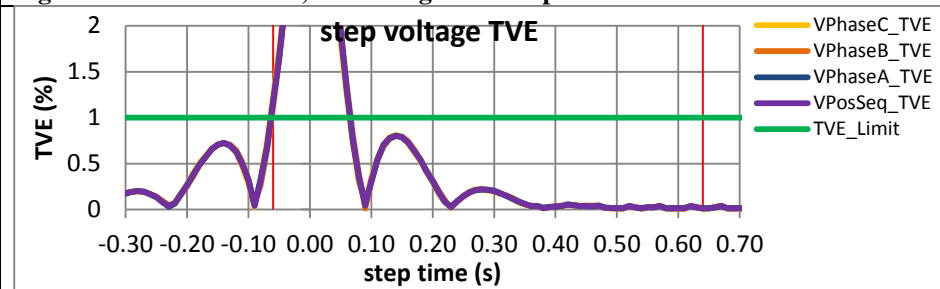
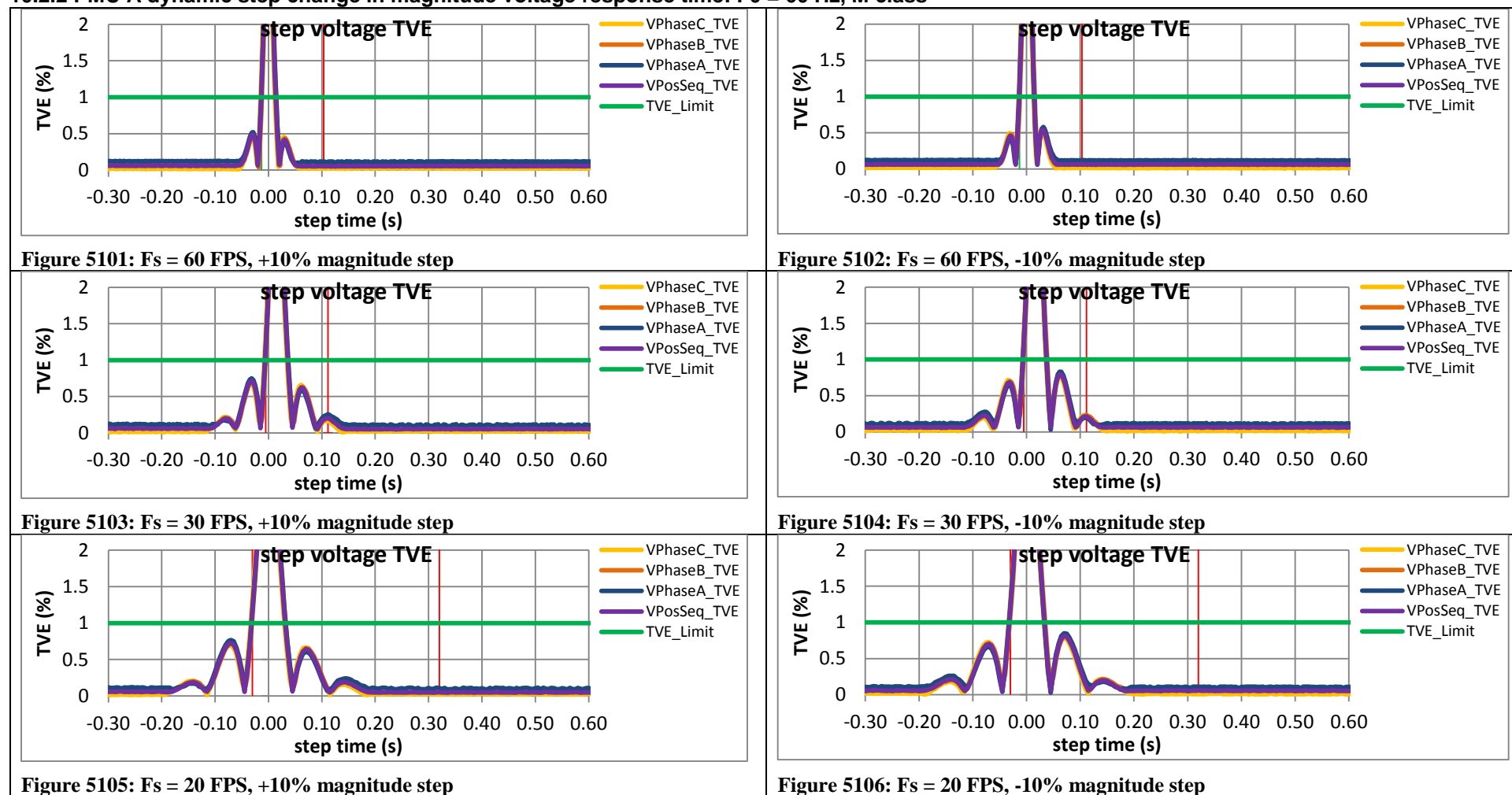


Figure 5100: Fs = 10 FPS, +10% magnitude step

### 10.2.2 PMU A dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class



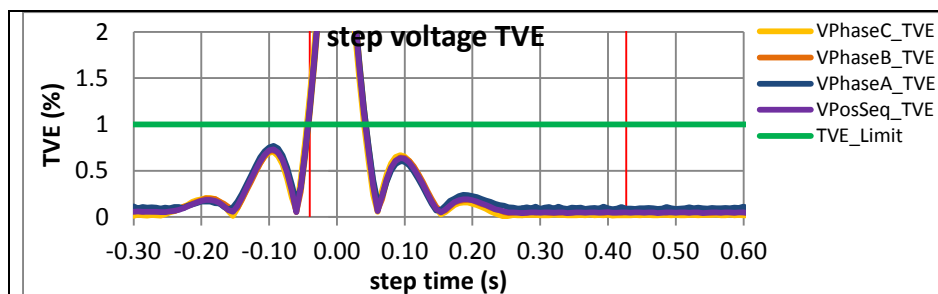


Figure 5107:  $F_s = 15$  FPS, +10% magnitude step

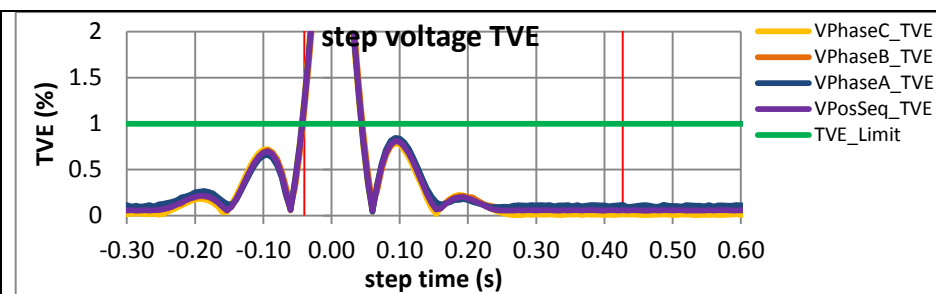


Figure 5108:  $F_s = 15$  FPS, -10% magnitude step

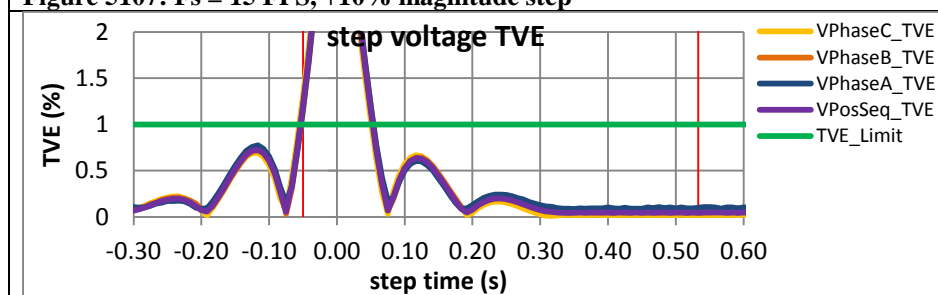


Figure 5109:  $F_s = 12$  FPS, +10% magnitude step

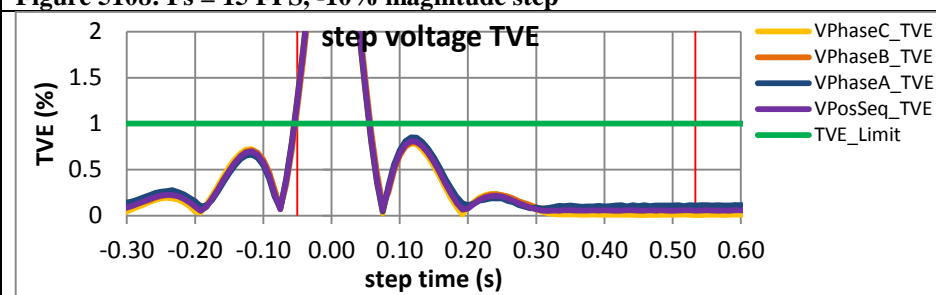


Figure 5110:  $F_s = 12$  FPS, -10% magnitude step

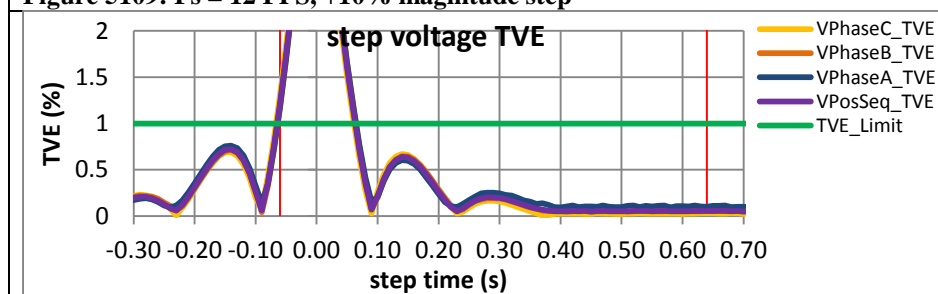


Figure 5111:  $F_s = 10$  FPS, +10% magnitude step

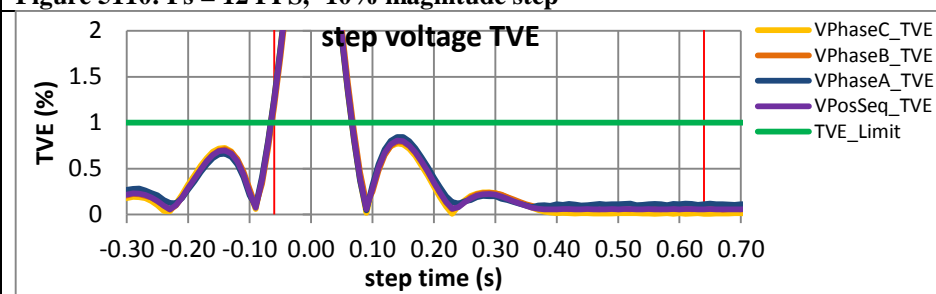


Figure 5112:  $F_s = 10$  FPS, -10% magnitude step

### 10.2.3 PMU B dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class

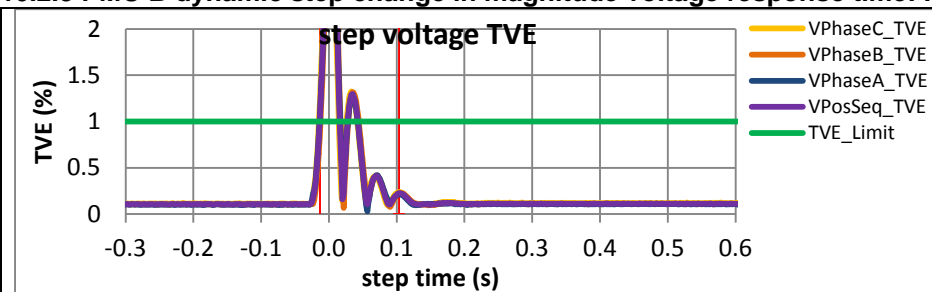


Figure 5113: Fs = 60 FPS, +10% magnitude step

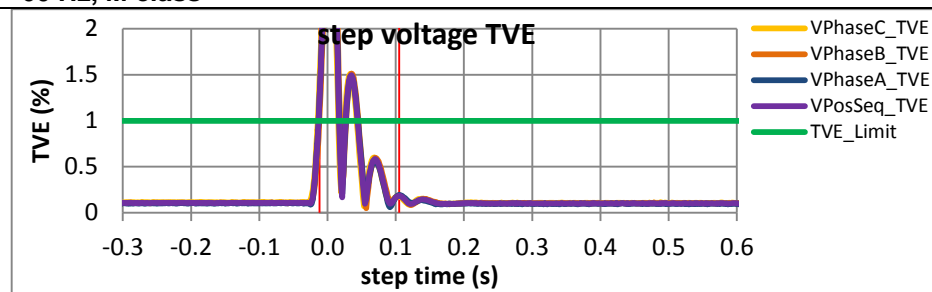


Figure 5114: Fs = 60 FPS, -10% magnitude step

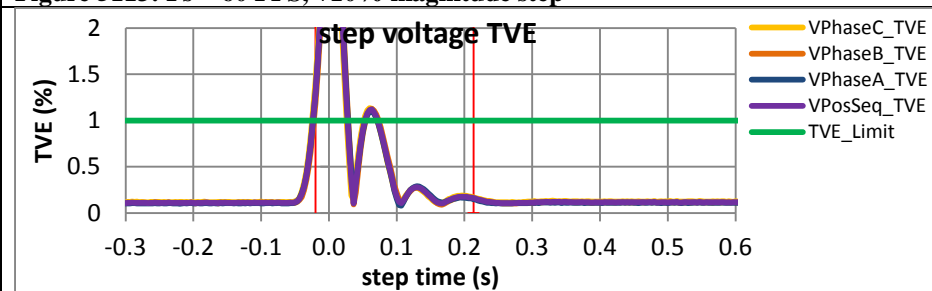


Figure 5115: Fs = 30 FPS, +10% magnitude step

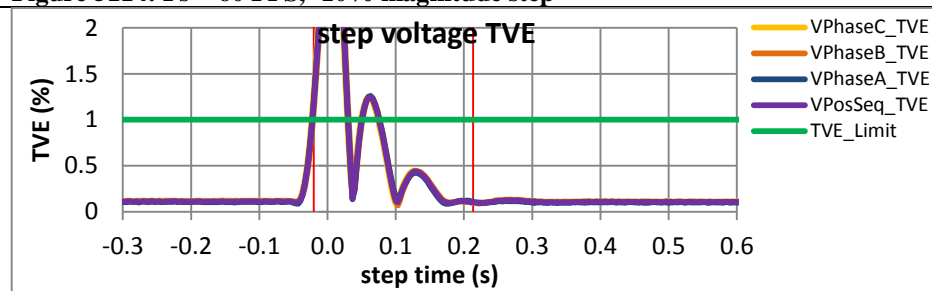


Figure 5116: Fs = 30 FPS, -10% magnitude step

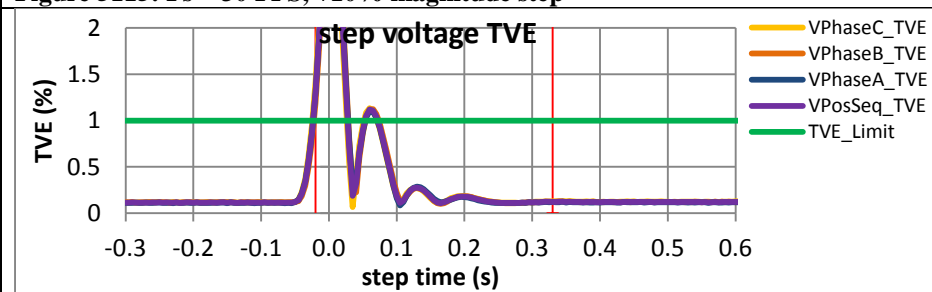


Figure 5117: Fs = 20 FPS, +10% magnitude step

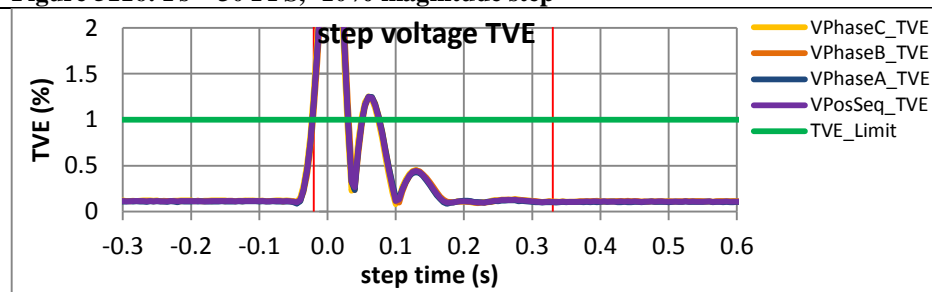


Figure 5118: Fs = 20 FPS, -10% magnitude step

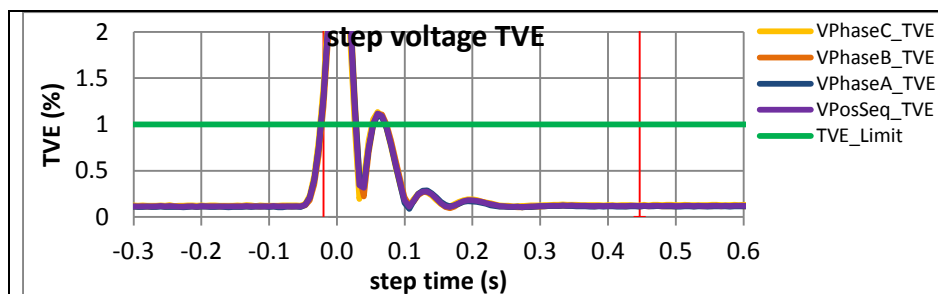


Figure 5119:  $F_s = 15$  FPS, +10% magnitude step

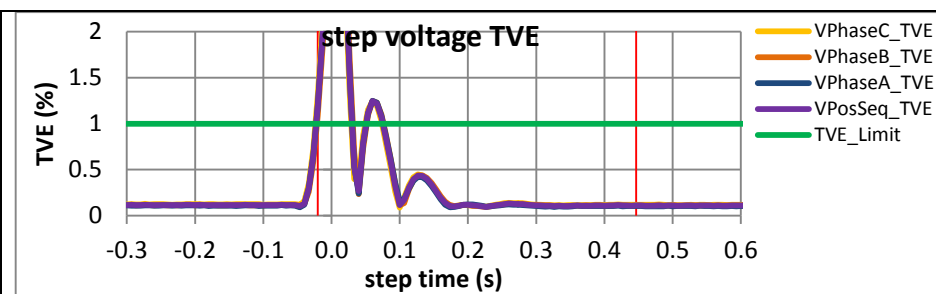


Figure 5120:  $F_s = 15$  FPS, -10% magnitude step

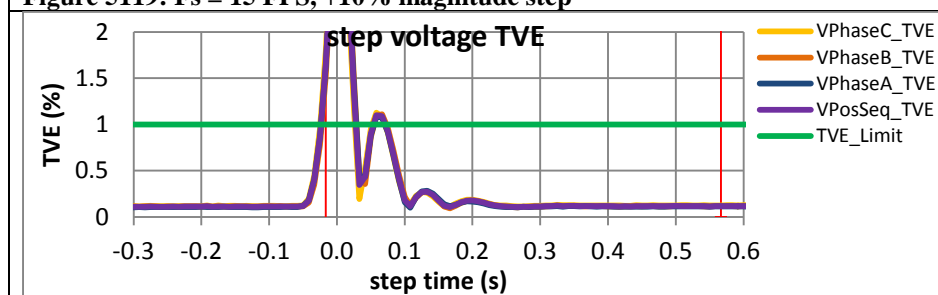


Figure 5121:  $F_s = 12$  FPS, +10% magnitude step

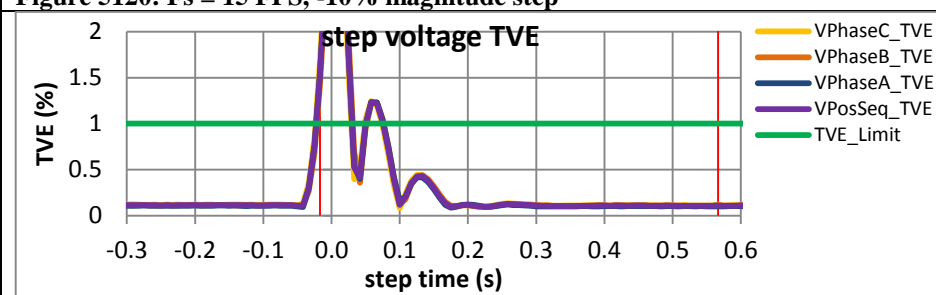


Figure 5122:  $F_s = 12$  FPS, -10% magnitude step

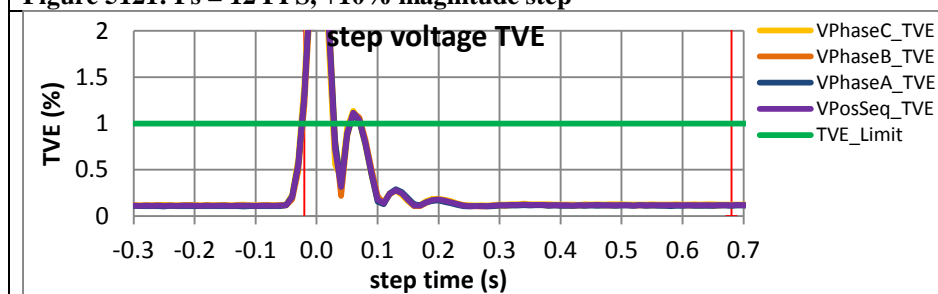


Figure 5123:  $F_s = 10$  FPS, +10% magnitude step

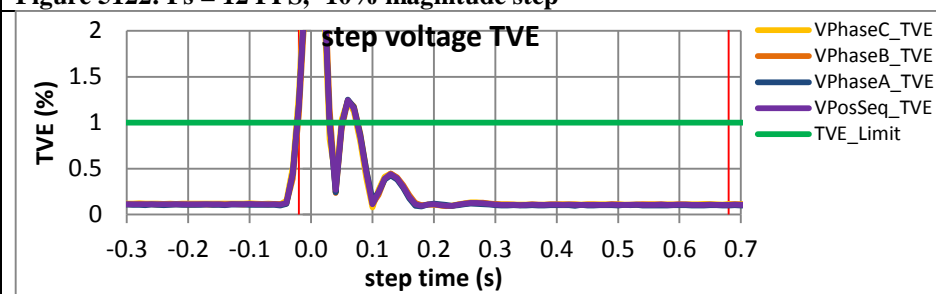


Figure 5124:  $F_s = 10$  FPS, +10% magnitude step

#### 10.2.4 PMU C dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class

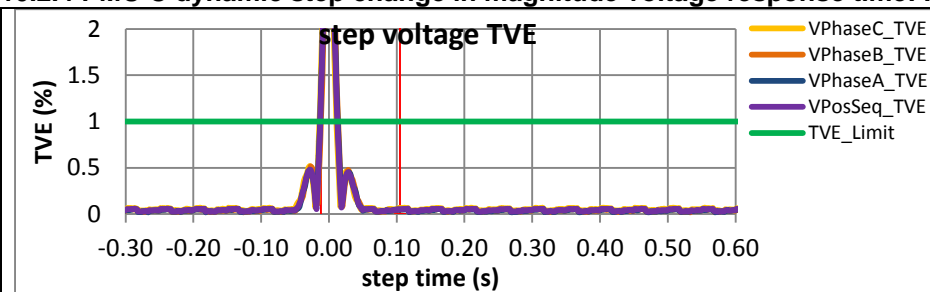


Figure 5125: Fs = 60 FPS, +10% magnitude step

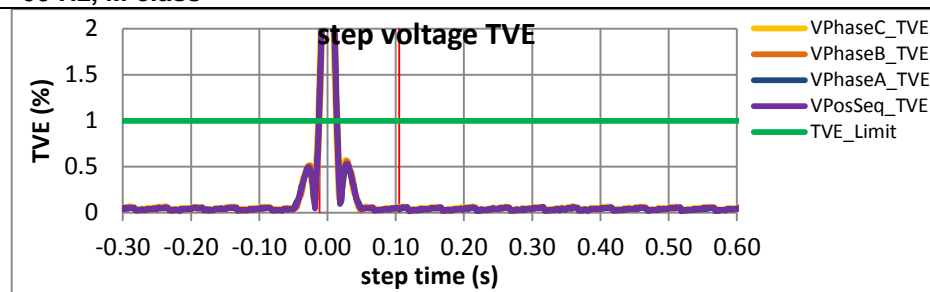


Figure 5126: Fs = 60 FPS, -10% magnitude step

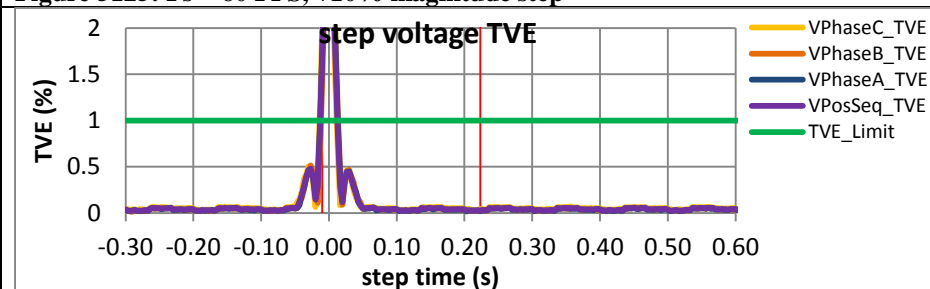


Figure 5127: Fs = 30 FPS, +10% magnitude step

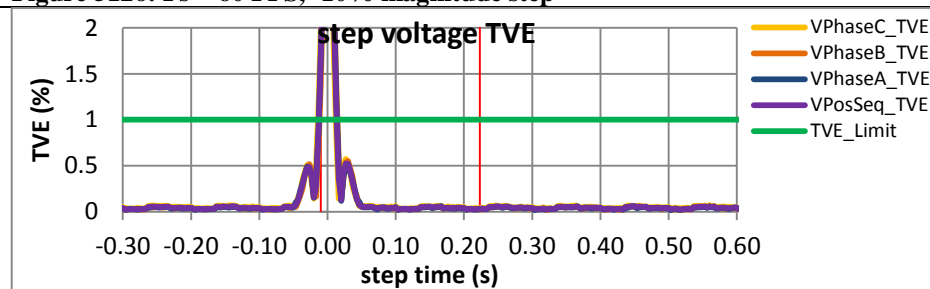


Figure 5128: Fs = 30 FPS, -10% magnitude step

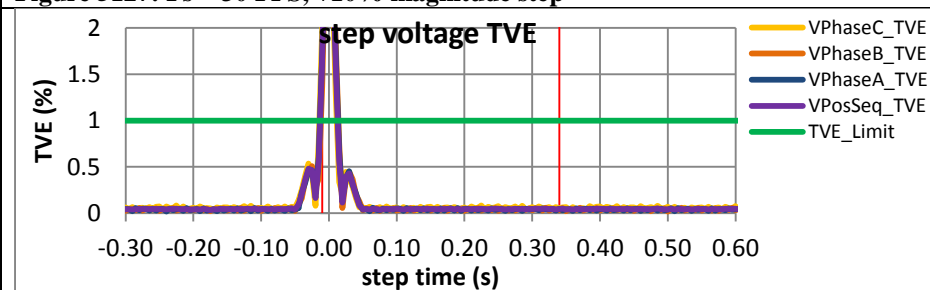


Figure 5129: Fs = 20 FPS, +10% magnitude step

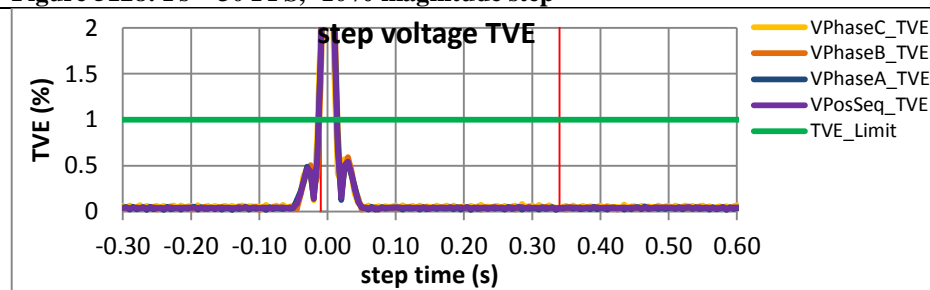


Figure 5130: Fs = 20 FPS, -10% magnitude step



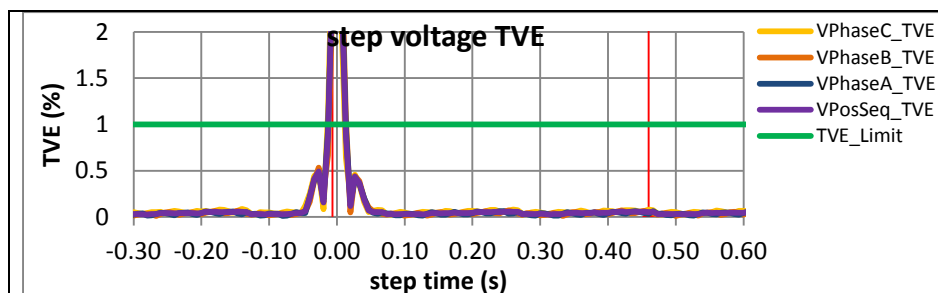


Figure 5131:  $F_s = 15$  FPS, +10% magnitude step

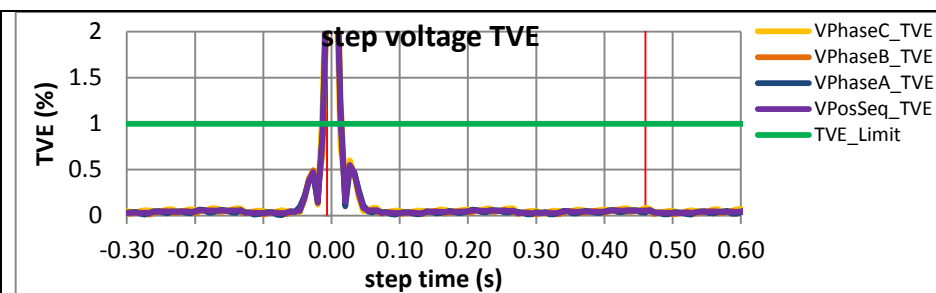


Figure 5132:  $F_s = 15$  FPS, -10% magnitude step

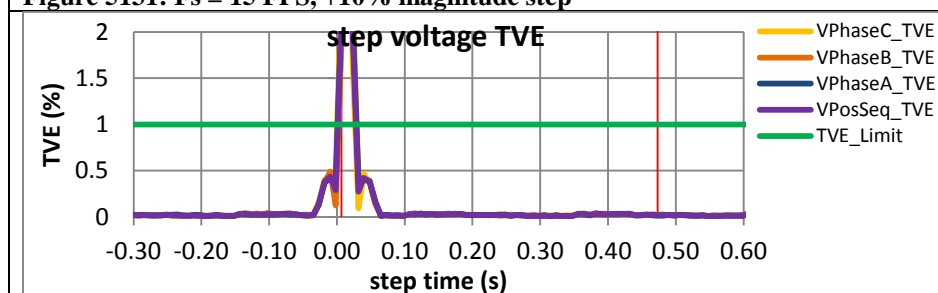


Figure 5133:  $F_s = 12$  FPS, +10% magnitude step

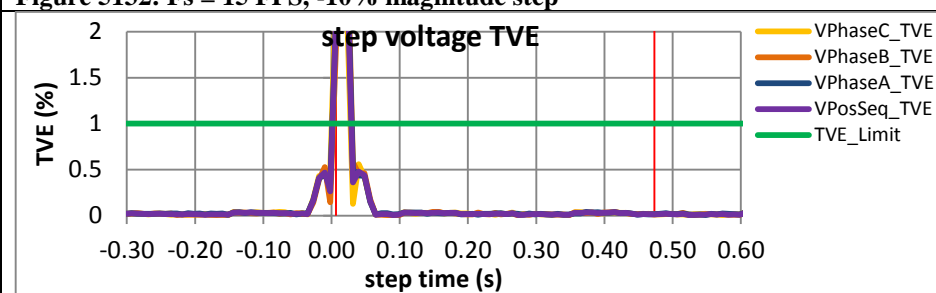


Figure 5134:  $F_s = 12$  FPS, -10% magnitude step

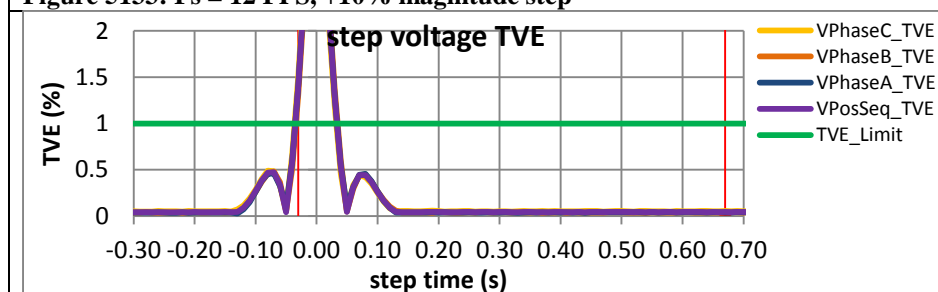


Figure 5135:  $F_s = 10$  FPS, +10% magnitude step

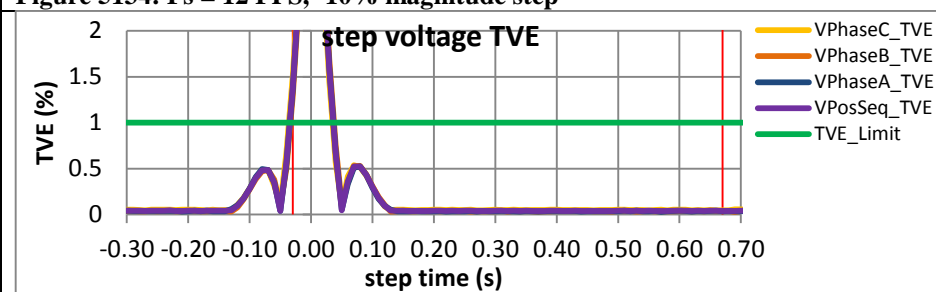


Figure 5136:  $F_s = 10$  FPS, -10% magnitude step

### 10.2.5 PMU D dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class

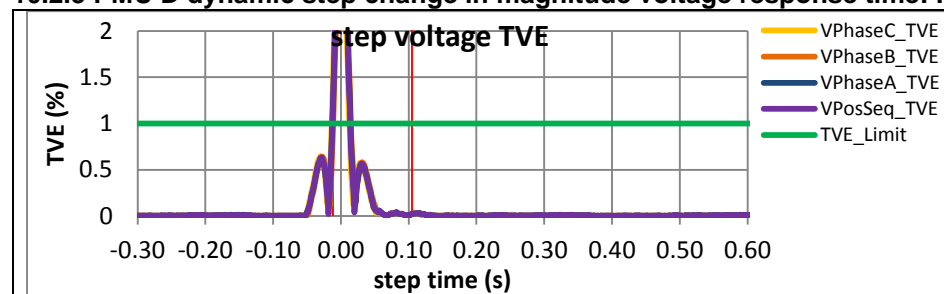


Figure 5137: Fs = 60 FPS, +10% magnitude step

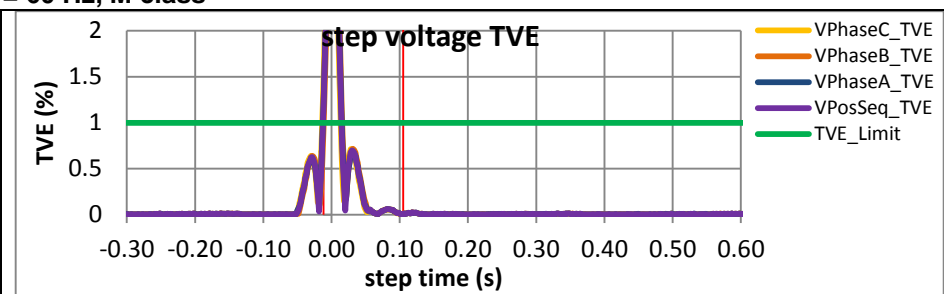


Figure 5138: Fs = 60 FPS, -10% magnitude step

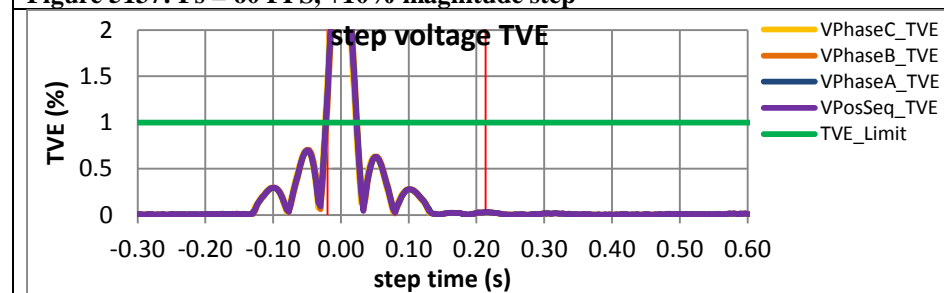


Figure 5139: Fs = 30 FPS, +10% magnitude step

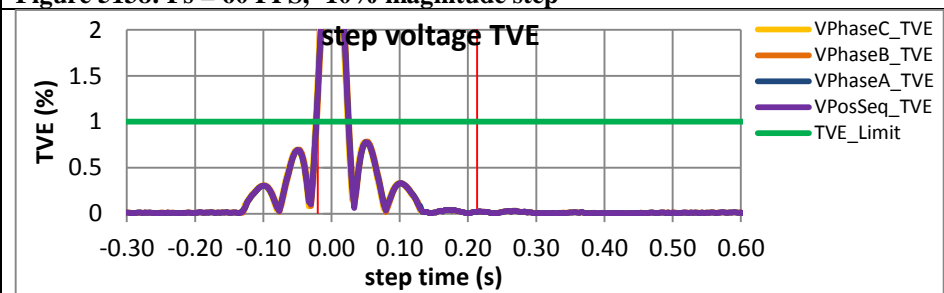


Figure 5140: Fs = 30 FPS, -10% magnitude step

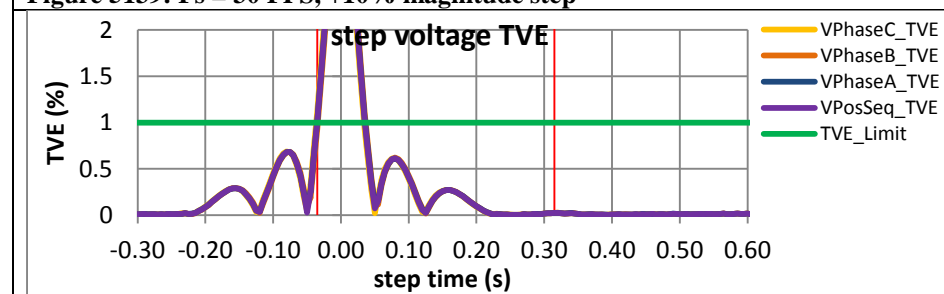


Figure 5141: Fs = 20 FPS, +10% magnitude step

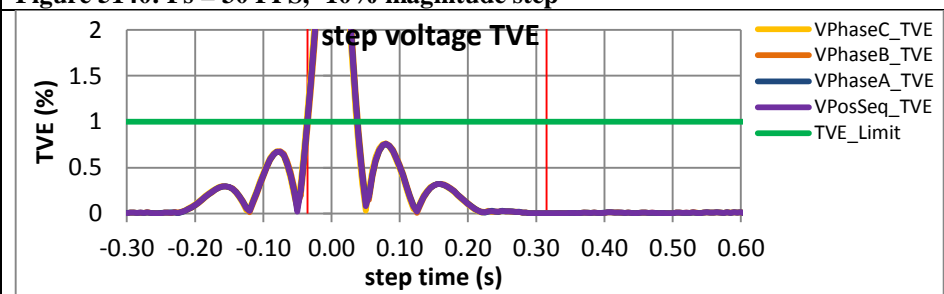


Figure 5142: Fs = 20 FPS, -10% magnitude step

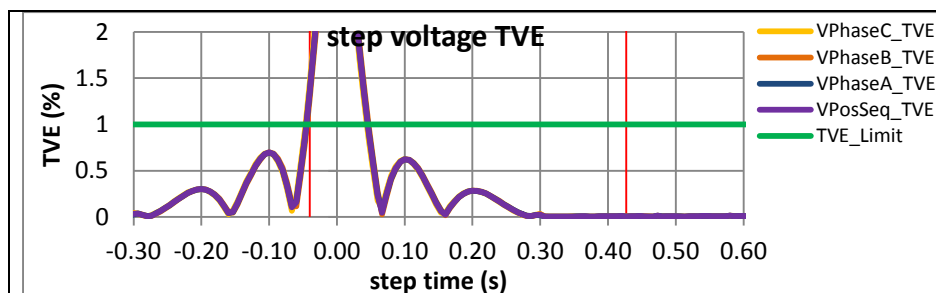


Figure 5143:  $F_s = 15$  FPS, +10% magnitude step

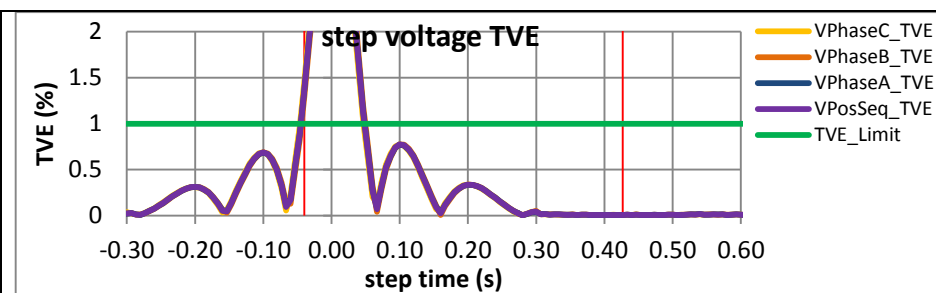


Figure 5144:  $F_s = 15$  FPS, -10% magnitude step

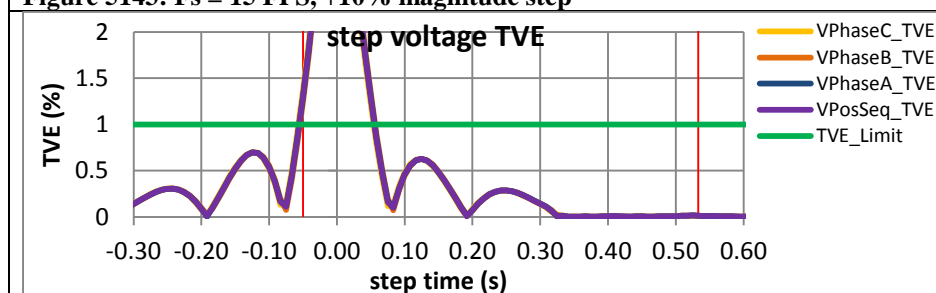


Figure 5145:  $F_s = 12$  FPS, +10% magnitude step

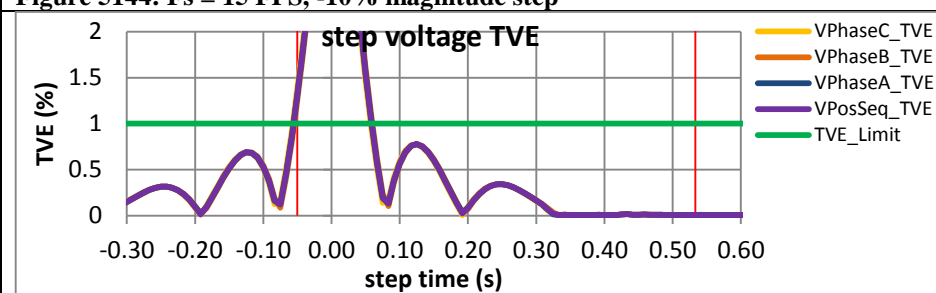


Figure 5146:  $F_s = 12$  FPS, -10% magnitude step

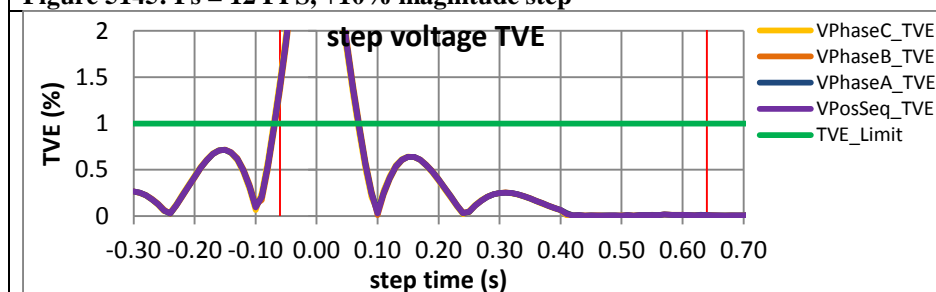


Figure 5147:  $F_s = 10$  FPS, +10% magnitude step

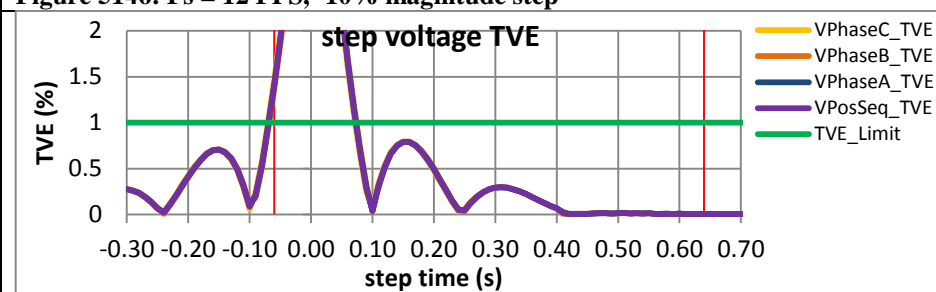


Figure 5148:  $F_s = 10$  FPS, -10% magnitude step

### 10.2.6 PMU E dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class

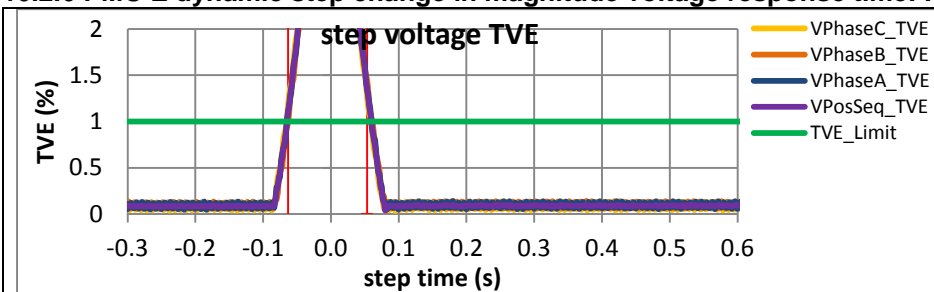


Figure 5149: Fs = 60 FPS, +10% magnitude step

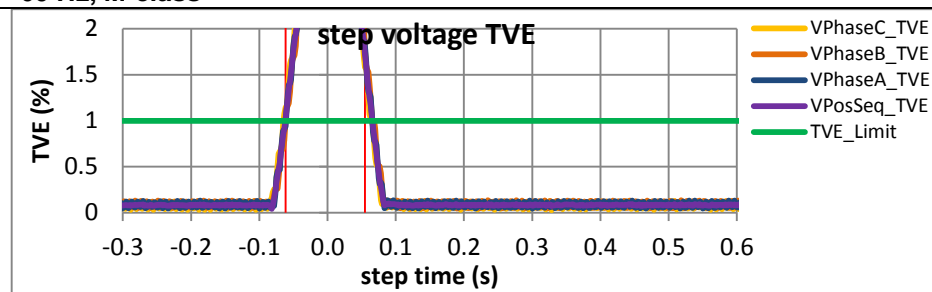


Figure 5150: Fs = 60 FPS, -10% magnitude step

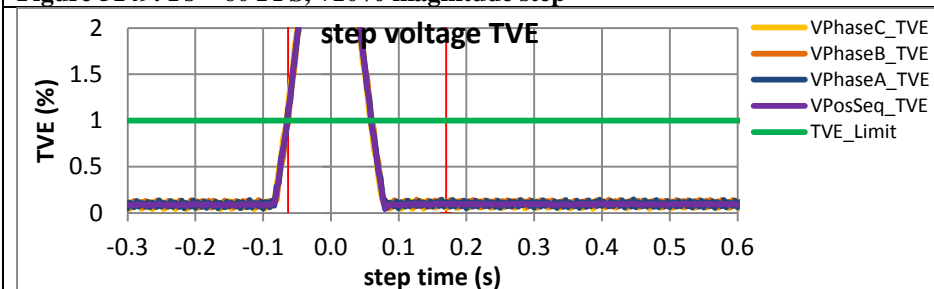


Figure 5151: Fs = 30 FPS, +10% magnitude step

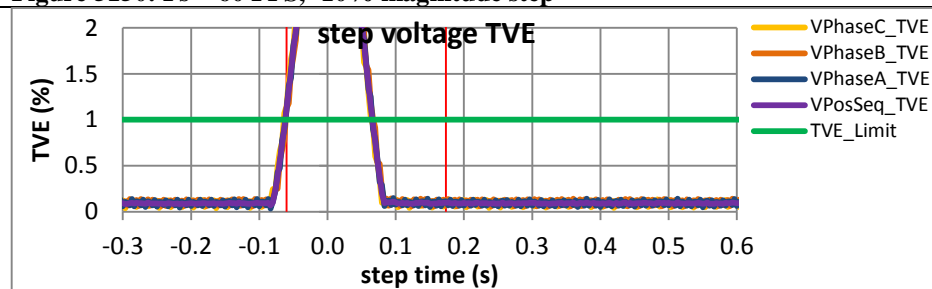


Figure 5152: Fs = 30 FPS, -10% magnitude step

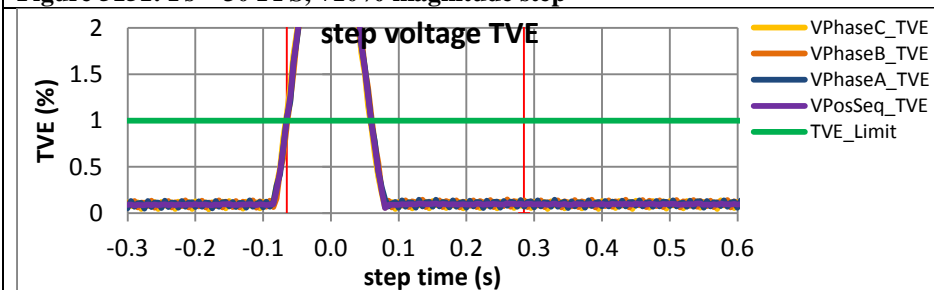


Figure 5153: Fs = 20 FPS, +10% magnitude step

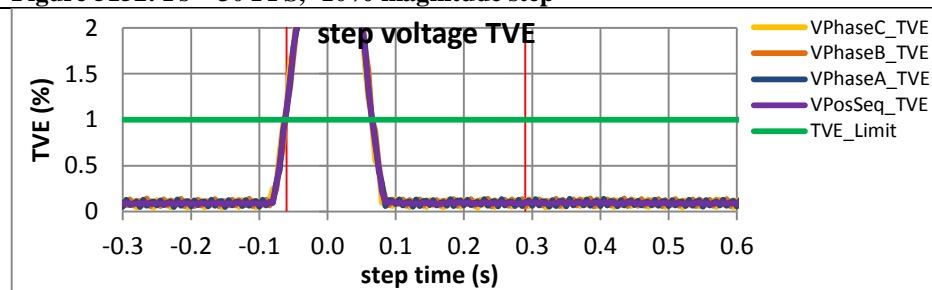


Figure 5154: Fs = 20 FPS, -10% magnitude step

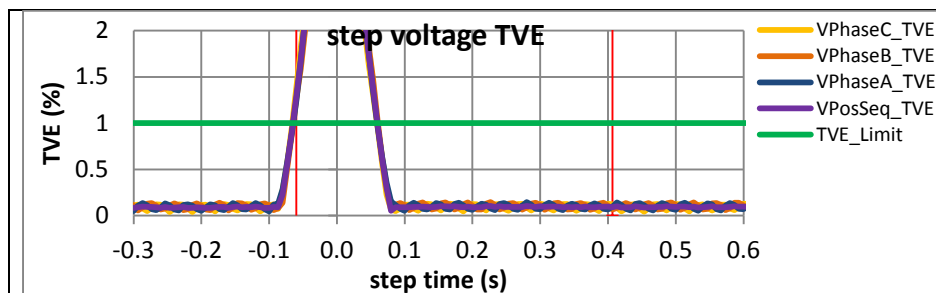


Figure 5155:  $F_s = 15$  FPS, +10% magnitude step

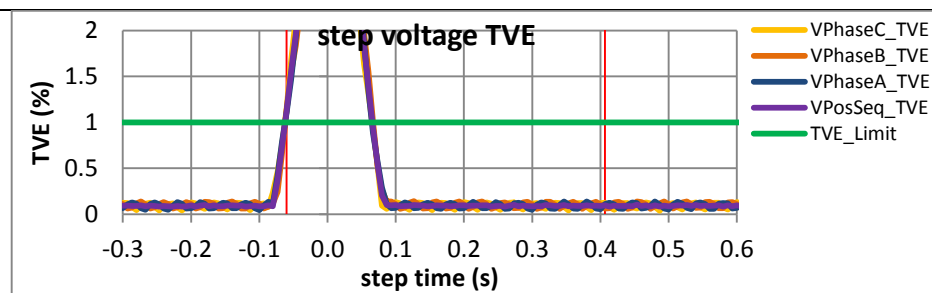


Figure 5156:  $F_s = 15$  FPS, -10% magnitude step

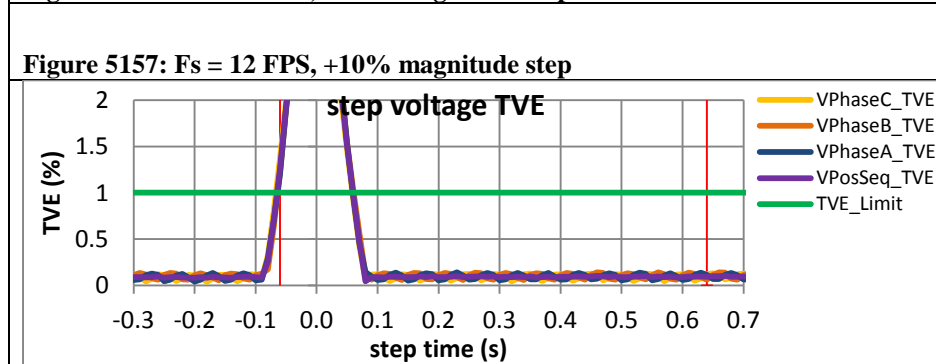


Figure 5157:  $F_s = 12$  FPS, +10% magnitude step

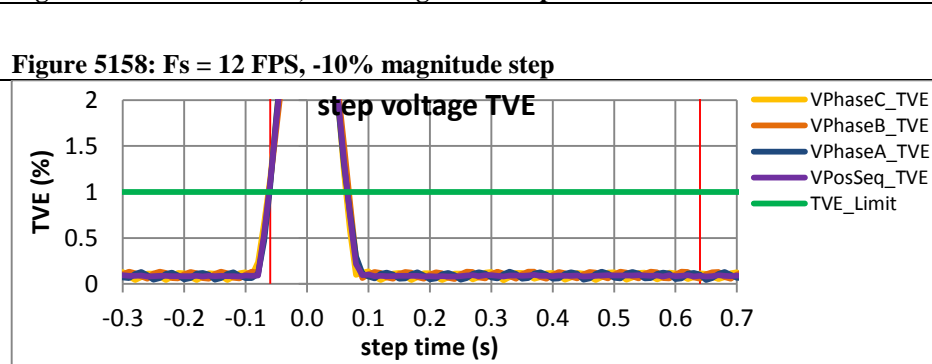


Figure 5158:  $F_s = 12$  FPS, -10% magnitude step

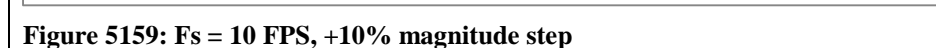


Figure 5159:  $F_s = 10$  FPS, +10% magnitude step

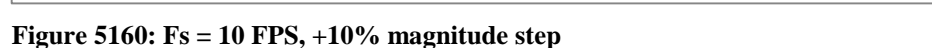
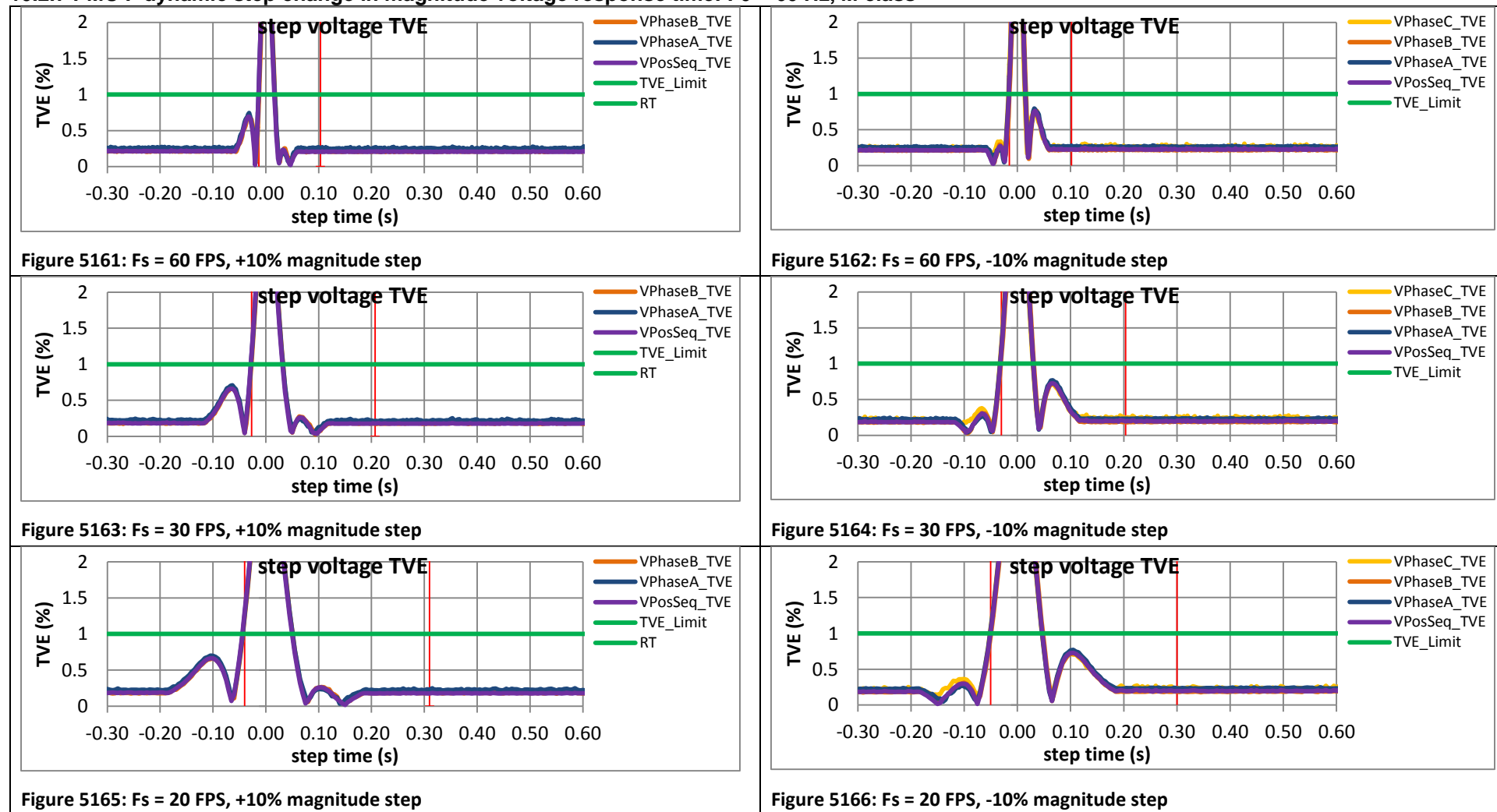


Figure 5160:  $F_s = 10$  FPS, -10% magnitude step

### 10.2.7 PMU F dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class



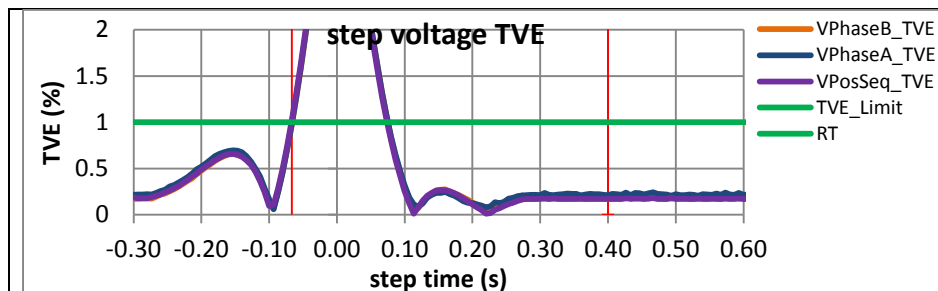


Figure 5167: Fs = 15 FPS, +10% magnitude step

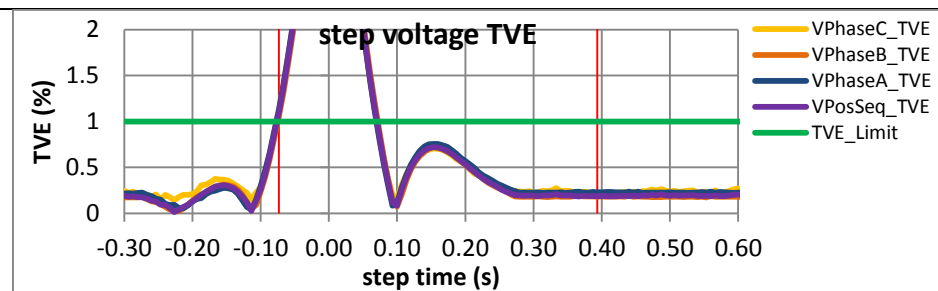


Figure 5168: Fs = 15 FPS, -10% magnitude step

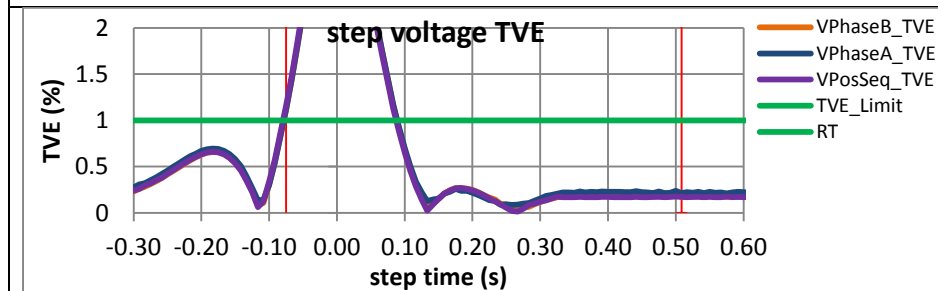


Figure 5169: Fs = 12 FPS, +10% magnitude step

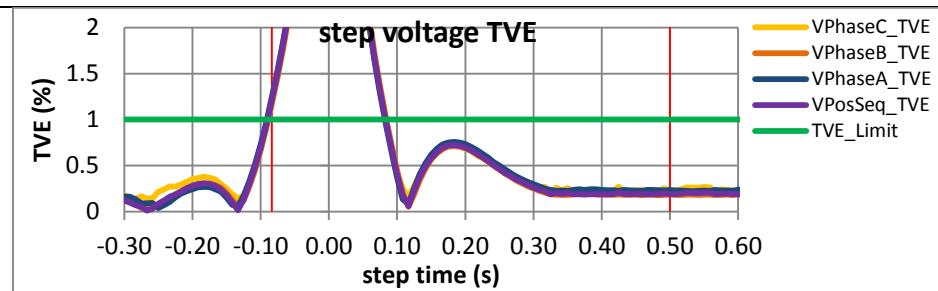


Figure 5170: Fs = 12 FPS, -10% magnitude step

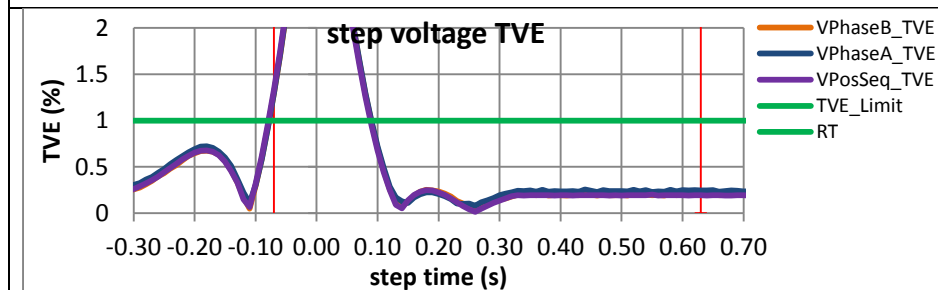


Figure 5171: Fs = 10 FPS, +10% magnitude step

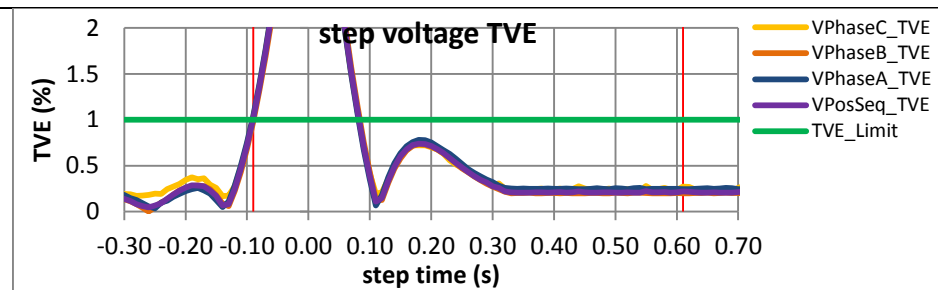
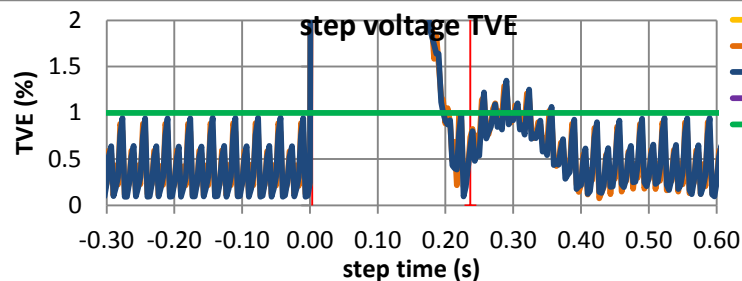


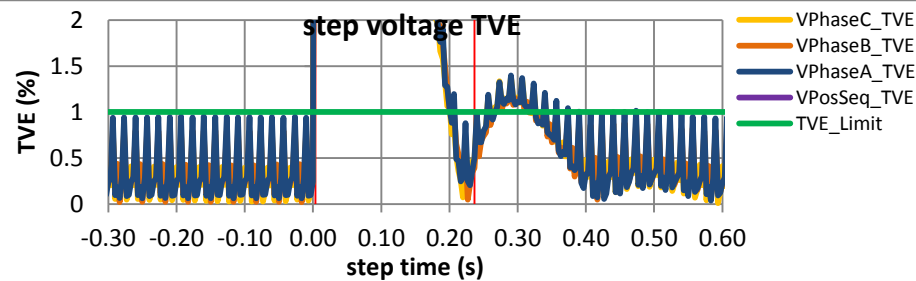
Figure 5172: Fs = 10 FPS, +10% magnitude step

## 10.2.8 PMU G dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class

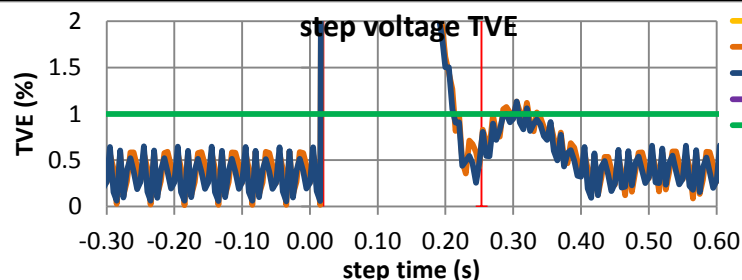
**Figure 5173: Fs = 60 FPS, +10% magnitude step**



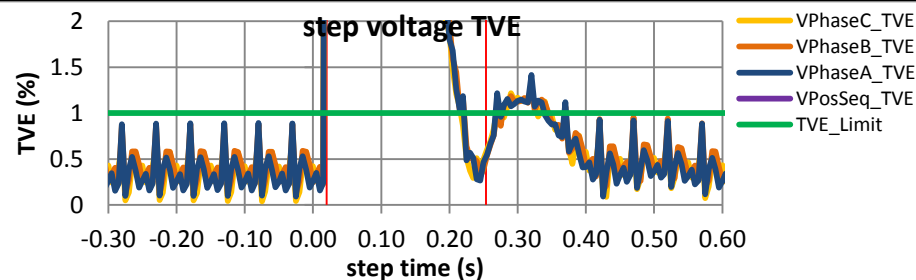
**Figure 5174: Fs = 60 FPS, -10% magnitude step**



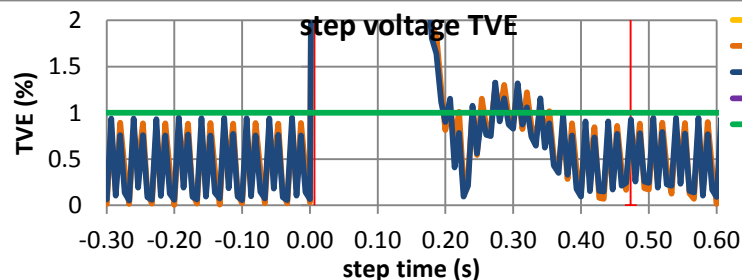
**Figure 5175: Fs = 30 FPS, +10% magnitude step**



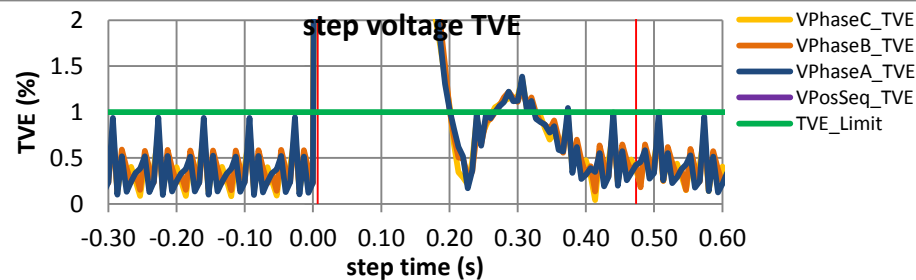
**Figure 5176: Fs = 30 FPS, -10% magnitude step**



**Figure 5177: Fs = 20 FPS, +10% magnitude step**



**Figure 5178: Fs = 20 FPS, -10% magnitude step**



**Figure 5179: Fs = 15 FPS, +10% magnitude step**



**Figure 5180: Fs = 15 FPS, -10% magnitude step**





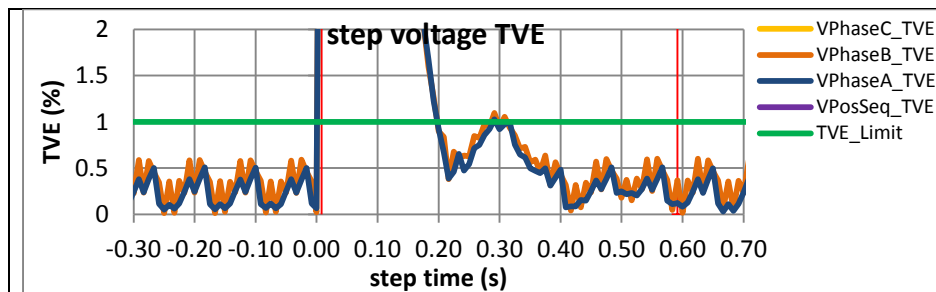


Figure 5181: Fs = 12 FPS, +10 degree magnitude step

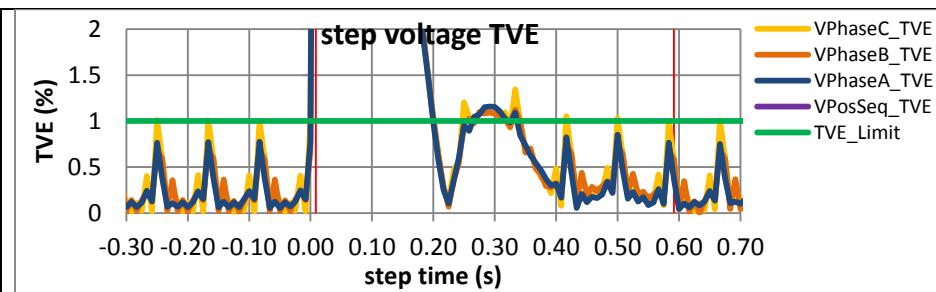


Figure 5182: Fs = 12 FPS, -10 degree magnitude step

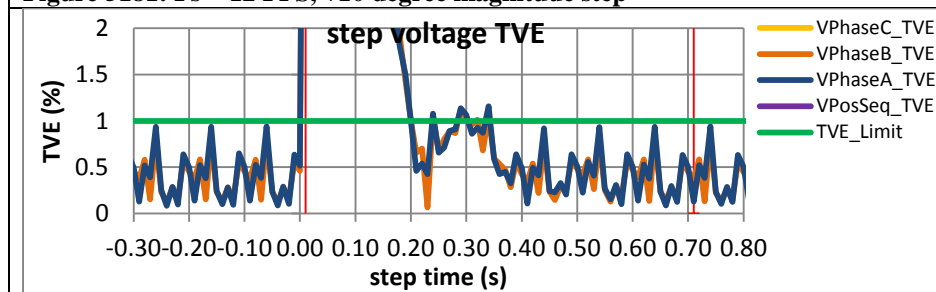


Figure 5183: Fs = 10 FPS, +10% magnitude step

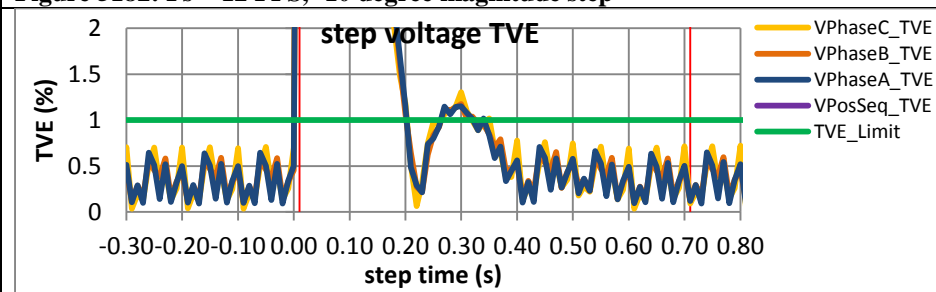


Figure 5184: Fs = 10 FPS, +10% magnitude step

### 10.2.9 PMU H dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class

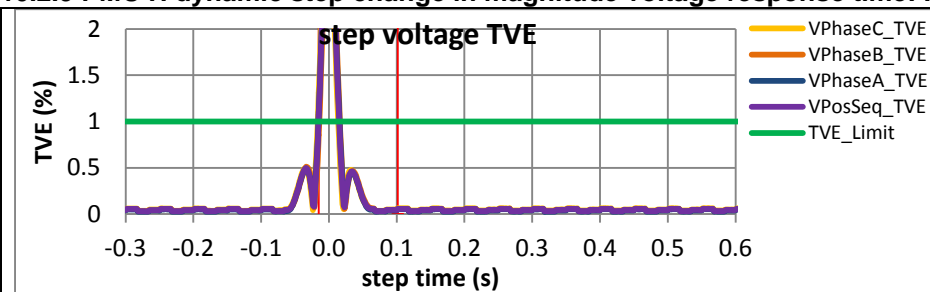


Figure 5185: Fs = 60 FPS, +10% magnitude step

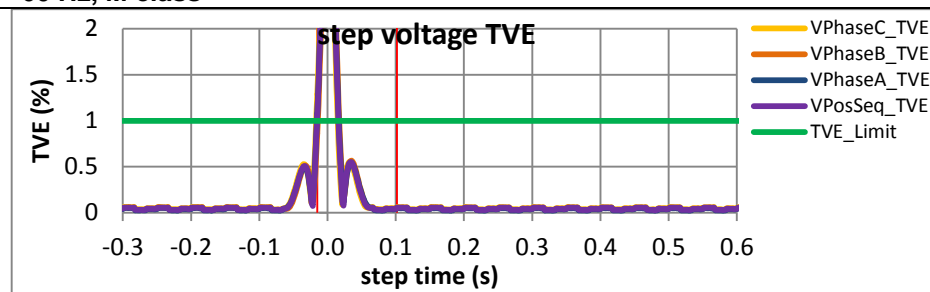


Figure 5186: Fs = 60 FPS, -10% magnitude step

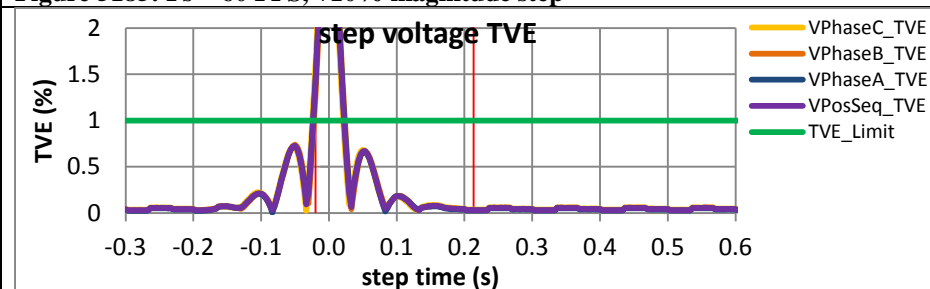


Figure 5187: Fs = 30 FPS, +10% magnitude step

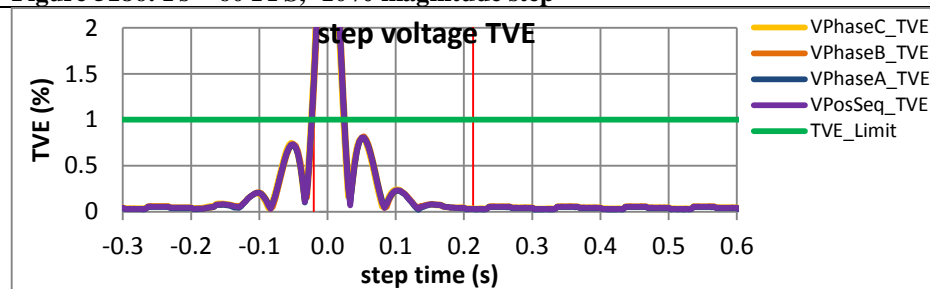


Figure 5188: Fs = 30 FPS, -10% magnitude step

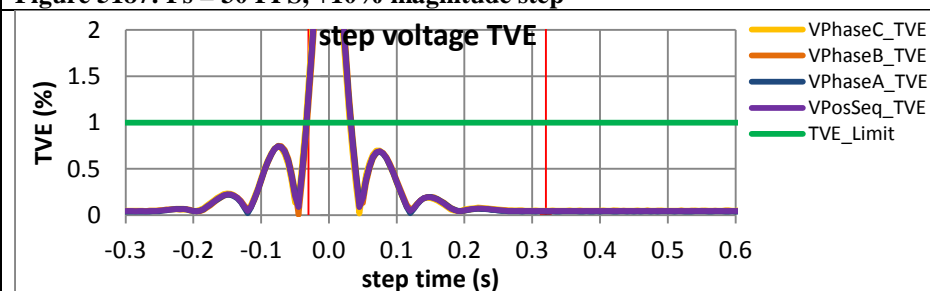


Figure 5189: Fs = 20 FPS, +10% magnitude step

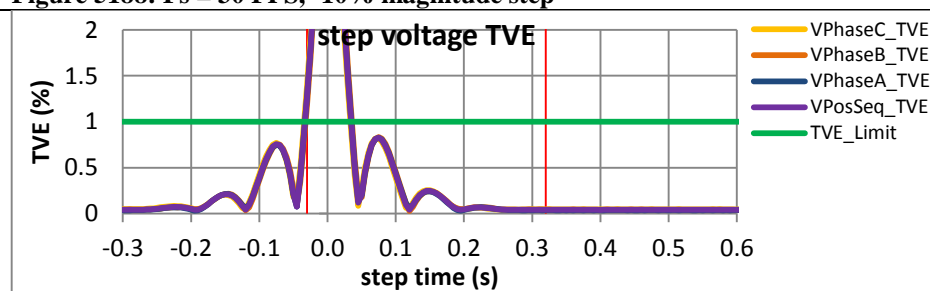


Figure 5190: Fs = 20 FPS, -10% magnitude step

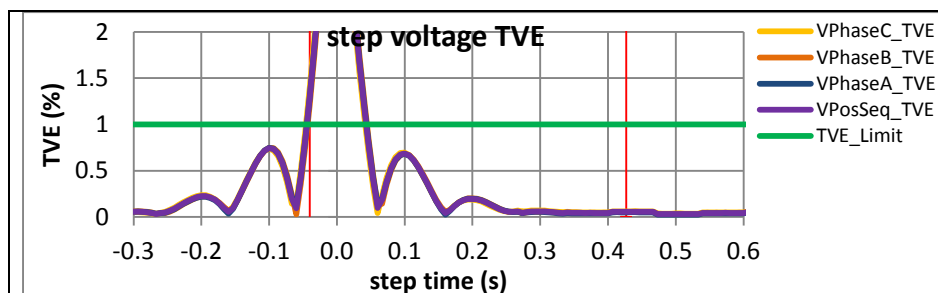


Figure 5191:  $F_s = 15$  FPS, +10% magnitude step

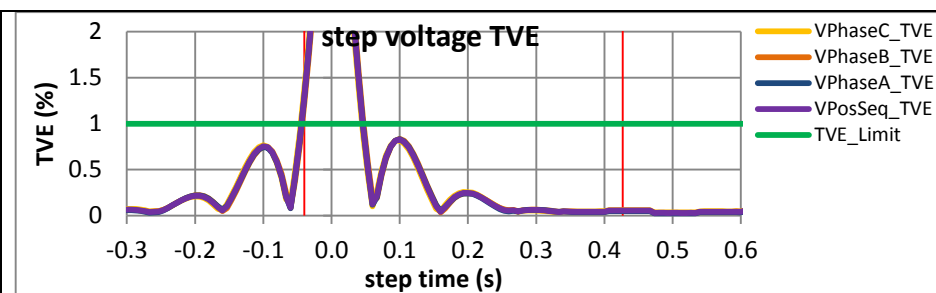


Figure 5192:  $F_s = 15$  FPS, -10% magnitude step

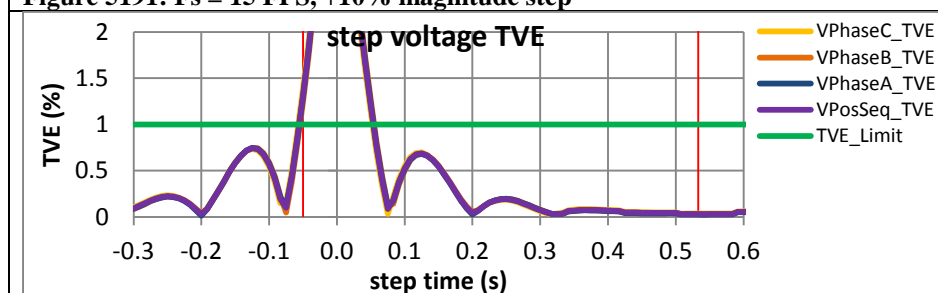


Figure 5193:  $F_s = 12$  FPS, +10% magnitude step

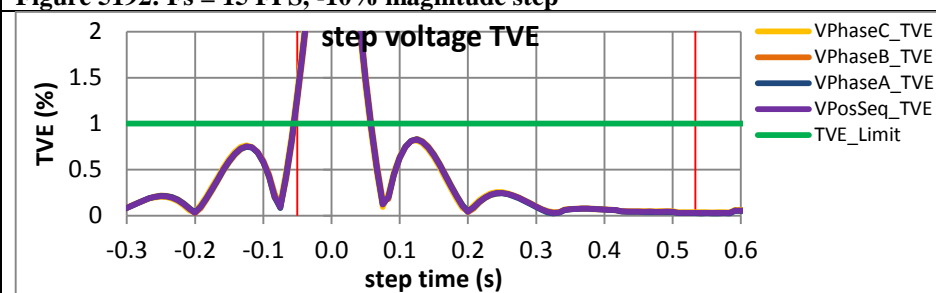


Figure 5194:  $F_s = 12$  FPS, -10% magnitude step

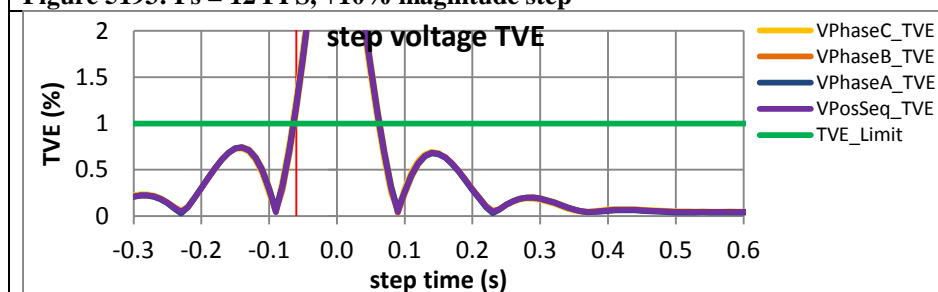


Figure 5195:  $F_s = 10$  FPS, +10% magnitude step

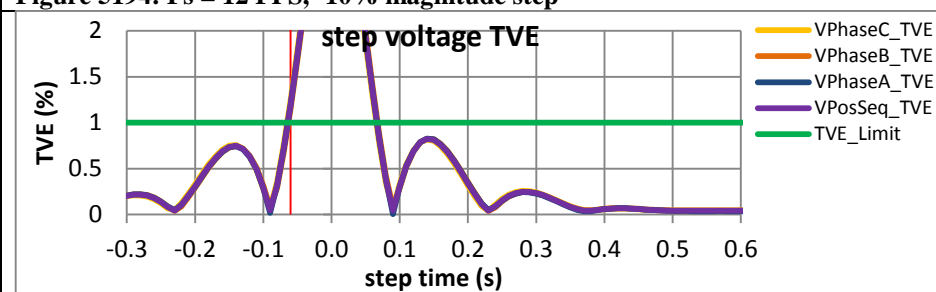


Figure 5196:  $F_s = 10$  FPS, -10% magnitude step

# 10.2.10 PMU I dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class

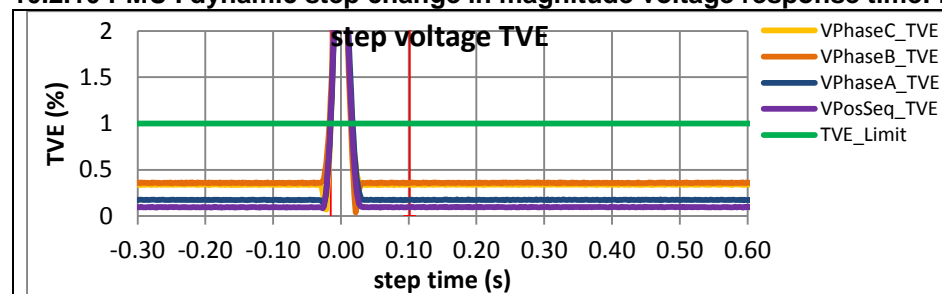


Figure 5197: Fs = 60 FPS, +10% magnitude step

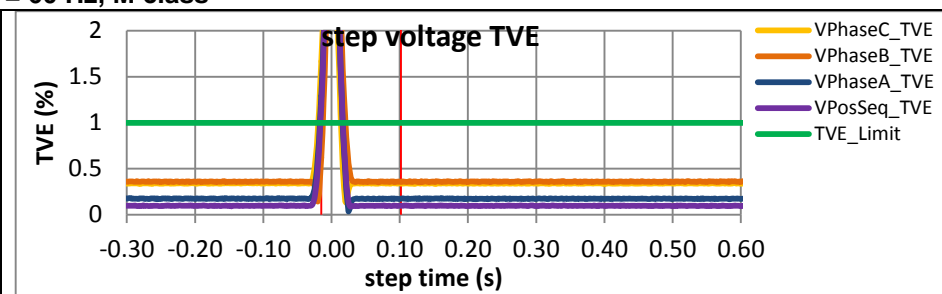


Figure 5198: Fs = 60 FPS, -10% magnitude step

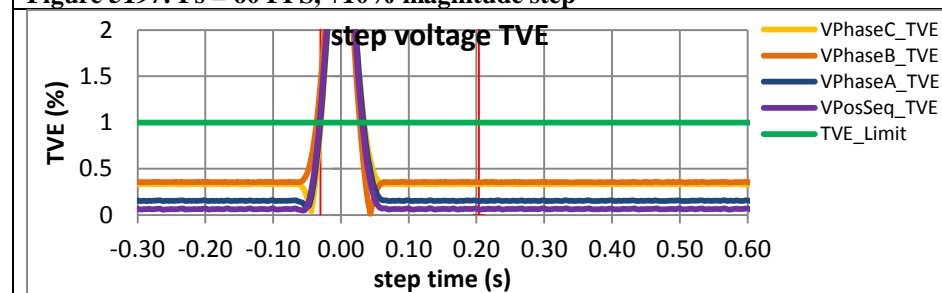


Figure 5199: Fs = 30 FPS, +10% magnitude step

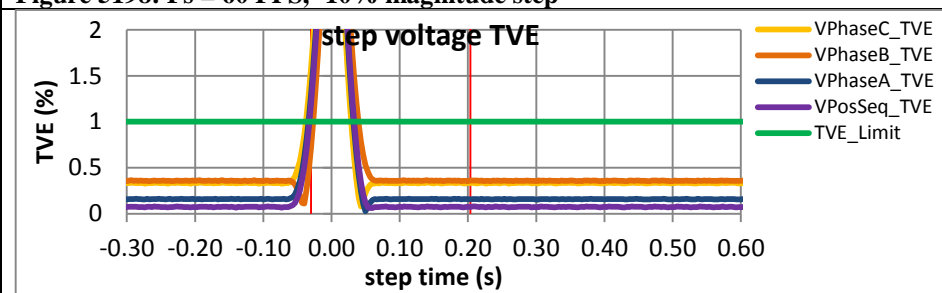


Figure 5200: Fs = 30 FPS, -10% magnitude step

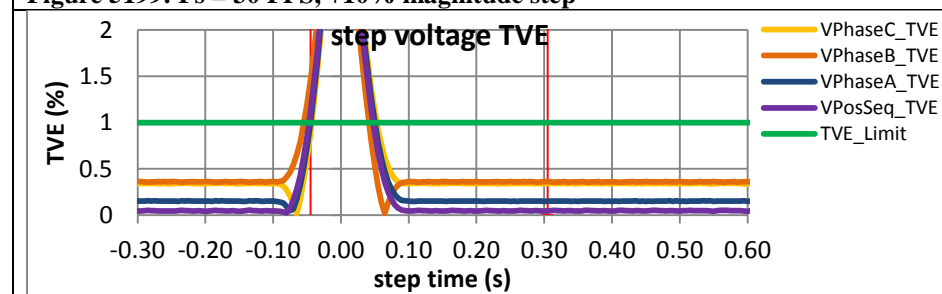


Figure 5201: Fs = 20 FPS, +10% magnitude step

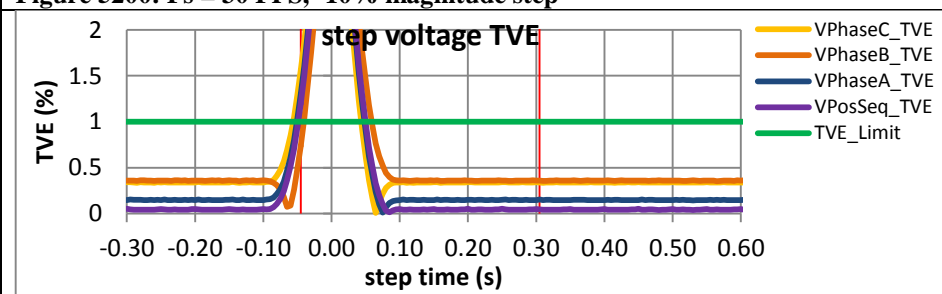


Figure 5202: Fs = 20 FPS, -10% magnitude step

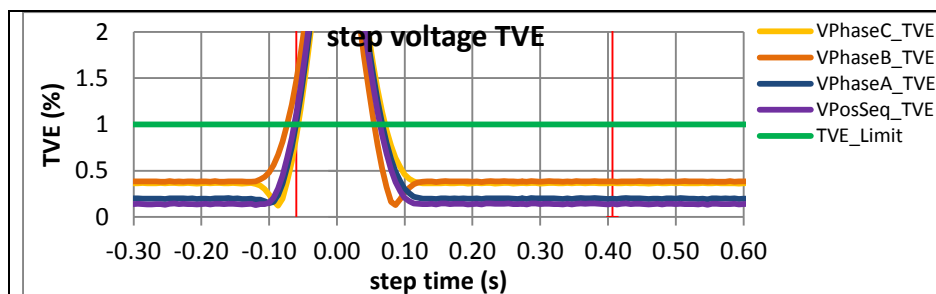


Figure 5203:  $F_s = 15$  FPS, +10% magnitude step

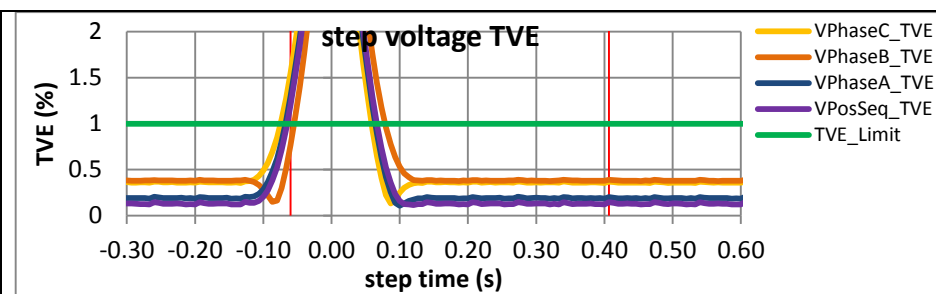


Figure 5204:  $F_s = 15$  FPS, -10% magnitude step

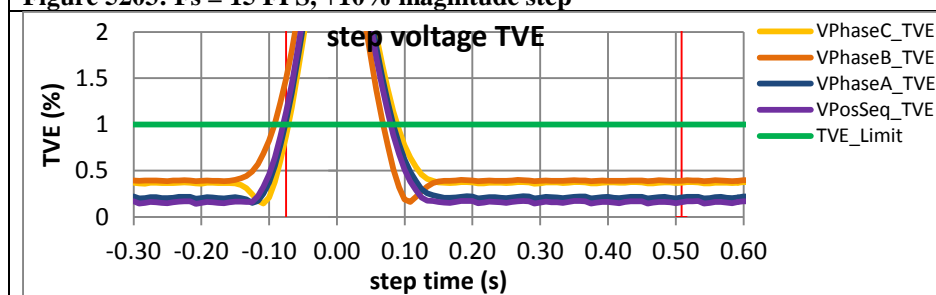


Figure 5205:  $F_s = 12$  FPS, +10% magnitude step

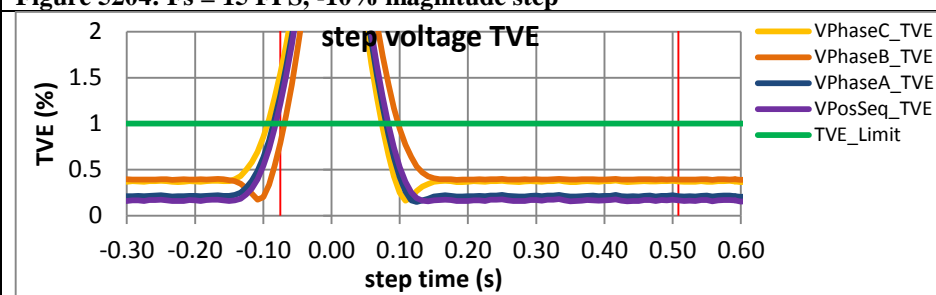


Figure 5206:  $F_s = 12$  FPS, -10% magnitude step

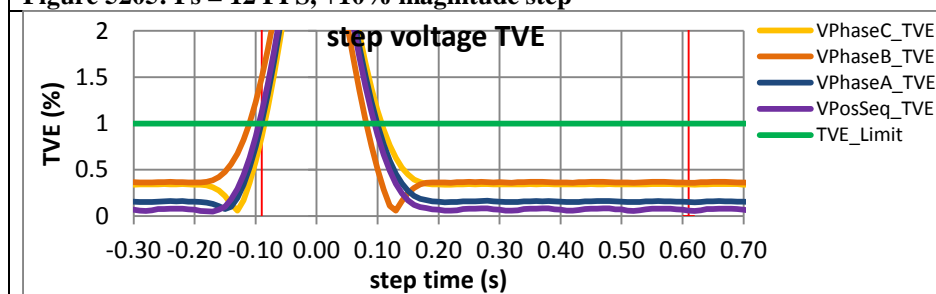


Figure 5207:  $F_s = 10$  FPS, +10% magnitude step

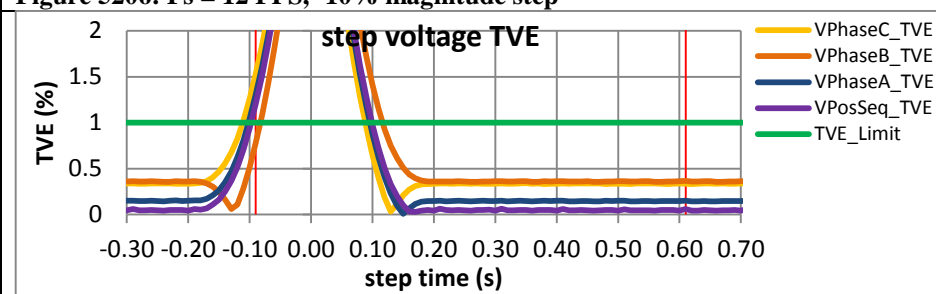


Figure 5208:  $F_s = 10$  FPS, -10% magnitude step

### 10.2.11 PMU J dynamic step change in magnitude voltage response time: F0 = 60 Hz, M class

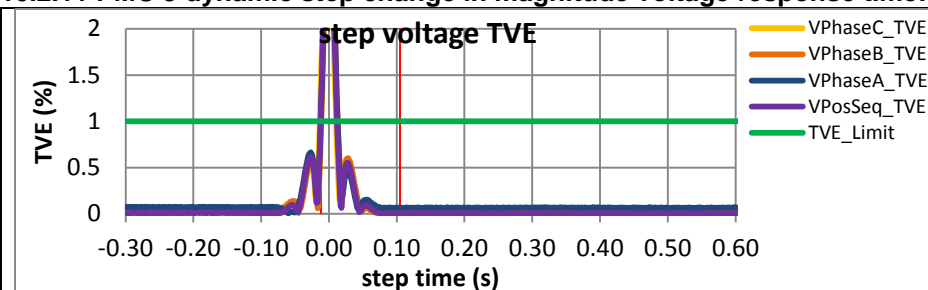


Figure 5209: Fs = 60 FPS, +10% magnitude step

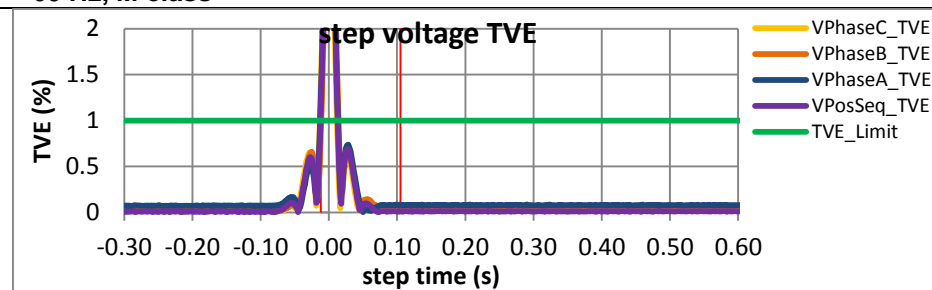


Figure 5210: Fs = 60 FPS, -10% magnitude step

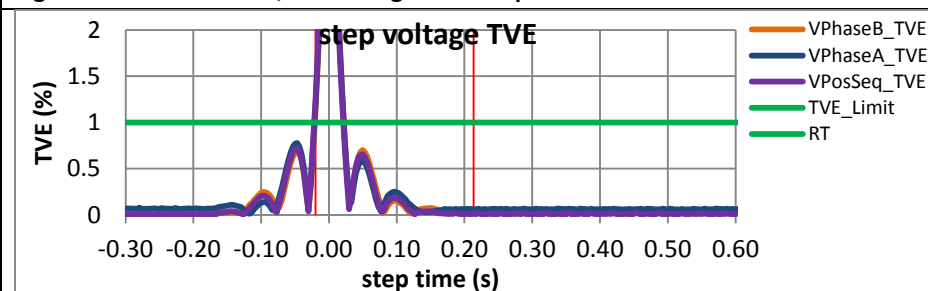


Figure 5211: Fs = 30 FPS, +10% magnitude step

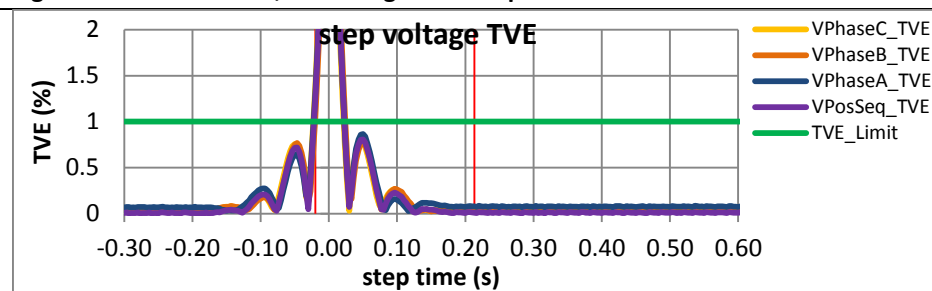


Figure 5212: Fs = 30 FPS, -10% magnitude step

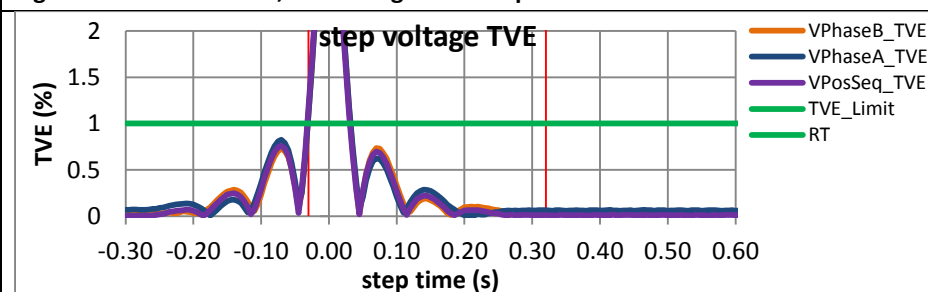


Figure 5213: Fs = 20 FPS, +10% magnitude step

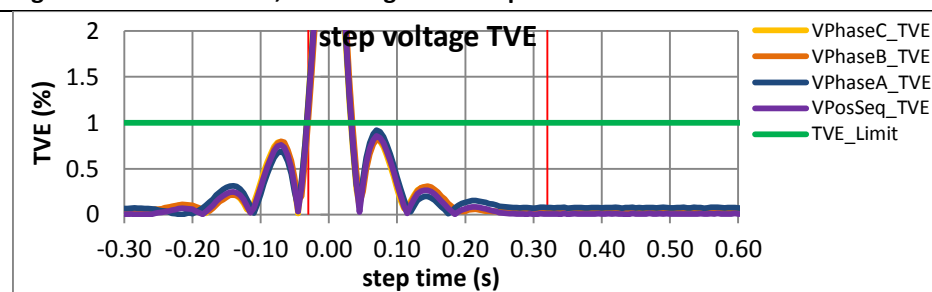


Figure 5214: Fs = 20 FPS, -10% magnitude step

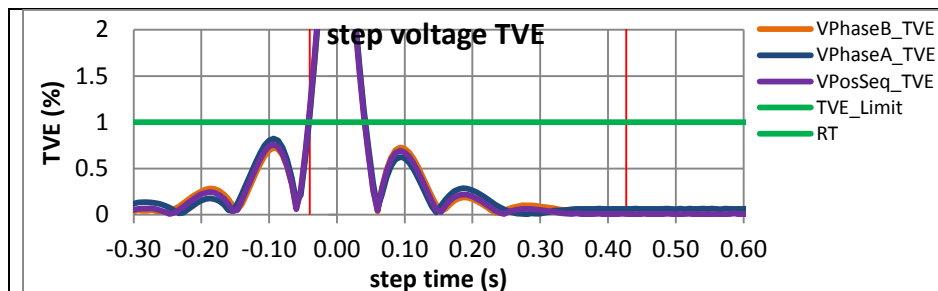


Figure 5215: Fs = 15 FPS, +10% magnitude step

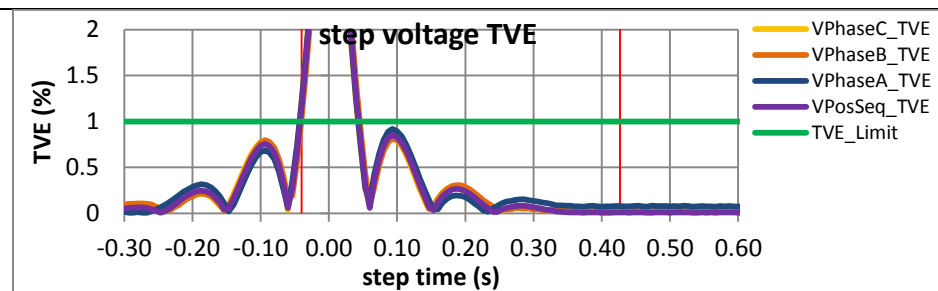


Figure 5216: Fs = 15 FPS, -10% magnitude step

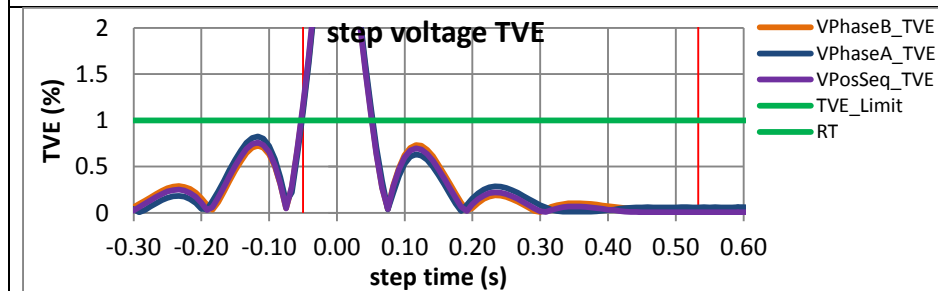


Figure 5217: Fs = 12 FPS, +10% magnitude step

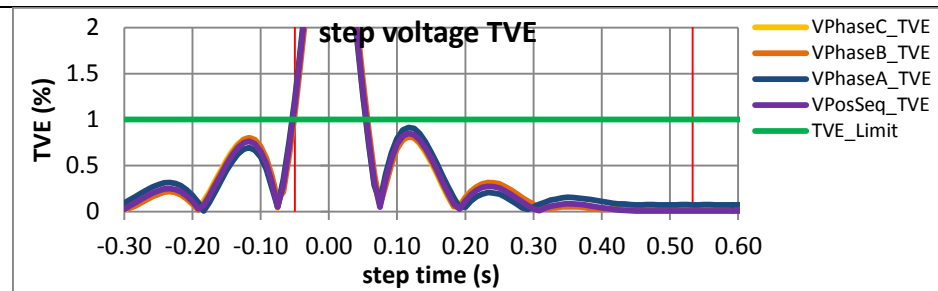


Figure 5218: Fs = 12 FPS, -10% magnitude step

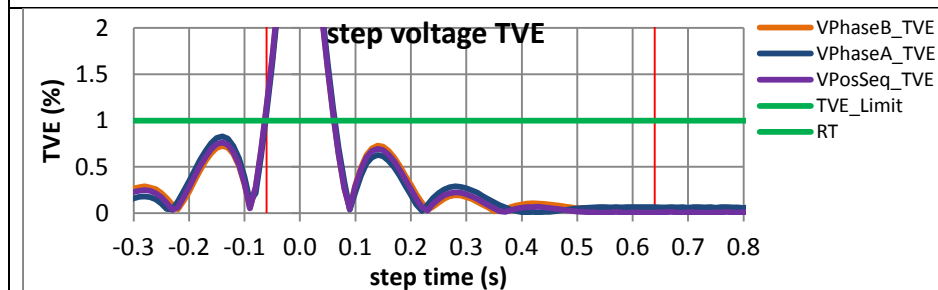


Figure 5219: Fs = 10 FPS, +10% magnitude step

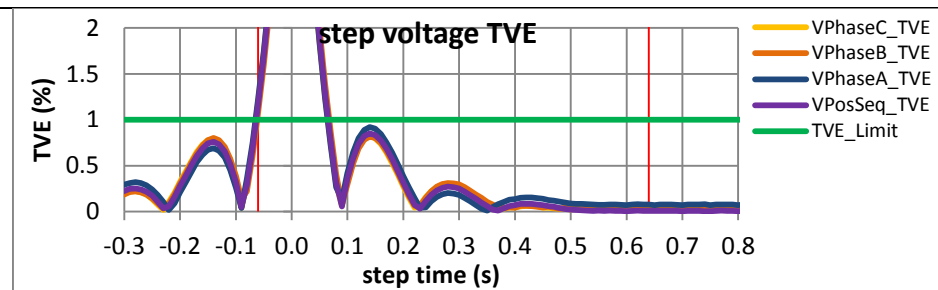


Figure 5220: Fs = 10 FPS, +10% magnitude step

### 10.3 Dynamic step change in magnitude current response time: F0 = 60 Hz, M class

#### 10.3.1 C37.118.1-2011 Annex C dynamic step change in magnitude current response time: F0 = 60 Hz, M class

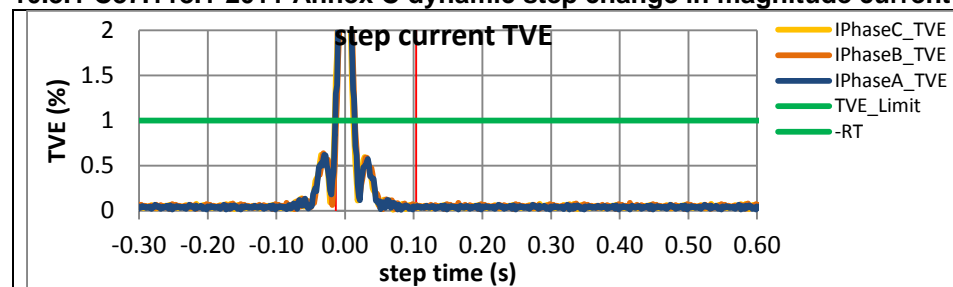


Figure 5221: Fs = 60 FPS, +10% magnitude step

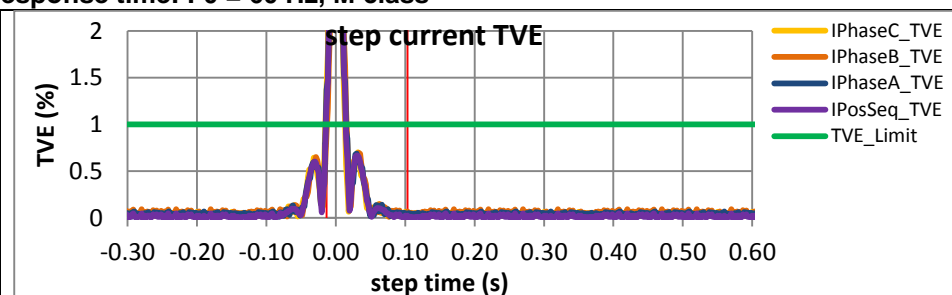


Figure 5222: Fs = 60 FPS, -10% magnitude step

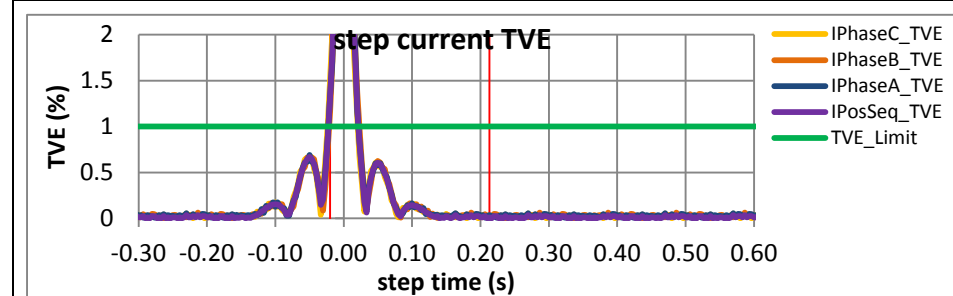


Figure 5223: Fs = 30 FPS, +10% magnitude step

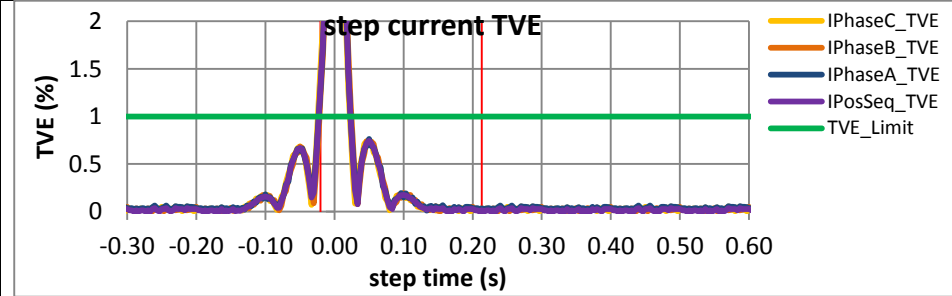


Figure 5224: Fs = 30 FPS, -10% magnitude step



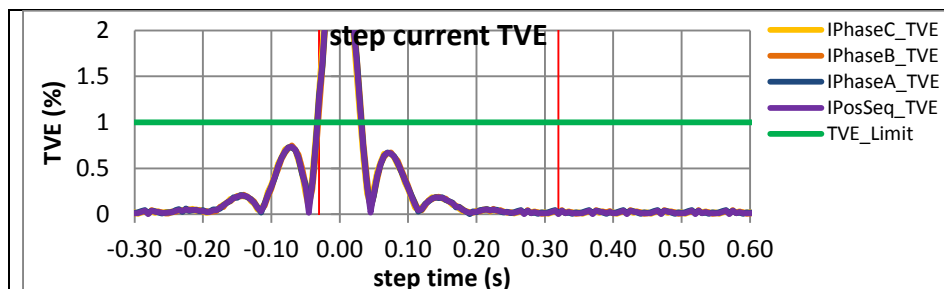


Figure 5225:  $F_s = 20$  FPS, +10% magnitude step

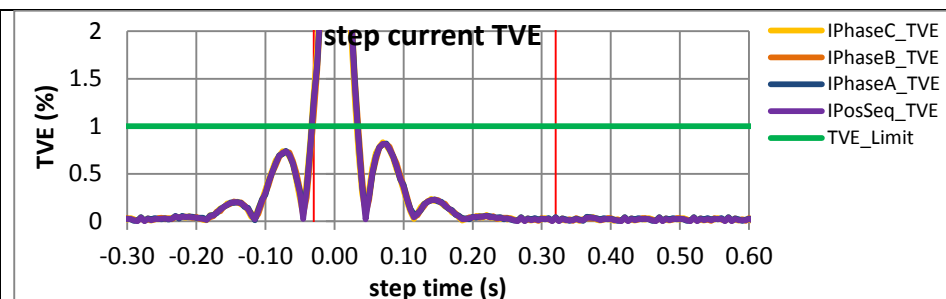


Figure 5226:  $F_s = 20$  FPS, +10% magnitude step

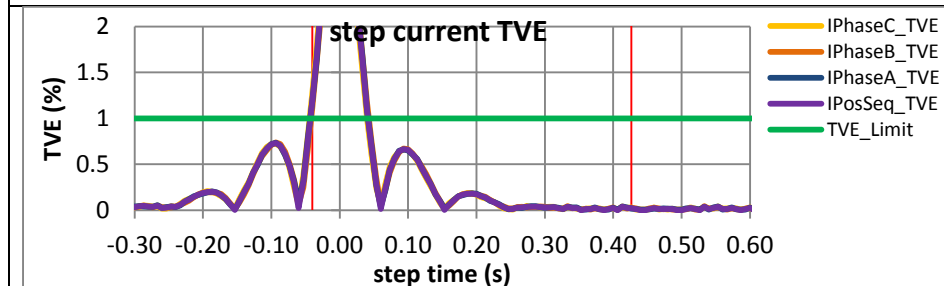


Figure 5227:  $F_s = 15$  FPS, +10% magnitude step

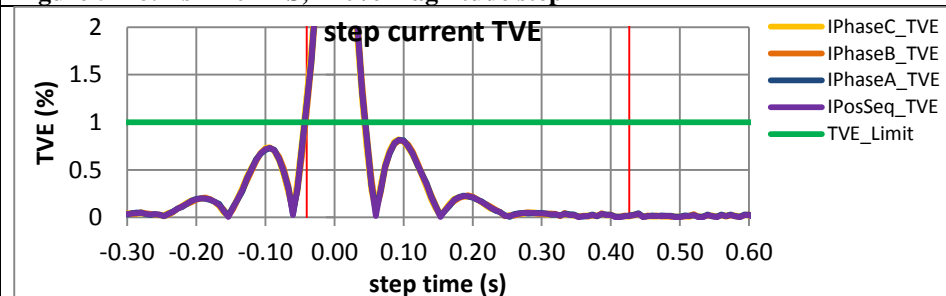


Figure 5228:  $F_s = 15$  FPS, -10% magnitude step

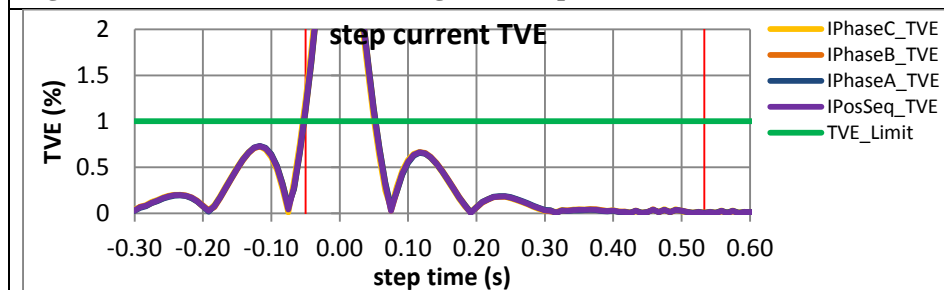


Figure 5229:  $F_s = 12$  FPS, +10% magnitude step

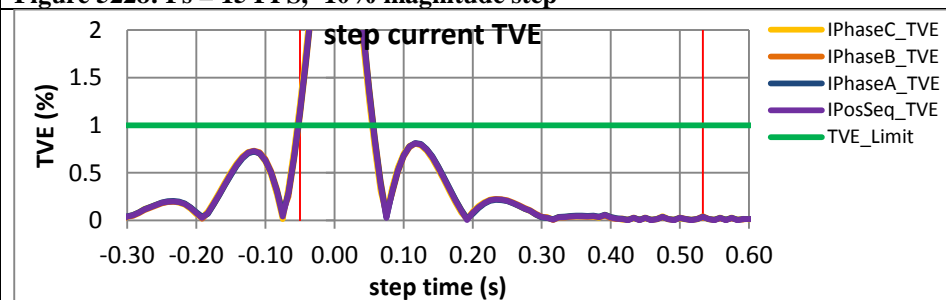


Figure 5230:  $F_s = 12$  FPS, -10% magnitude step

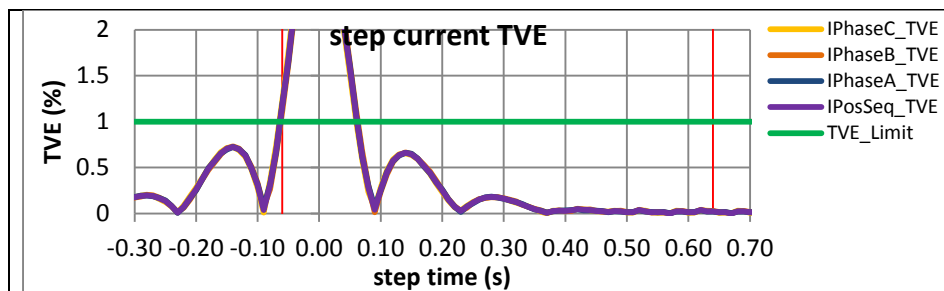


Figure 5231: Fs = 10 FPS, +10% magnitude step

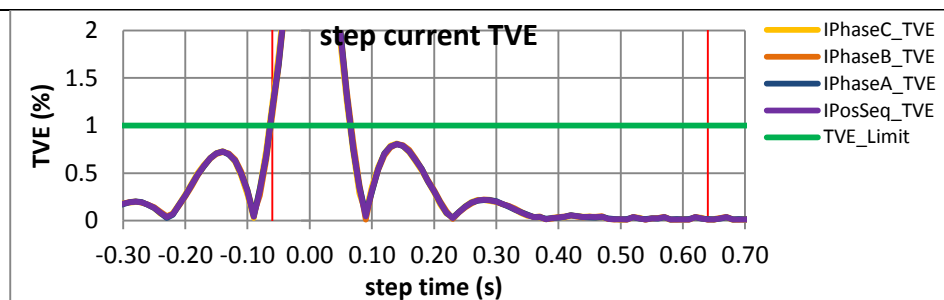
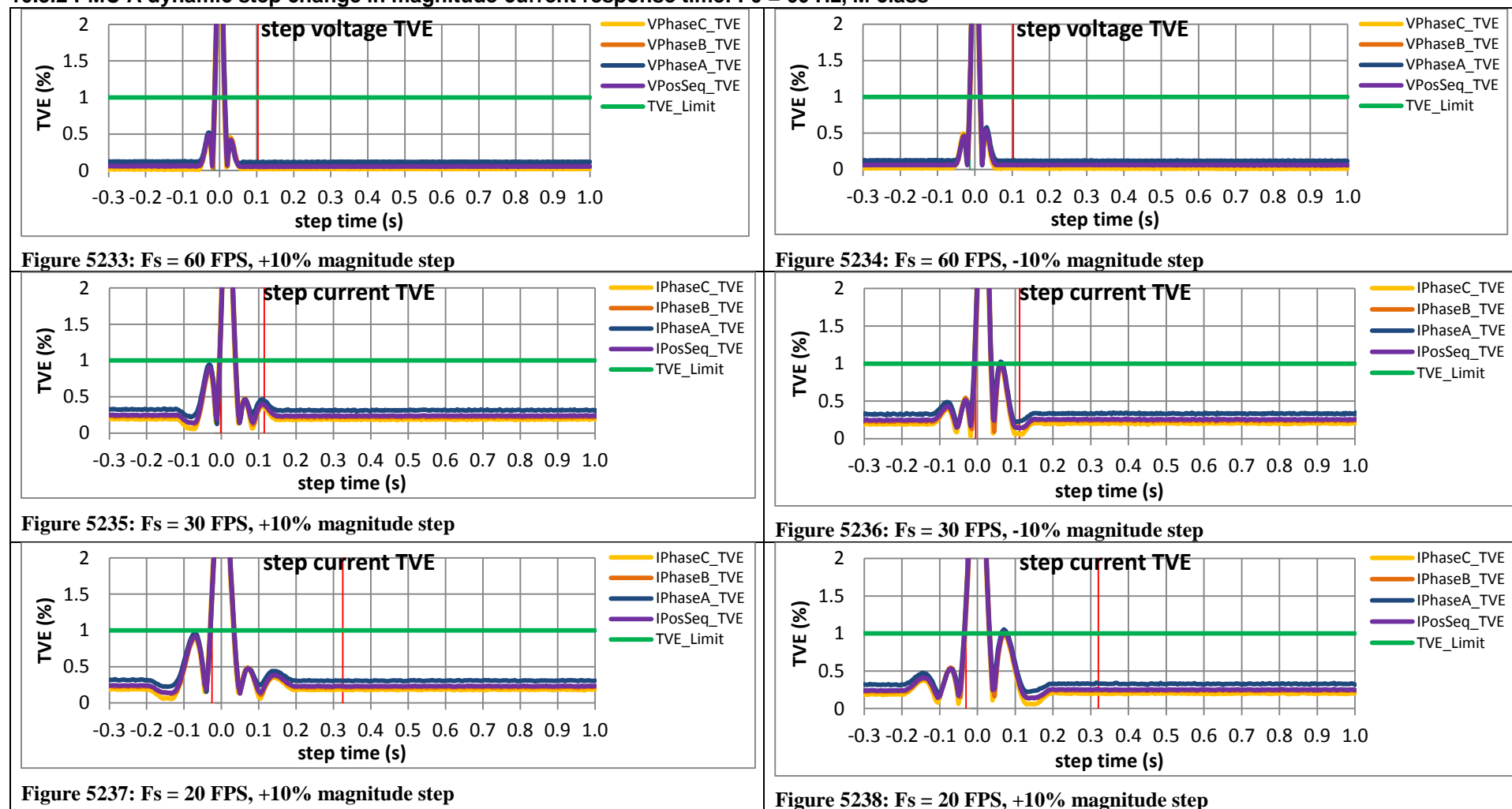


Figure 5232: Fs = 10 FPS, -10% magnitude step

### 10.3.2 PMU A dynamic step change in magnitude current response time: F0 = 60 Hz, M class



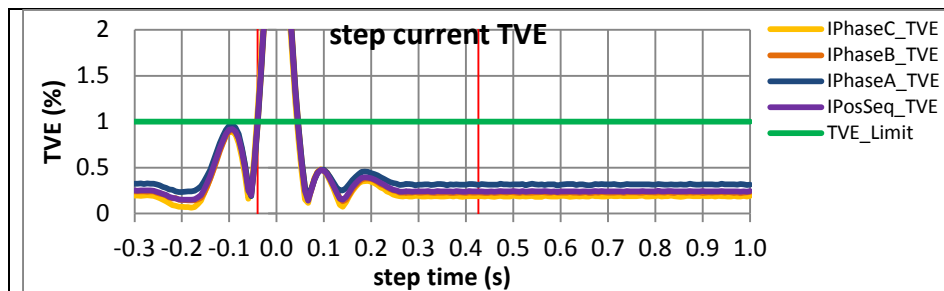


Figure 5239: Fs = 15 FPS, +10% magnitude step

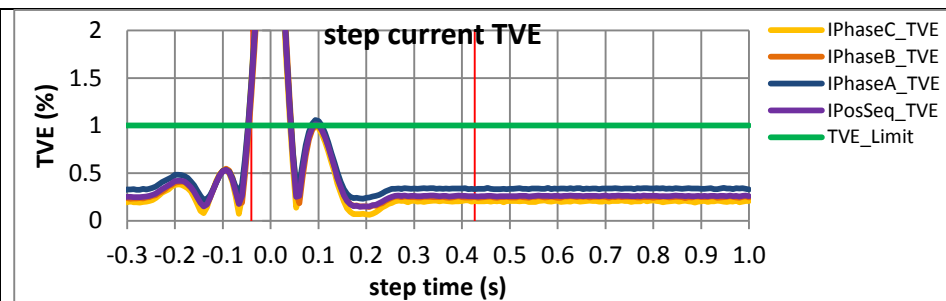


Figure 5240: Fs = 15 FPS, -10% magnitude step

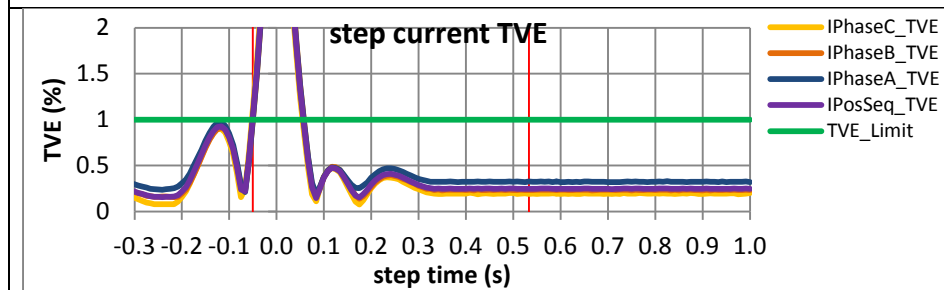


Figure 5241: Fs = 12 FPS, +10% magnitude step

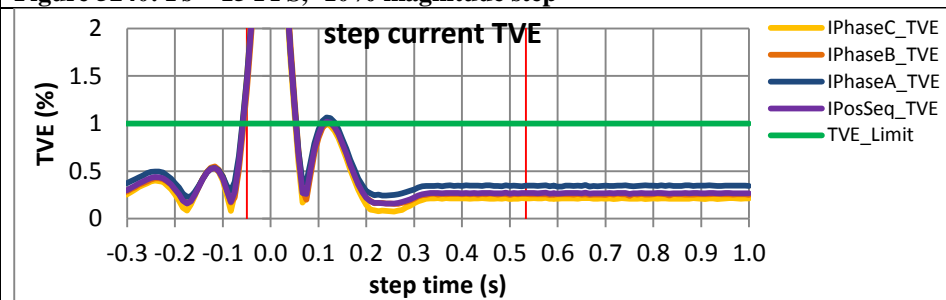


Figure 5242: Fs = 12 FPS, -10% magnitude step

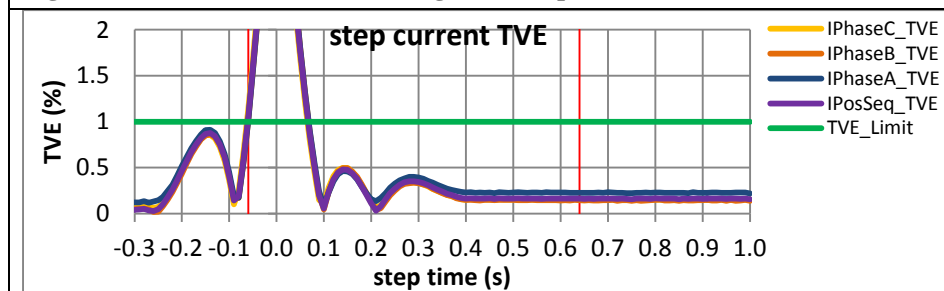


Figure 5243: Fs = 10 FPS, +10% magnitude step

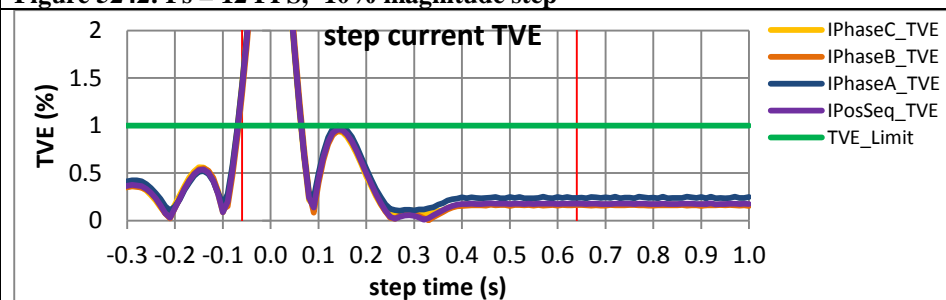


Figure 5244: Fs = 10 FPS, -10% magnitude step

### 10.3.3 PMU B dynamic step change in magnitude current response time: $F_0 = 60$ Hz, M class

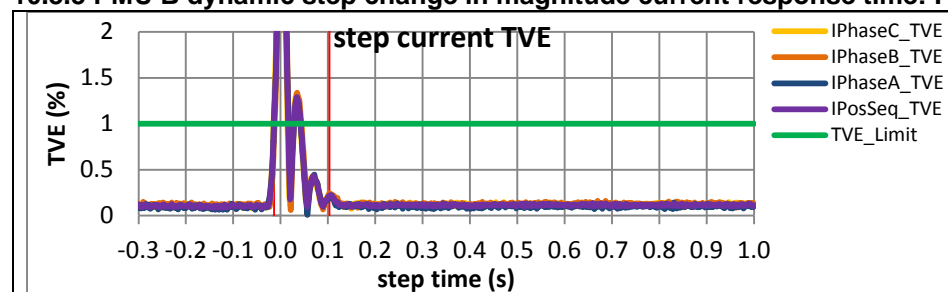


Figure 5245:  $F_s = 60$  FPS, +10% magnitude step

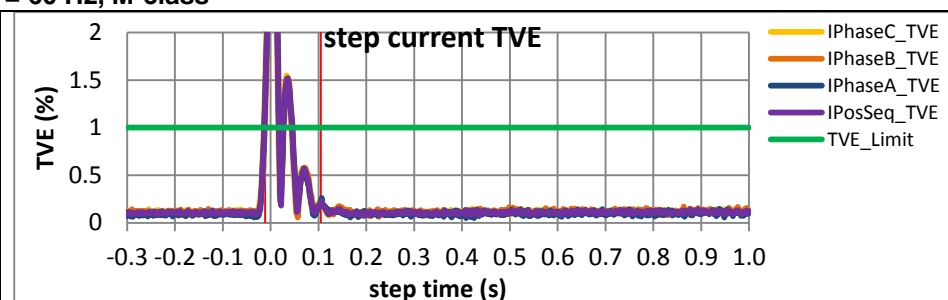


Figure 5246:  $F_s = 60$  FPS, -10% magnitude step

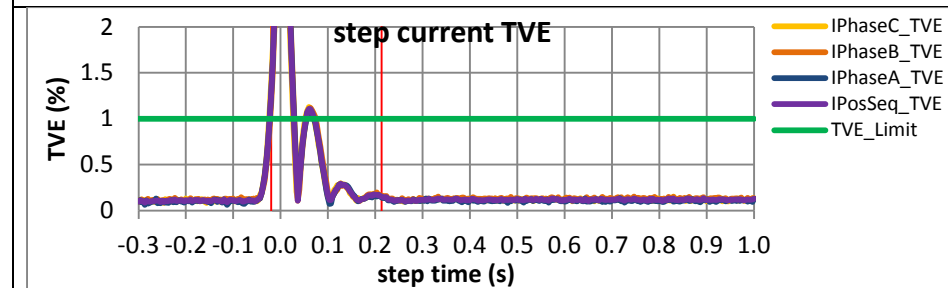


Figure 5247:  $F_s = 30$  FPS, +10% magnitude step

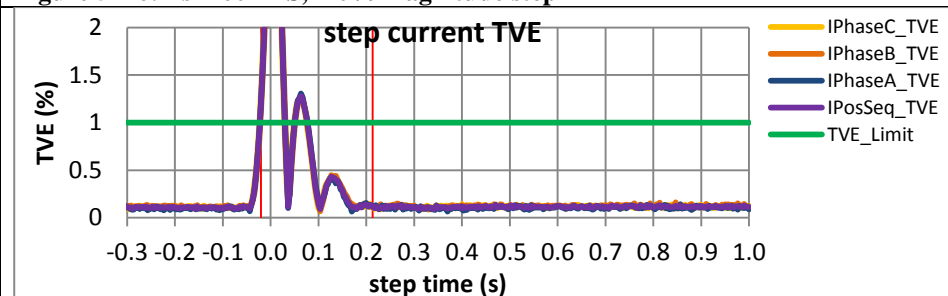


Figure 5248:  $F_s = 30$  FPS, -10% magnitude step

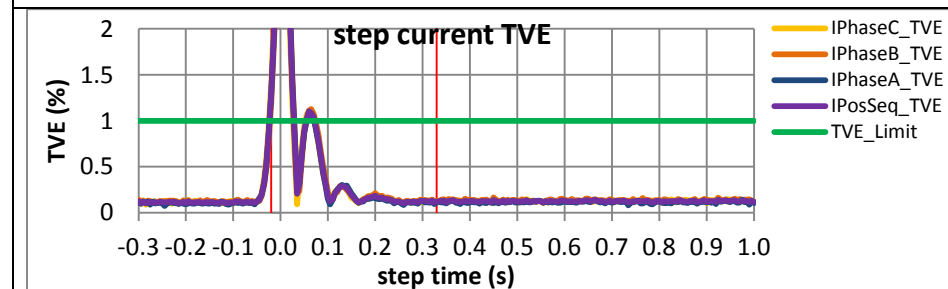


Figure 5249:  $F_s = 20$  FPS, +10% magnitude step

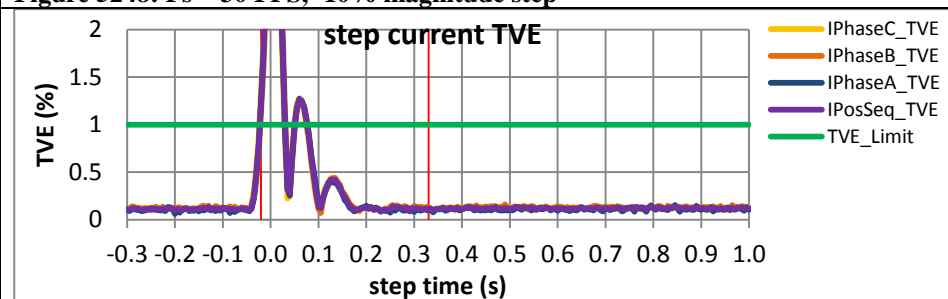


Figure 5250:  $F_s = 20$  FPS, +10% magnitude step

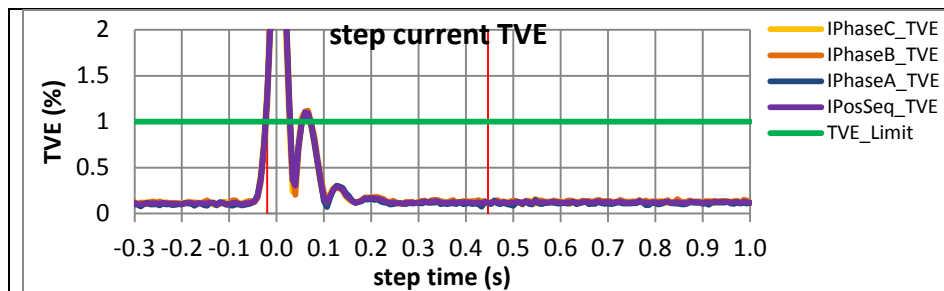


Figure 5251: Fs = 15 FPS, +10% magnitude step

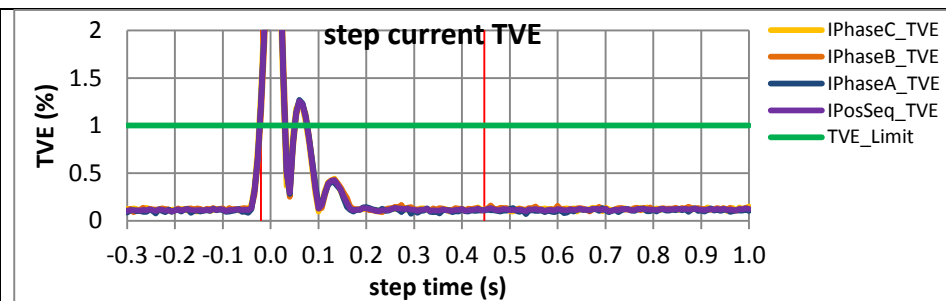


Figure 5252: Fs = 15 FPS, -10% magnitude step

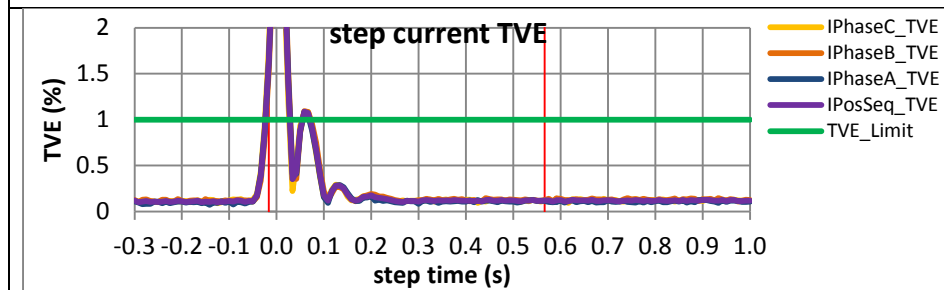


Figure 5253: Fs = 12 FPS, +10% magnitude step

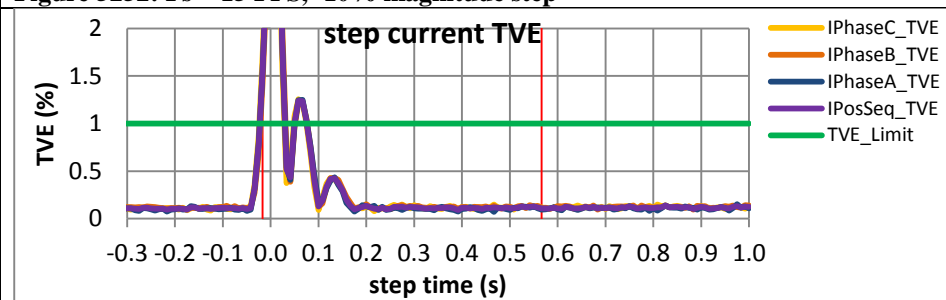


Figure 5254: Fs = 12 FPS, -10% magnitude step

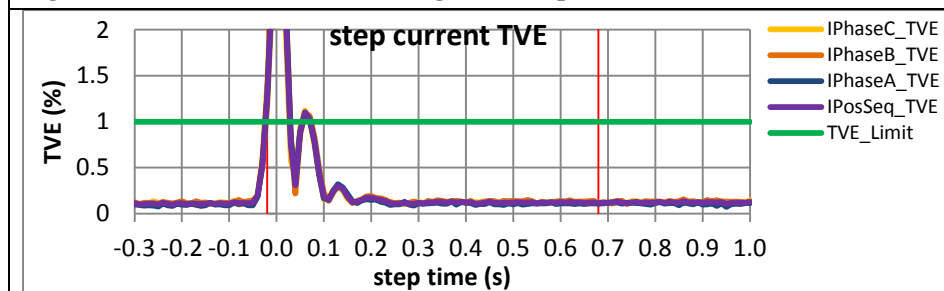


Figure 5255: Fs = 10 FPS, +10% magnitude step

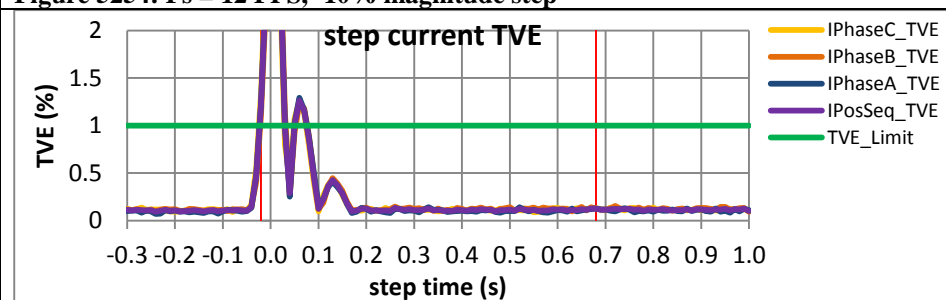


Figure 5256: Fs = 10 FPS, -10% magnitude step

#### 10.3.4 PMU C dynamic step change in magnitude current response time: F0 = 60 Hz, M class

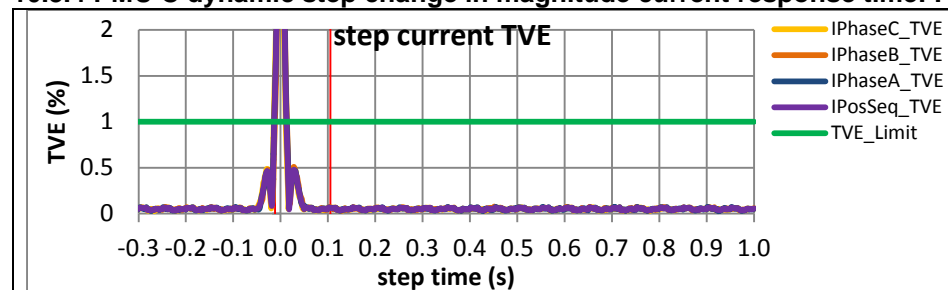


Figure 5257: Fs = 60 FPS, +10% magnitude step

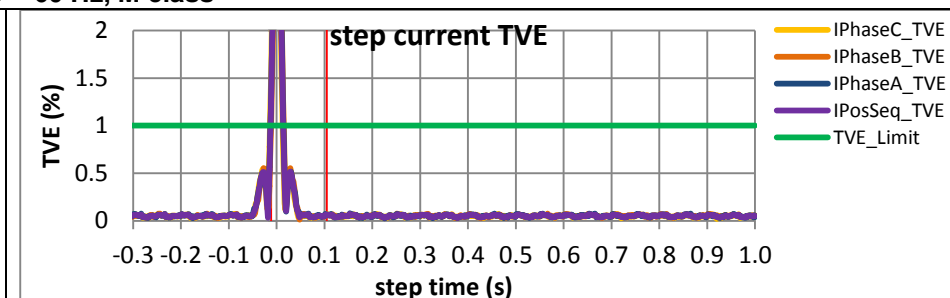


Figure 5258: Fs = 60 FPS, -10% magnitude step

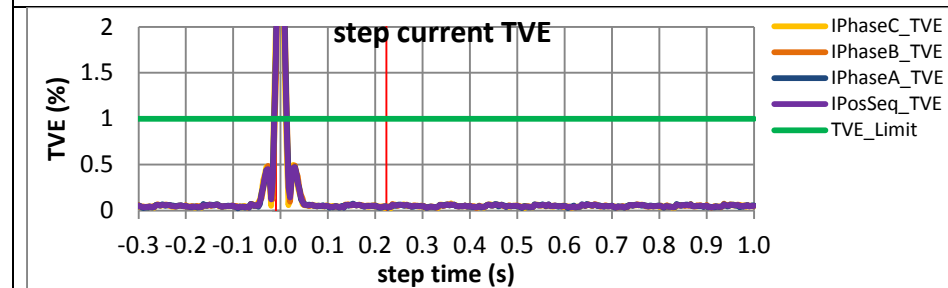


Figure 5259: Fs = 30 FPS, +10% magnitude step

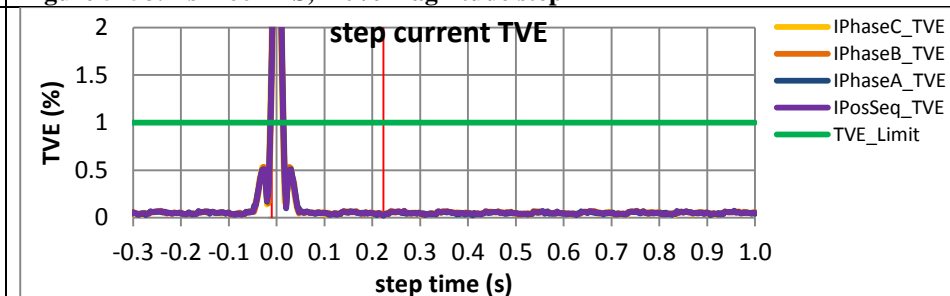


Figure 5260: Fs = 30 FPS, -10% magnitude step

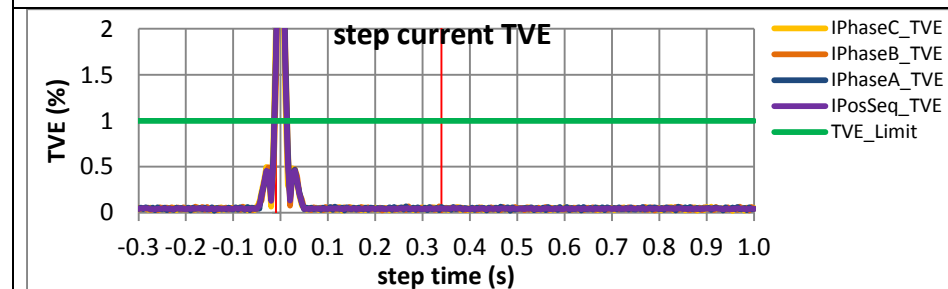


Figure 5261: Fs = 20 FPS, +10% magnitude step

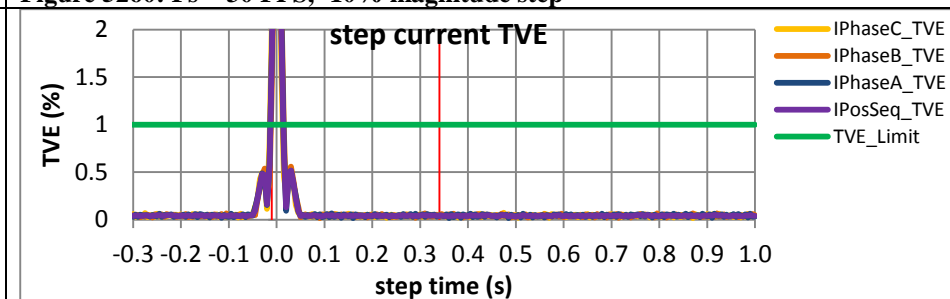


Figure 5262: Fs = 20 FPS, +10% magnitude step

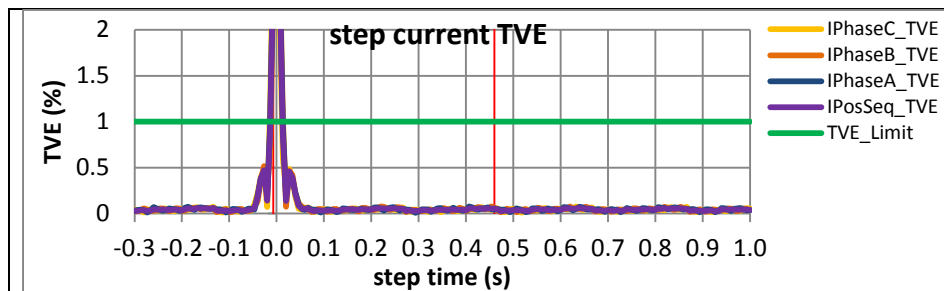


Figure 5263: Fs = 15 FPS, +10% magnitude step

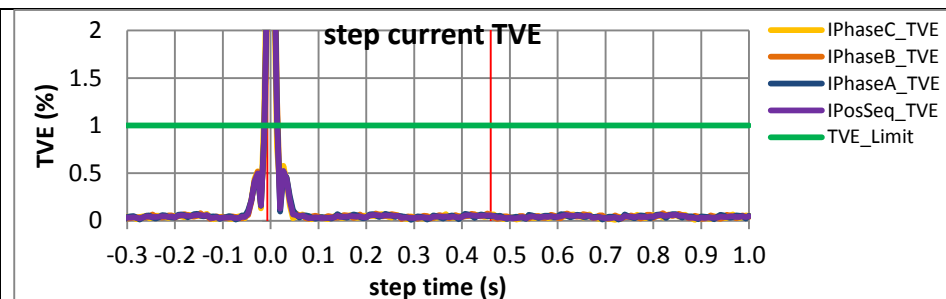


Figure 5264: Fs = 15 FPS, -10% magnitude step

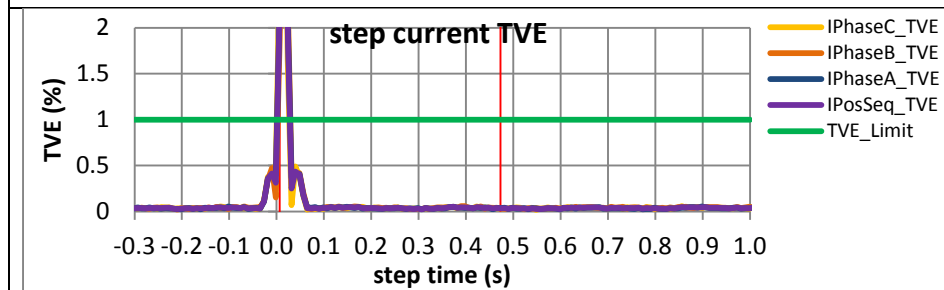


Figure 5265: Fs = 12 FPS, +10% magnitude step

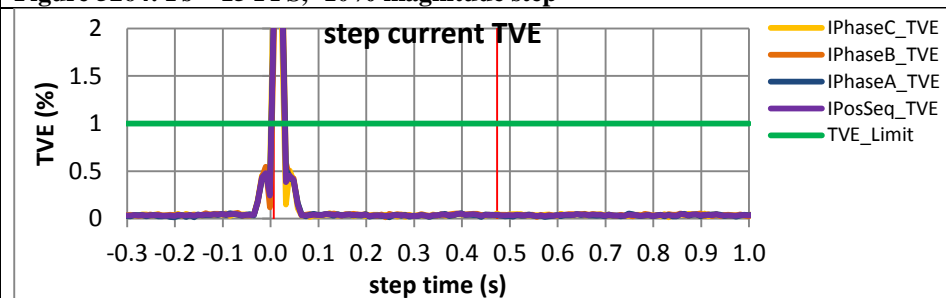


Figure 5266: Fs = 12 FPS, -10% magnitude step

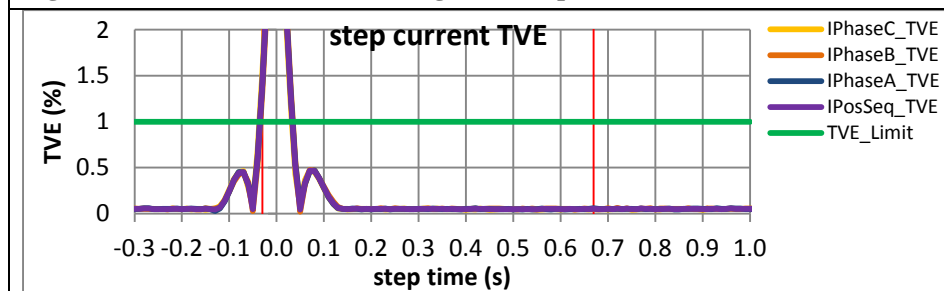


Figure 5267: Fs = 10 FPS, +10% magnitude step

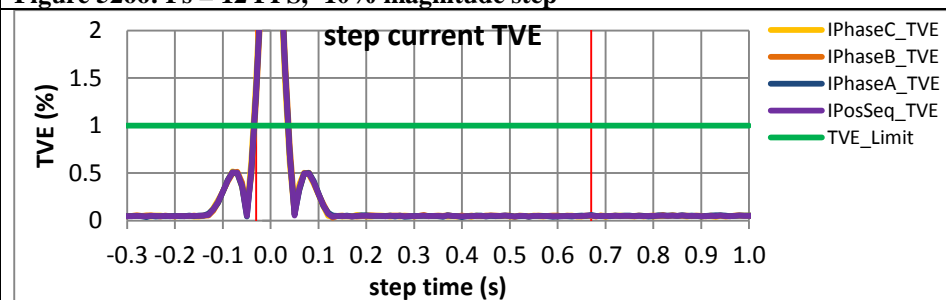


Figure 5268: Fs = 10 FPS, -10% magnitude step



### 10.3.5 PMU D dynamic step change in magnitude current response time: F0 = 60 Hz, M class

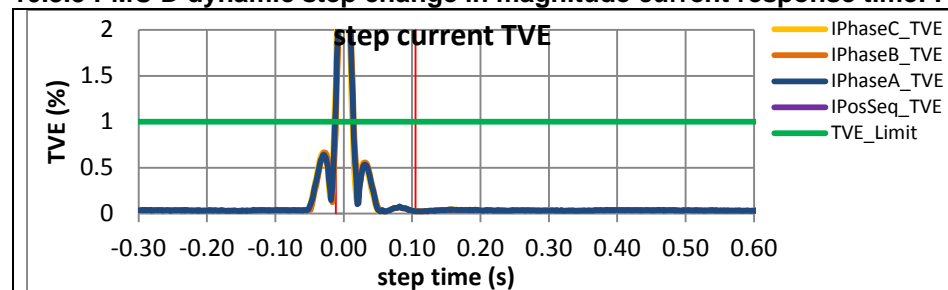


Figure 5269: Fs = 60 FPS, +10% magnitude step

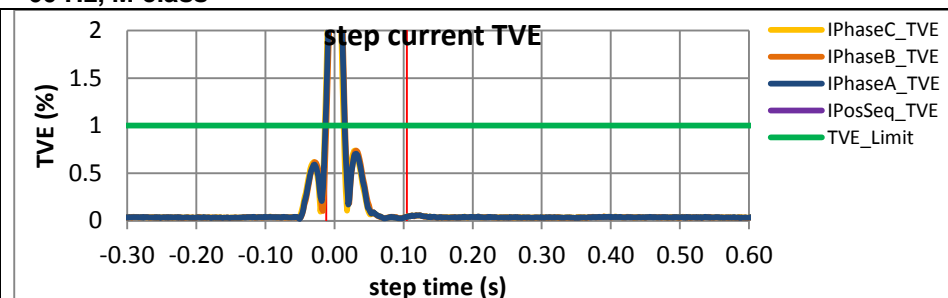


Figure 5270: Fs = 60 FPS, -10% magnitude step

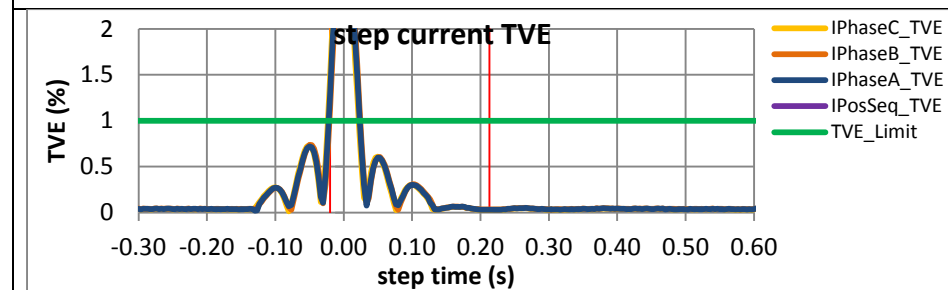


Figure 5271: Fs = 30 FPS, +10% magnitude step

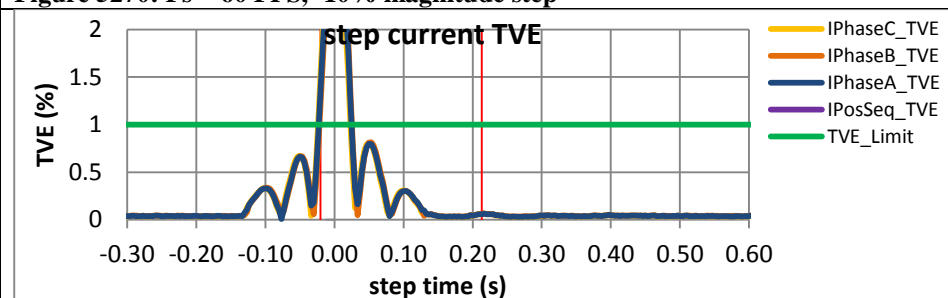


Figure 5272: Fs = 30 FPS, -10% magnitude step

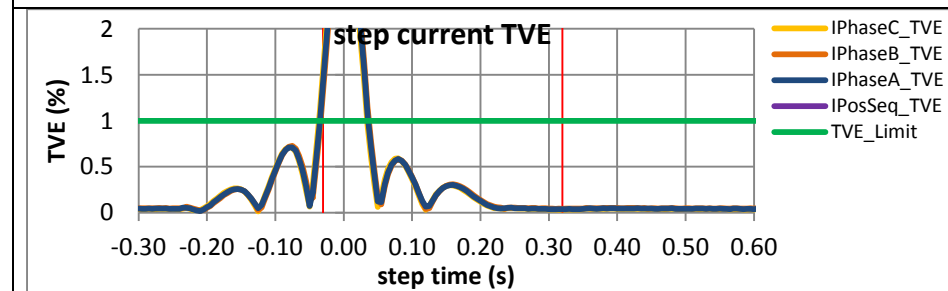


Figure 5273: Fs = 20 FPS, +10% magnitude step

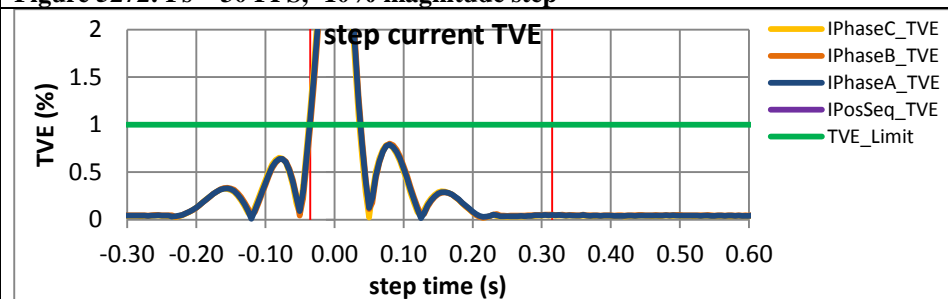


Figure 5274: Fs = 20 FPS, +10% magnitude step

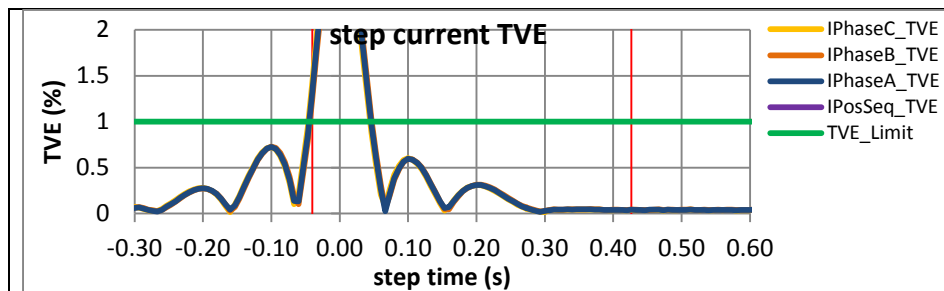


Figure 5275: Fs = 15 FPS, +10% magnitude step

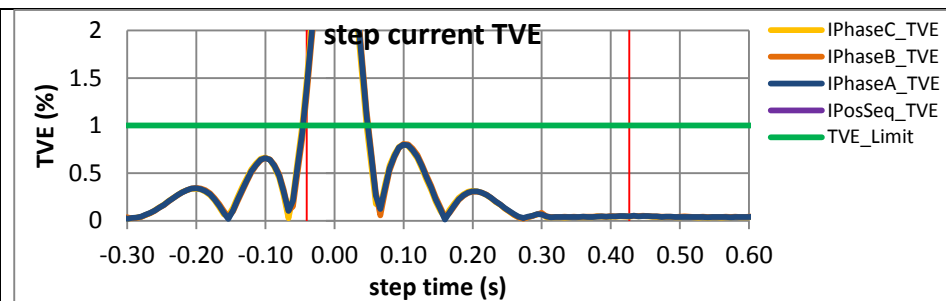


Figure 5276: Fs = 15 FPS, -10% magnitude step

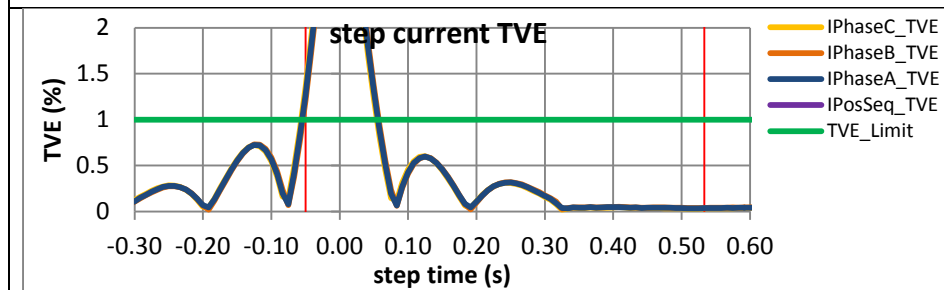


Figure 5277: Fs = 12 FPS, +10% magnitude step

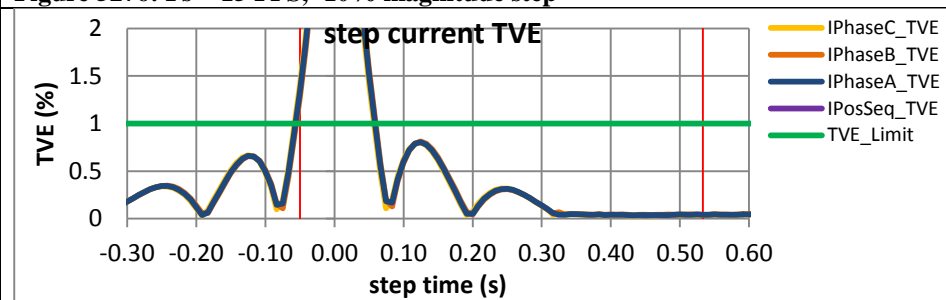


Figure 5278: Fs = 12 FPS, -10% magnitude step

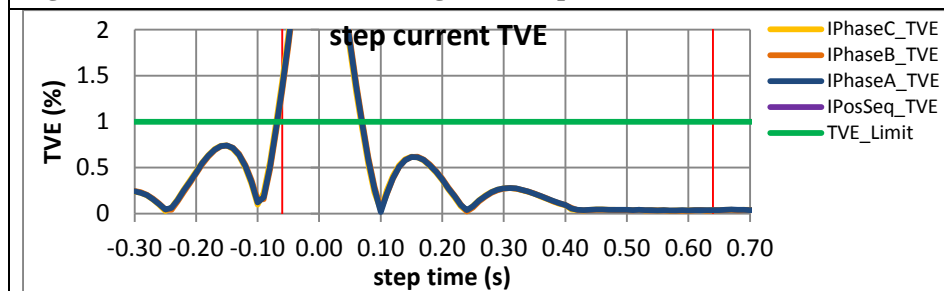


Figure 5279: Fs = 10 FPS, +10% magnitude step

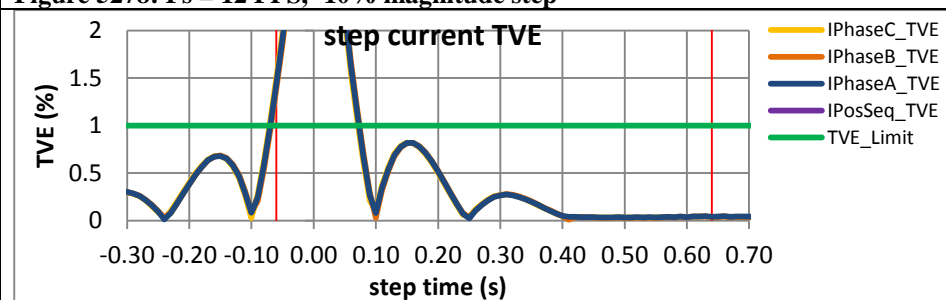


Figure 5280: Fs = 10 FPS, -10% magnitude step

### 10.3.6 PMU E dynamic step change in magnitude current response time: F0 = 60 Hz, M class

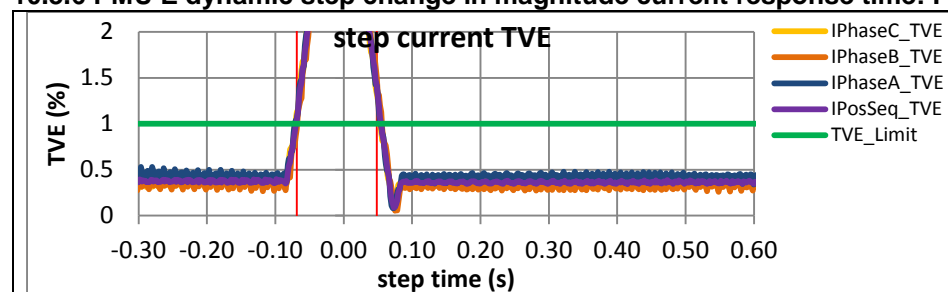


Figure 5281: Fs = 60 FPS, +10% magnitude step

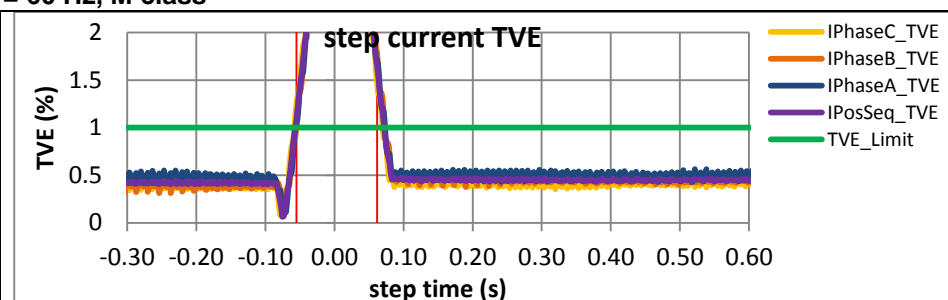


Figure 5282: Fs = 60 FPS, -10% magnitude step

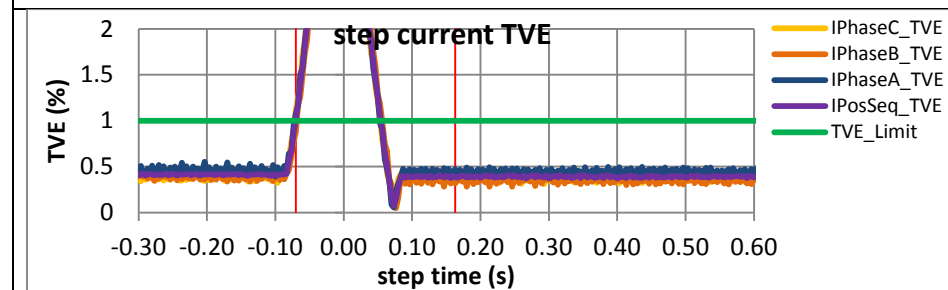


Figure 5283: Fs = 30 FPS, +10% magnitude step

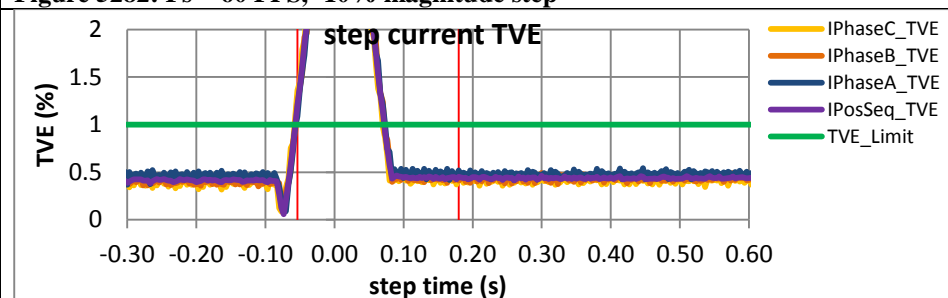


Figure 5284: Fs = 30 FPS, -10% magnitude step

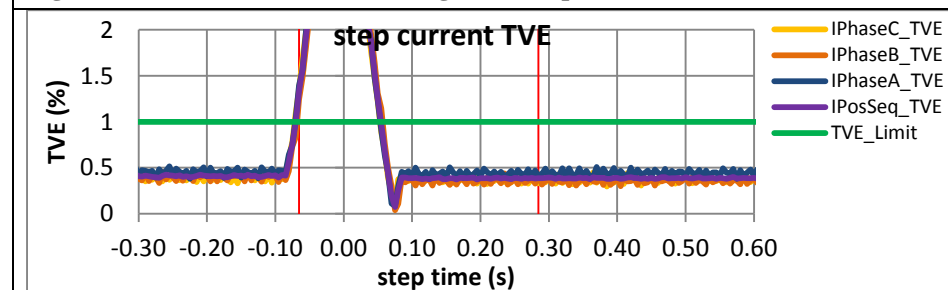


Figure 5285: Fs = 20 FPS, +10% magnitude step

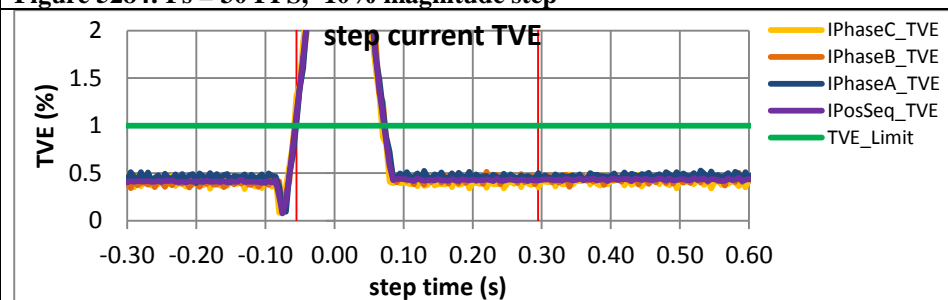


Figure 5286: Fs = 20 FPS, +10% magnitude step

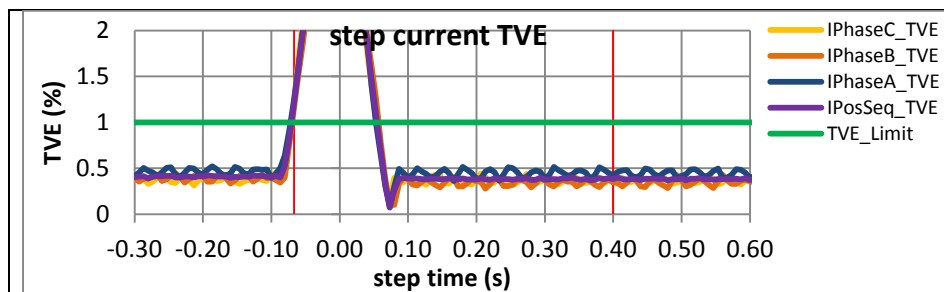


Figure 5287: Fs = 15 FPS, +10% magnitude step

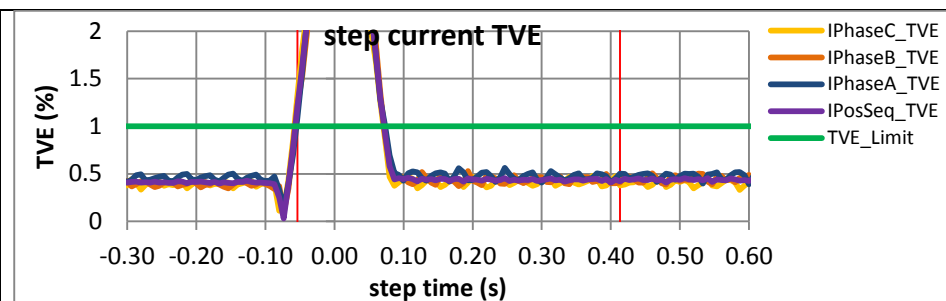


Figure 5288: Fs = 15 FPS, -10% magnitude step

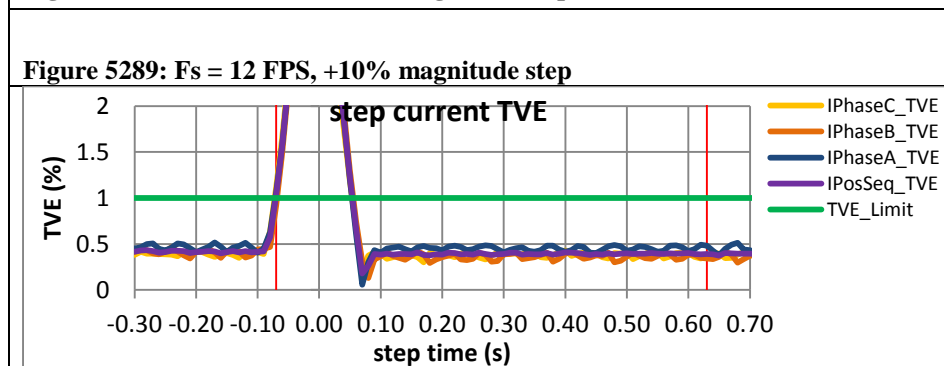


Figure 5291: Fs = 10 FPS, +10% magnitude step

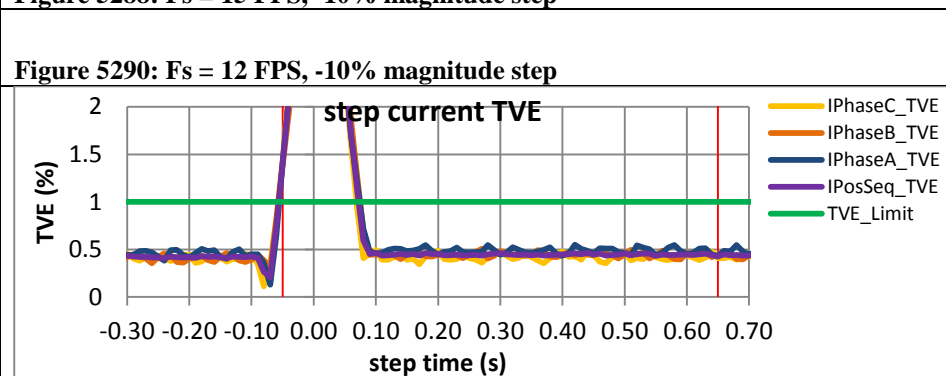


Figure 5292: Fs = 10 FPS, -10% magnitude step

### 10.3.7 PMU F dynamic step change in magnitude current response time: F0 = 60 Hz, M class

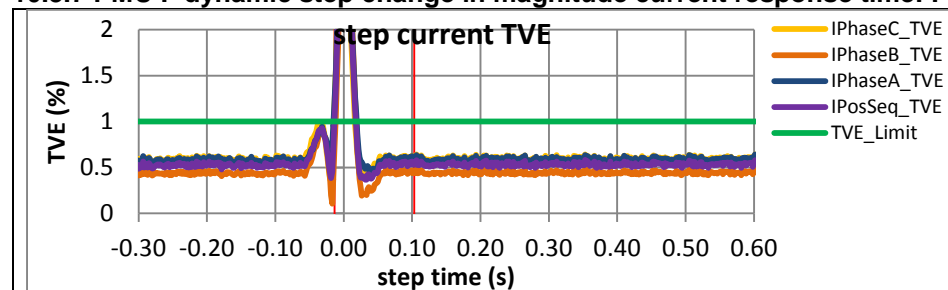


Figure 5293: Fs = 60 FPS, +10% magnitude step

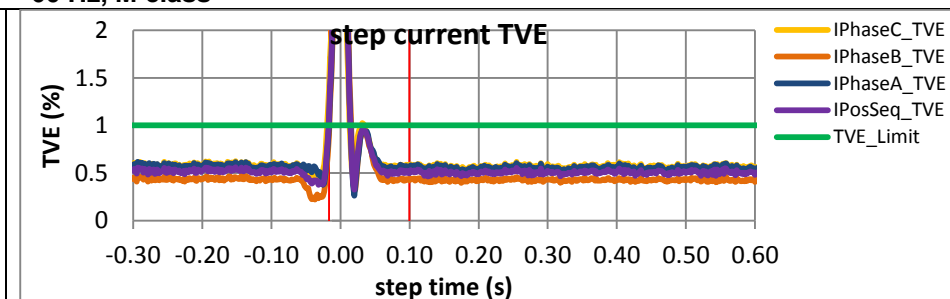


Figure 5294: Fs = 60 FPS, -10% magnitude step

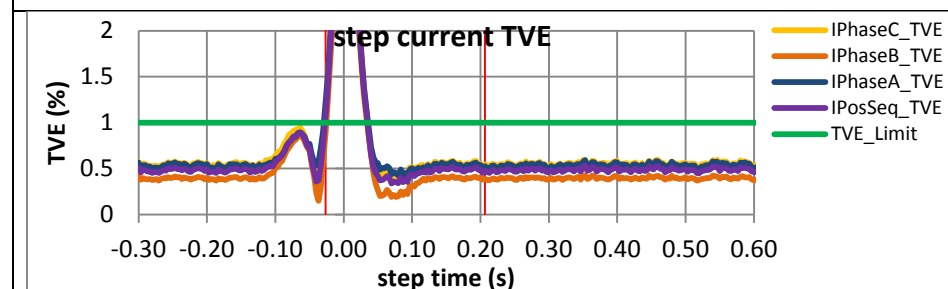


Figure 5295: Fs = 30 FPS, +10% magnitude step

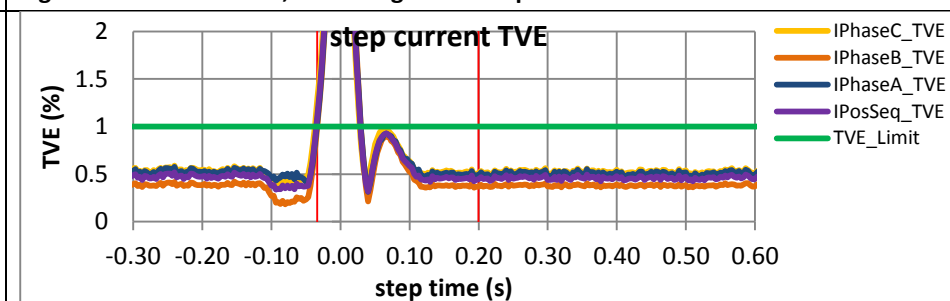


Figure 5296: Fs = 30 FPS, -10% magnitude step

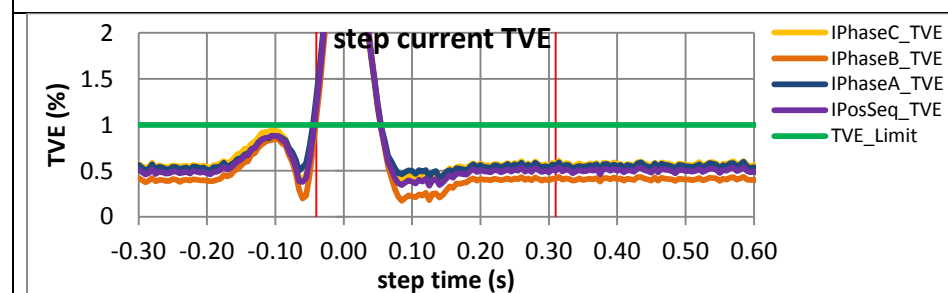


Figure 5297: Fs = 20 FPS, +10% magnitude step

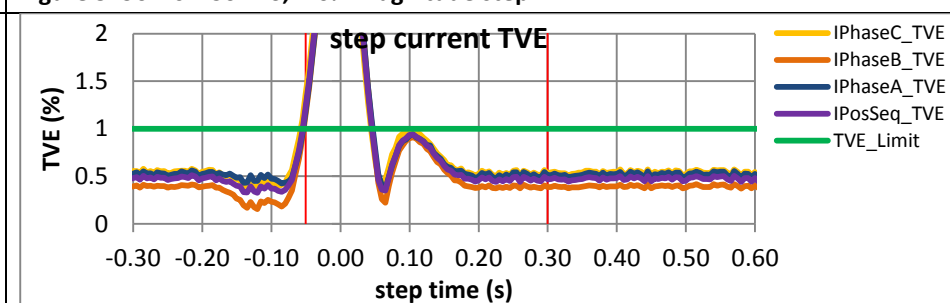


Figure 5298: Fs = 20 FPS, +10% magnitude step

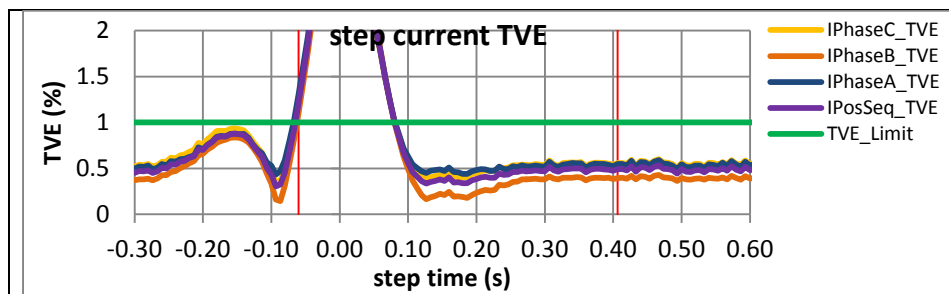


Figure 5299:  $F_s = 15$  FPS, +10% magnitude step

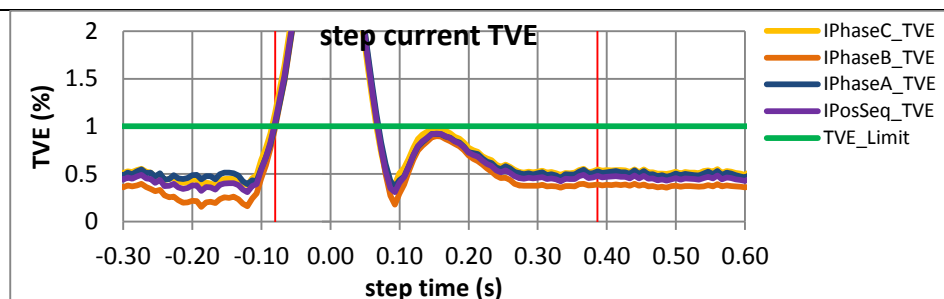


Figure 5300:  $F_s = 15$  FPS, -10% magnitude step

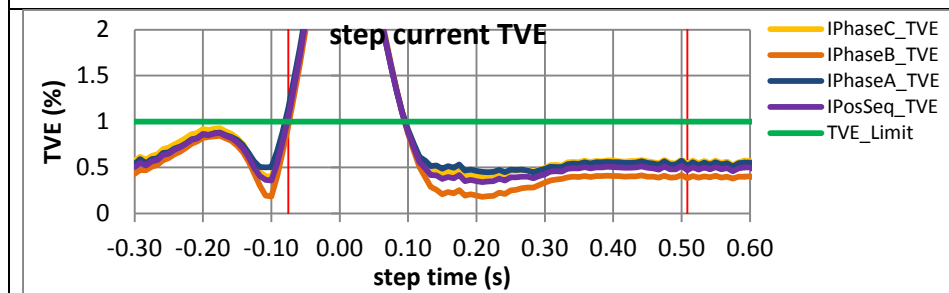


Figure 5301:  $F_s = 12$  FPS, +10% magnitude step

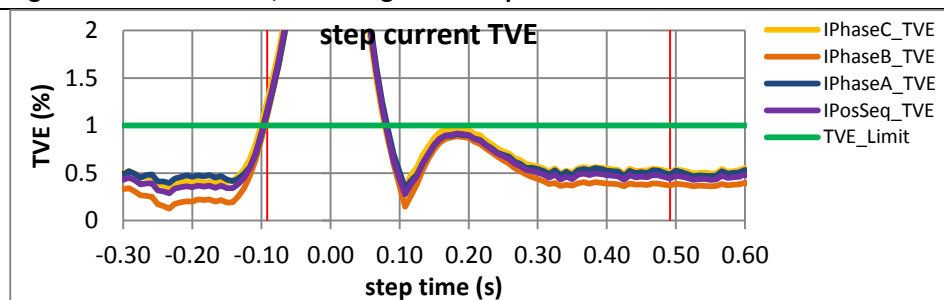


Figure 5302:  $F_s = 12$  FPS, -10% magnitude step

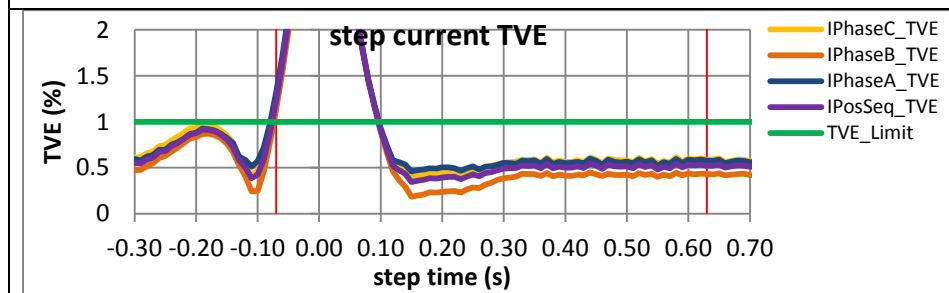


Figure 5303:  $F_s = 10$  FPS, +10% magnitude step

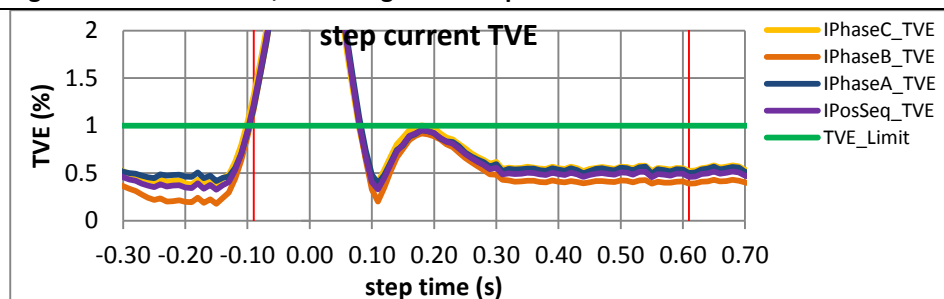


Figure 5304:  $F_s = 10$  FPS, -10% magnitude step

### 10.3.8 PMU G dynamic step change in magnitude current response time: F0 = 60 Hz, M class

Figure 5305: Fs = 60 FPS is not supported by this PMU

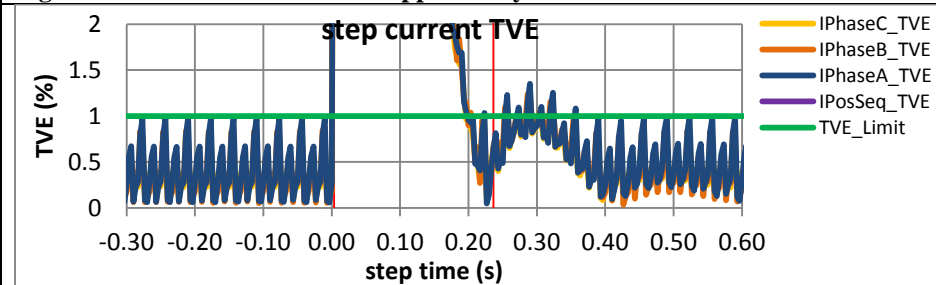


Figure 5306: Fs = 60 FPS is not supported by this PMU

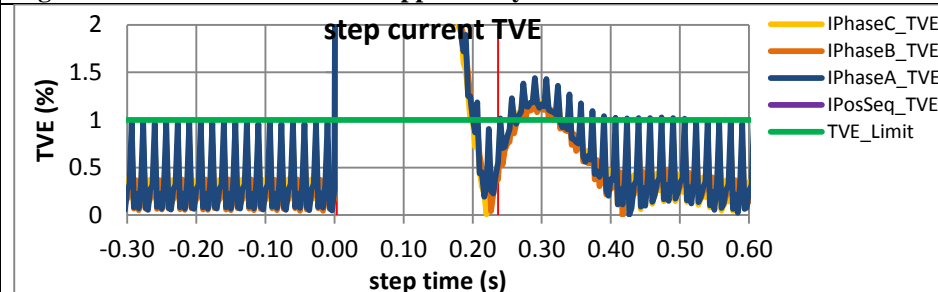


Figure 5307: Fs = 30 FPS, +10% magnitude step

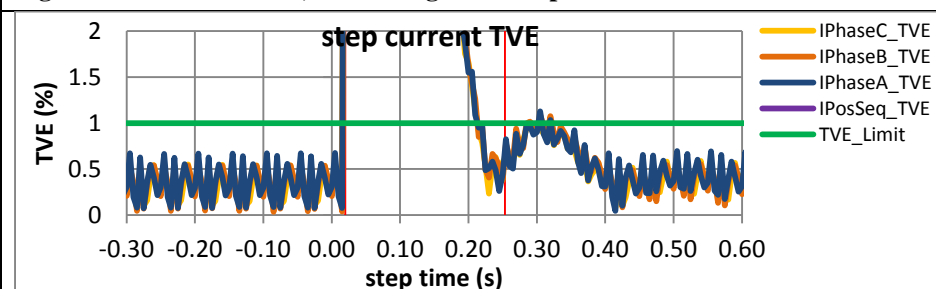


Figure 5308: Fs = 30 FPS, -10% magnitude step

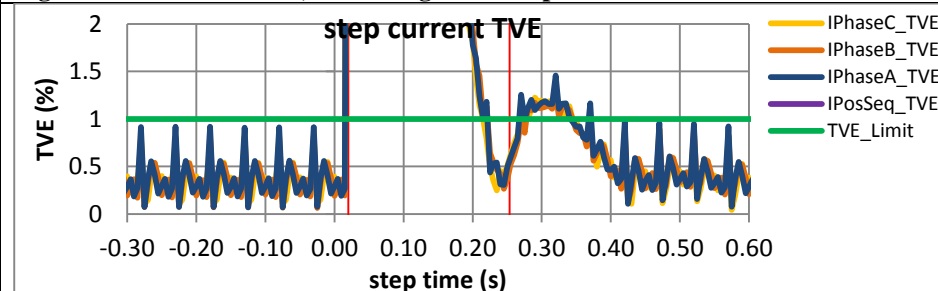


Figure 5309: Fs = 20 FPS, +10% magnitude step

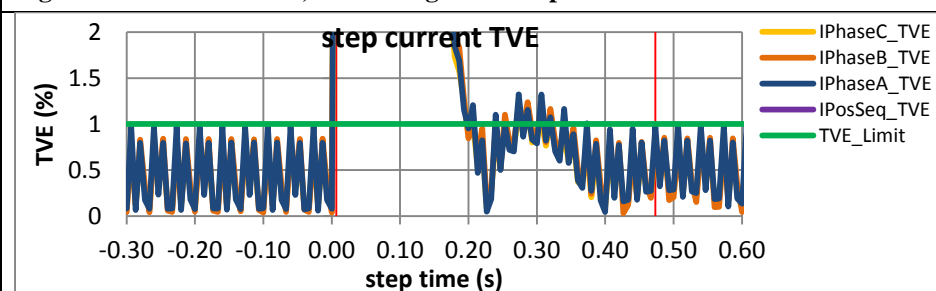


Figure 5310: Fs = 20 FPS, +10% magnitude step

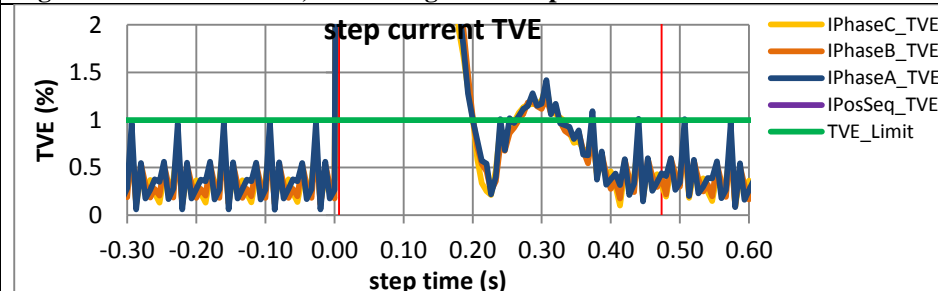


Figure 5311: Fs = 15 FPS, +10% magnitude step



Figure 5312: Fs = 15 FPS, -10% magnitude step



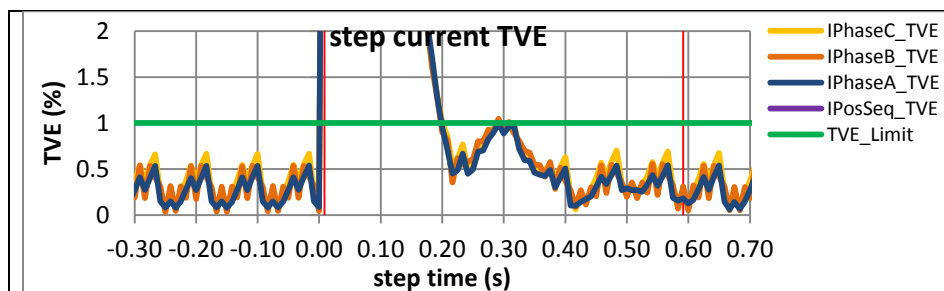


Figure 5313: Fs = 15 FPS, +10% magnitude step

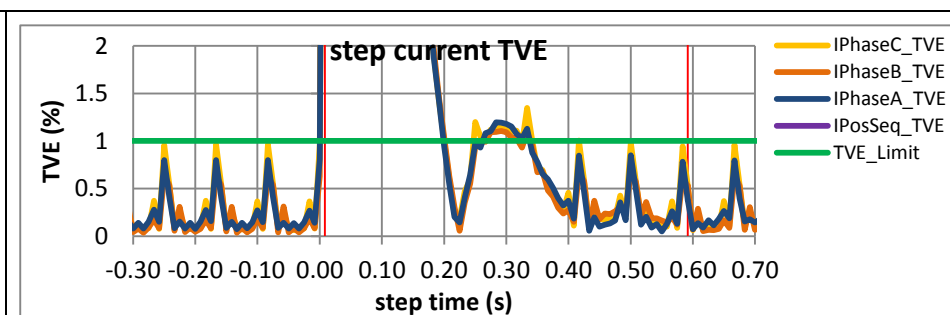


Figure 5314: Fs = 15 FPS, -10% magnitude step

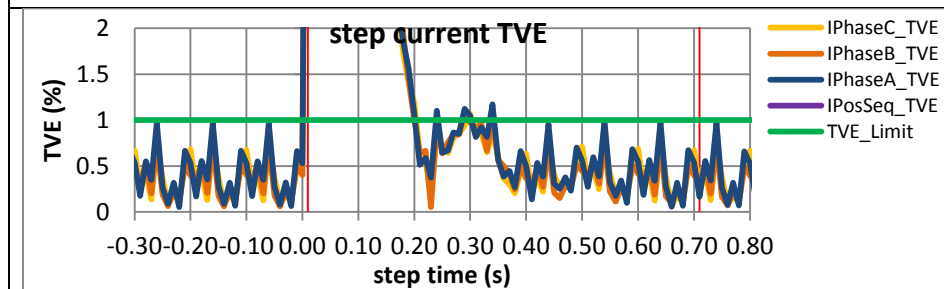


Figure 5315: Fs = 10 FPS, +10% magnitude step

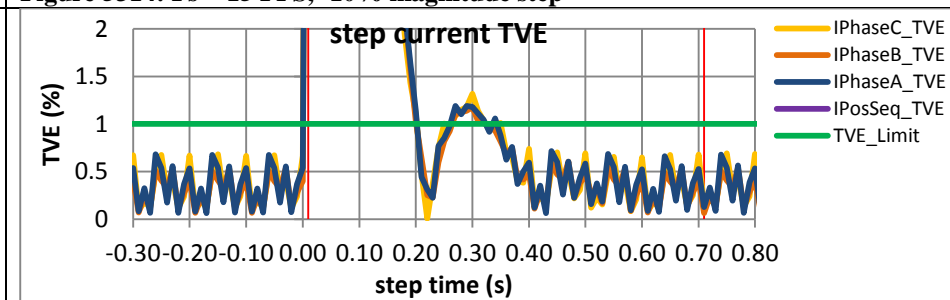


Figure 5316: Fs = 10 FPS, -10% magnitude step



### 10.3.9 PMU H dynamic step change in magnitude current response time: F0 = 60 Hz, M class

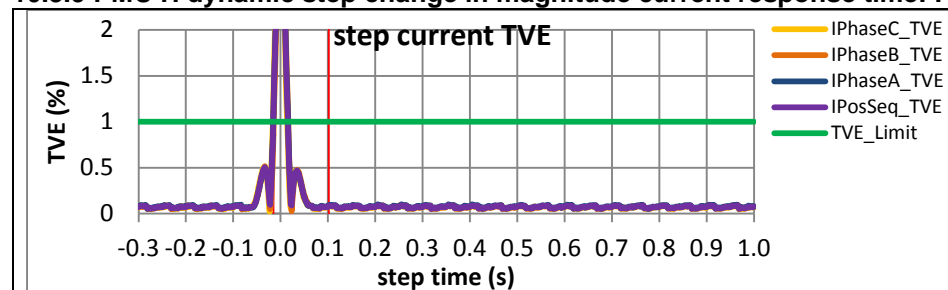


Figure 5317: Fs = 60 FPS, +10% magnitude step

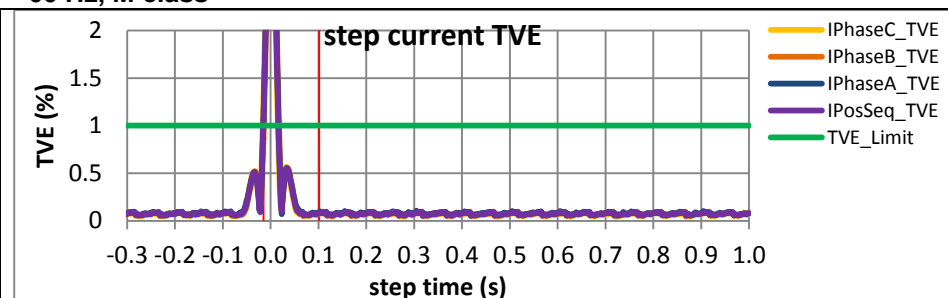


Figure 5318: Fs = 60 FPS, -10% magnitude step

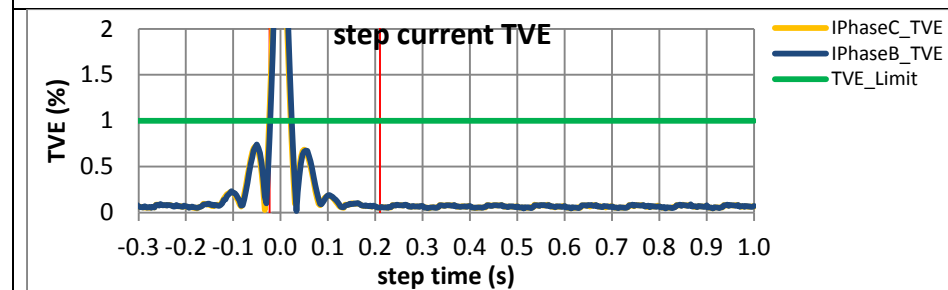


Figure 5319: Fs = 30 FPS, +10% magnitude step

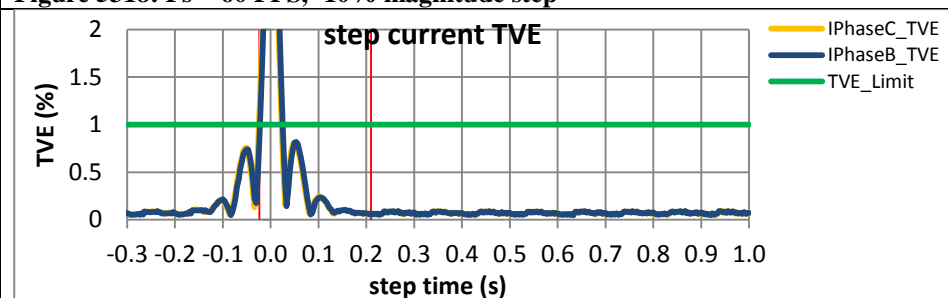


Figure 5320: Fs = 30 FPS, -10% magnitude step

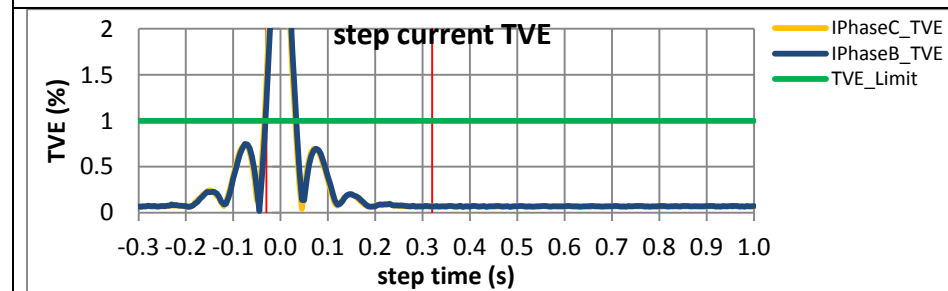


Figure 5321: Fs = 20 FPS, +10% magnitude step

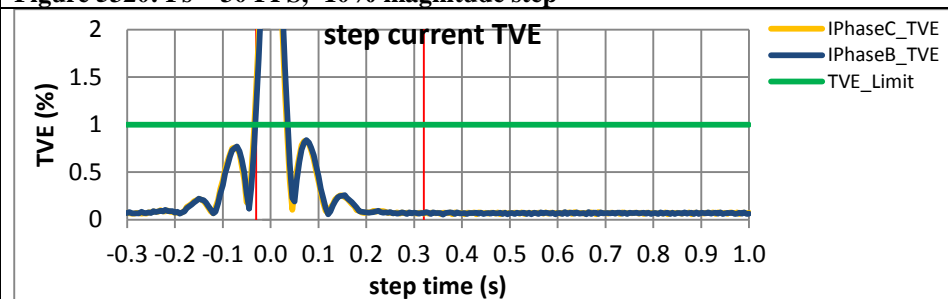


Figure 5322: Fs = 20 FPS, +10% magnitude step

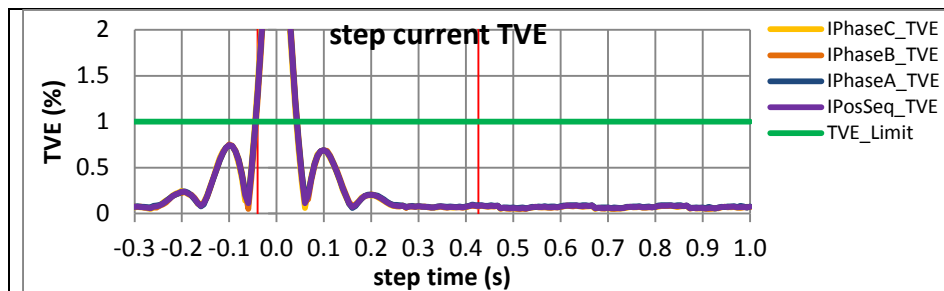


Figure 5323: Fs = 15 FPS, +10% magnitude step

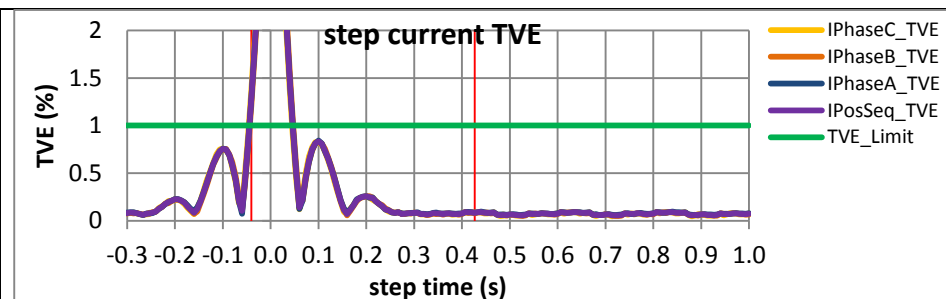


Figure 5324: Fs = 15 FPS, -10% magnitude step

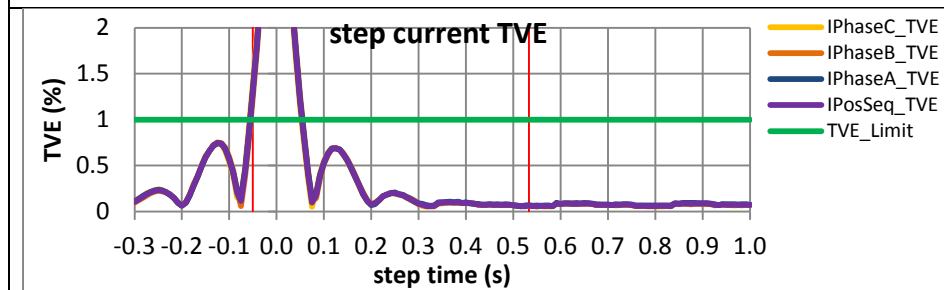


Figure 5325: Fs = 12 FPS, +10% magnitude step

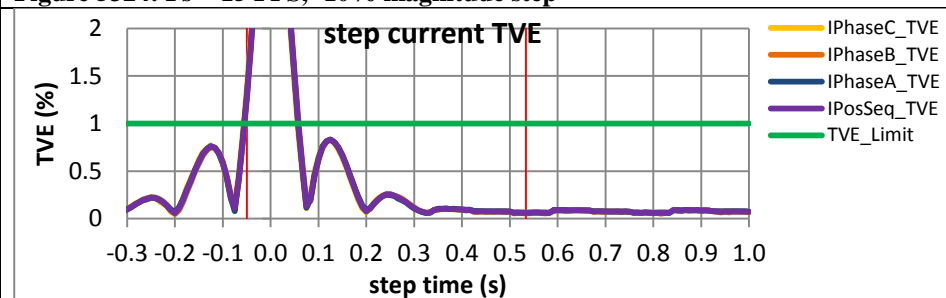


Figure 5326: Fs = 12 FPS, -10% magnitude step

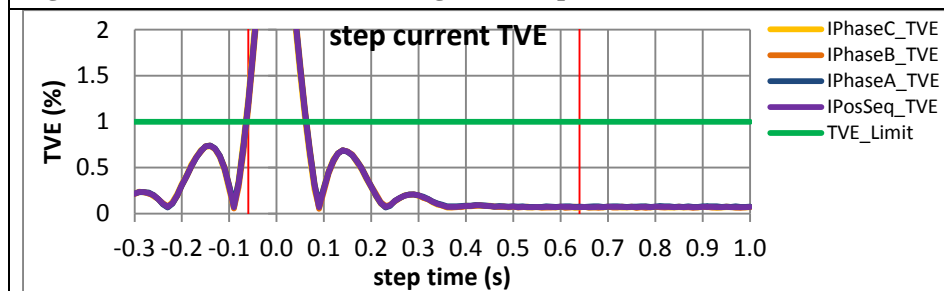


Figure 5327: Fs = 10 FPS, +10% magnitude step

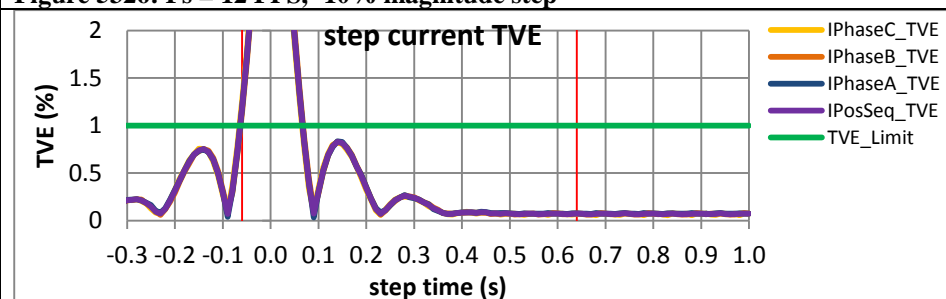


Figure 5328: Fs = 10 FPS, -10% magnitude step

### 10.3.10 PMU I dynamic step change in magnitude current response time: F0 = 60 Hz, M class

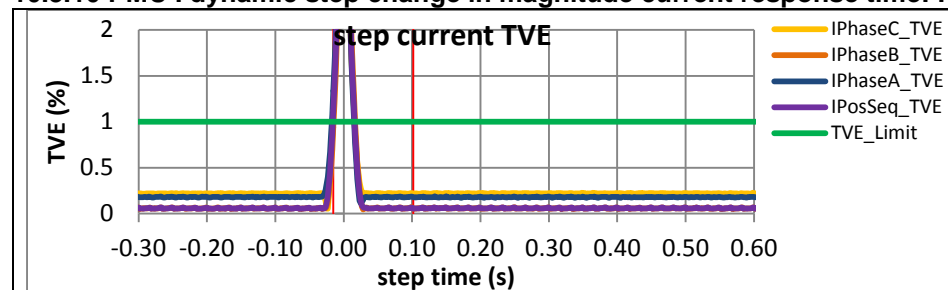


Figure 5329: Fs = 60 FPS, +10% magnitude step

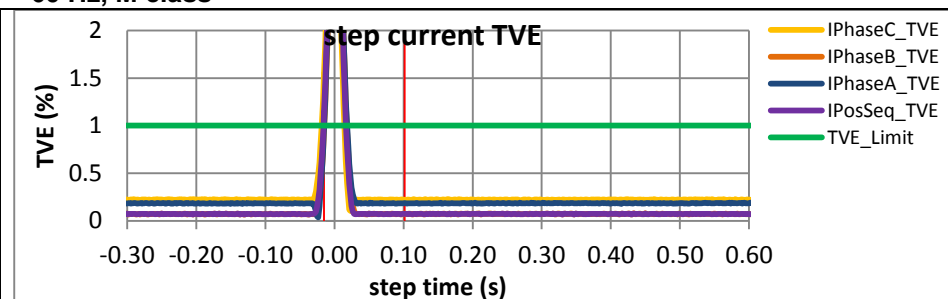


Figure 5330: Fs = 60 FPS, -10% magnitude step

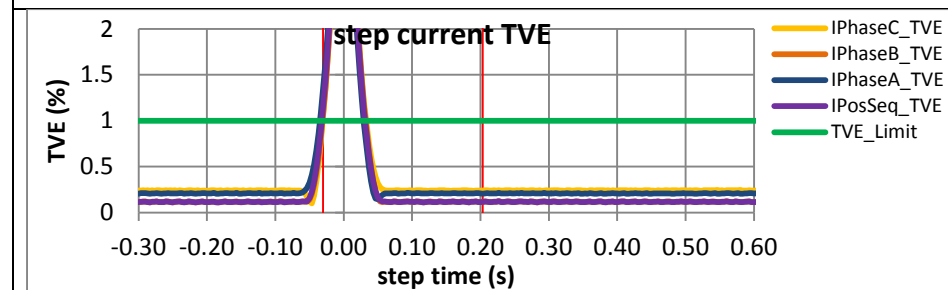


Figure 5331: Fs = 30 FPS, +10% magnitude step

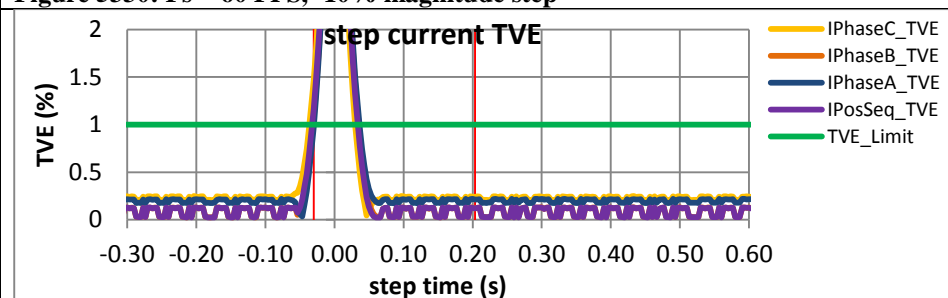


Figure 5332: Fs = 30 FPS, -10% magnitude step

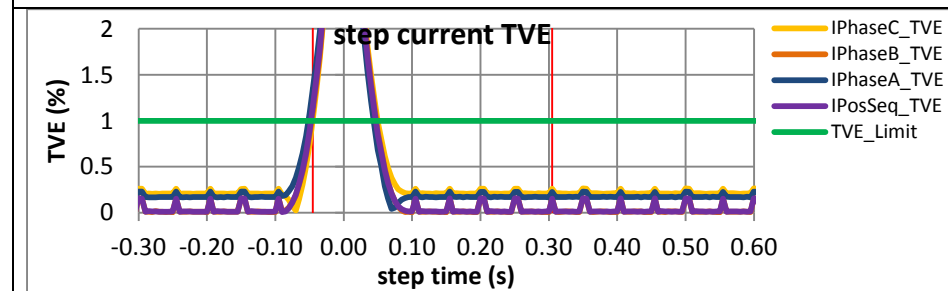


Figure 5333: Fs = 20 FPS, +10% magnitude step

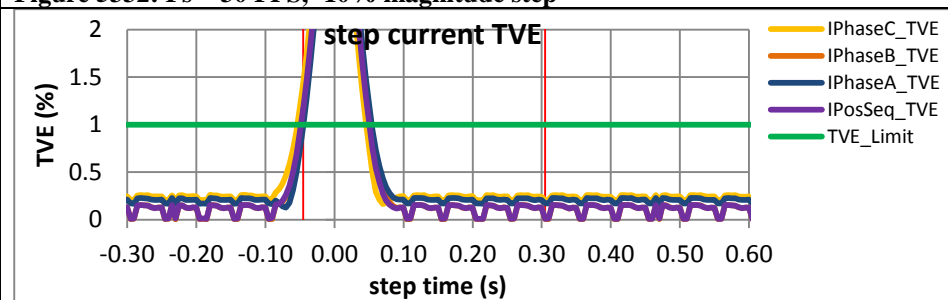


Figure 5334: Fs = 20 FPS, +10% magnitude step

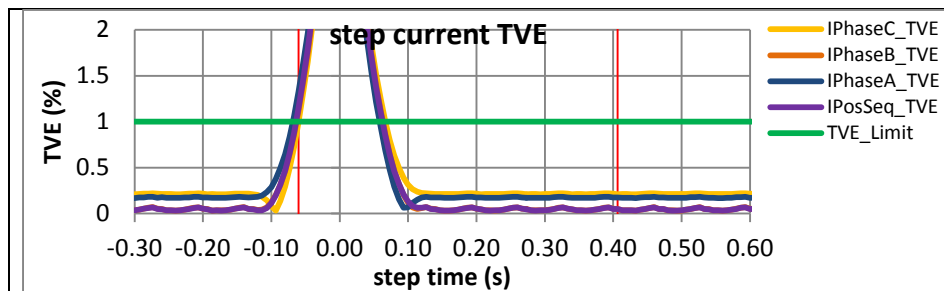


Figure 5335: Fs = 15 FPS, +10% magnitude step

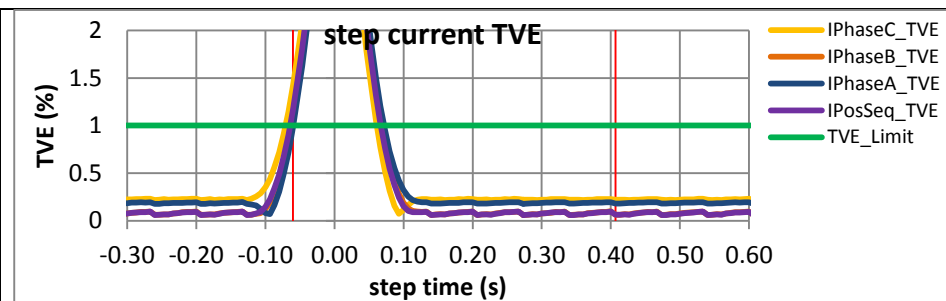


Figure 5336: Fs = 15 FPS, -10% magnitude step

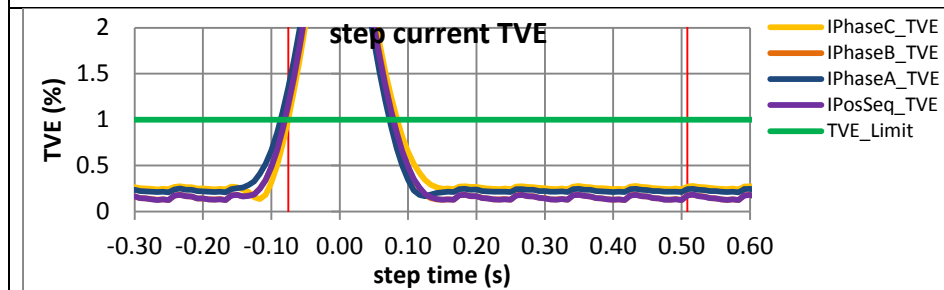


Figure 5337: Fs = 12 FPS, +10% magnitude step

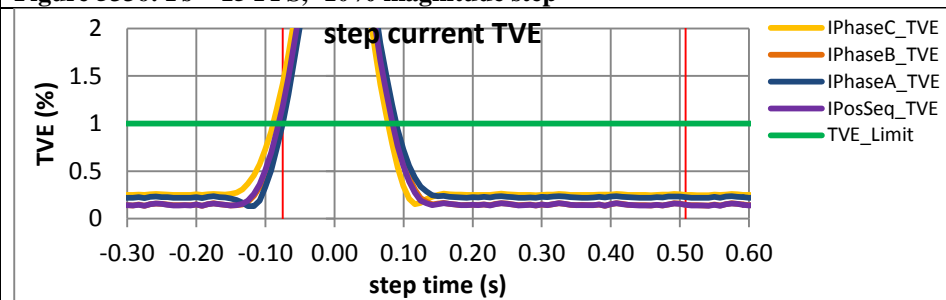


Figure 5338: Fs = 12 FPS, -10% magnitude step

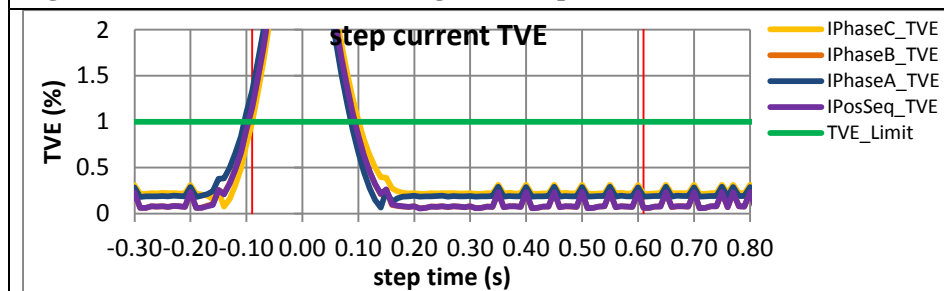


Figure 5339: Fs = 10 FPS, +10% magnitude step

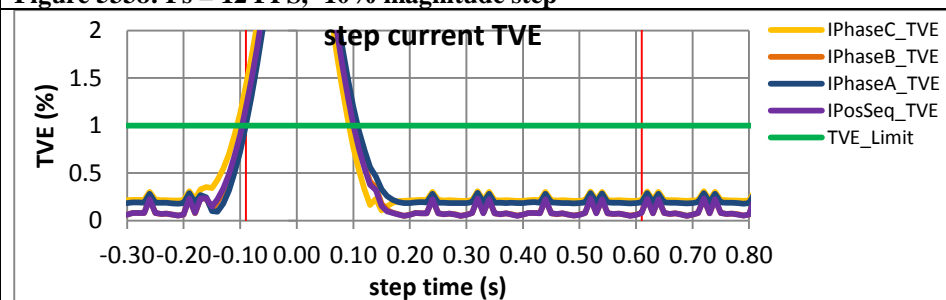


Figure 5340: Fs = 10 FPS, -10% magnitude step

### 10.3.11 PMU J dynamic step change in magnitude current response time: F0 = 60 Hz, M class

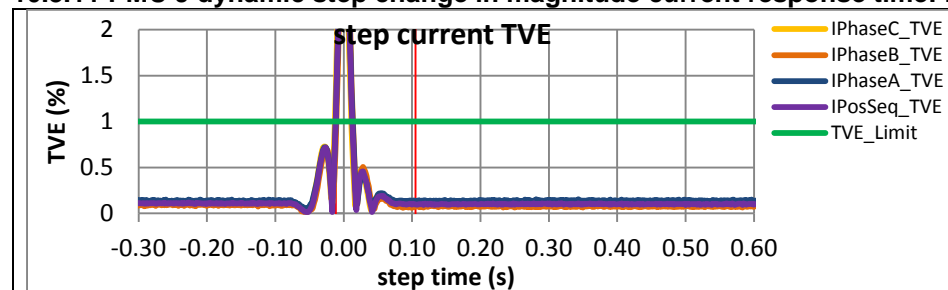


Figure 5341: Fs = 60 FPS, +10% magnitude step

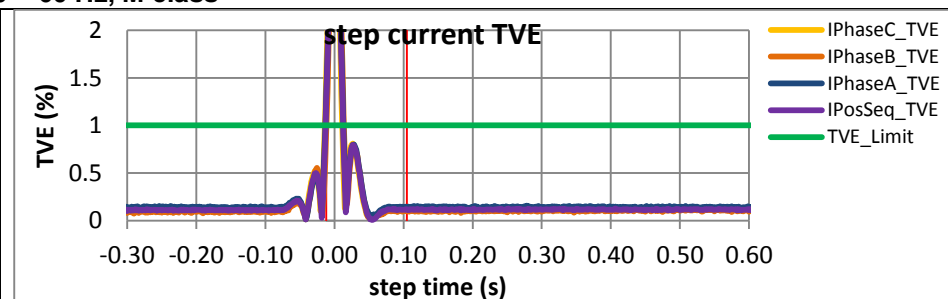


Figure 5342: Fs = 60 FPS, -10% magnitude step

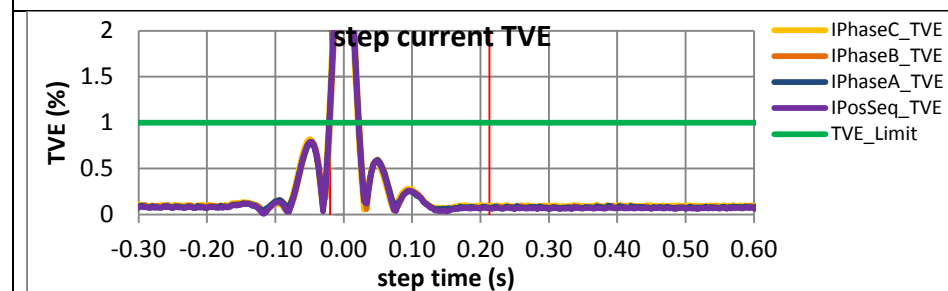


Figure 5343: Fs = 30 FPS, +10% magnitude step

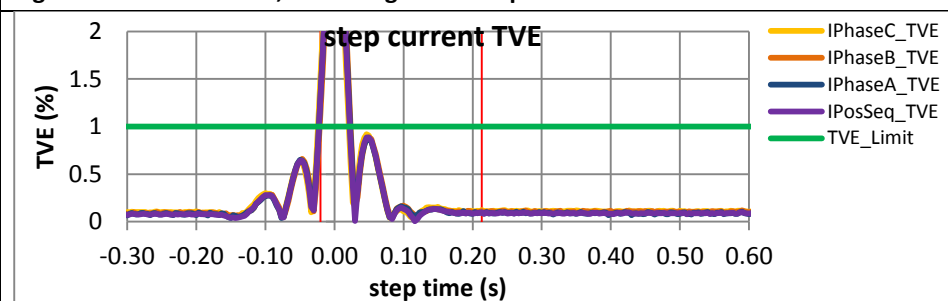


Figure 5344: Fs = 30 FPS, -10% magnitude step

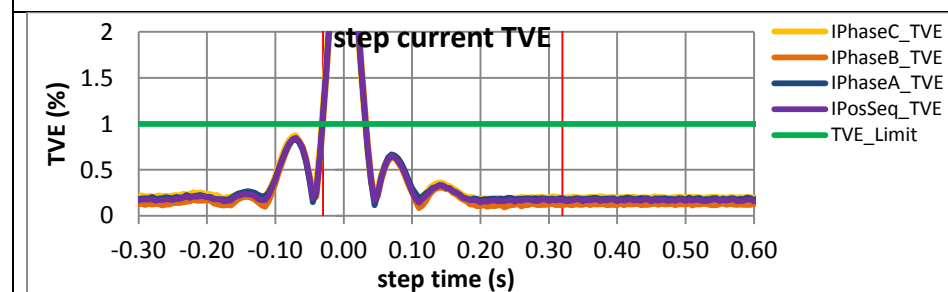


Figure 5345: Fs = 20 FPS, +10% magnitude step

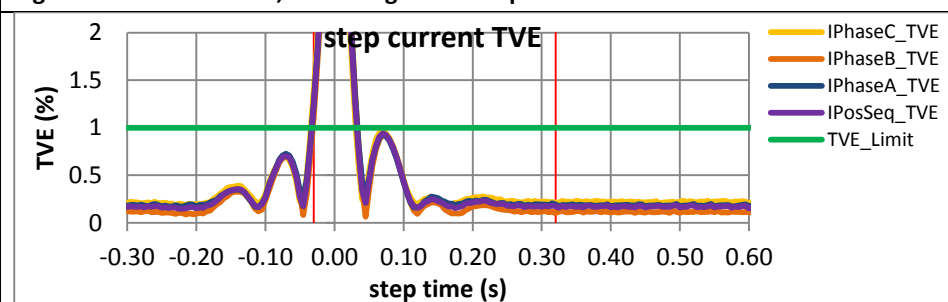


Figure 5346: Fs = 20 FPS, +10% magnitude step

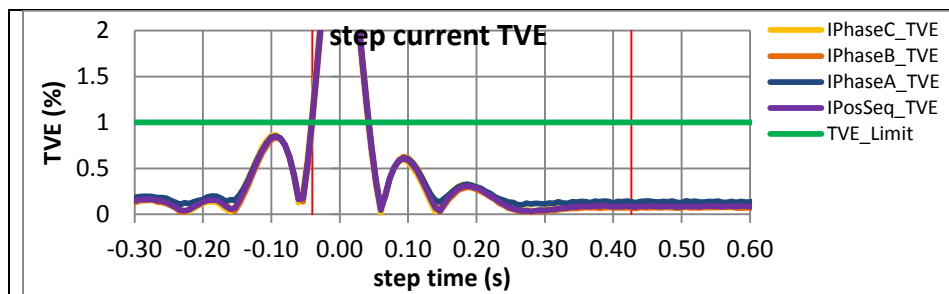


Figure 5347:  $F_s = 15$  FPS, +10% magnitude step

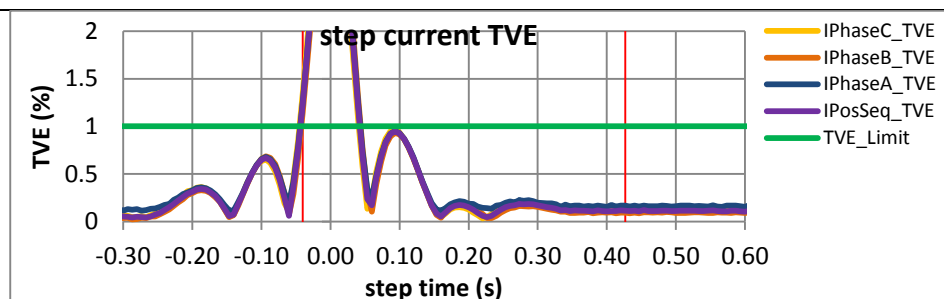


Figure 5348:  $F_s = 15$  FPS, -10% magnitude step

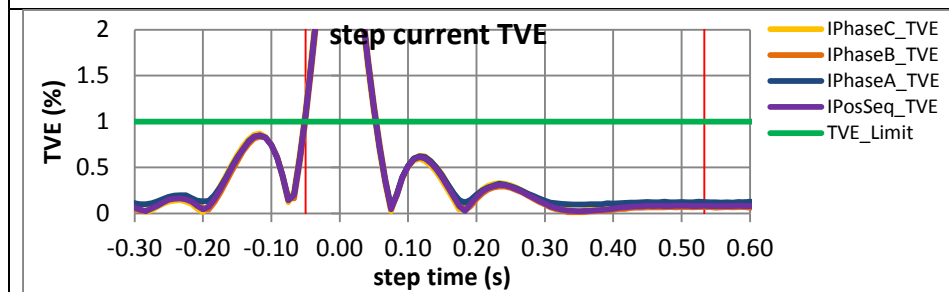


Figure 5349:  $F_s = 12$  FPS, +10% magnitude step

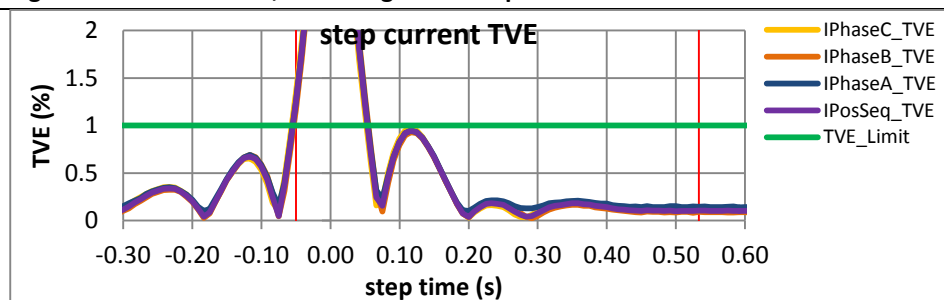


Figure 5350:  $F_s = 12$  FPS, -10% magnitude step

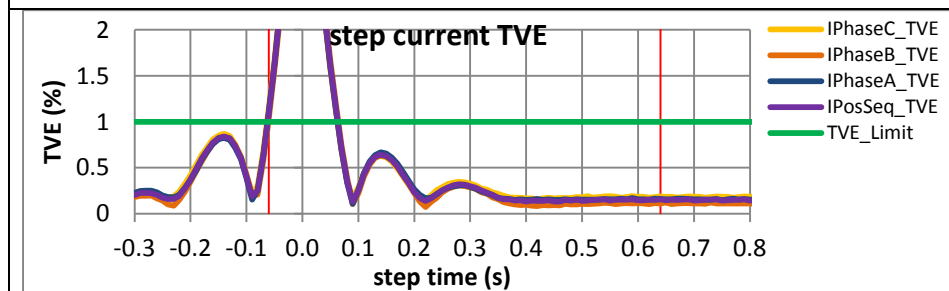


Figure 5351:  $F_s = 10$  FPS, +10% magnitude step

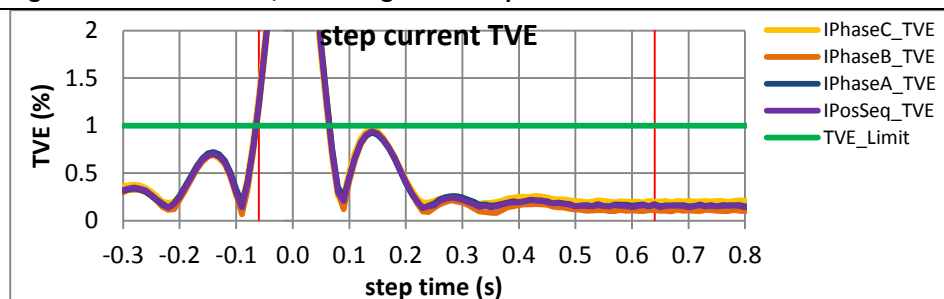
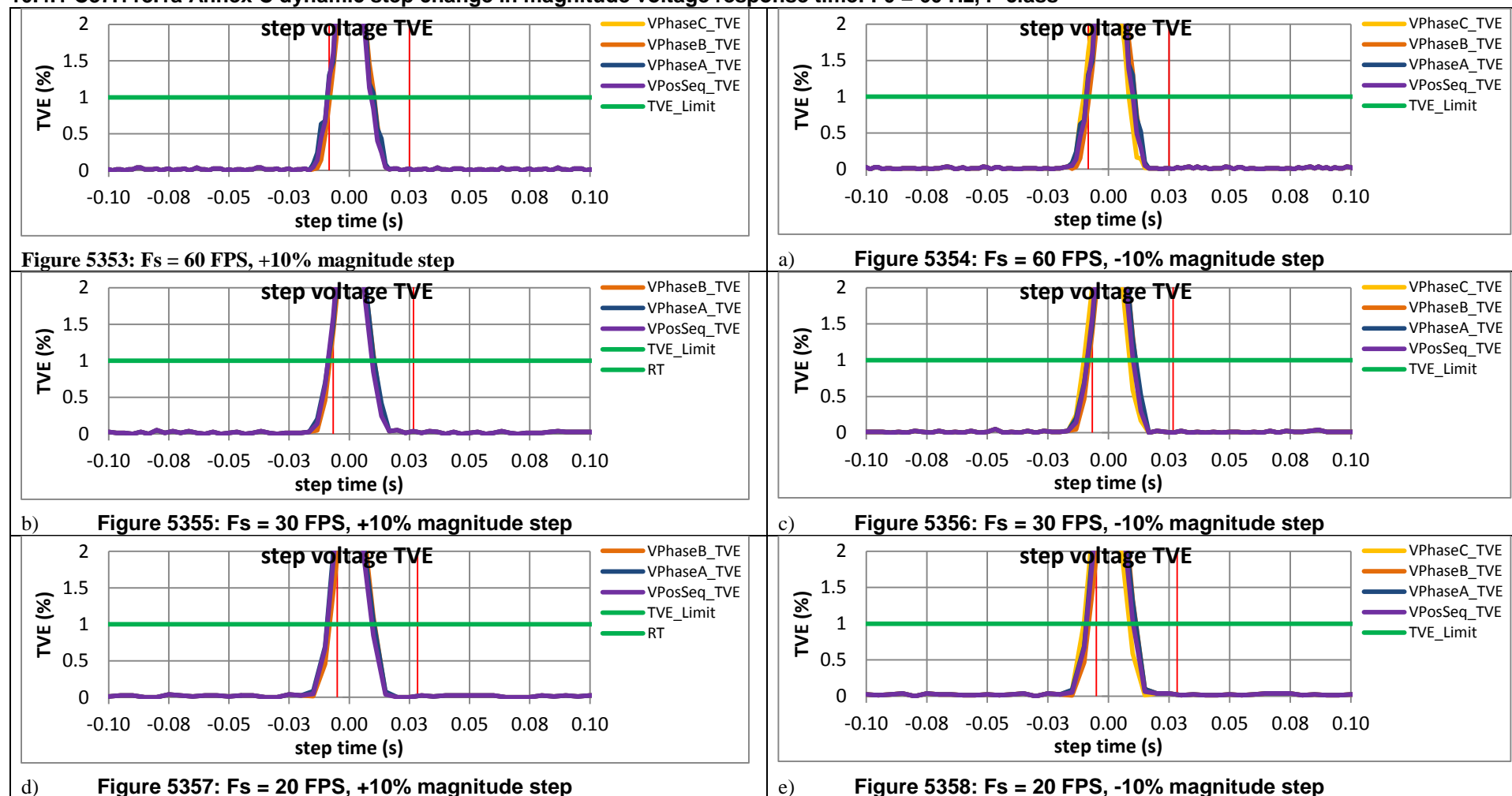
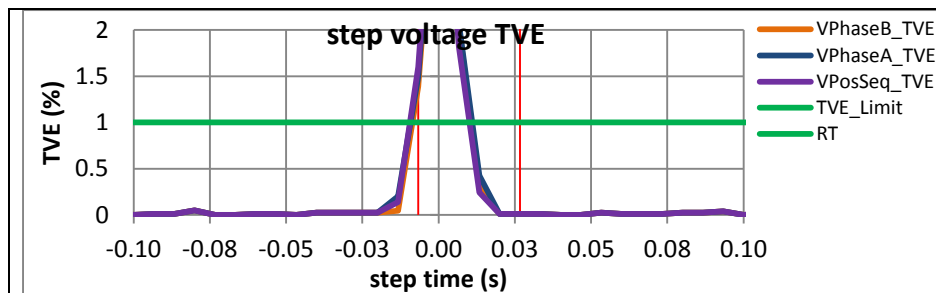


Figure 5352:  $F_s = 10$  FPS, -10% magnitude step

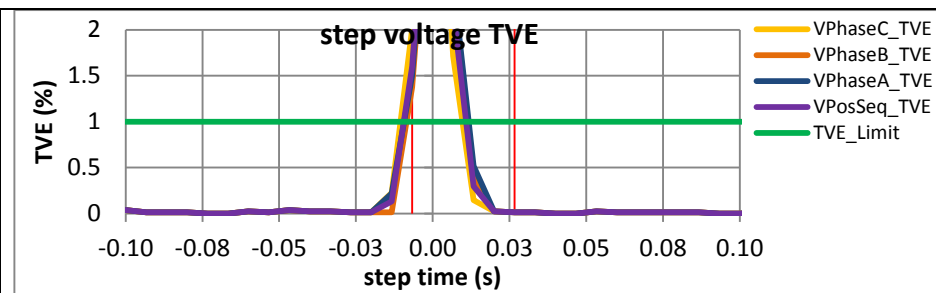
## 10.4 Dynamic step change in magnitude voltage response time: F0 = 60 Hz, P Class

### 10.4.1 C37.118.1a Annex C dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class

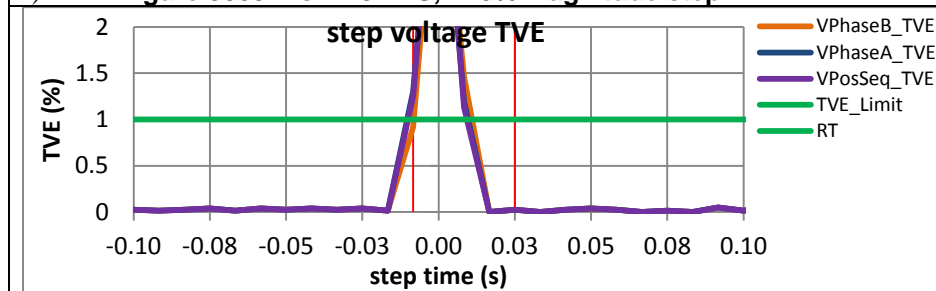




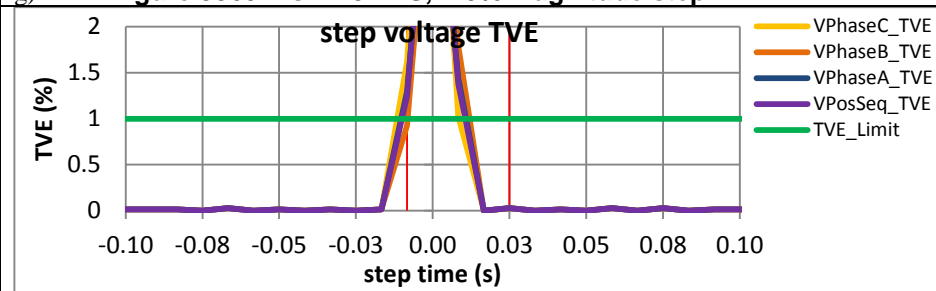
f) **Figure 5359: Fs = 15 FPS, +10% magnitude step**



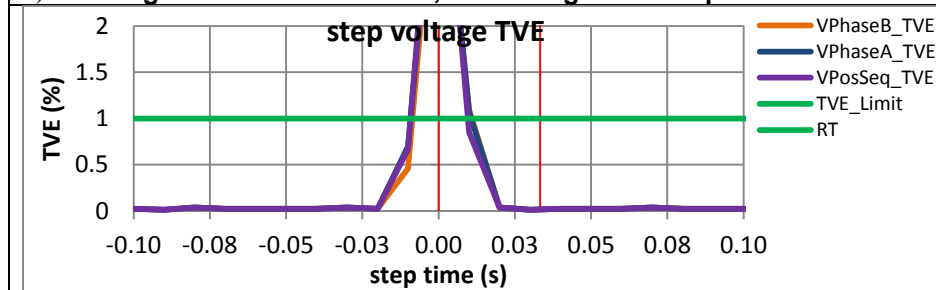
g) **Figure 5360: Fs = 15 FPS, -10% magnitude step**



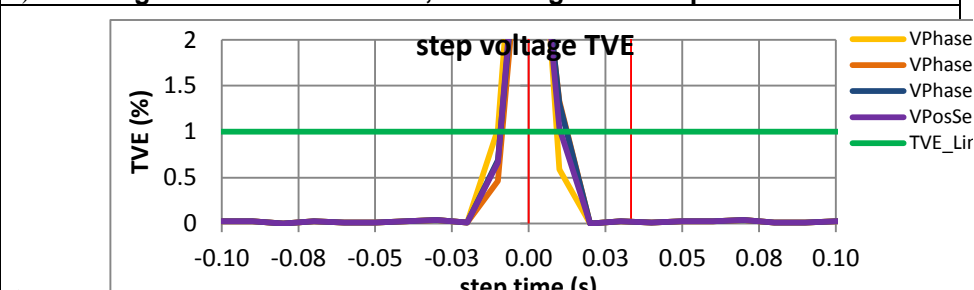
h) **Figure 5361: Fs = 12 FPS, +10% magnitude step**



i) **Figure 5362: Fs = 12 FPS, -10% magnitude step**



j) **Figure 5363: Fs = 10 FPS, +10% magnitude step**



k) **Figure 5364: Fs = 10 FPS, +10% magnitude step**



#### 10.4.2 PMU A dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class

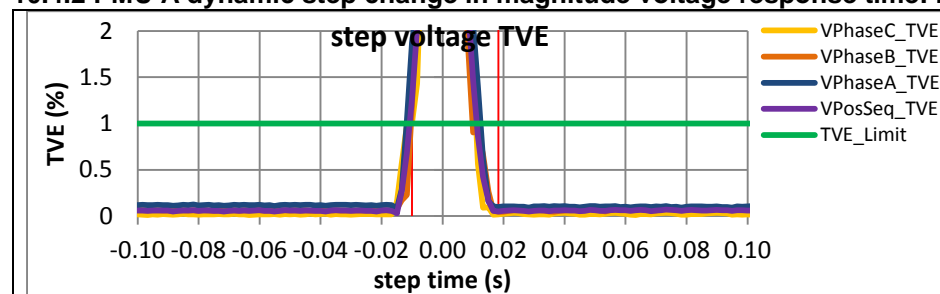


Figure 5365: Fs = 60 FPS, +10% magnitude step

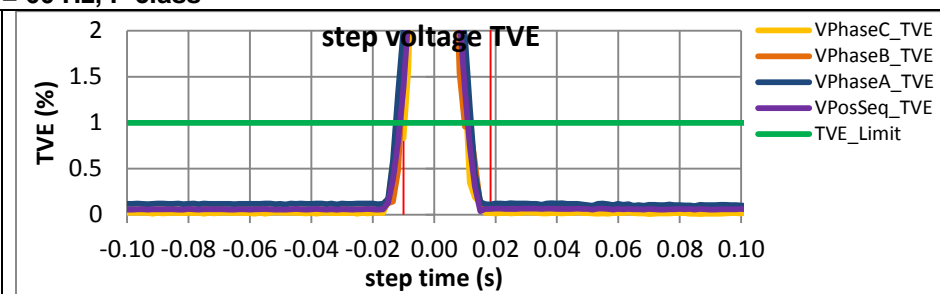


Figure 5366: Fs = 60 FPS, -10% magnitude step

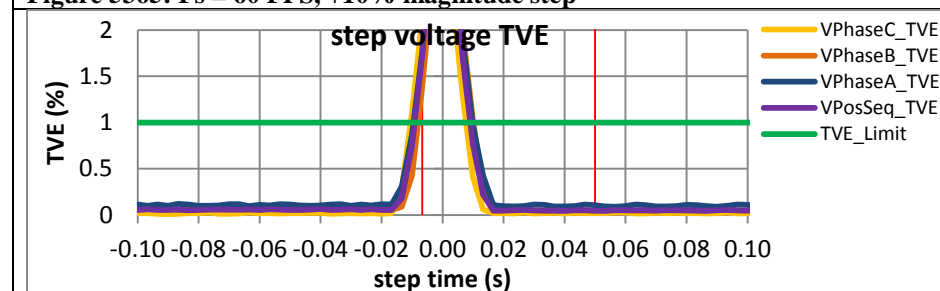


Figure 5367: Fs = 30 FPS, +10% magnitude step

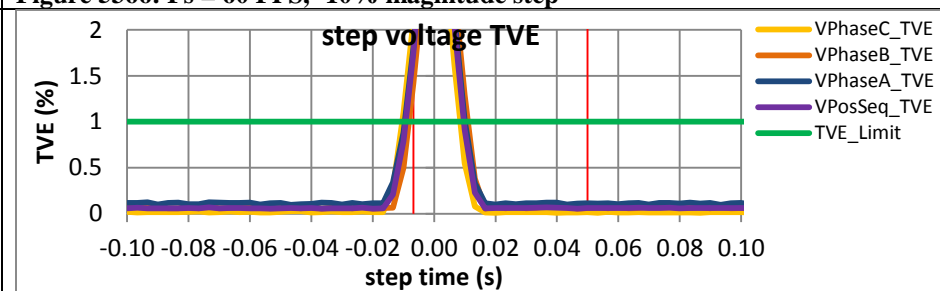


Figure 5368: Fs = 30 FPS, -10% magnitude step

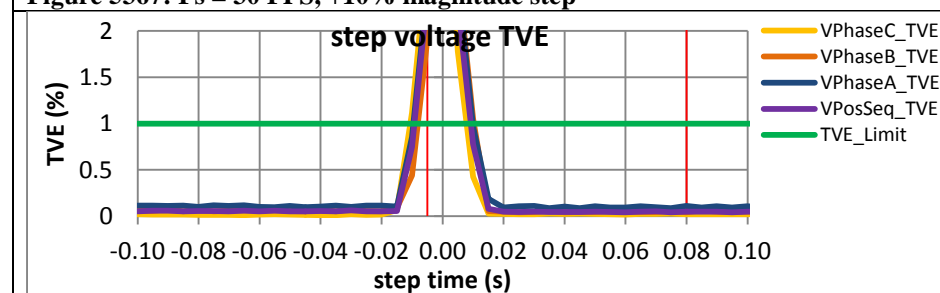


Figure 5369: Fs = 20 FPS, +10% magnitude step

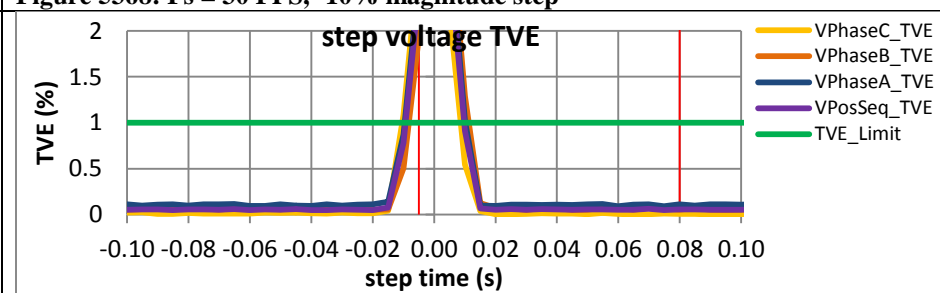


Figure 5370: Fs = 20 FPS, -10% magnitude step

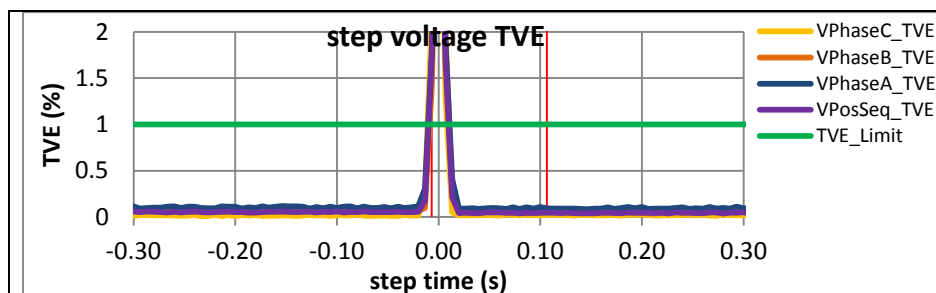


Figure 5371:  $F_s = 15$  FPS, +10% magnitude step

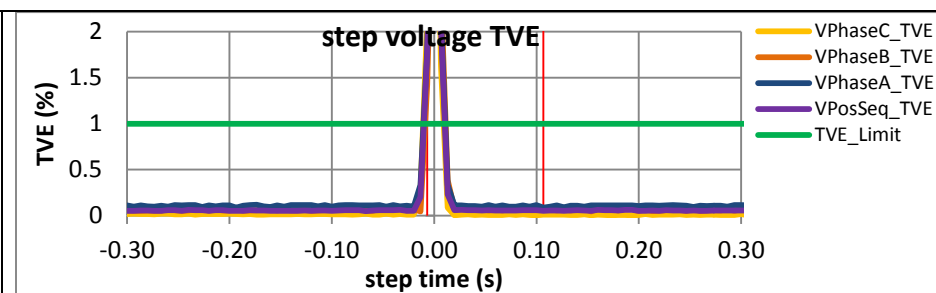


Figure 5372:  $F_s = 15$  FPS, -10% magnitude step

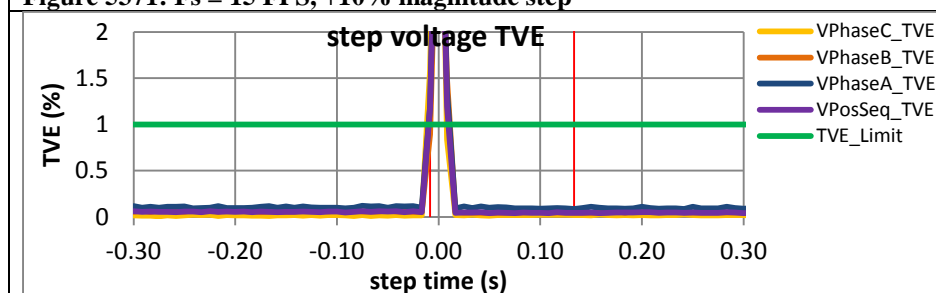


Figure 5373:  $F_s = 12$  FPS, +10% magnitude step

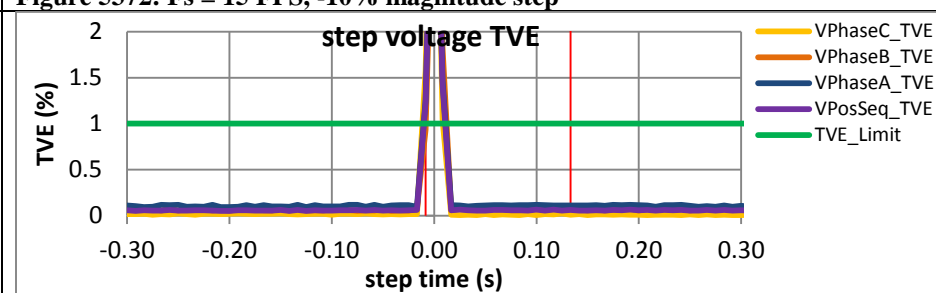


Figure 5374:  $F_s = 12$  FPS, -10% magnitude step

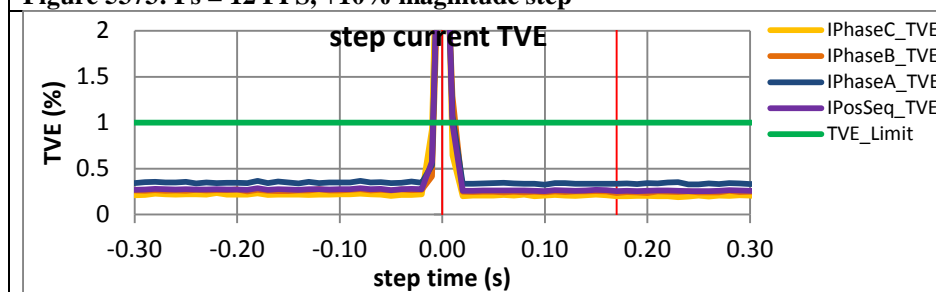


Figure 5375:  $F_s = 10$  FPS, +10% magnitude step

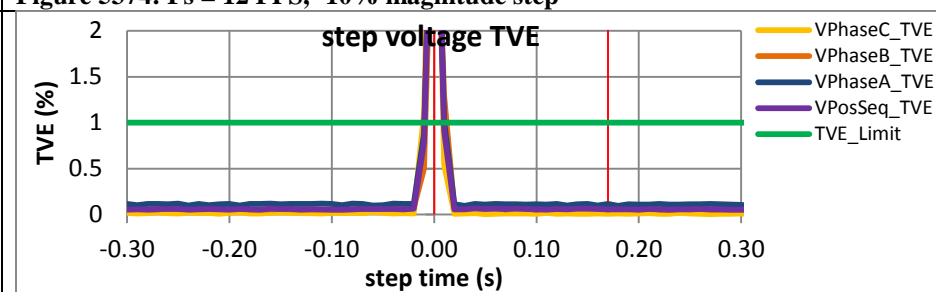


Figure 5376:  $F_s = 10$  FPS, +10% magnitude step

### 10.4.3 PMU B dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class

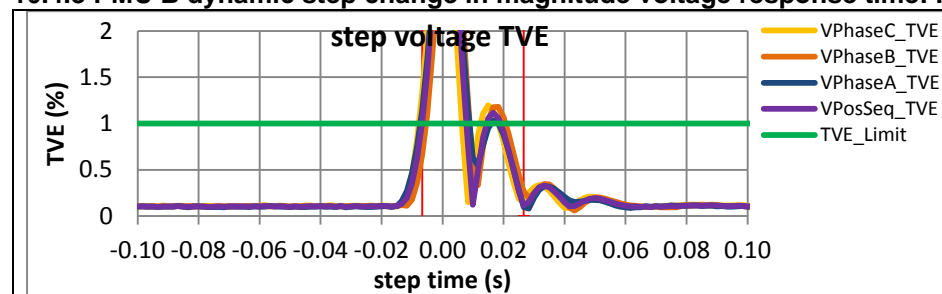


Figure 5377: Fs = 60 FPS, +10% magnitude step

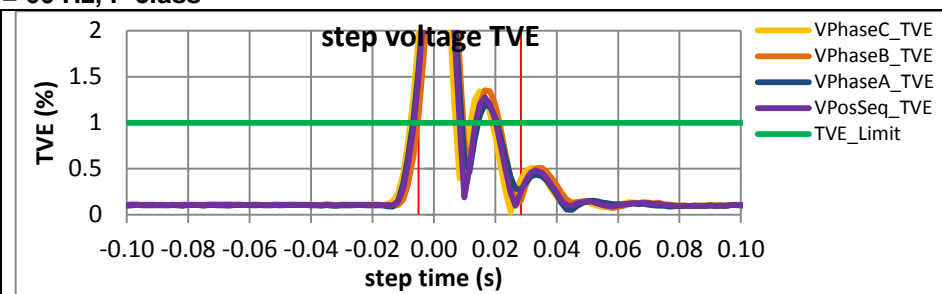


Figure 5378: Fs = 60 FPS, -10% magnitude step

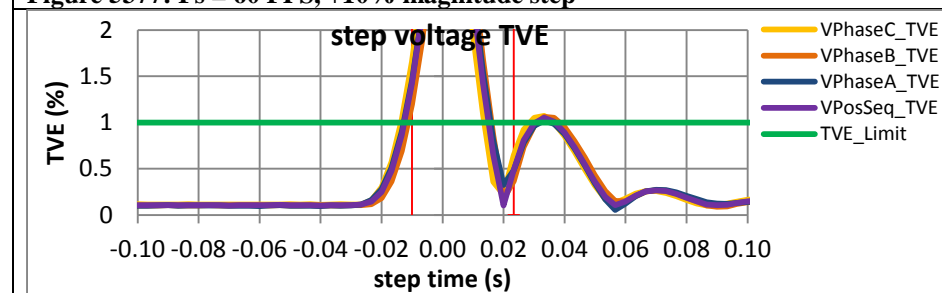


Figure 5379: Fs = 30 FPS, +10% magnitude step

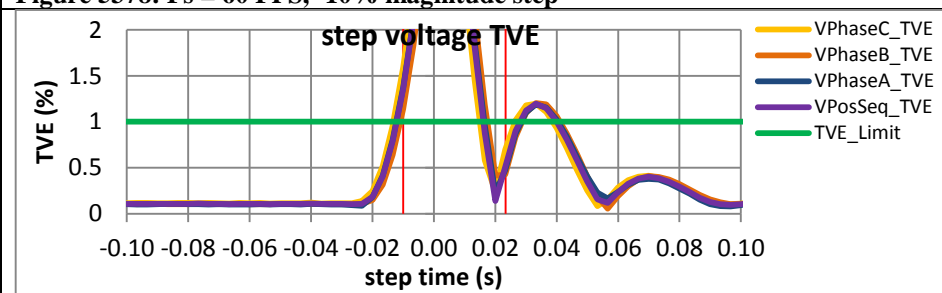


Figure 5380: Fs = 30 FPS, -10% magnitude step

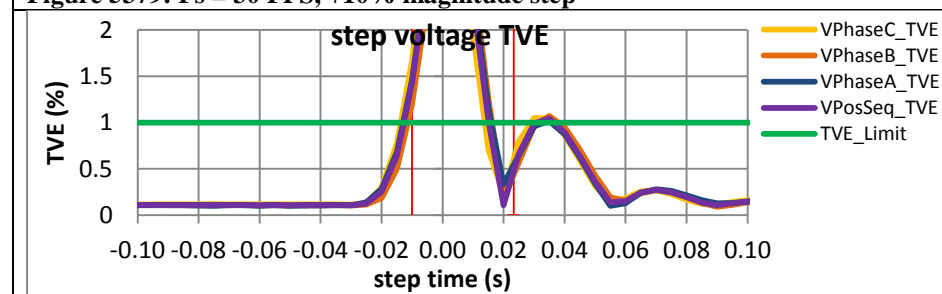


Figure 5381: Fs = 20 FPS, +10% magnitude step

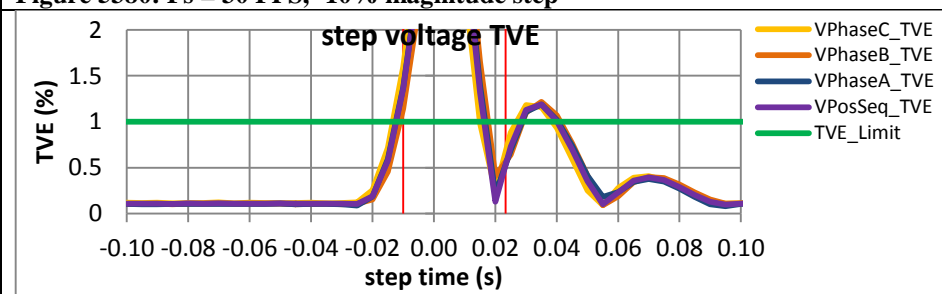


Figure 5382: Fs = 20 FPS, -10% magnitude step

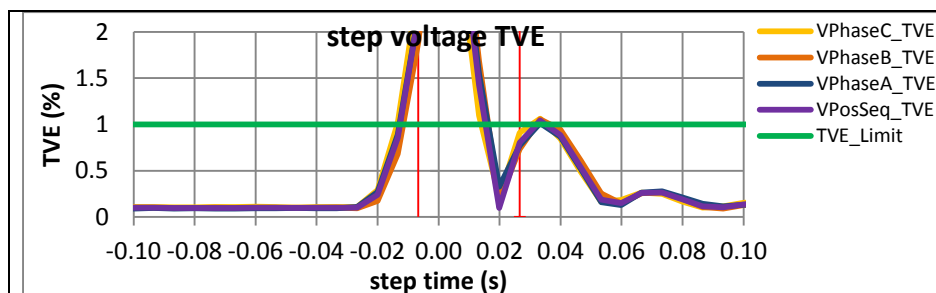


Figure 5383: Fs = 15 FPS, +10% magnitude step

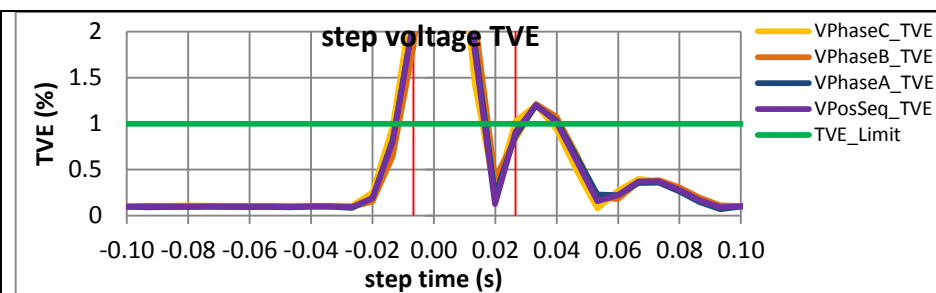


Figure 5384: Fs = 15 FPS, -10% magnitude step

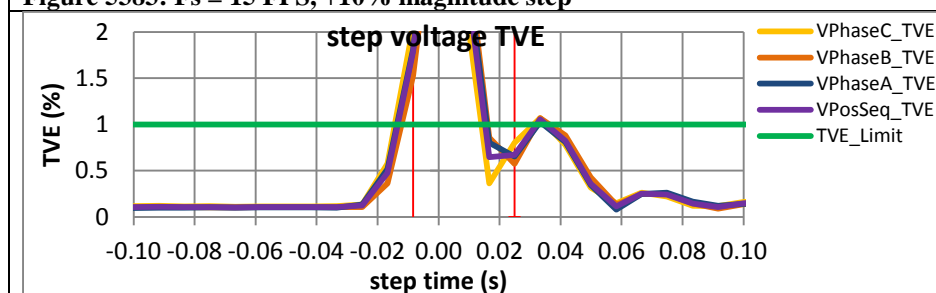


Figure 5385: Fs = 12 FPS, +10% magnitude step

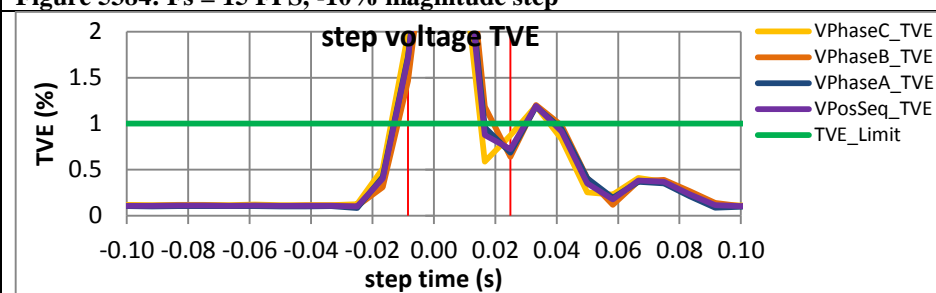


Figure 5386: Fs = 12 FPS, -10% magnitude step

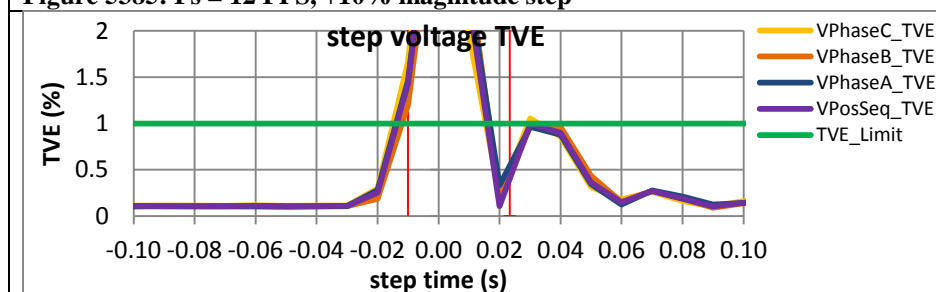


Figure 5387: Fs = 10 FPS, +10% magnitude step

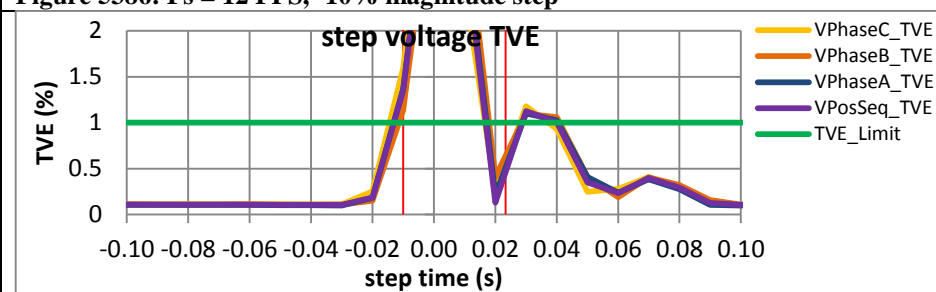


Figure 5388: Fs = 10 FPS, +10% magnitude step

#### 10.4.4 PMU C dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class

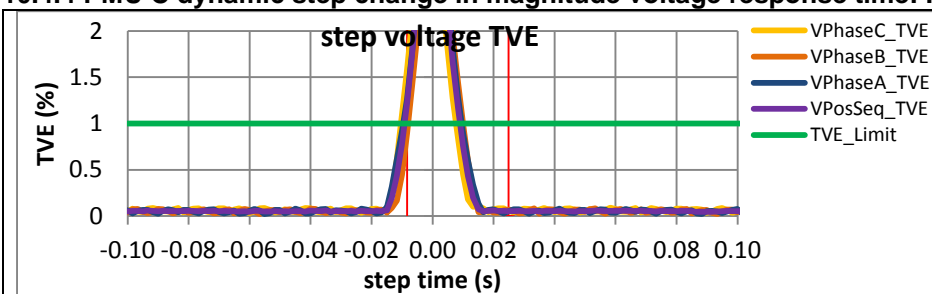


Figure 5389: Fs = 60 FPS, +10% magnitude step

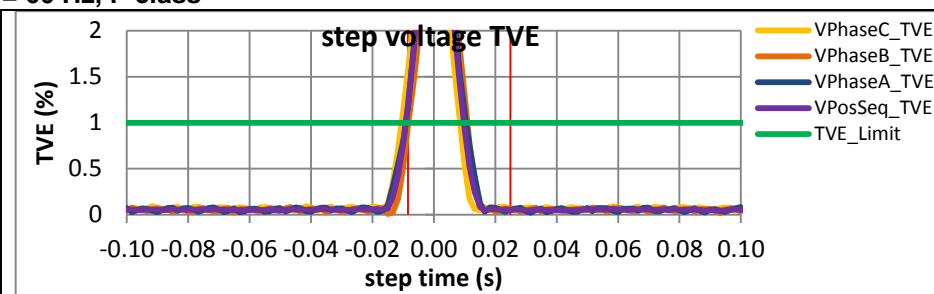


Figure 5390: Fs = 60 FPS, -10% magnitude step

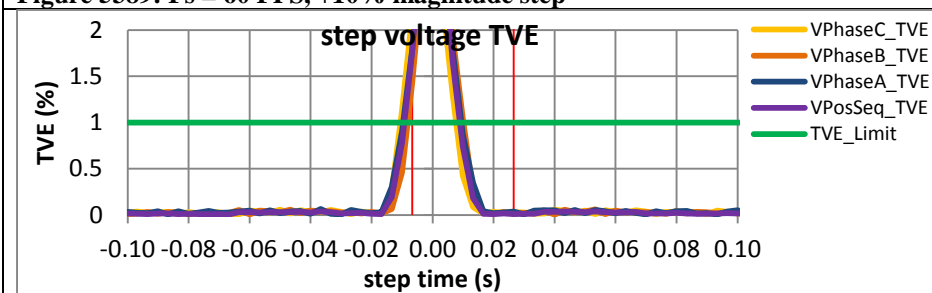


Figure 5391: Fs = 30 FPS, +10% magnitude step

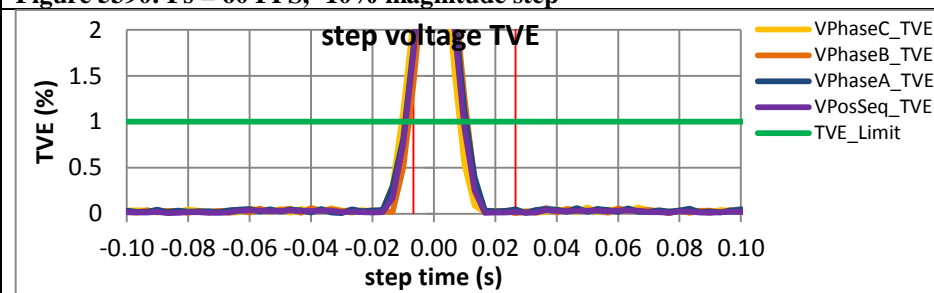


Figure 5392: Fs = 30 FPS, -10% magnitude step

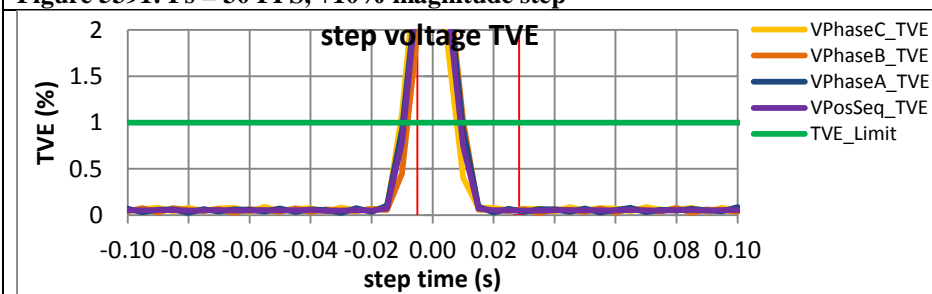


Figure 5393: Fs = 20 FPS, +10% magnitude step

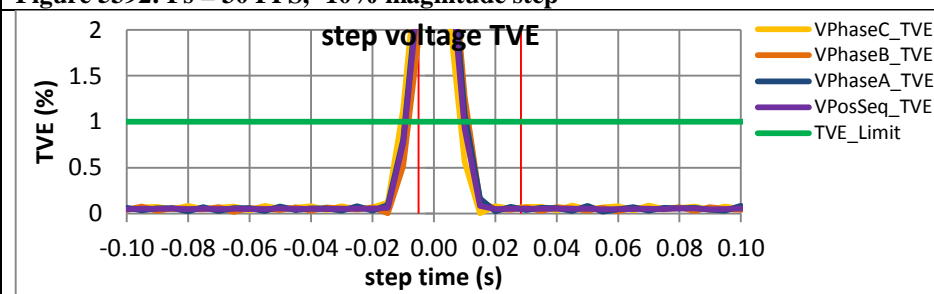


Figure 5394: Fs = 20 FPS, -10% magnitude step

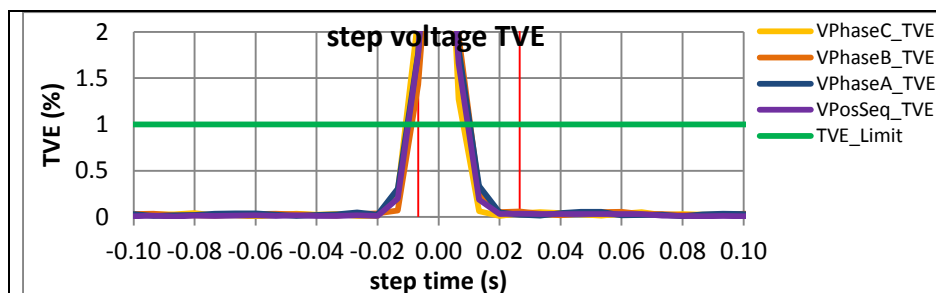


Figure 5395: Fs = 15 FPS, +10% magnitude step

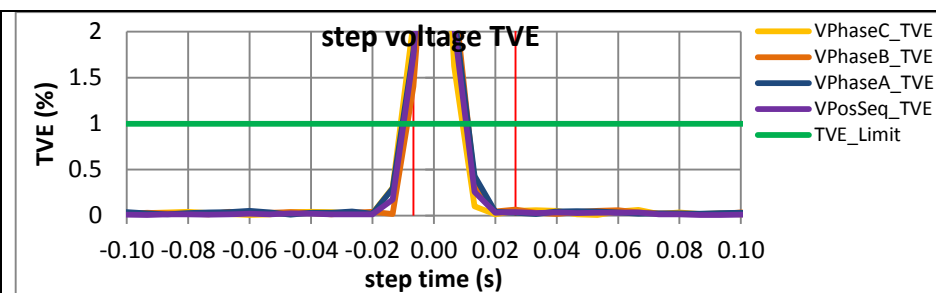


Figure 5396: Fs = 15 FPS, -10% magnitude step

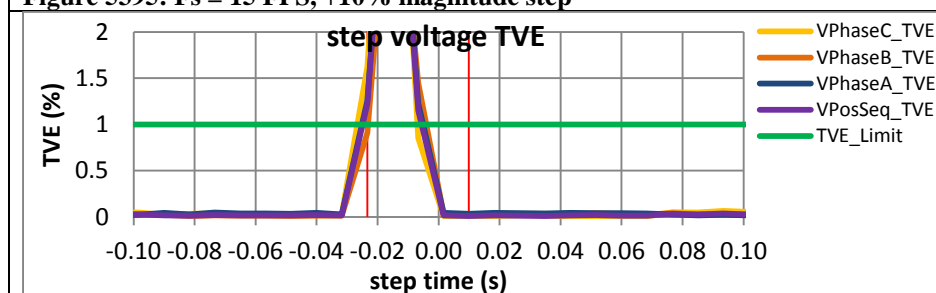


Figure 5397: Fs = 12 FPS, +10% magnitude step

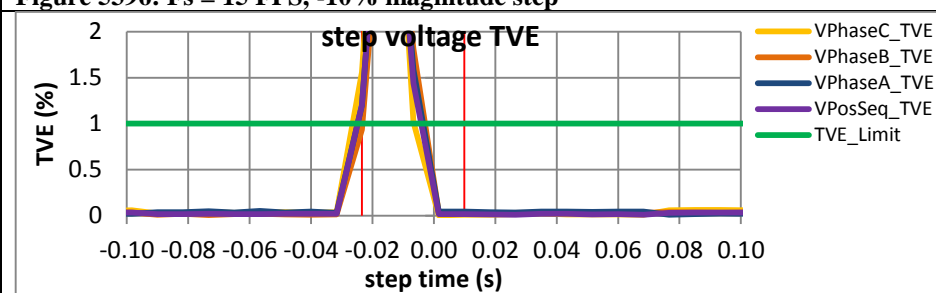


Figure 5398: Fs = 12 FPS, -10% magnitude step

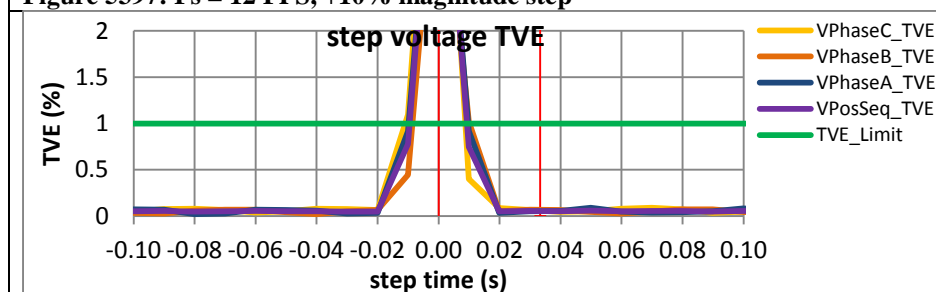


Figure 5399: Fs = 10 FPS, +10% magnitude step

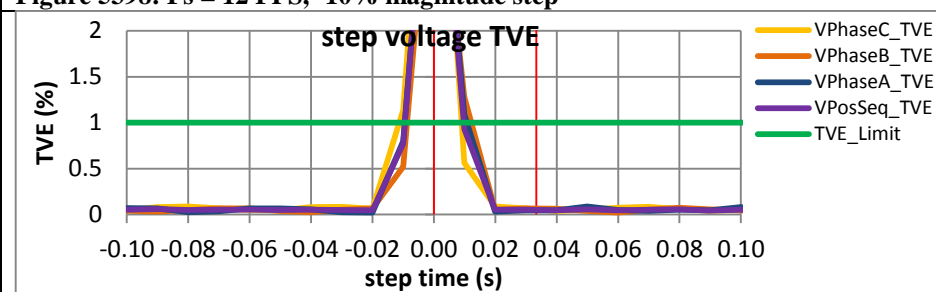


Figure 5400: Fs = 10 FPS, +10% magnitude step

#### 10.4.5 PMU D dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class

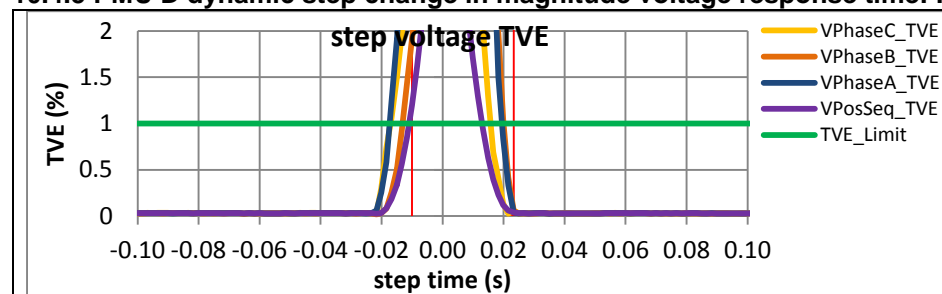


Figure 5401: Fs = 60 FPS, +10% magnitude step

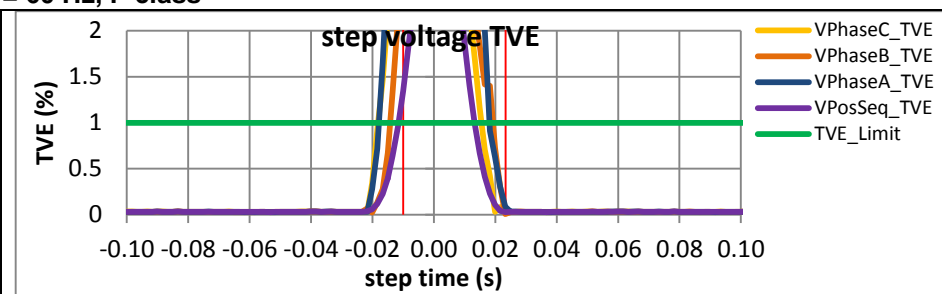


Figure 5402: Fs = 60 FPS, -10% magnitude step

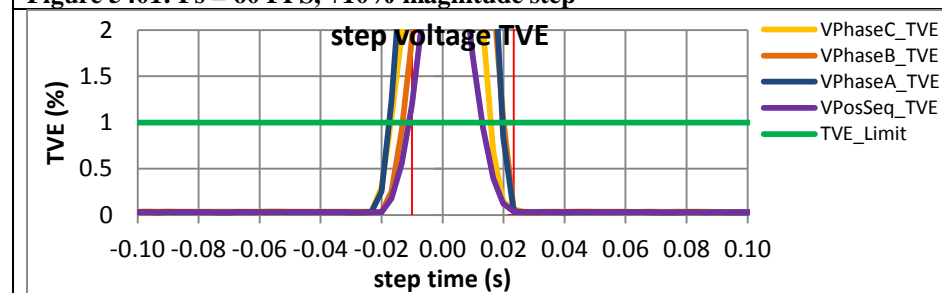


Figure 5403: Fs = 30 FPS, +10% magnitude step

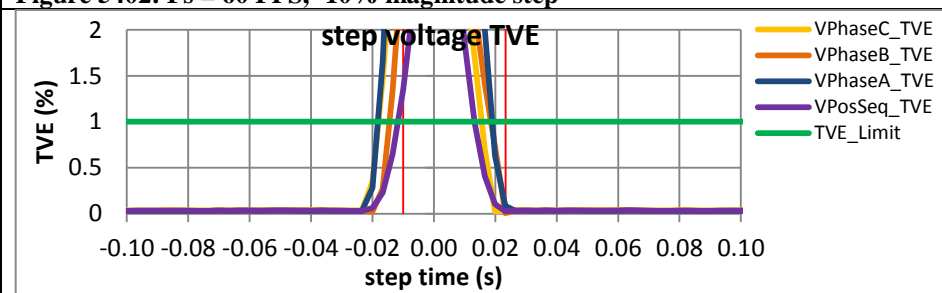


Figure 5404: Fs = 30 FPS, -10% magnitude step

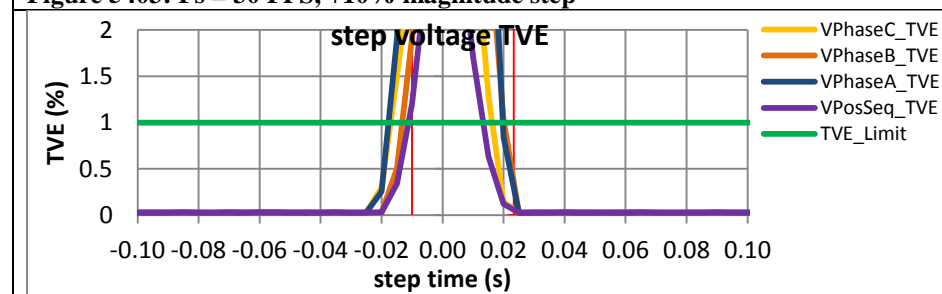


Figure 5405: Fs = 20 FPS, +10% magnitude step

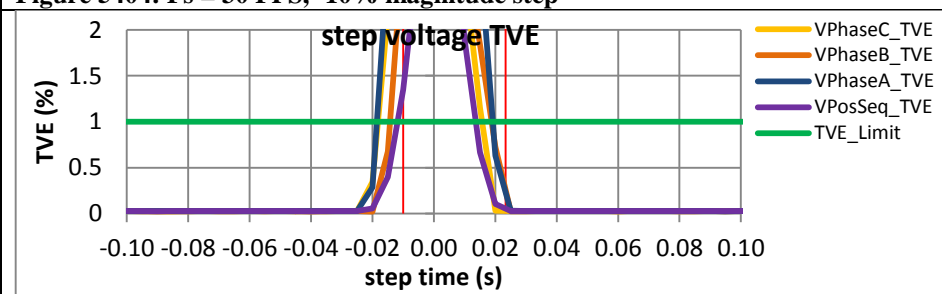


Figure 5406: Fs = 20 FPS, -10% magnitude step

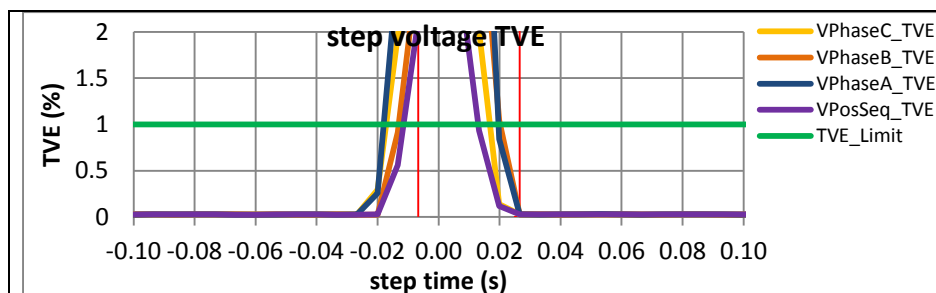


Figure 5407:  $F_s = 15$  FPS, +10% magnitude step

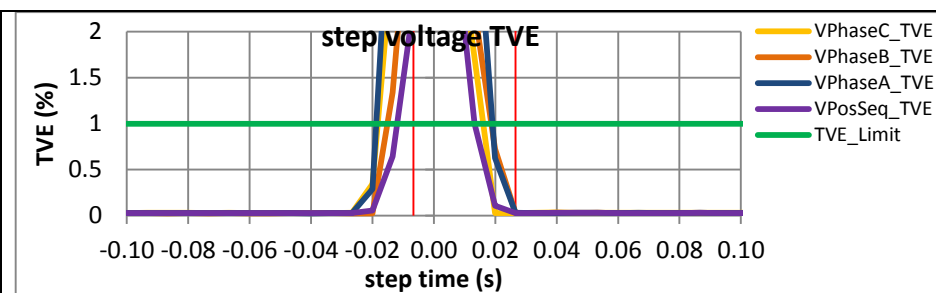


Figure 5408:  $F_s = 15$  FPS, -10% magnitude step

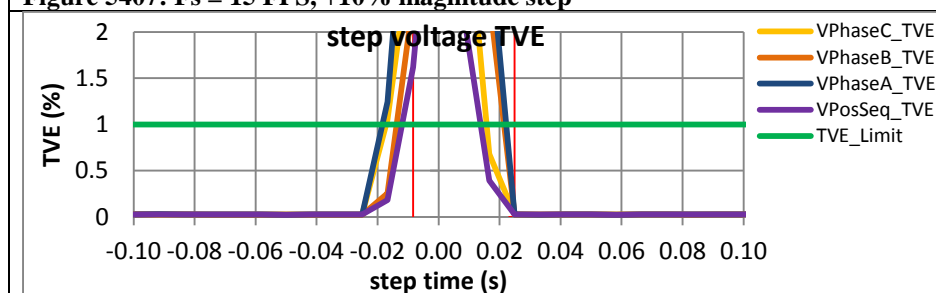


Figure 5409:  $F_s = 12$  FPS, +10% magnitude step

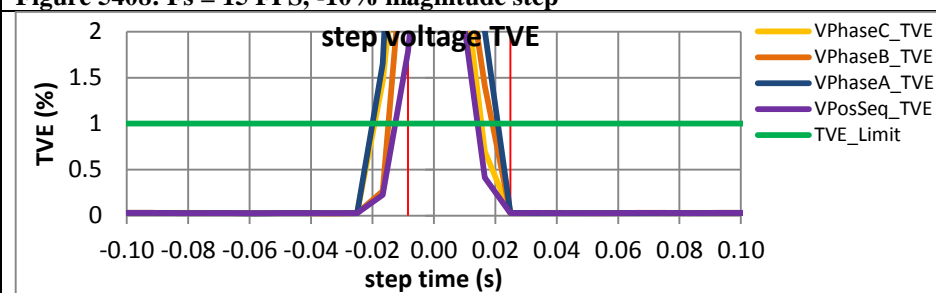


Figure 5410:  $F_s = 12$  FPS, -10% magnitude step

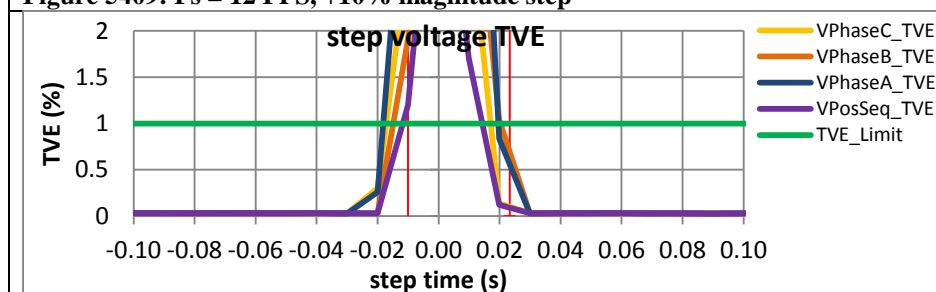


Figure 5411:  $F_s = 10$  FPS, +10% magnitude step

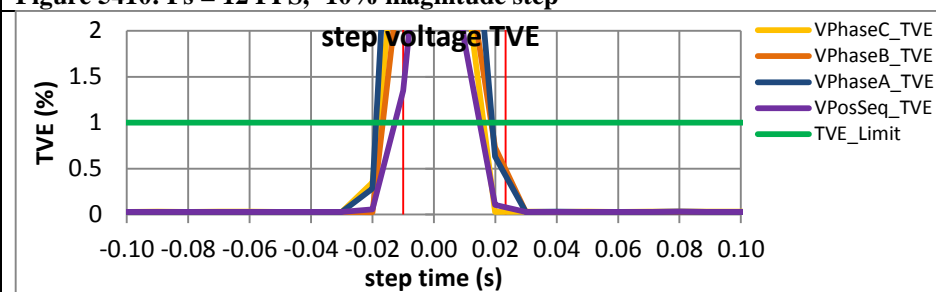


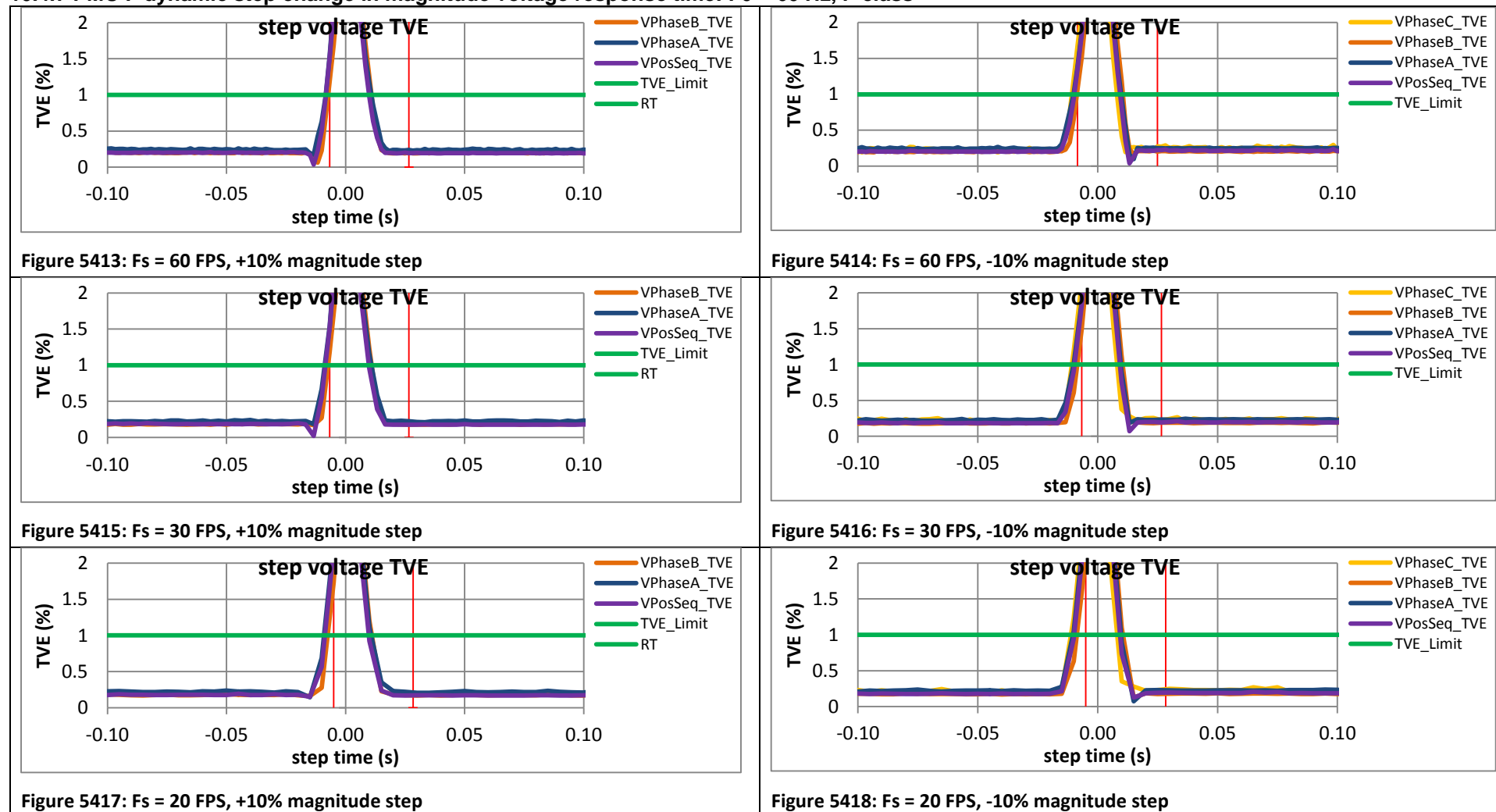
Figure 5412:  $F_s = 10$  FPS, -10% magnitude step



#### 10.4.6 PMU E dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class

PMU E does not support P class.

#### 10.4.7 PMU F dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class



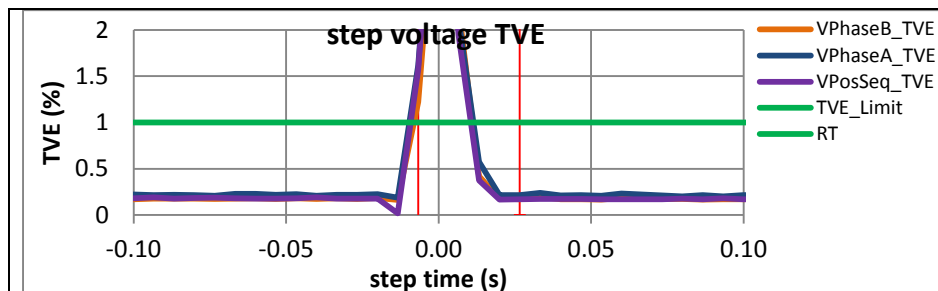


Figure 5419: Fs = 15 FPS, +10% magnitude step

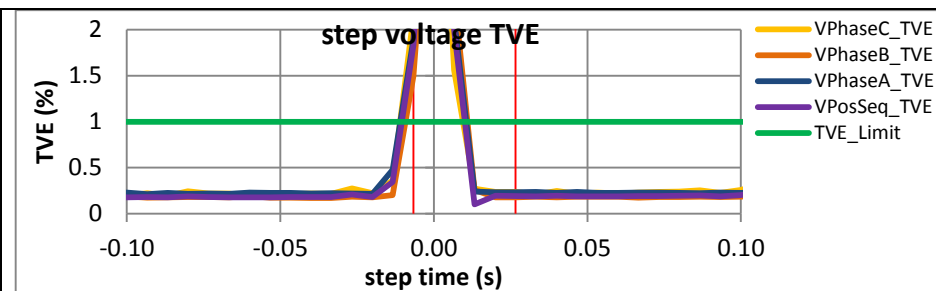


Figure 5420: Fs = 15 FPS, -10% magnitude step

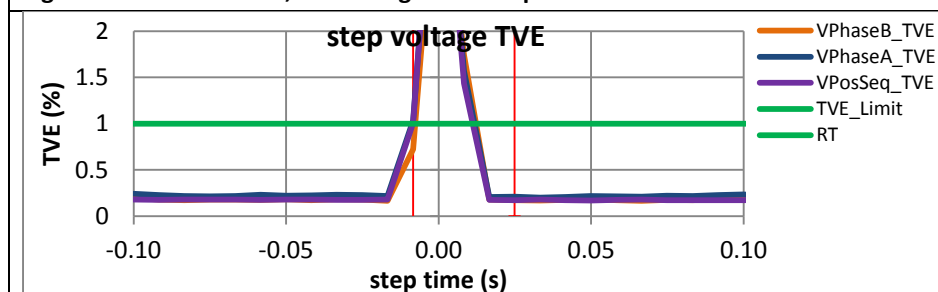


Figure 5421: Fs = 12 FPS, +10% magnitude step

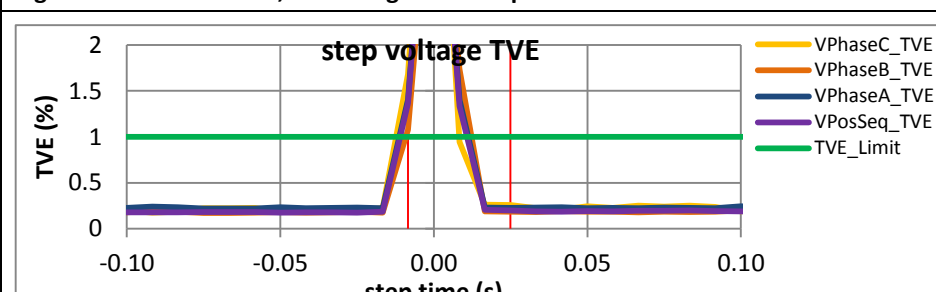


Figure 5422: Fs = 12 FPS, -10% magnitude step

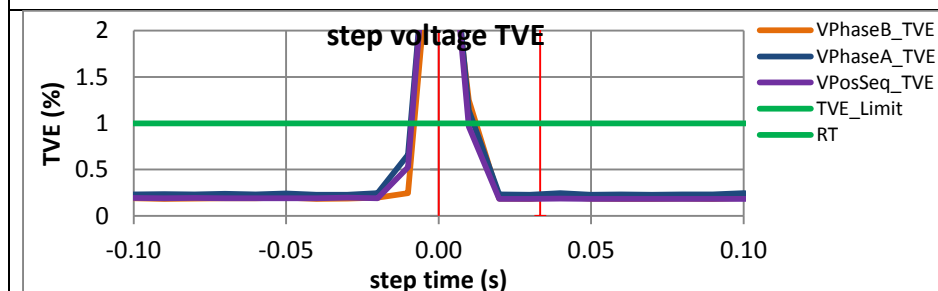


Figure 5423: Fs = 10 FPS, +10% magnitude step

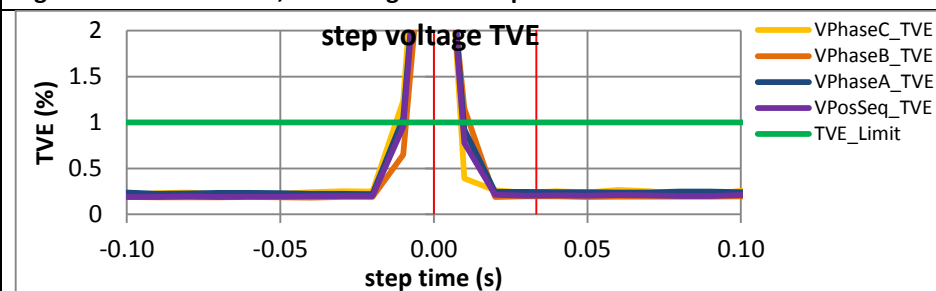
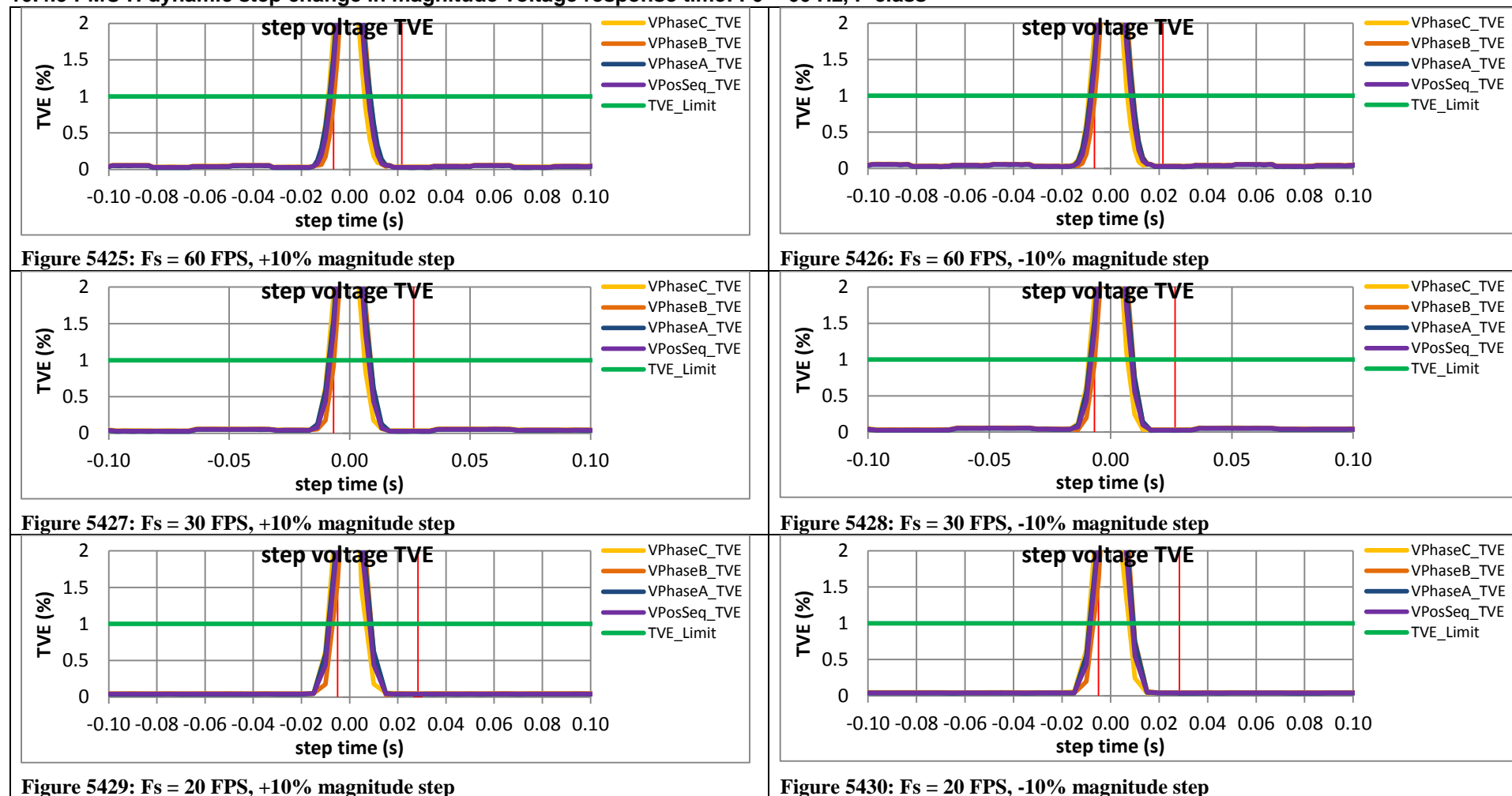


Figure 5424: Fs = 10 FPS, +10% magnitude step

#### 10.4.8 PMU G dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class

PMU G does not support P class.

#### 10.4.9 PMU H dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class



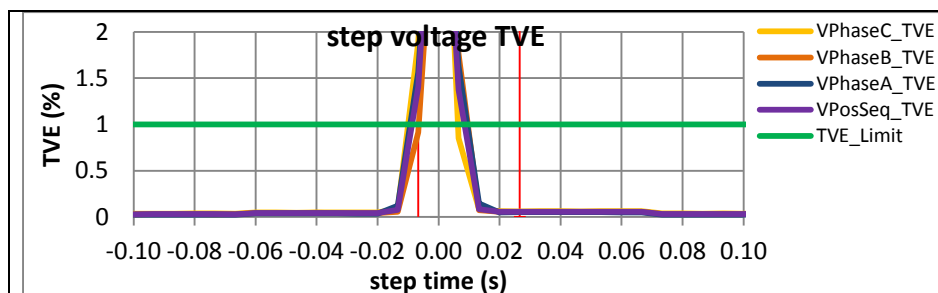


Figure 5431:  $F_s = 15$  FPS, +10% magnitude step

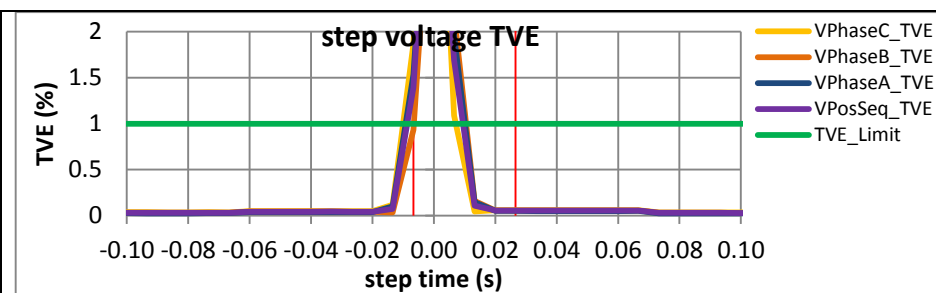


Figure 5432:  $F_s = 15$  FPS, -10% magnitude step

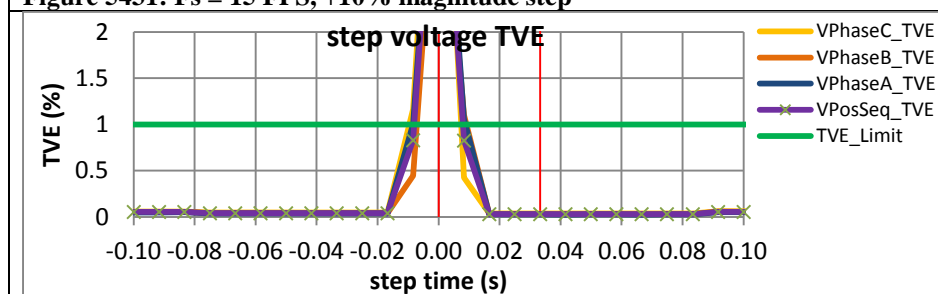


Figure 5433:  $F_s = 12$  FPS, +10% magnitude step

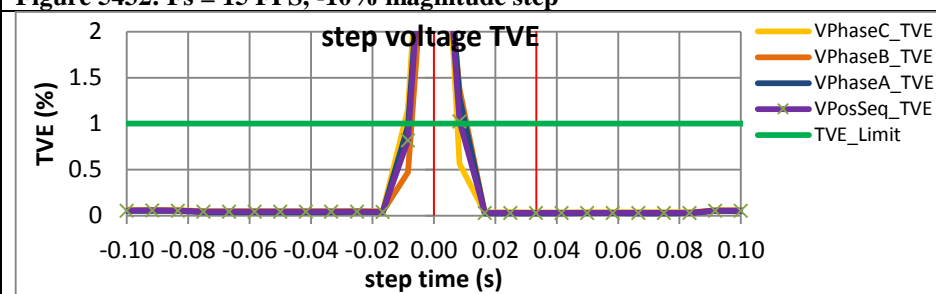


Figure 5434:  $F_s = 12$  FPS, -10% magnitude step

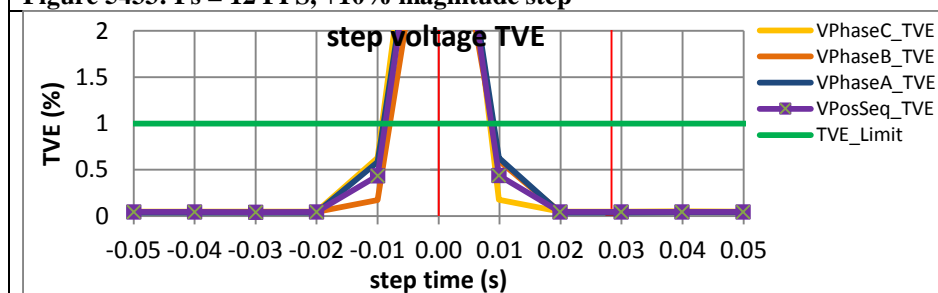


Figure 5435:  $F_s = 10$  FPS, +10% magnitude step

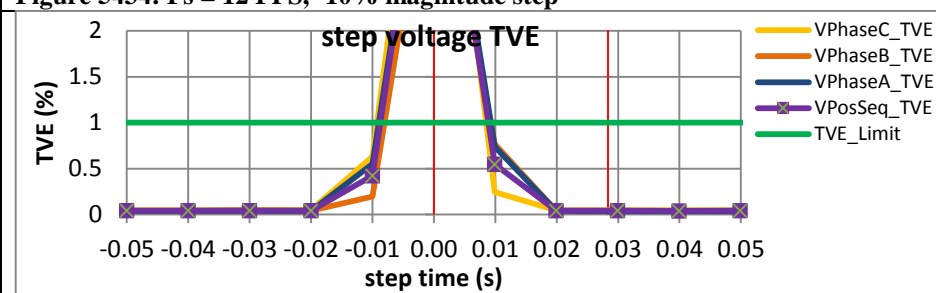
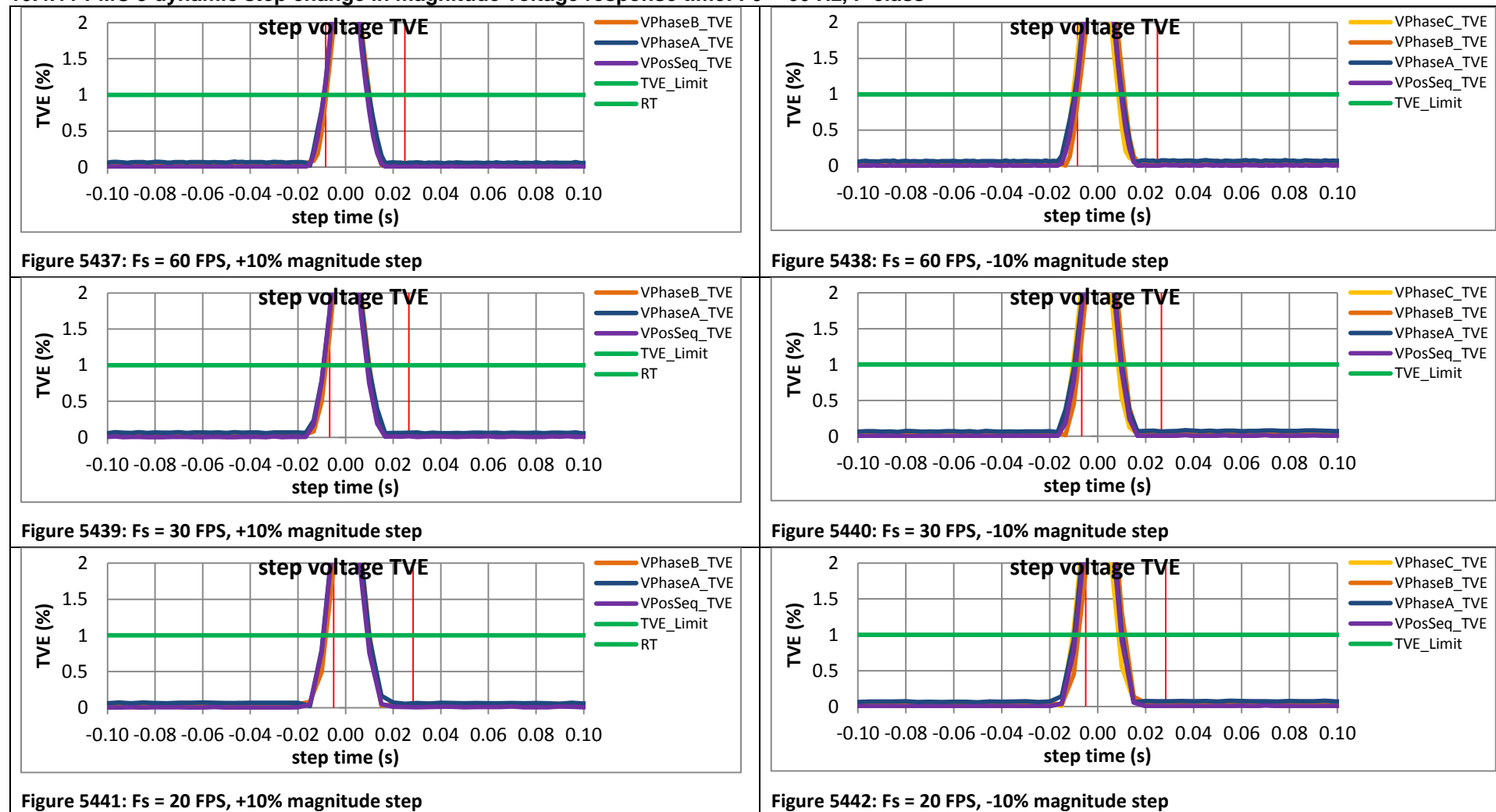


Figure 5436:  $F_s = 10$  FPS, -10% magnitude step

#### 10.4.10 PMU I dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class

PMI I does not support P class

#### 10.4.11 PMU J dynamic step change in magnitude voltage response time: F0 = 60 Hz, P class



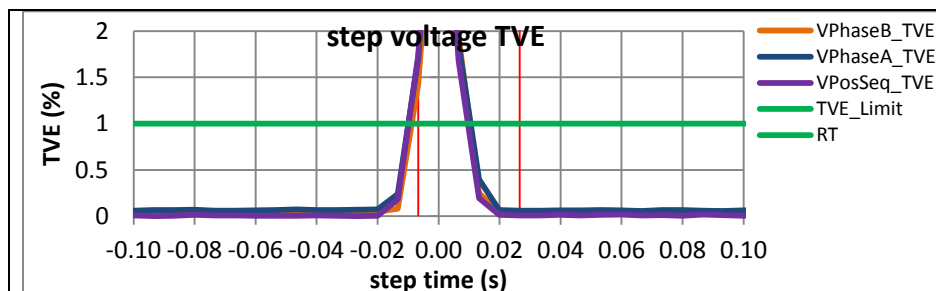


Figure 5443: Fs = 15 FPS, +10% magnitude step

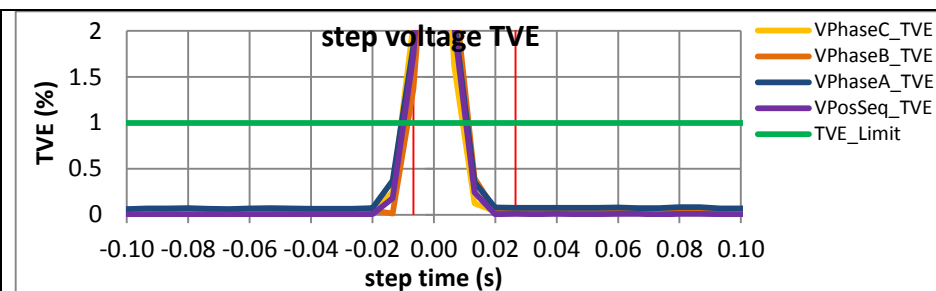


Figure 5444: Fs = 15 FPS, -10% magnitude step

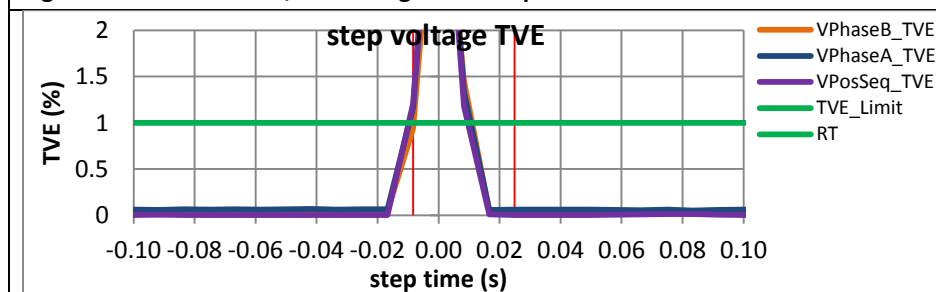


Figure 5445: Fs = 12 FPS, +10% magnitude step

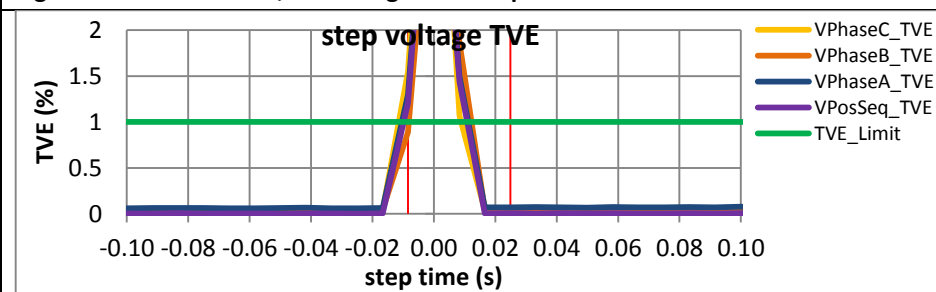


Figure 5446: Fs = 12 FPS, -10% magnitude step

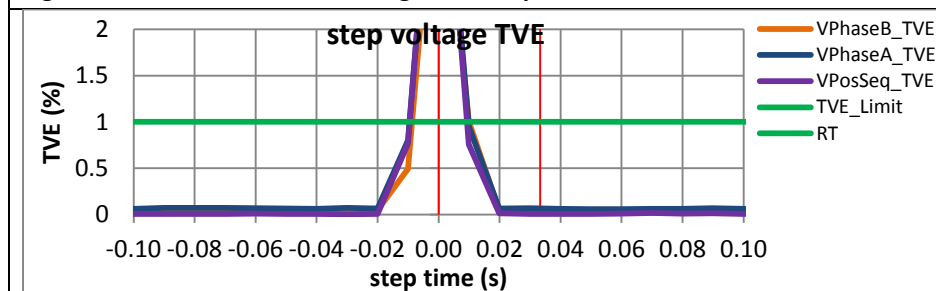


Figure 5447: Fs = 10 FPS, +10% magnitude step

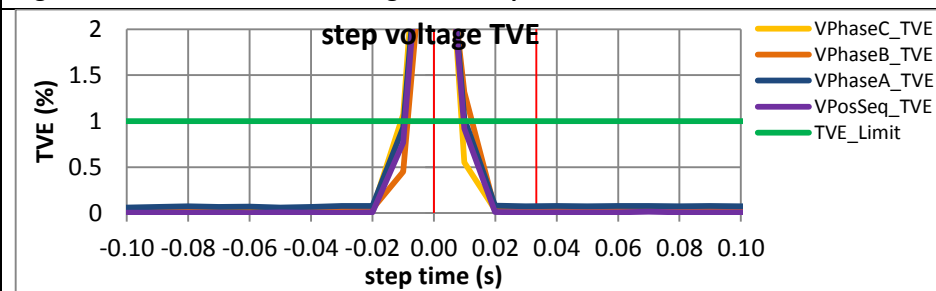


Figure 5448: Fs = 10 FPS, -10% magnitude step

## 10.5 Dynamic step change in magnitude current response time: $F_0 = 60$ Hz, P class

### 10.5.1 C37.118.1-2011 Annex C dynamic step change in magnitude current response time: $F_0 = 60$ Hz, P class

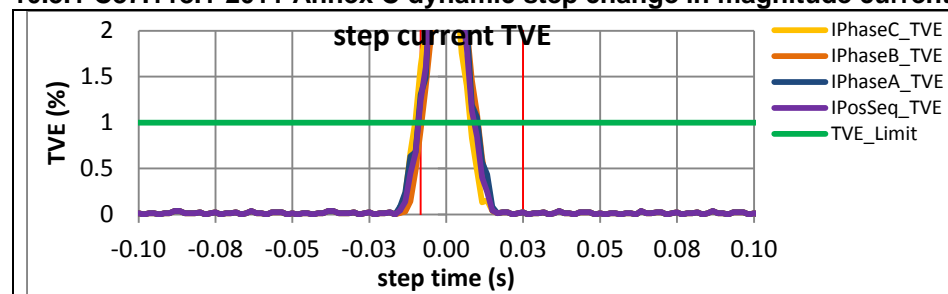


Figure 5449:  $F_s = 60$  FPS, +10% magnitude step

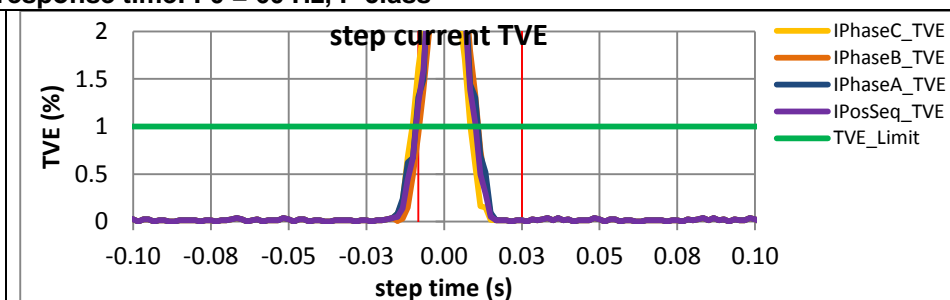


Figure 5450:  $F_s = 60$  FPS, -10% magnitude step

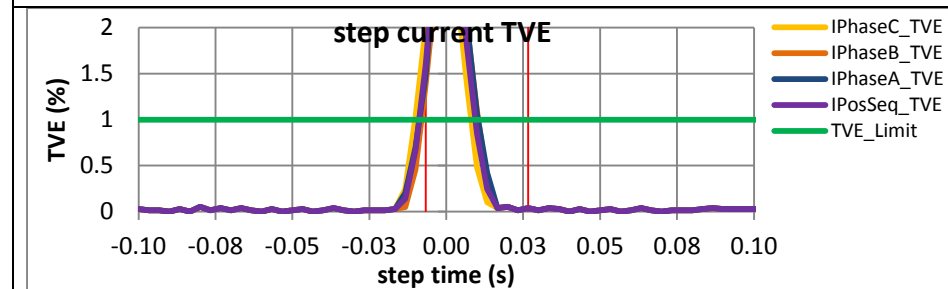


Figure 5451:  $F_s = 30$  FPS, +10% magnitude step

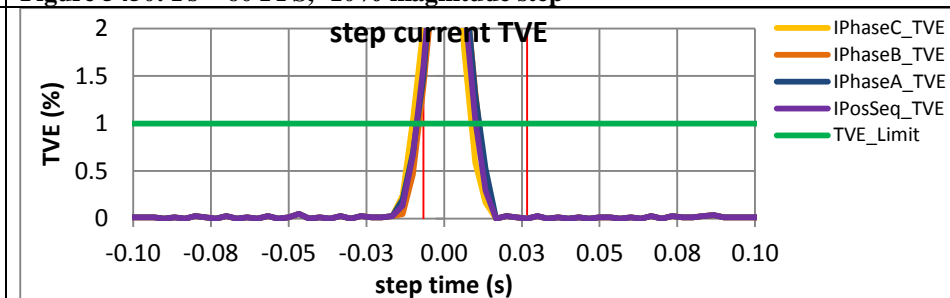


Figure 5452:  $F_s = 30$  FPS, -10% magnitude step

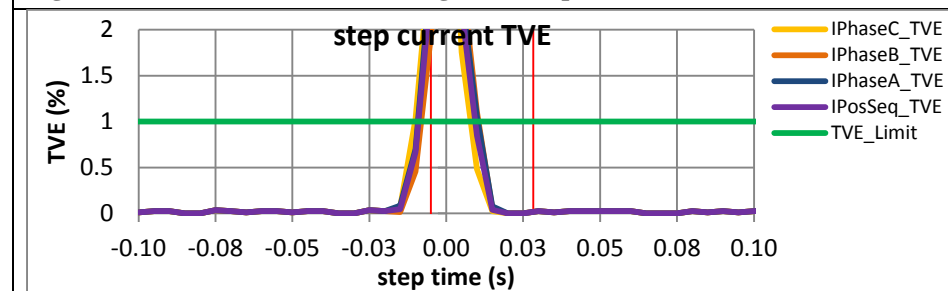


Figure 5453:  $F_s = 20$  FPS, +10% magnitude step

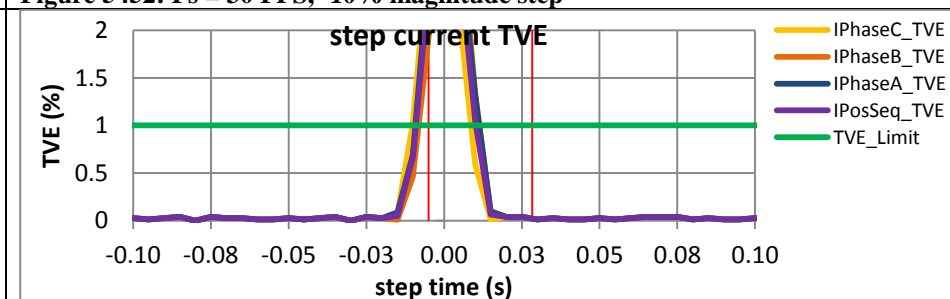


Figure 5454:  $F_s = 20$  FPS, +10% magnitude step

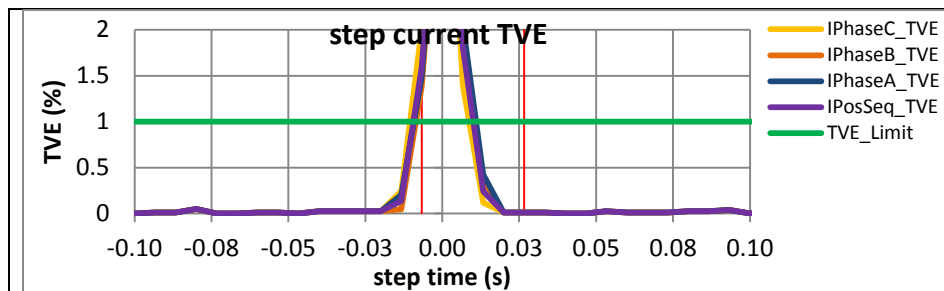


Figure 5455: Fs = 15 FPS, +10% magnitude step

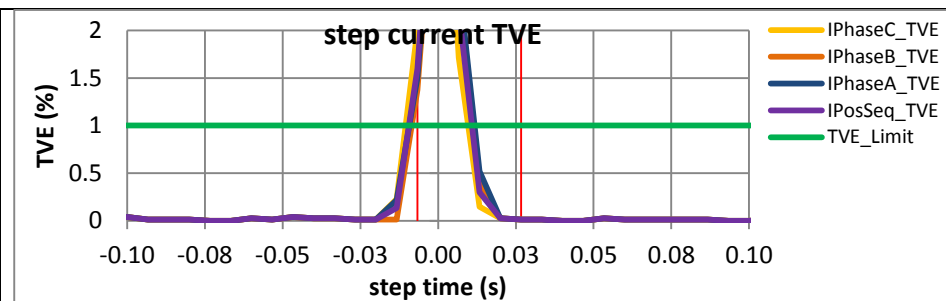


Figure 5456: Fs = 15 FPS, -10% magnitude step

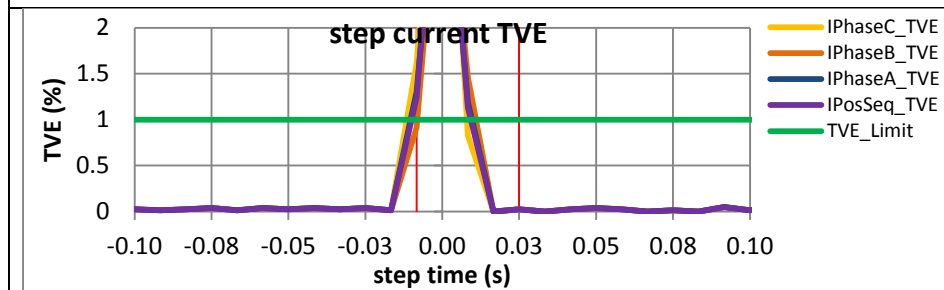


Figure 5457: Fs = 12 FPS, +10% magnitude step

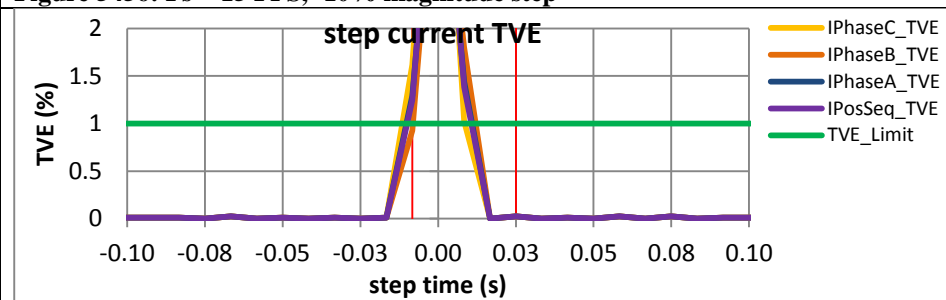


Figure 5458: Fs = 12 FPS, -10% magnitude step

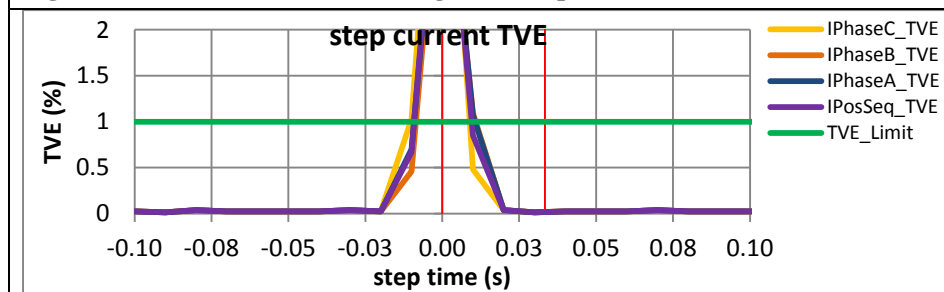


Figure 5459: Fs = 10 FPS, +10% magnitude step

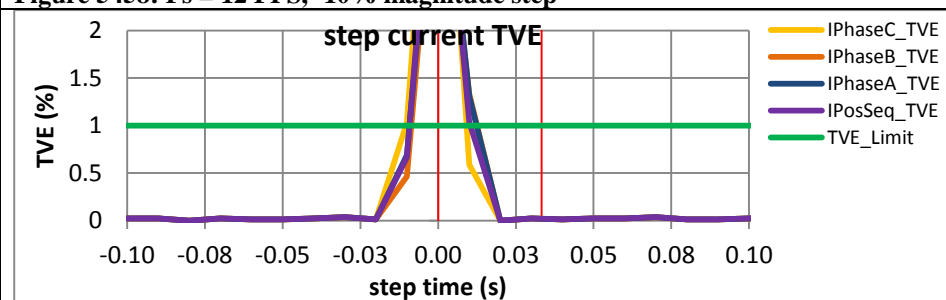


Figure 5460: Fs = 10 FPS, -10% magnitude step



### 10.5.2 PMU A dynamic step change in magnitude current response time: F0 = 60 Hz, P class

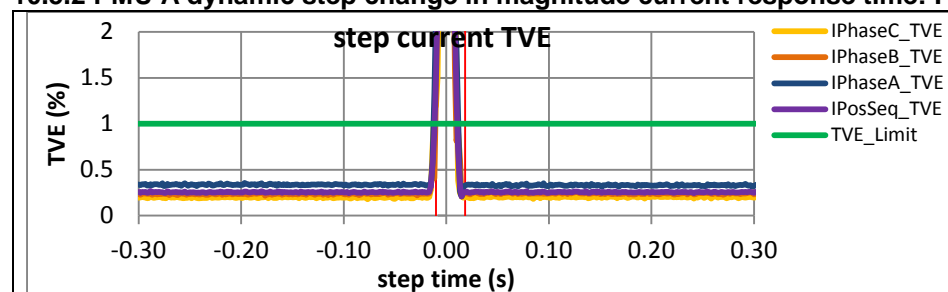


Figure 5461: Fs = 60 FPS, +10% magnitude step

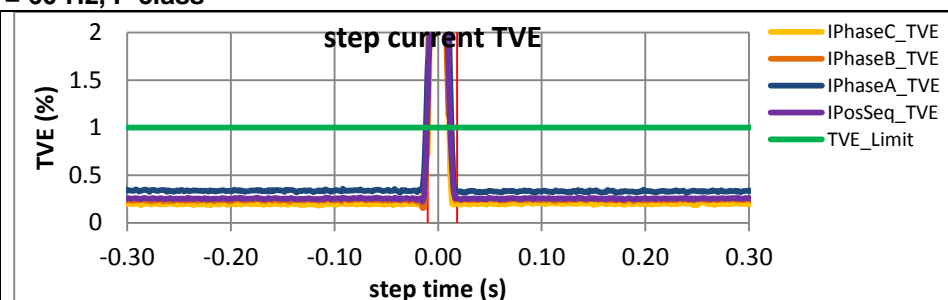


Figure 5462: Fs = 60 FPS, -10% magnitude step

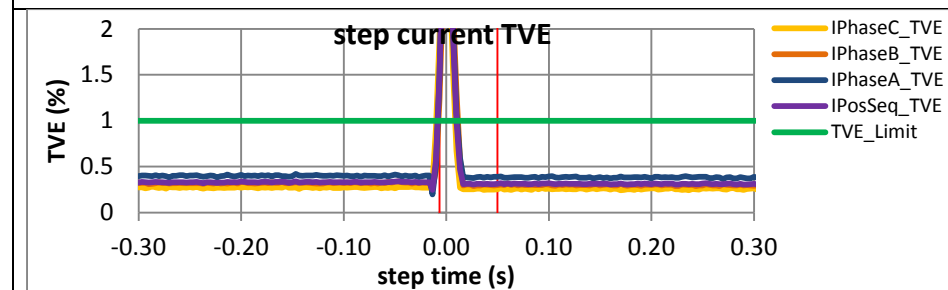


Figure 5463: Fs = 30 FPS, +10% magnitude step

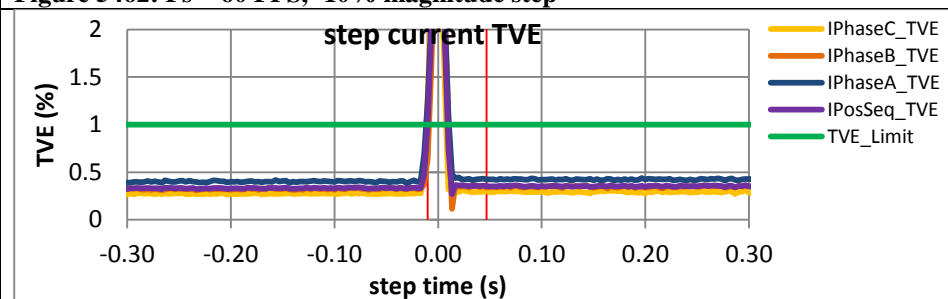


Figure 5464: Fs = 30 FPS, -10% magnitude step

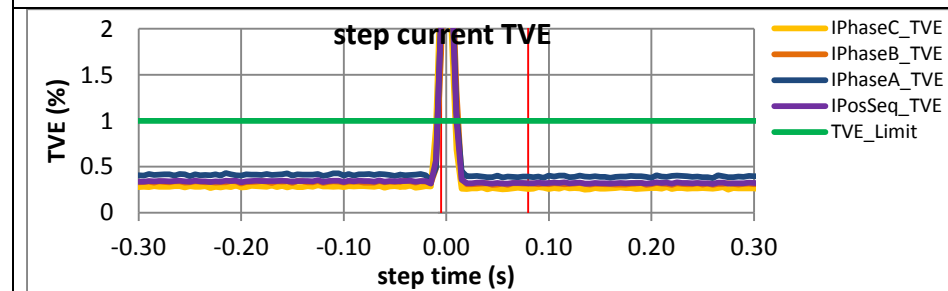


Figure 5465: Fs = 20 FPS, +10% magnitude step

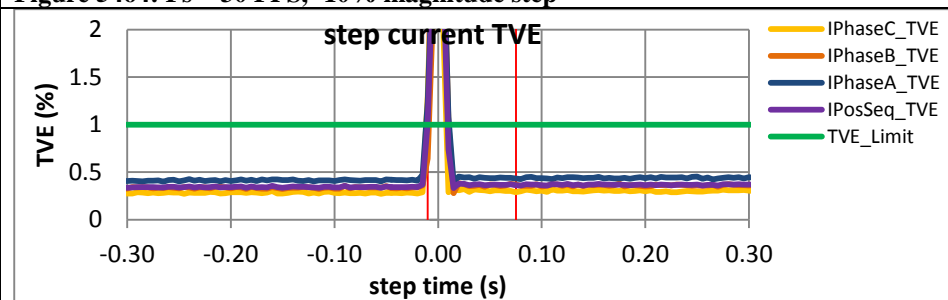


Figure 5466: Fs = 20 FPS, -10% magnitude step

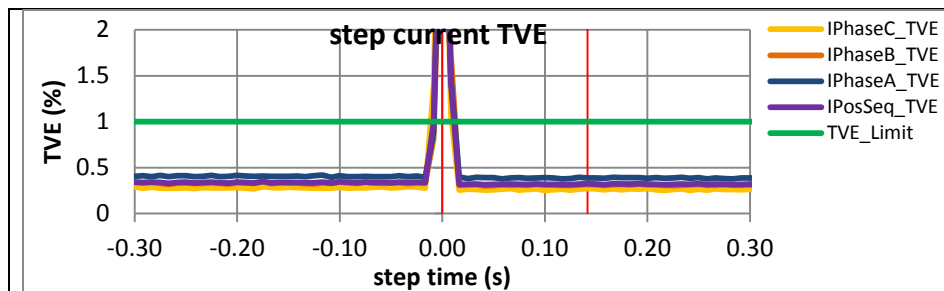


Figure 5467: Fs = 15 FPS, +10% magnitude step

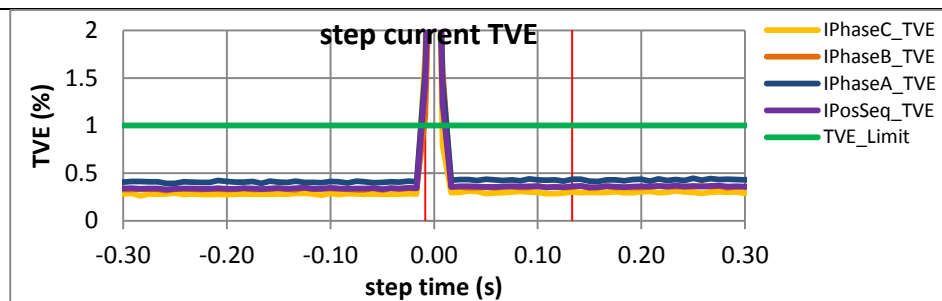


Figure 5468: Fs = 15 FPS, -10% magnitude step

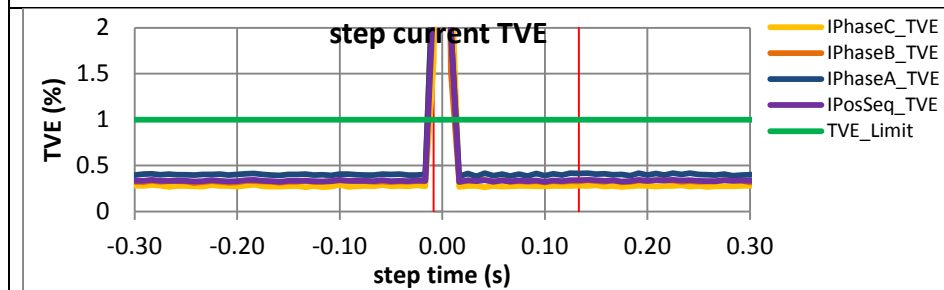


Figure 5469: Fs = 12 FPS, +10% magnitude step

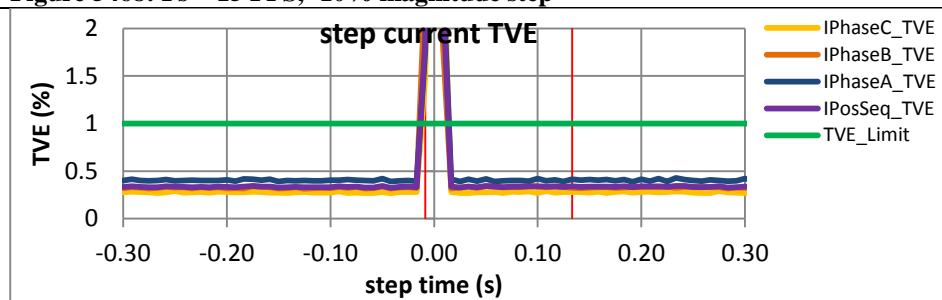


Figure 5470: Fs = 12 FPS, -10% magnitude step

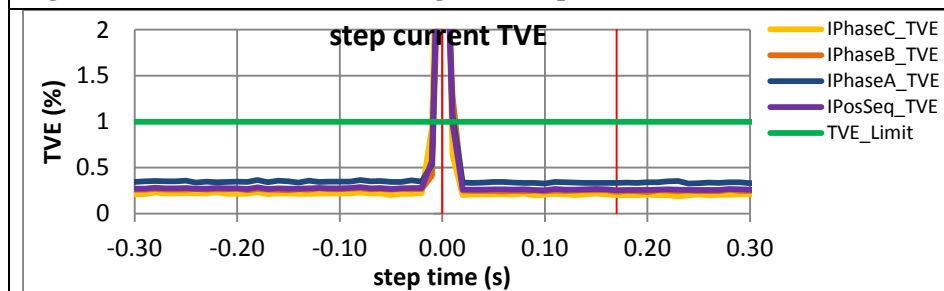


Figure 5471: Fs = 10 FPS, +10% magnitude step

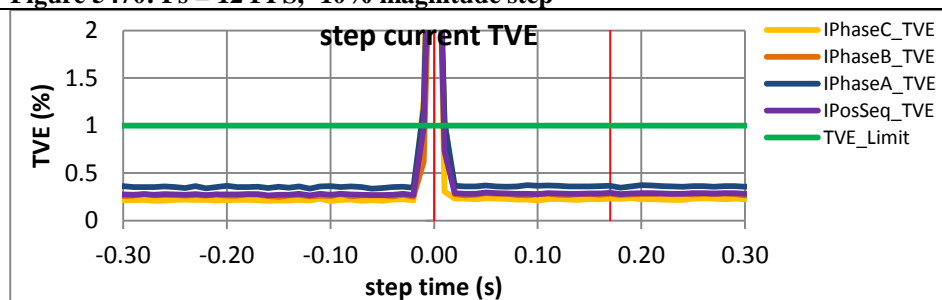


Figure 5472: Fs = 10 FPS, +10% magnitude step

### 10.5.3 PMU B dynamic step change in magnitude current response time: F0 = 60 Hz, P class

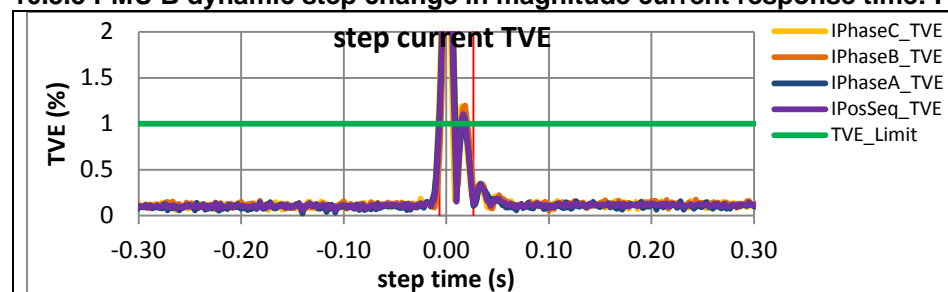


Figure 5473: Fs = 60 FPS, +10% magnitude step

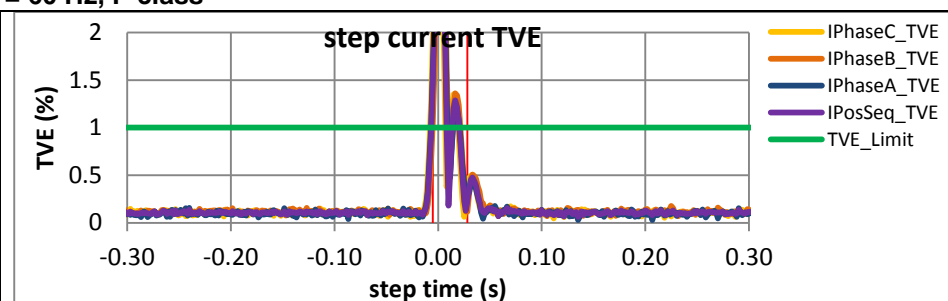


Figure 5474: Fs = 60 FPS, -10% magnitude step

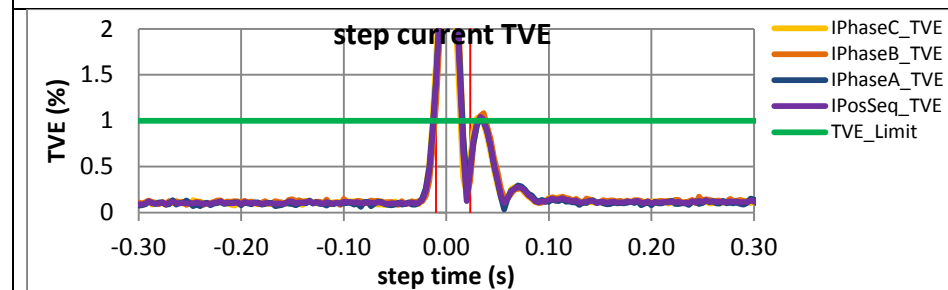


Figure 5475: Fs = 30 FPS, +10% magnitude step

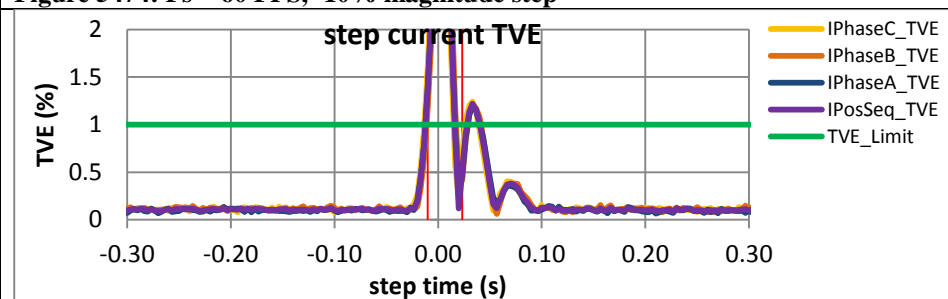


Figure 5476: Fs = 30 FPS, -10% magnitude step

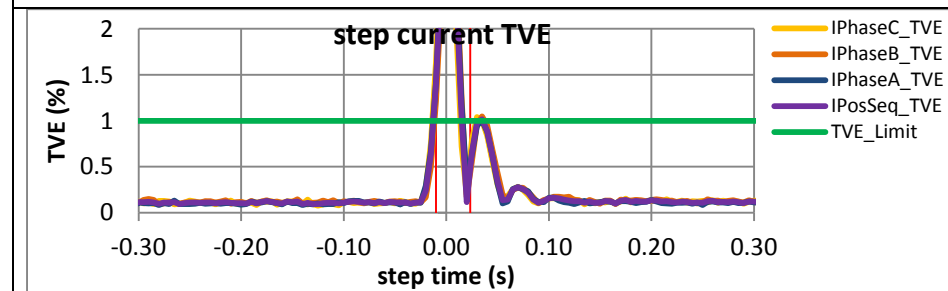


Figure 5477: Fs = 20 FPS, +10% magnitude step

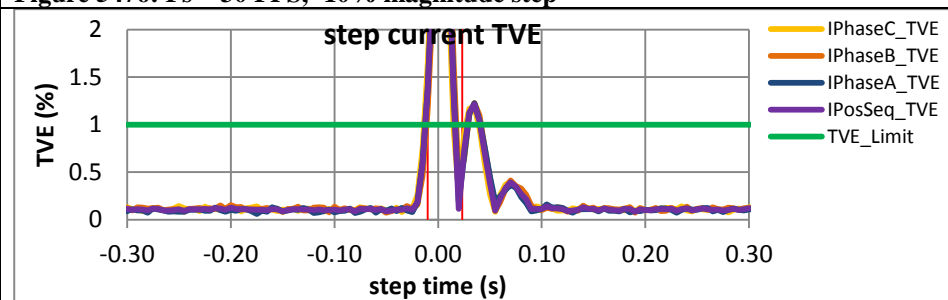


Figure 5478: Fs = 20 FPS, +10% magnitude step

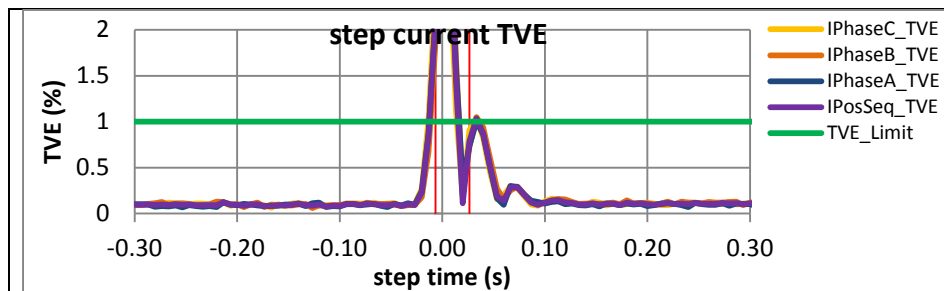


Figure 5479: Fs = 15 FPS, +10% magnitude step

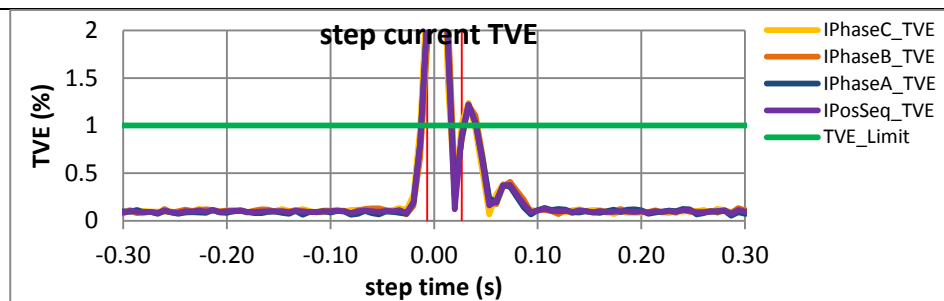


Figure 5480: Fs = 15 FPS, -10% magnitude step

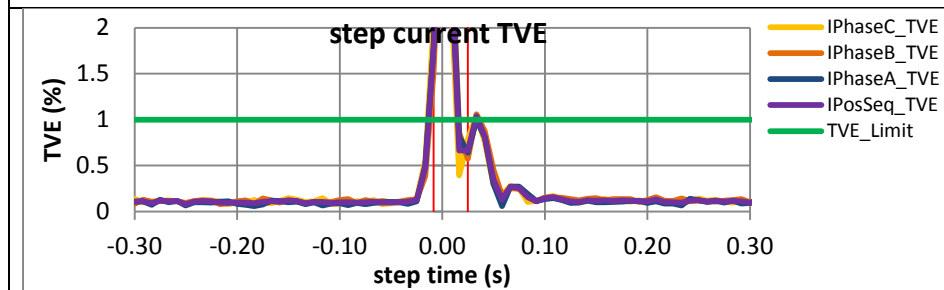


Figure 5481: Fs = 12 FPS, +10% magnitude step

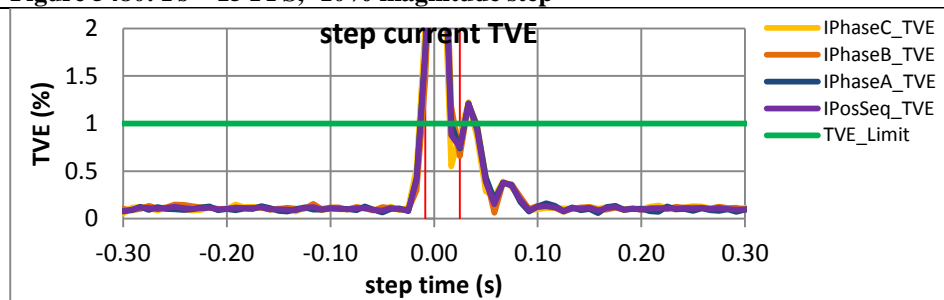


Figure 5482: Fs = 12 FPS, -10% magnitude step

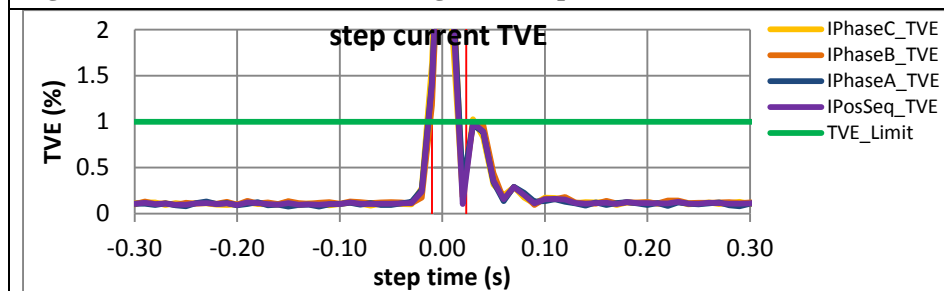


Figure 5483: Fs = 10 FPS, +10% magnitude step

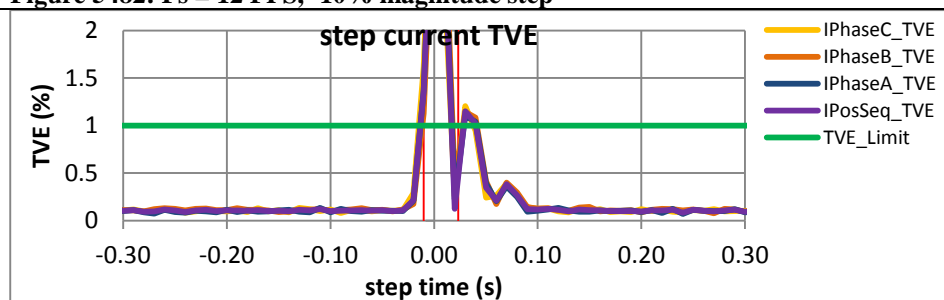


Figure 5484: Fs = 10 FPS, -10% magnitude step

#### 10.5.4 PMU C dynamic step change in magnitude current response time: F0 = 60 Hz, P class

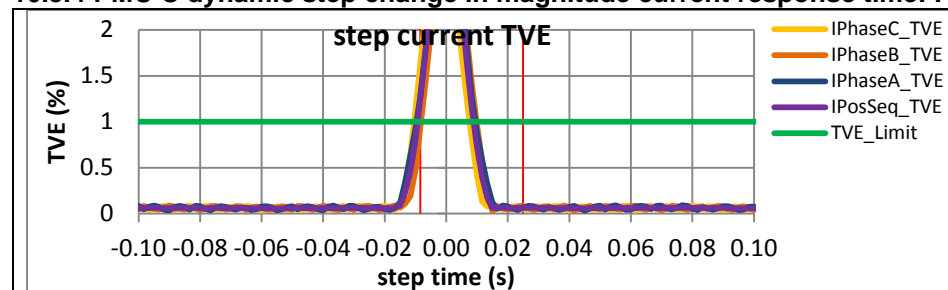


Figure 5485: Fs = 60 FPS, +10% magnitude step

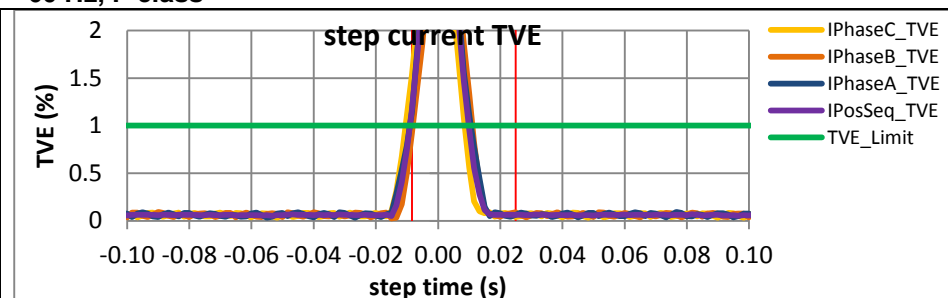


Figure 5486: Fs = 60 FPS, -10% magnitude step

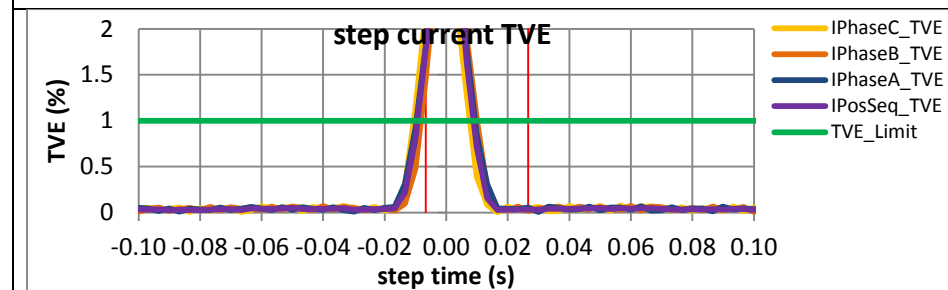


Figure 5487: Fs = 30 FPS, +10% magnitude step

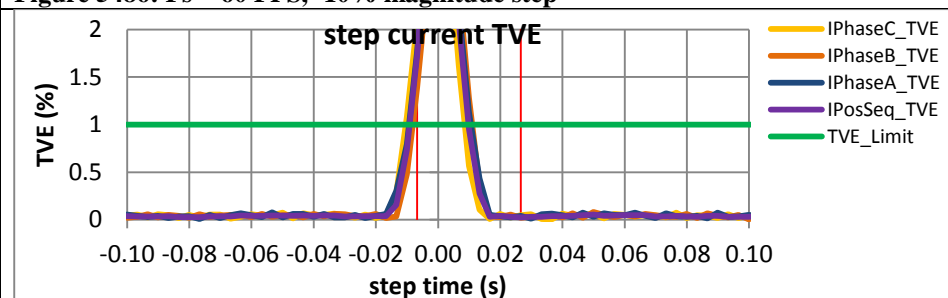


Figure 5488: Fs = 30 FPS, -10% magnitude step

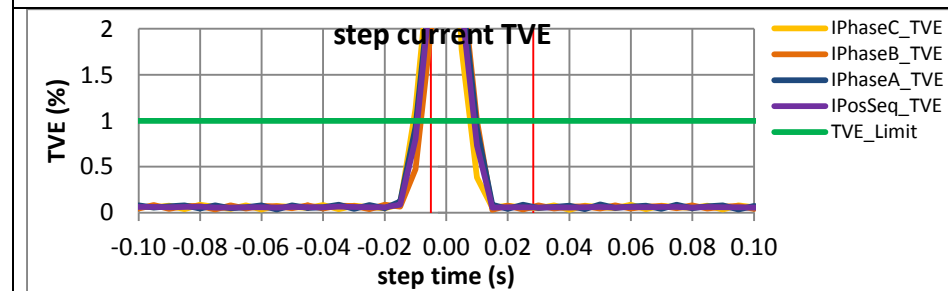


Figure 5489: Fs = 20 FPS, +10% magnitude step

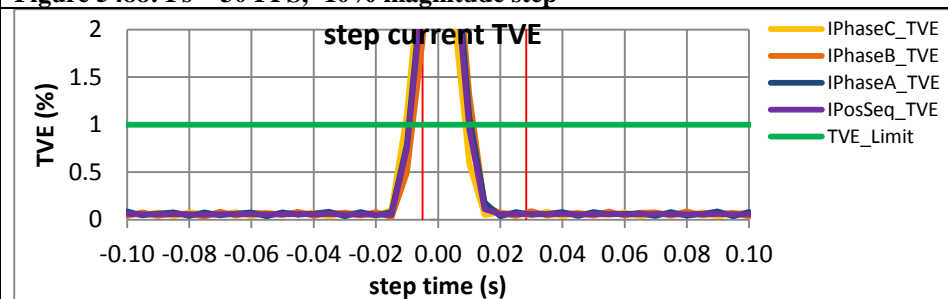


Figure 5490: Fs = 20 FPS, +10% magnitude step

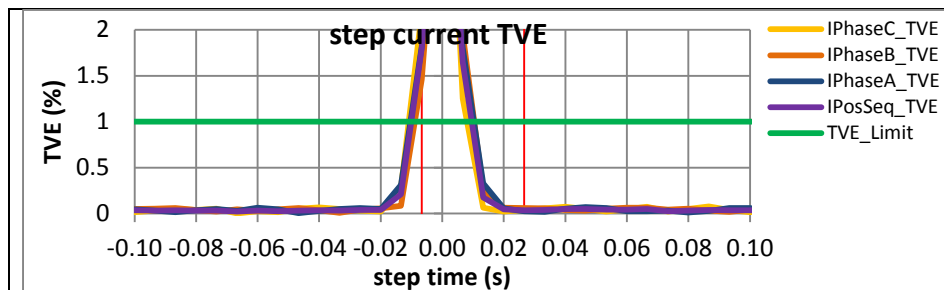


Figure 5491: Fs = 15 FPS, +10% magnitude step

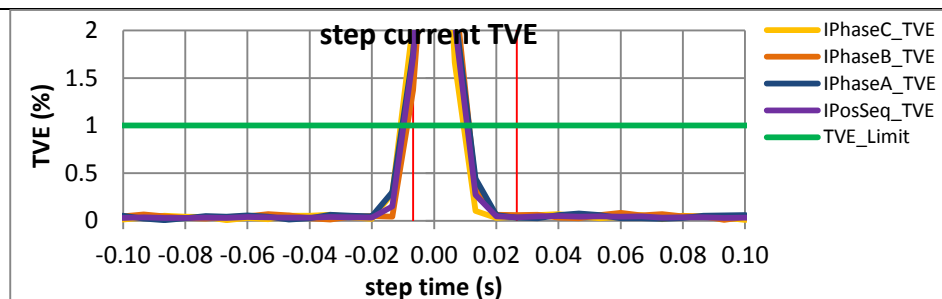


Figure 5492: Fs = 15 FPS, -10% magnitude step

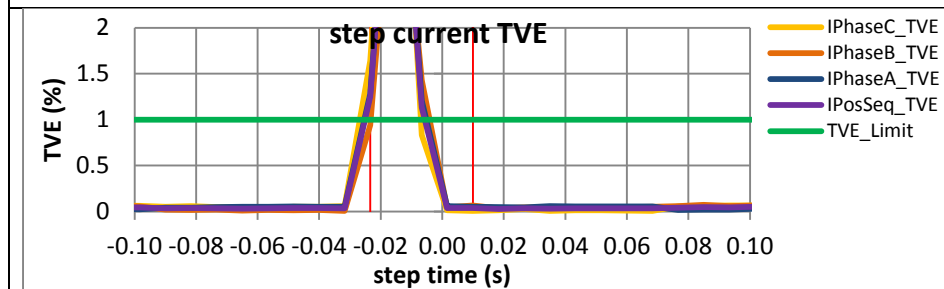


Figure 5493: Fs = 12 FPS, +10% magnitude step

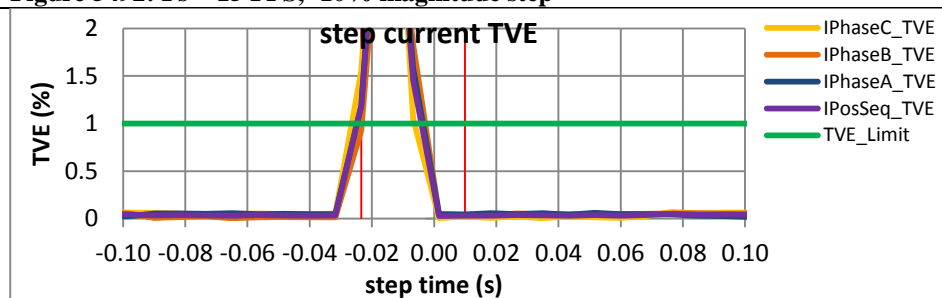


Figure 5494: Fs = 12 FPS, -10% magnitude step

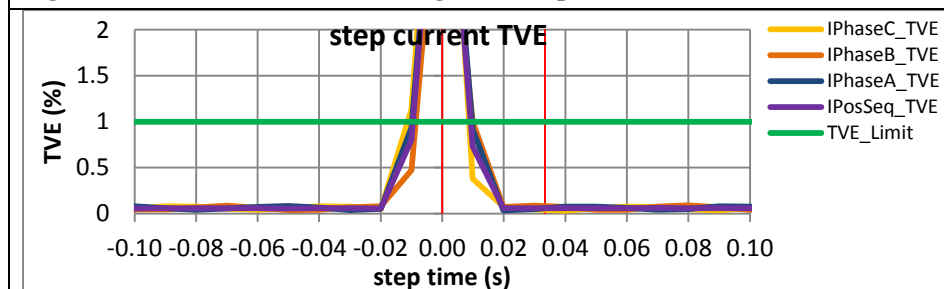


Figure 5495: Fs = 10 FPS, +10% magnitude step

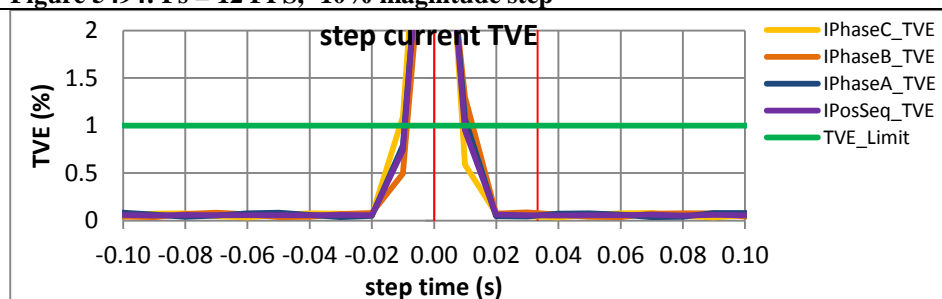


Figure 5496: Fs = 10 FPS, -10% magnitude step

### 10.5.5 PMU D dynamic step change in magnitude current response time: F0 = 60 Hz, P class

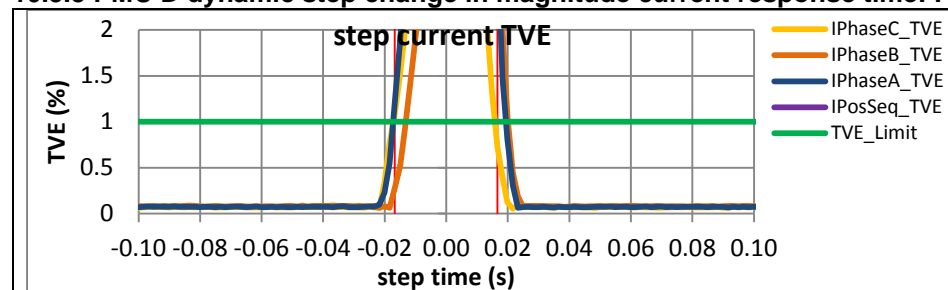


Figure 5497: Fs = 60 FPS, +10% magnitude step

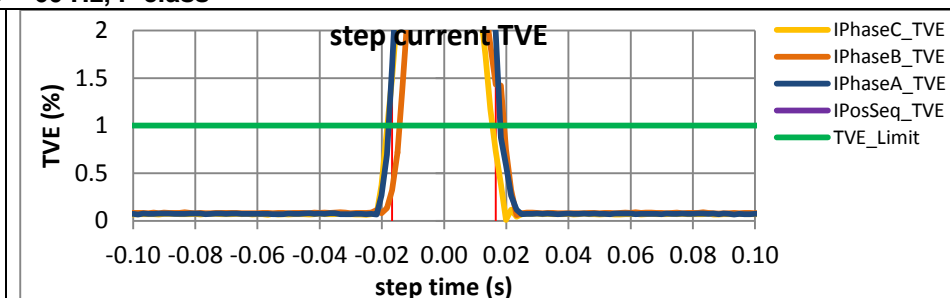


Figure 5498: Fs = 60 FPS, -10% magnitude step

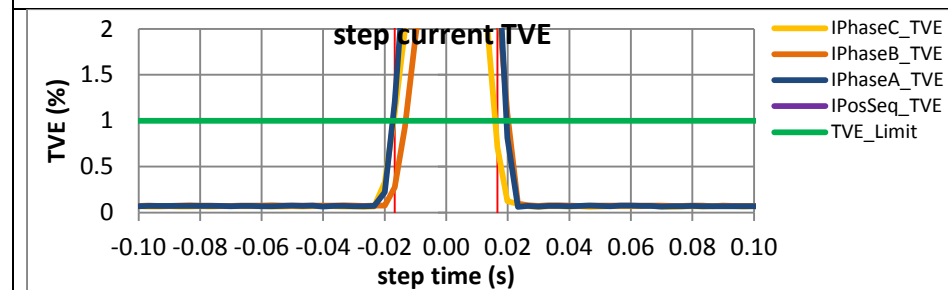


Figure 5499: Fs = 30 FPS, +10% magnitude step

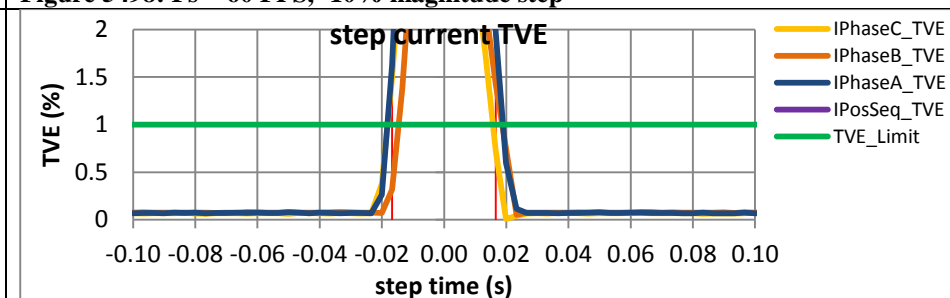


Figure 5500: Fs = 30 FPS, -10% magnitude step

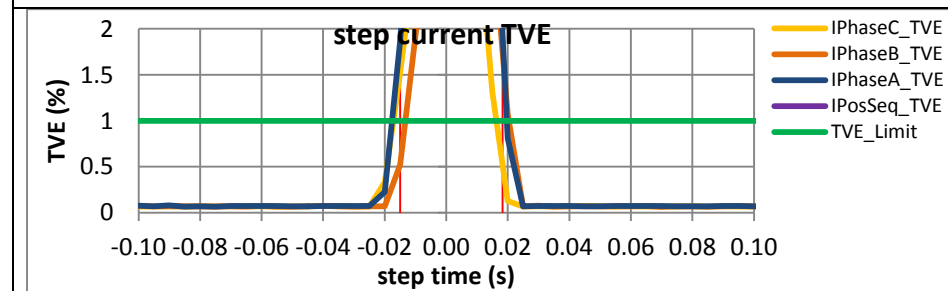


Figure 5501: Fs = 20 FPS, +10% magnitude step

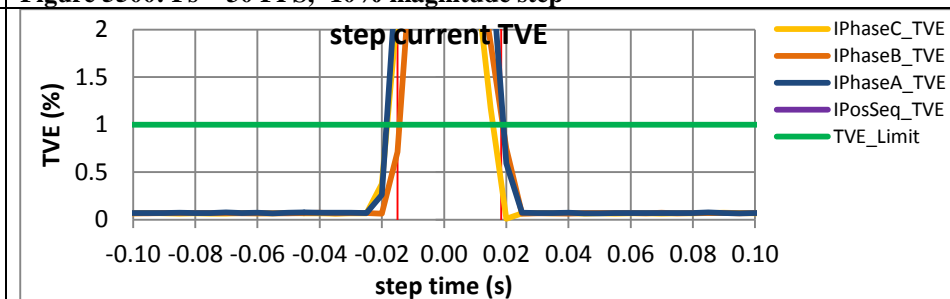


Figure 5502: Fs = 20 FPS, +10% magnitude step

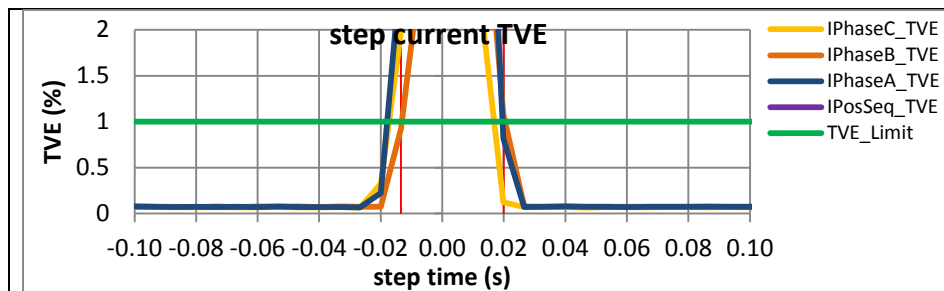


Figure 5503: Fs = 15 FPS, +10% magnitude step

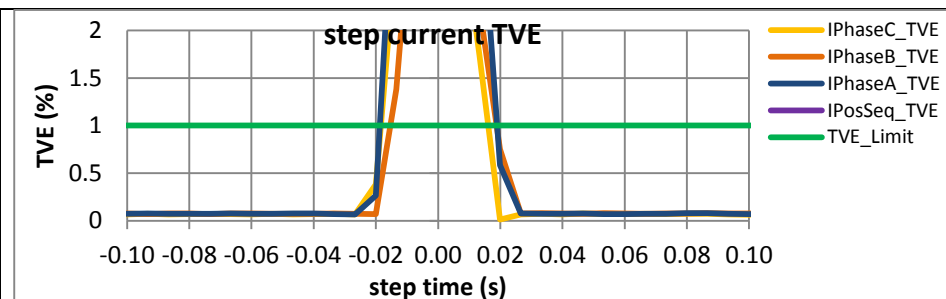


Figure 5504: Fs = 15 FPS, -10% magnitude step

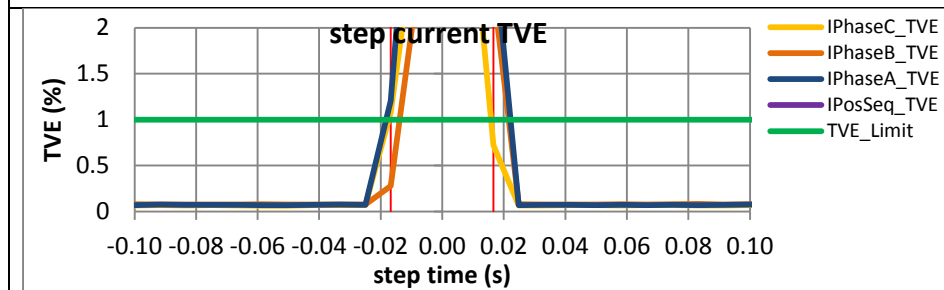


Figure 5505: Fs = 12 FPS, +10% magnitude step

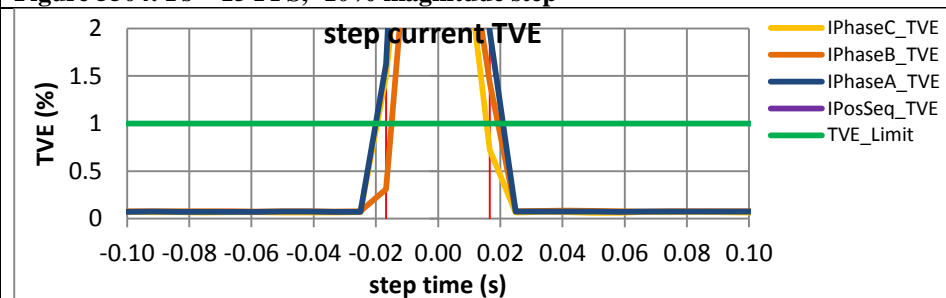


Figure 5506: Fs = 12 FPS, -10% magnitude step

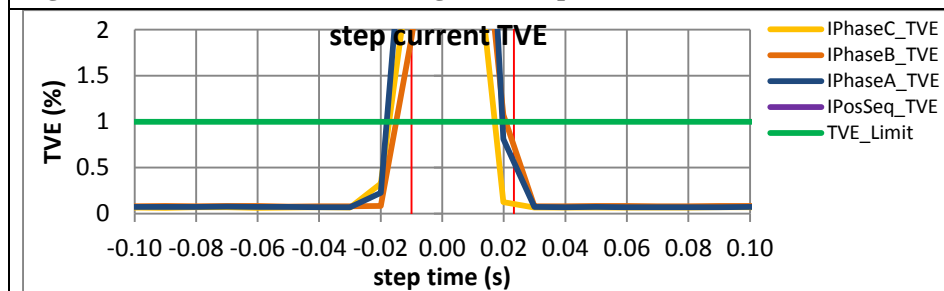


Figure 5507: Fs = 10 FPS, +10% magnitude step

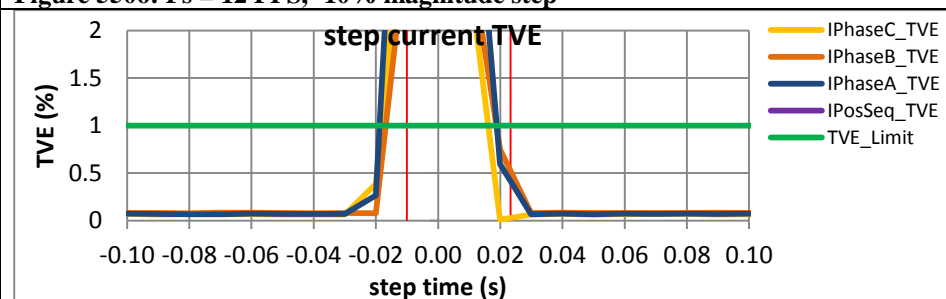


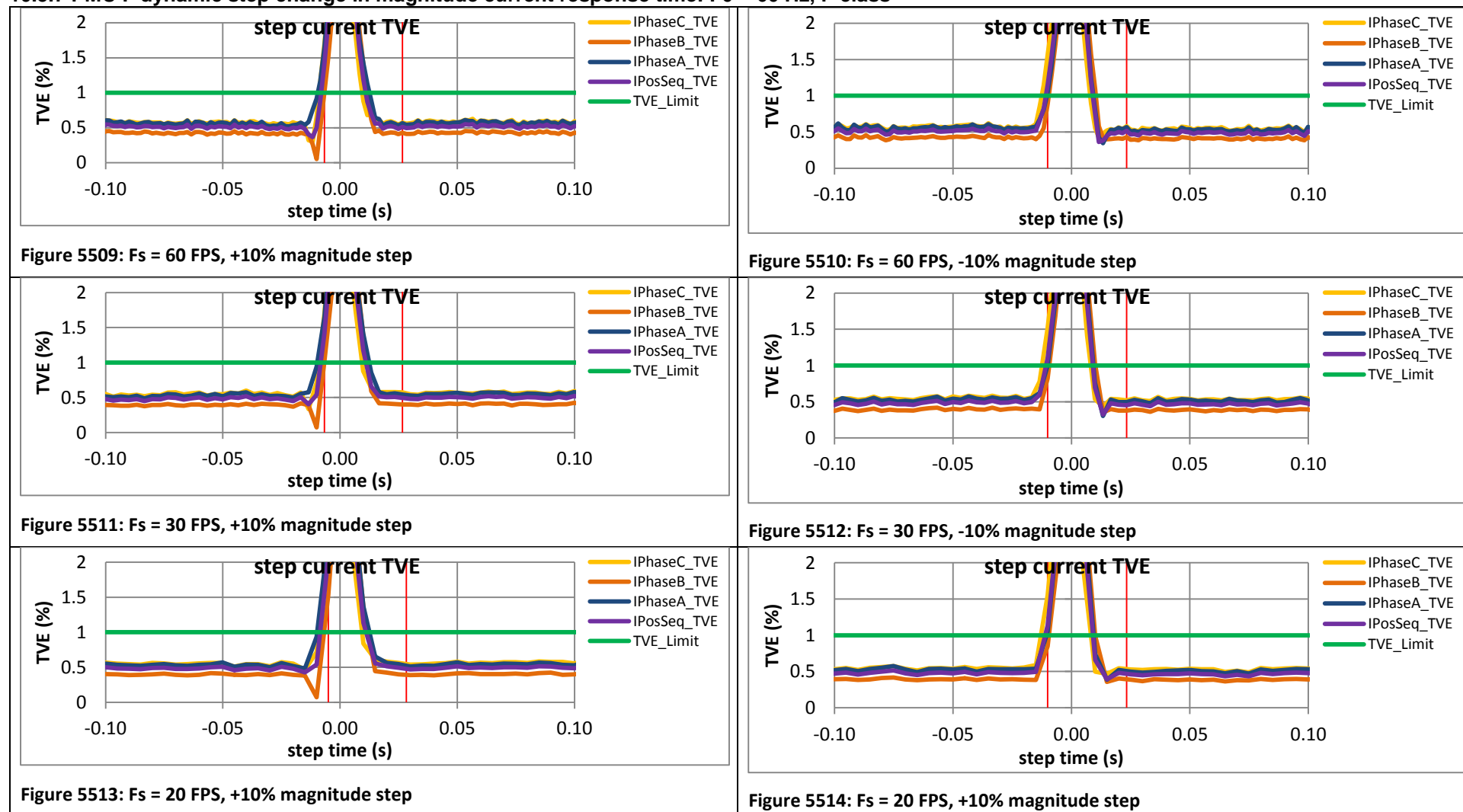
Figure 5508: Fs = 10 FPS, -10% magnitude step



### 10.5.6 PMU E dynamic step change in magnitude current response time: F0 = 60 Hz, P class

PMU E does not support P class.

### 10.5.7 PMU F dynamic step change in magnitude current response time: F0 = 60 Hz, P class



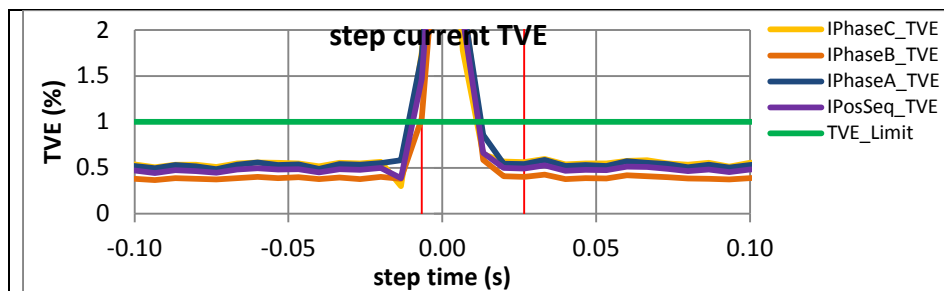


Figure 5515:  $F_s = 15$  FPS, +10% magnitude step

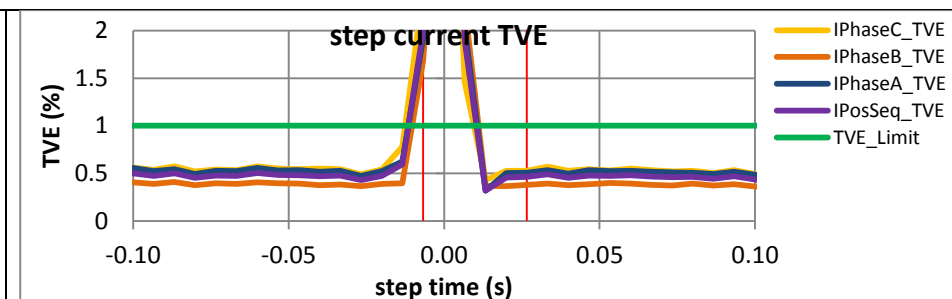


Figure 5516:  $F_s = 15$  FPS, -10% magnitude step

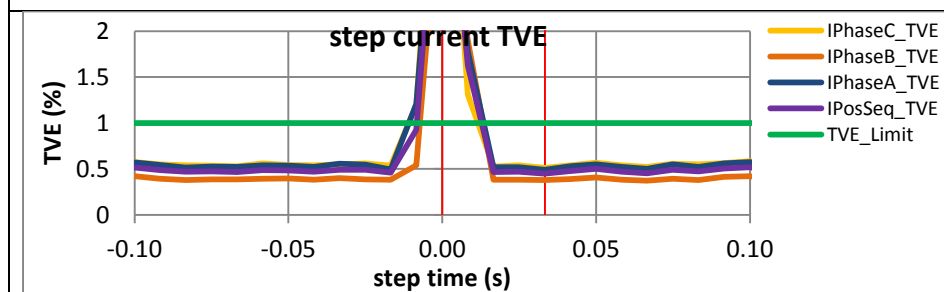


Figure 5517:  $F_s = 12$  FPS, +10% magnitude step

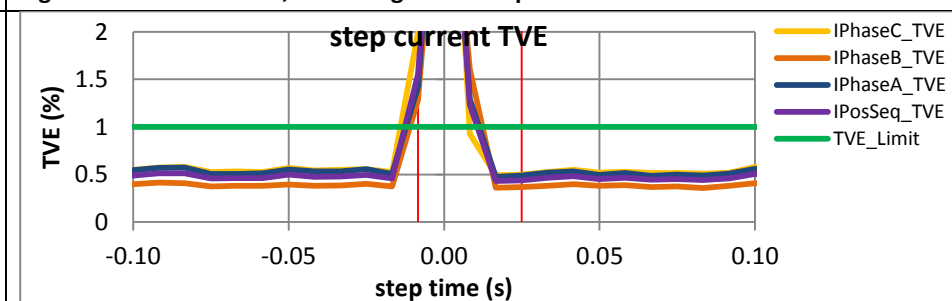


Figure 5518:  $F_s = 12$  FPS, -10% magnitude step

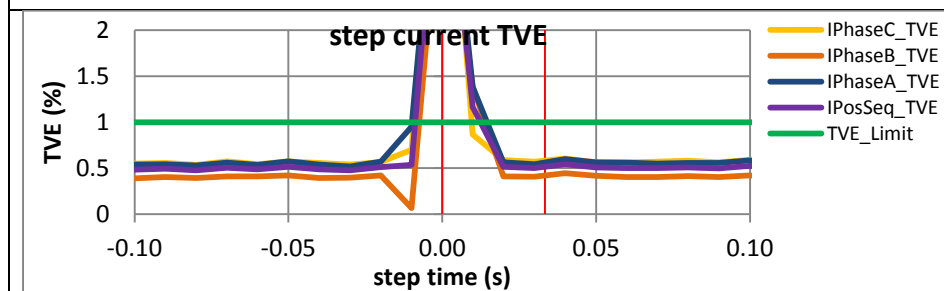


Figure 5519:  $F_s = 10$  FPS, +10% magnitude step

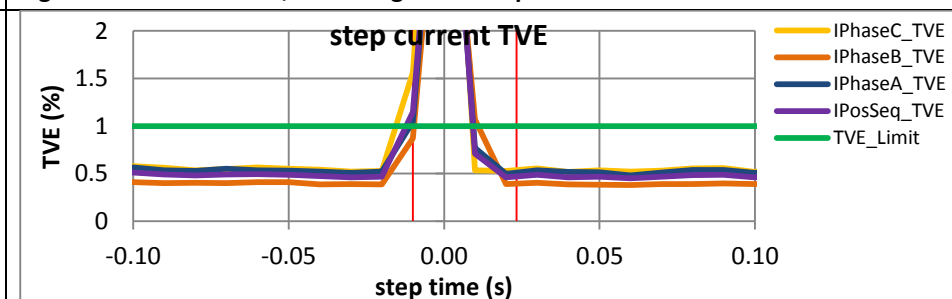
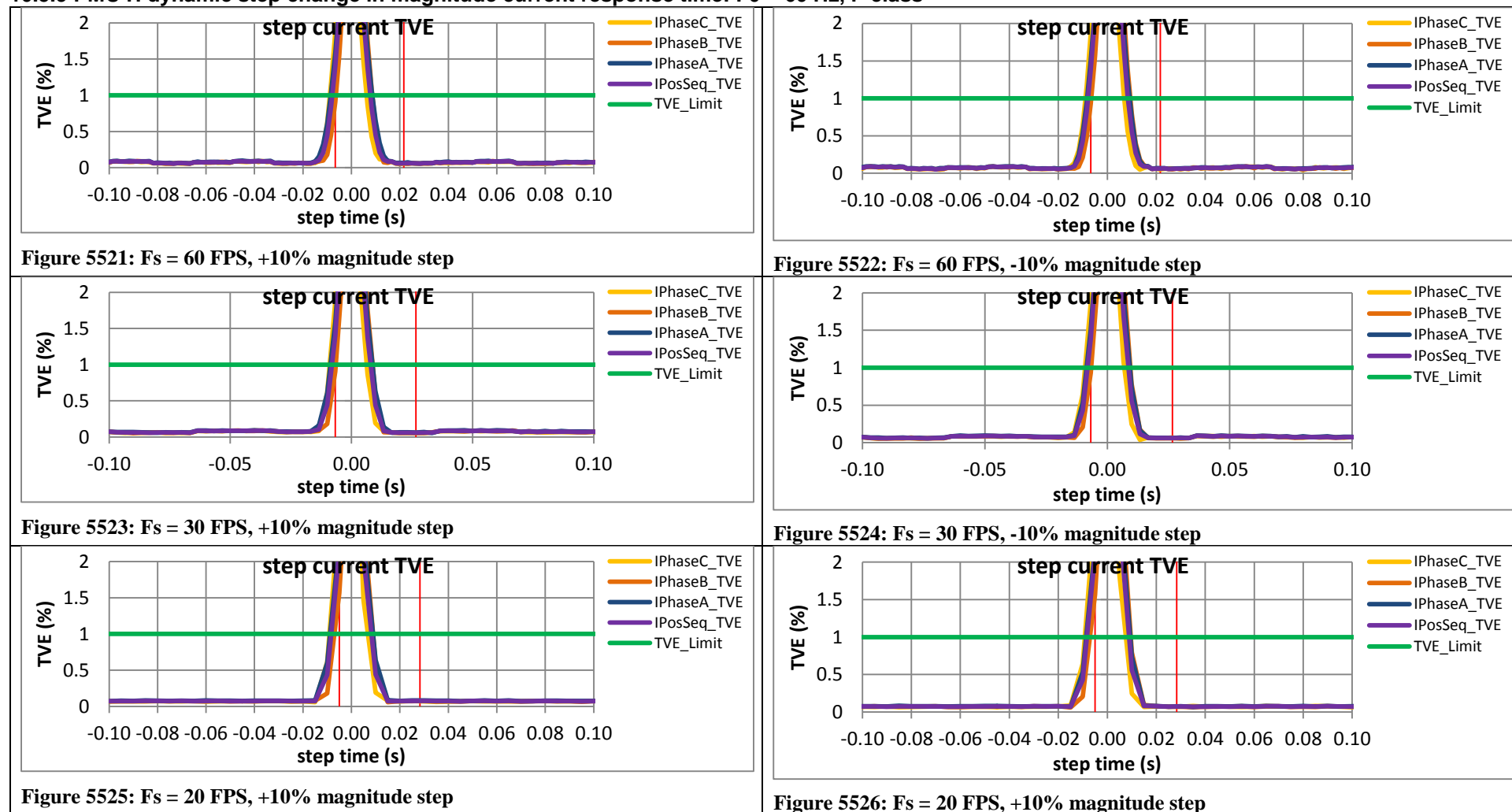


Figure 5520:  $F_s = 10$  FPS, -10% magnitude step

### 10.5.8 PMU G dynamic step change in magnitude current response time: F0 = 60 Hz, P class

PMU G does not support P class.

### 10.5.9 PMU H dynamic step change in magnitude current response time: F0 = 60 Hz, P class



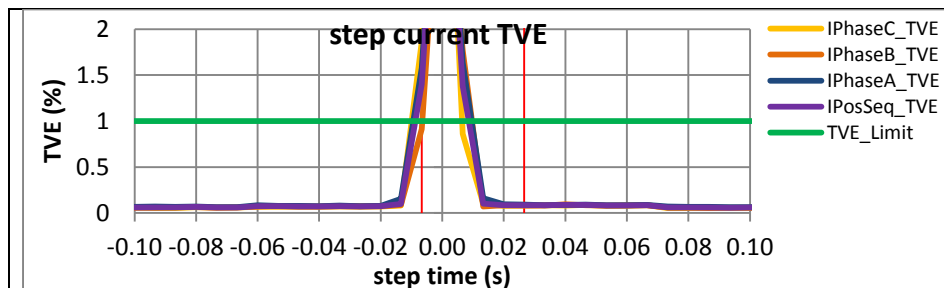


Figure 5527: Fs = 15 FPS, +10% magnitude step

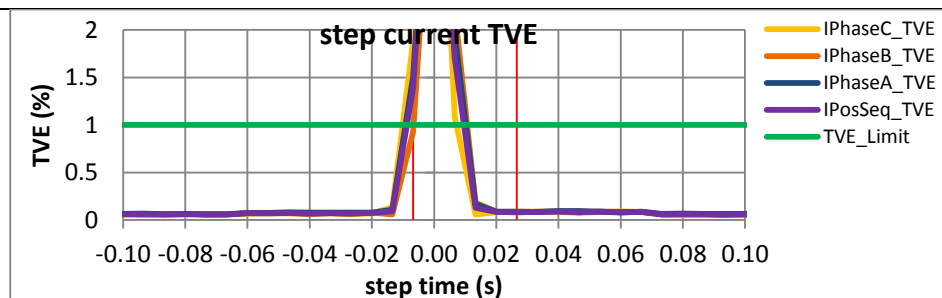


Figure 5528: Fs = 15 FPS, -10% magnitude step

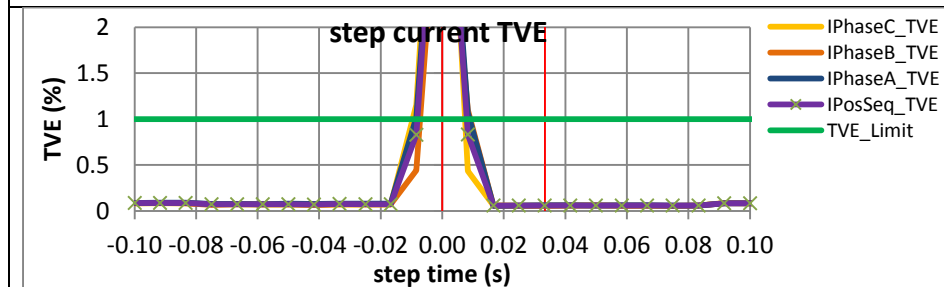


Figure 5529: Fs = 12 FPS, +10% magnitude step

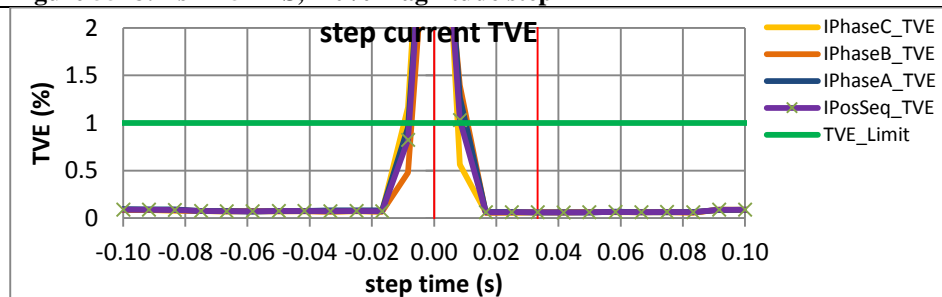


Figure 5530: Fs = 12 FPS, -10% magnitude step

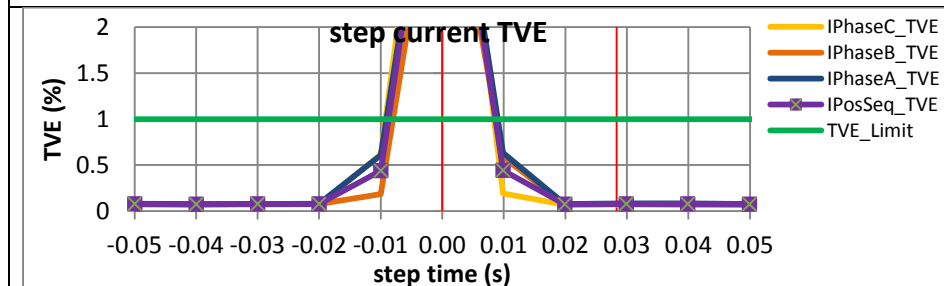


Figure 5531: Fs = 10 FPS, +10% magnitude step

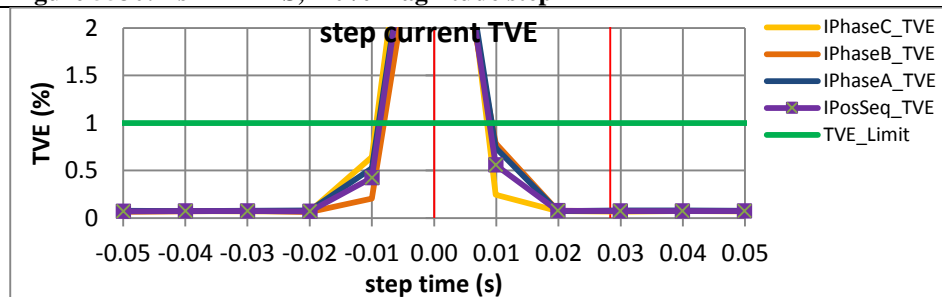
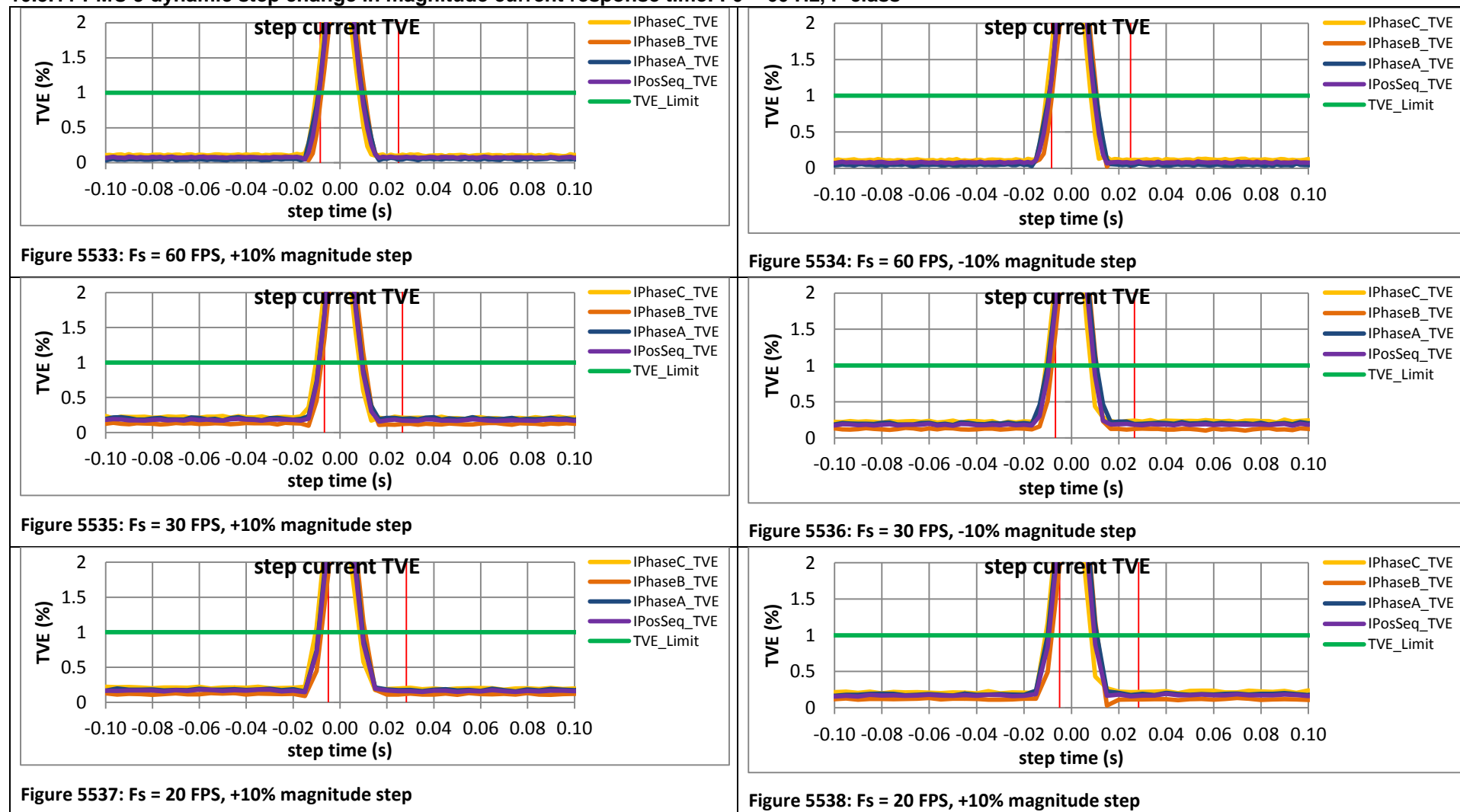


Figure 5532: Fs = 10 FPS, -10% magnitude step

### 10.5.10 PMU I dynamic step change in magnitude current response time: F0 = 60 Hz, P class

PMU I does not support P class

### 10.5.11 PMU J dynamic step change in magnitude current response time: F0 = 60 Hz, P class



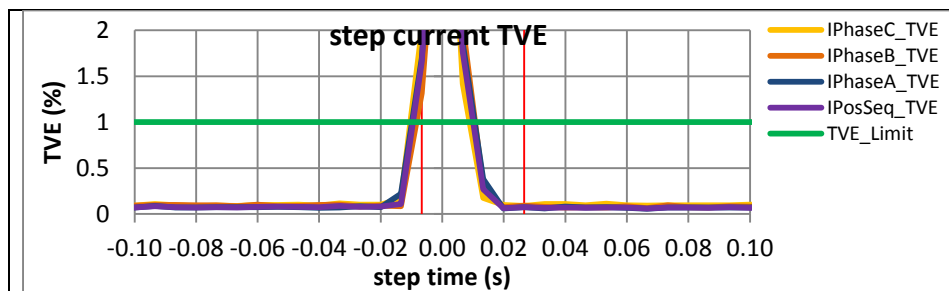


Figure 5539: Fs = 15 FPS, +10% magnitude step

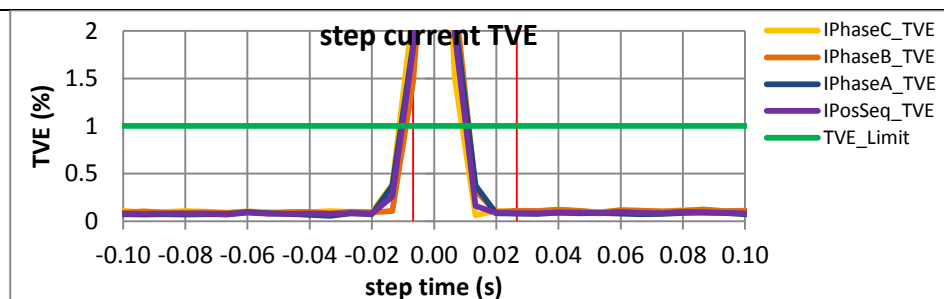


Figure 5540: Fs = 15 FPS, -10% magnitude step

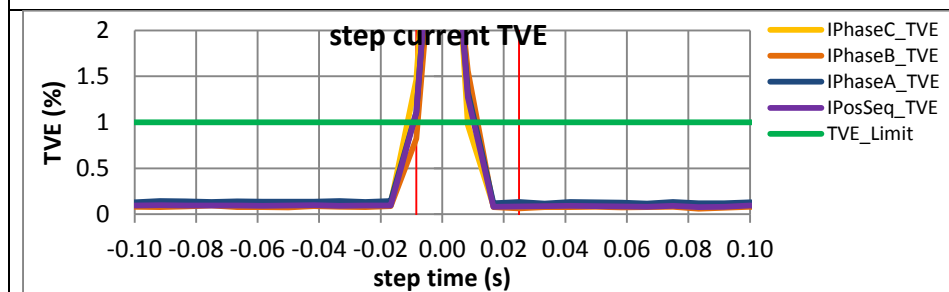


Figure 5541: Fs = 12 FPS, +10% magnitude step

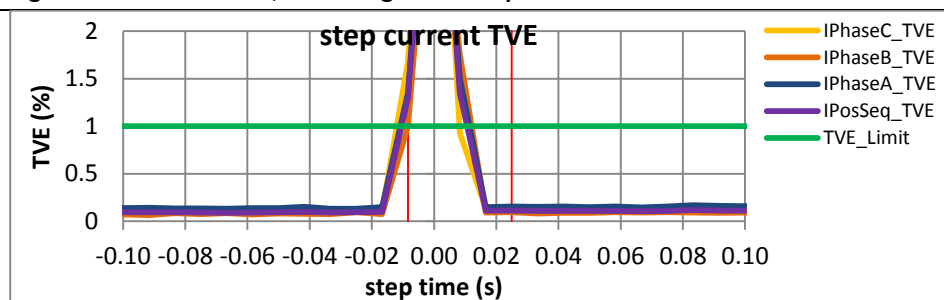


Figure 5542: Fs = 12 FPS, -10% magnitude step

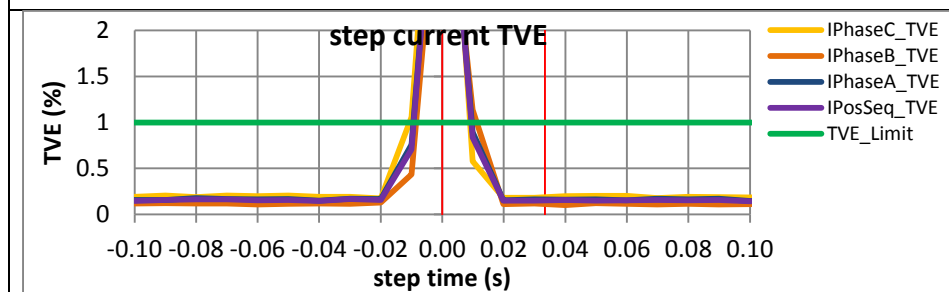


Figure 5543: Fs = 10 FPS, +10% magnitude step

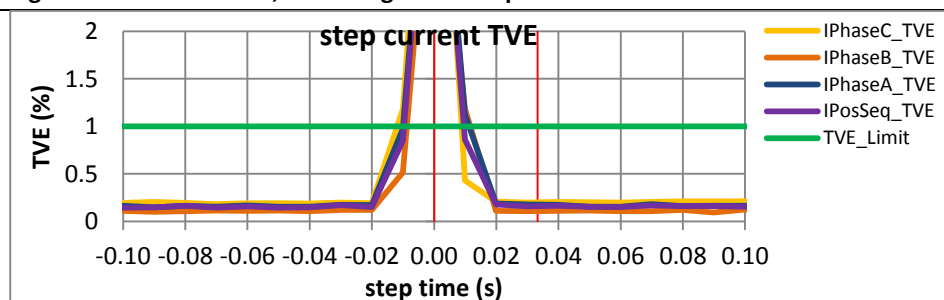
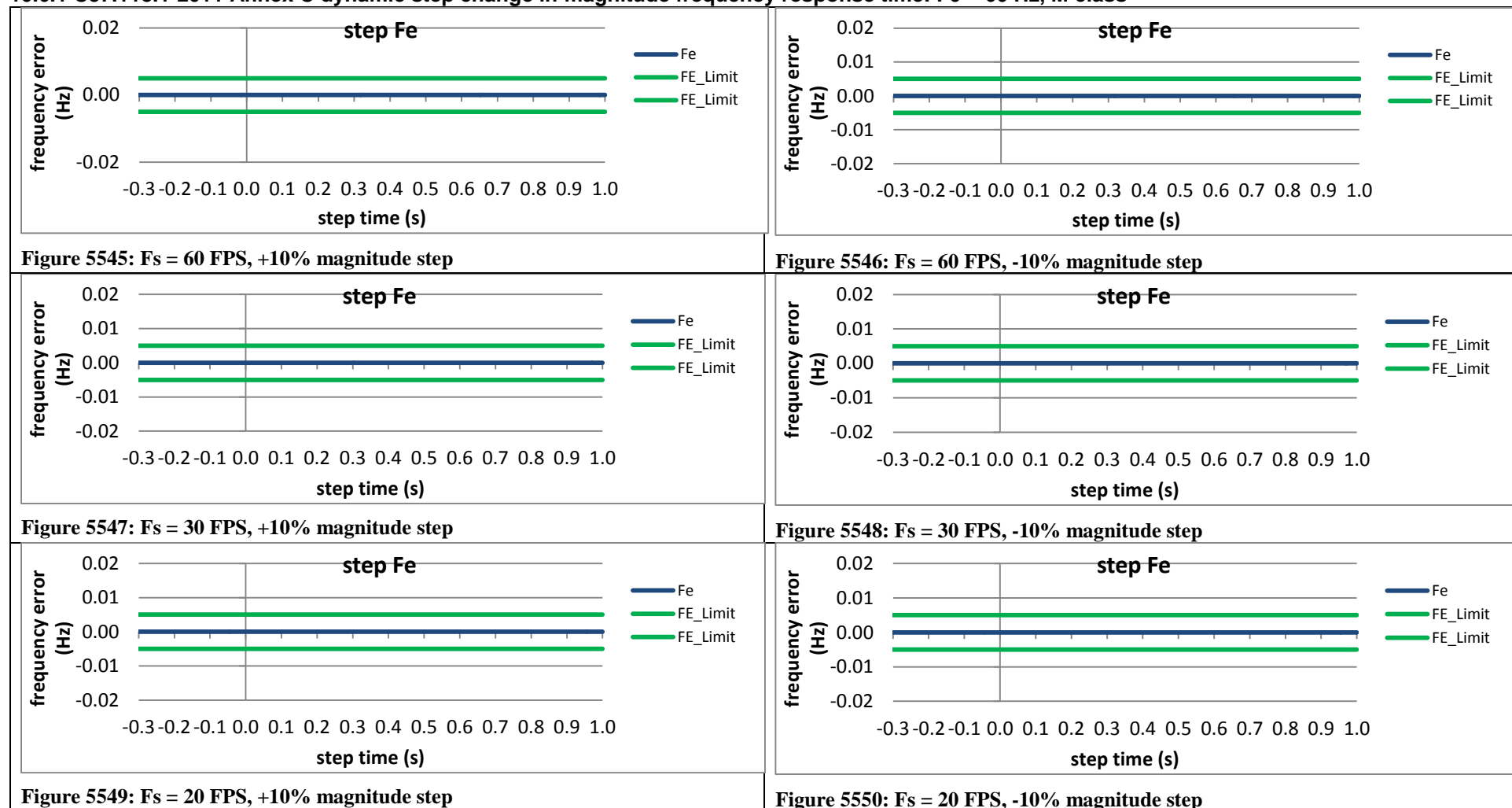


Figure 5544: Fs = 10 FPS, -10% magnitude step

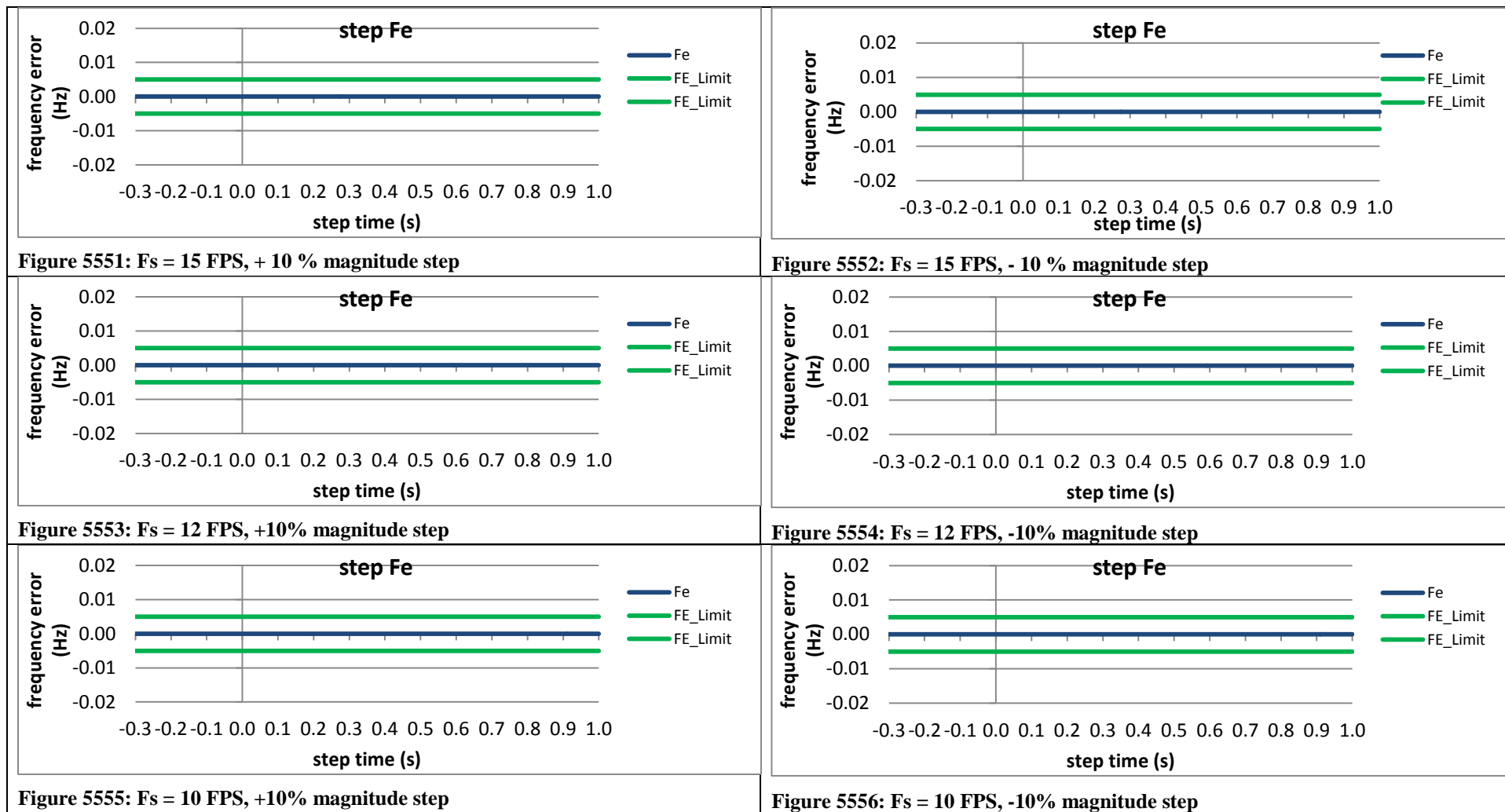
## 10.6 Dynamic step change in magnitude: frequency response time

Fs (FPS)	10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P
PMU A	P	P	P	P	P	P	P	P	P	P	P	P
PMU B	P	P	P	P	P	P	P	P	P	P	P	P
PMU C	P	F	P	F	P	F	P	F	P	P	P	F
PMU D	P	P	P	P	P	P	P	P	P	P	P	P
PMU E	P	-	-	-	P	-	P	-	P	-	P	-
PMU F	P	P	P	P	P	P	P	P	P	P	P	P
PMU G	P	-	P	-	P	-	P	-	P	-	-	-
PMU H	P	P	P	P	P	P	P	P	P	P	P	P
PMU I	P	-	P	-	P	-	P	-	P	-	P	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P

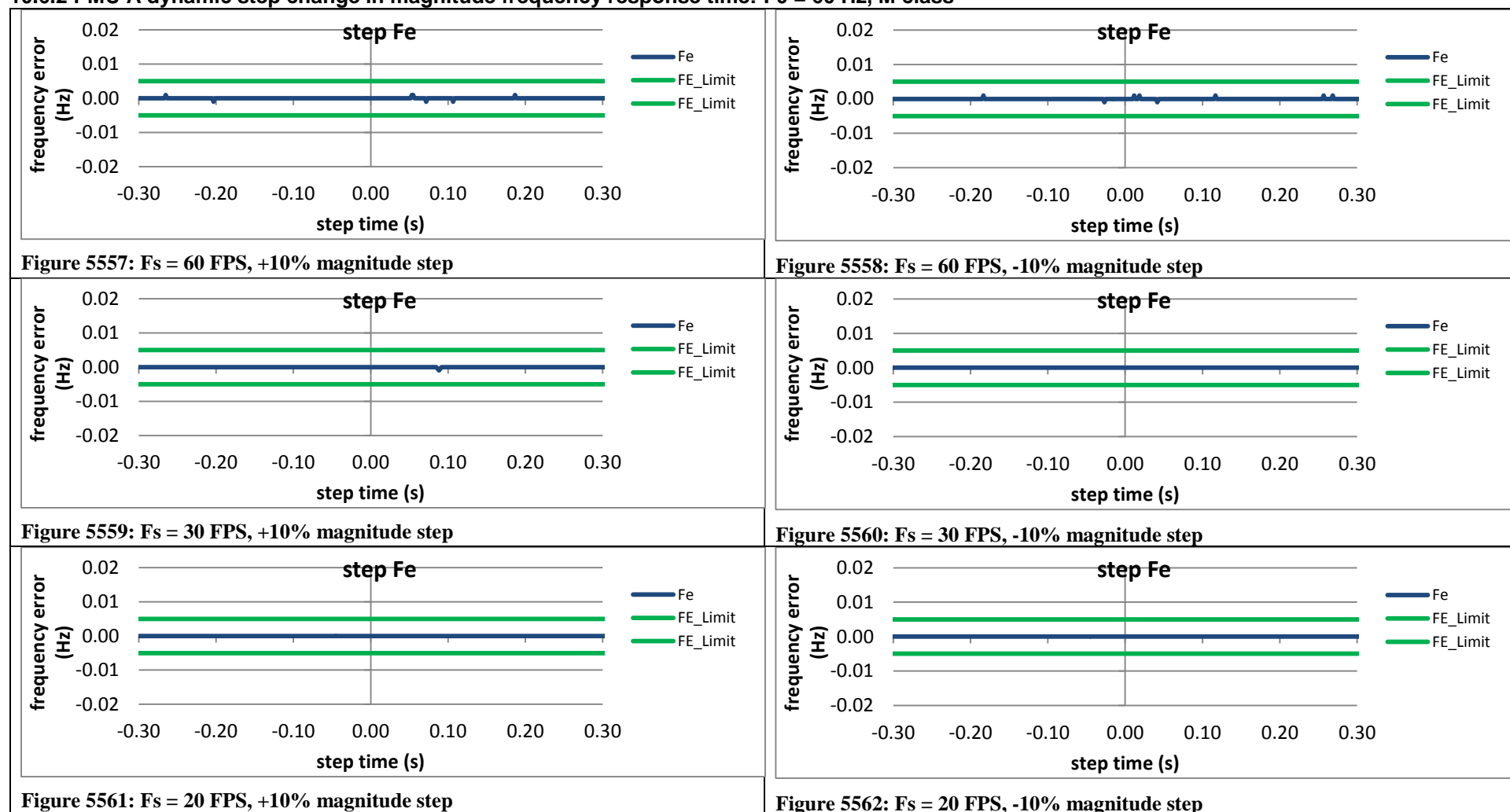
10.6.1 C37.118.1-2011 Annex C dynamic step change in magnitude frequency response time:  $F_0 = 60$  Hz, M class

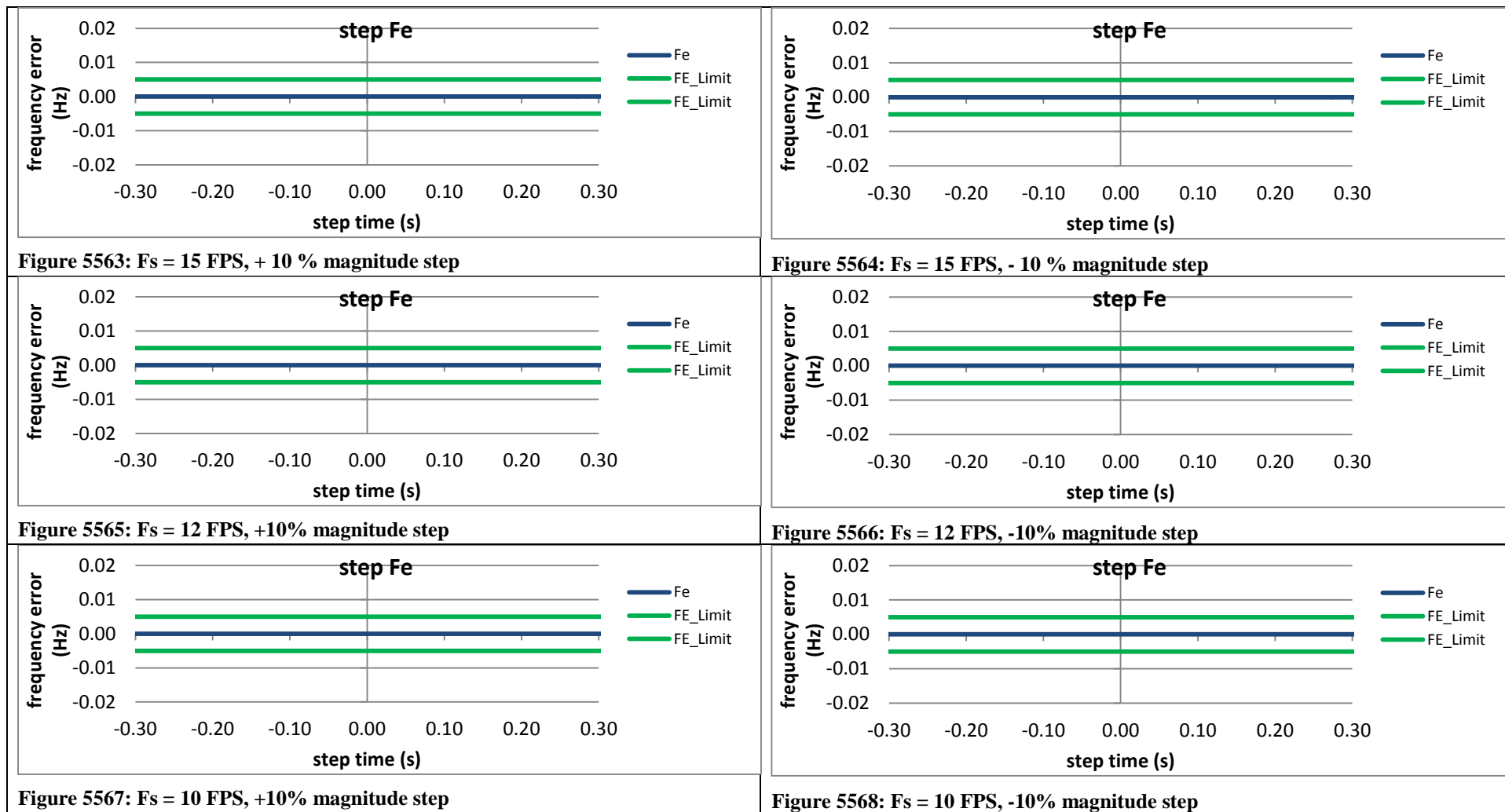




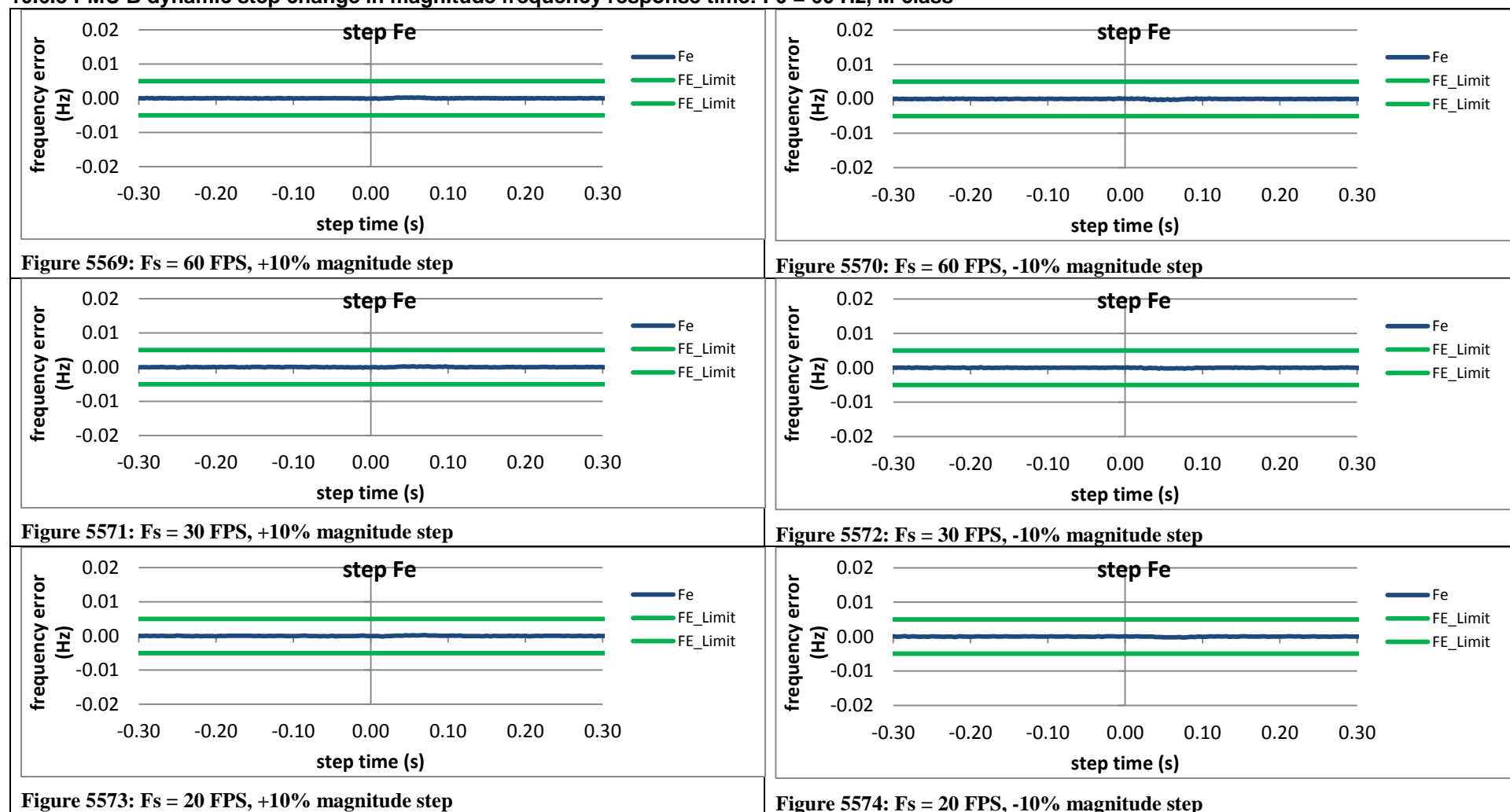


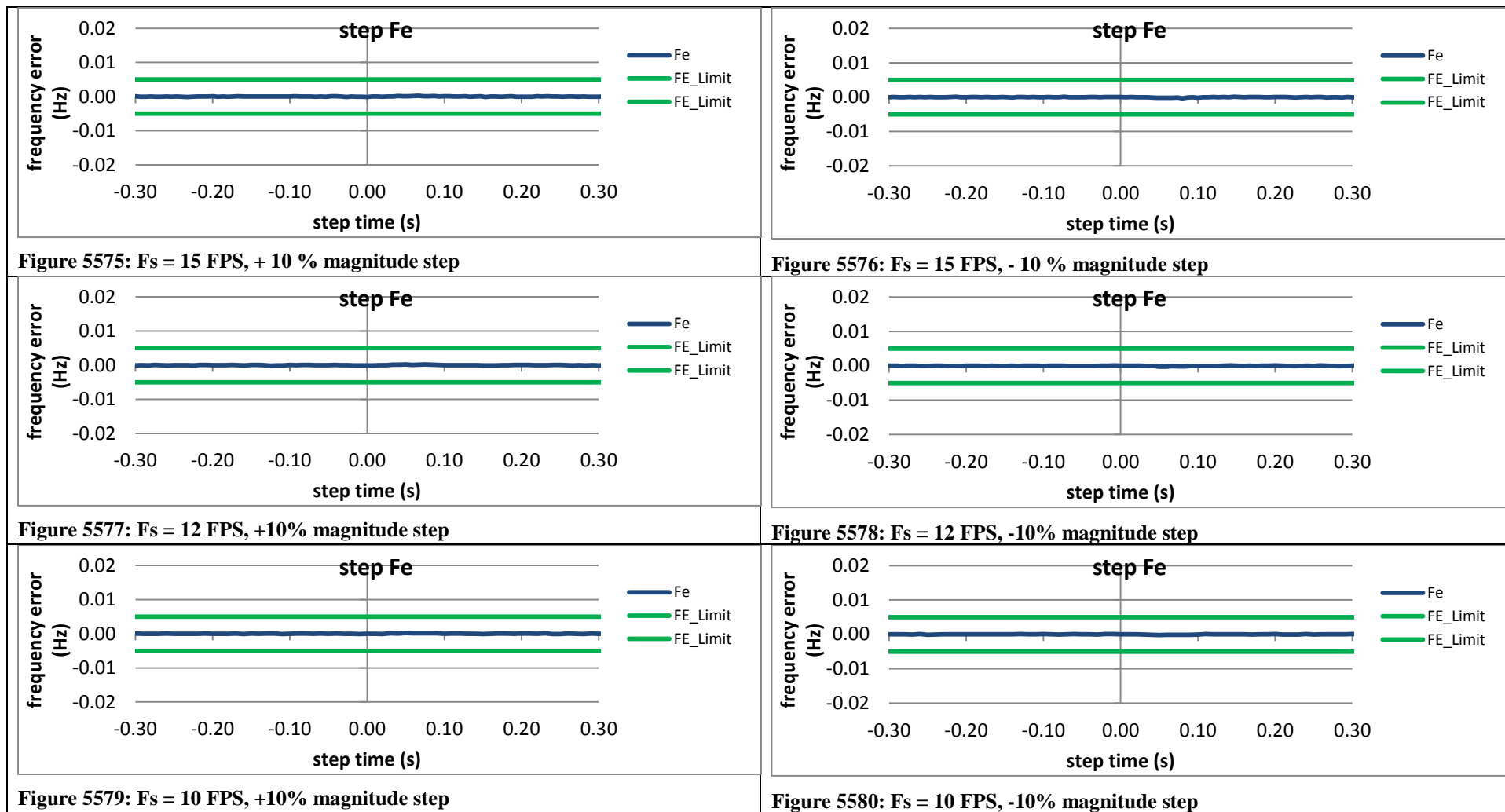
## 10.6.2 PMU A dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, M class



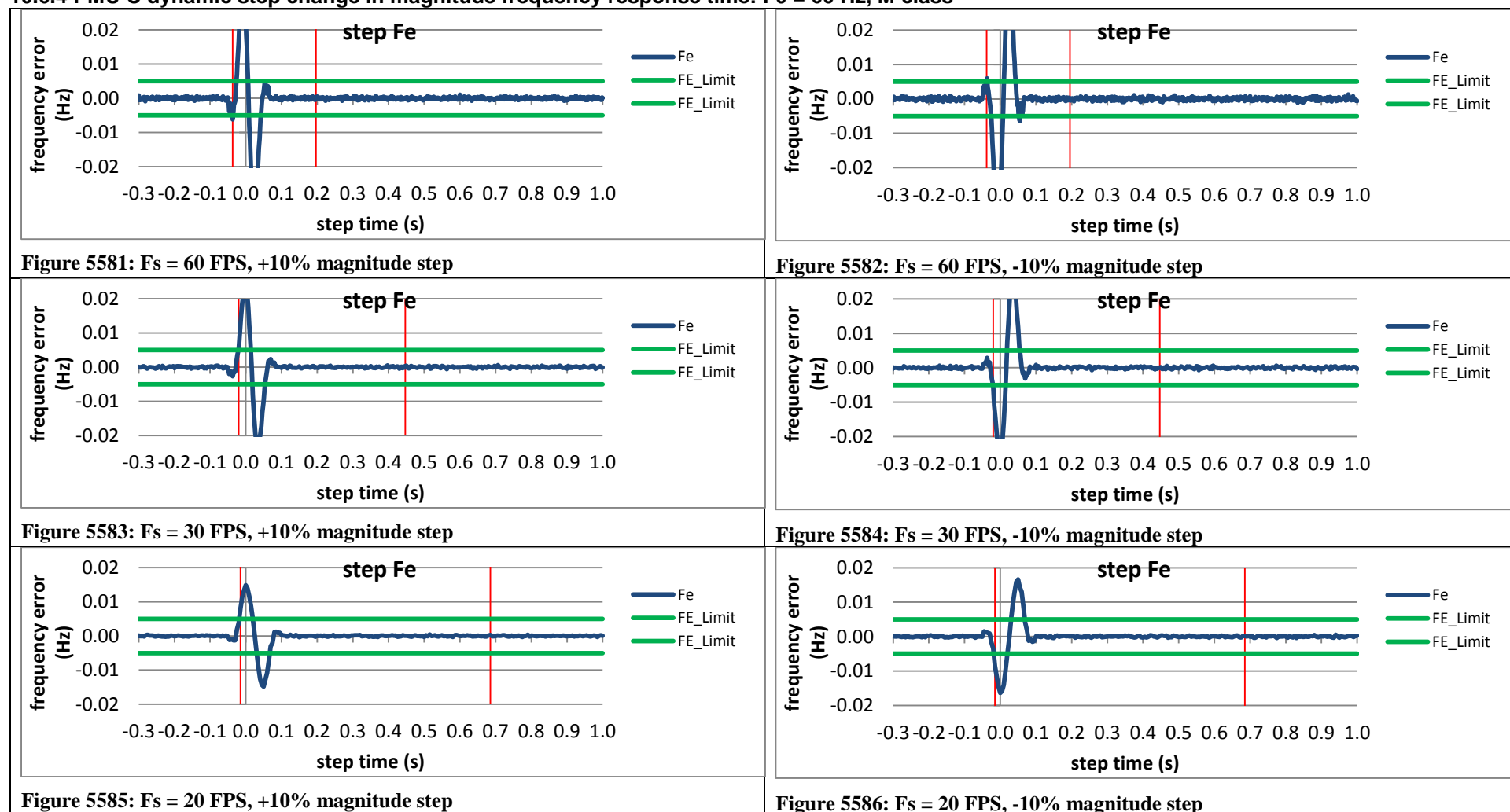


### 10.6.3 PMU B dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, M class





#### 10.6.4 PMU C dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, M class



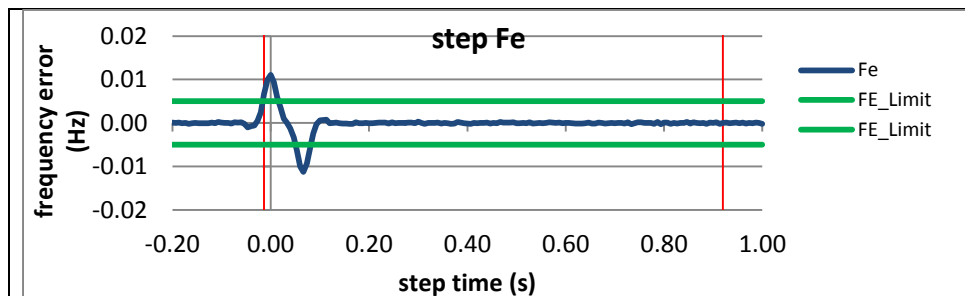


Figure 5587:  $F_s = 15$  FPS, + 10 % magnitude step

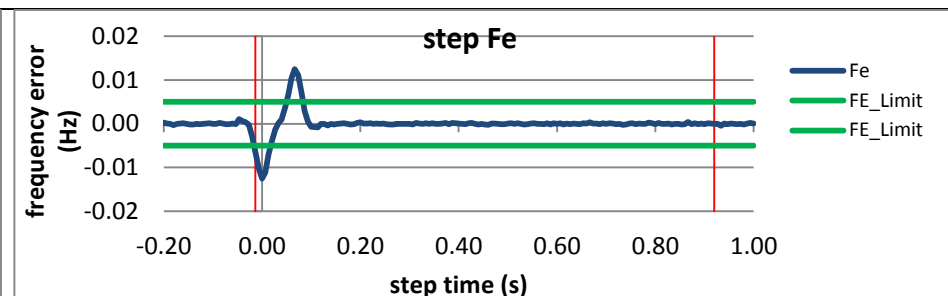


Figure 5588:  $F_s = 15$  FPS, - 10 % magnitude step

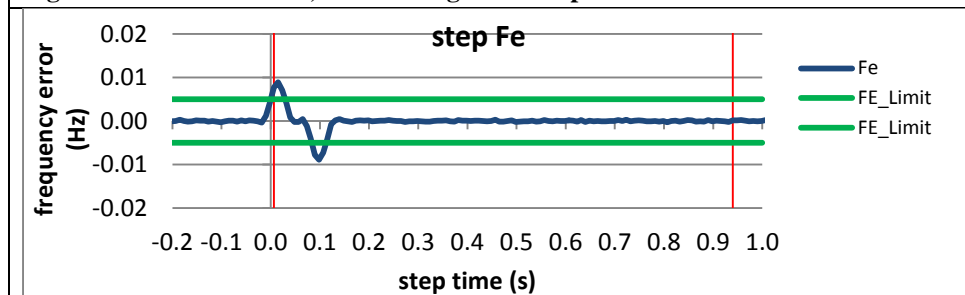


Figure 5589:  $F_s = 12$  FPS, +10% magnitude step

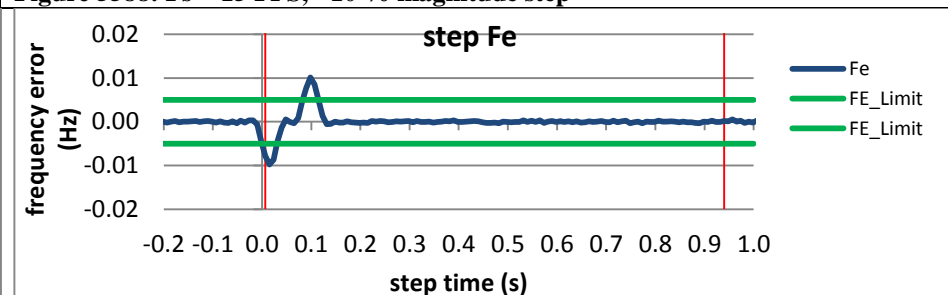


Figure 5590:  $F_s = 12$  FPS, -10% magnitude step

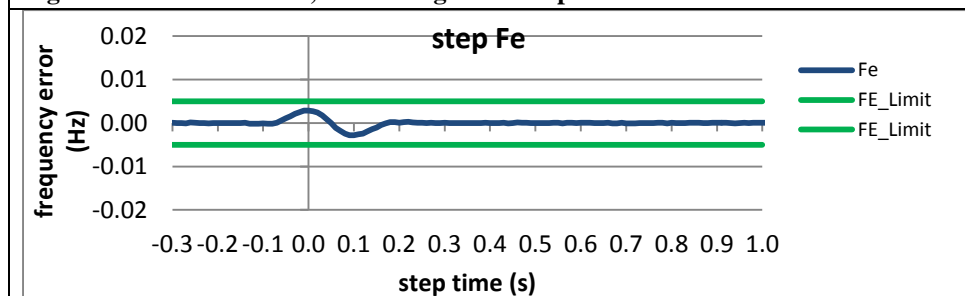


Figure 5591:  $F_s = 10$  FPS, +10% magnitude step

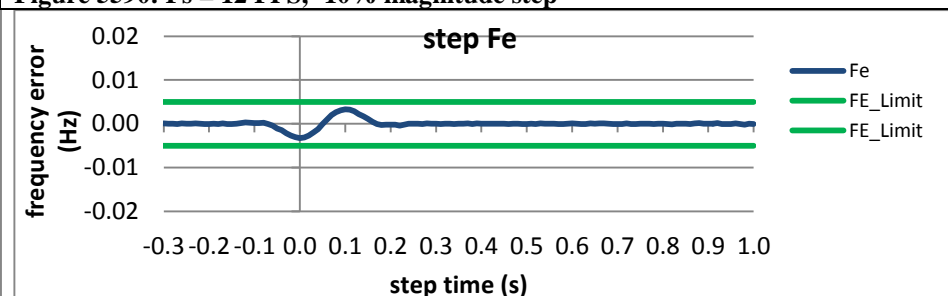
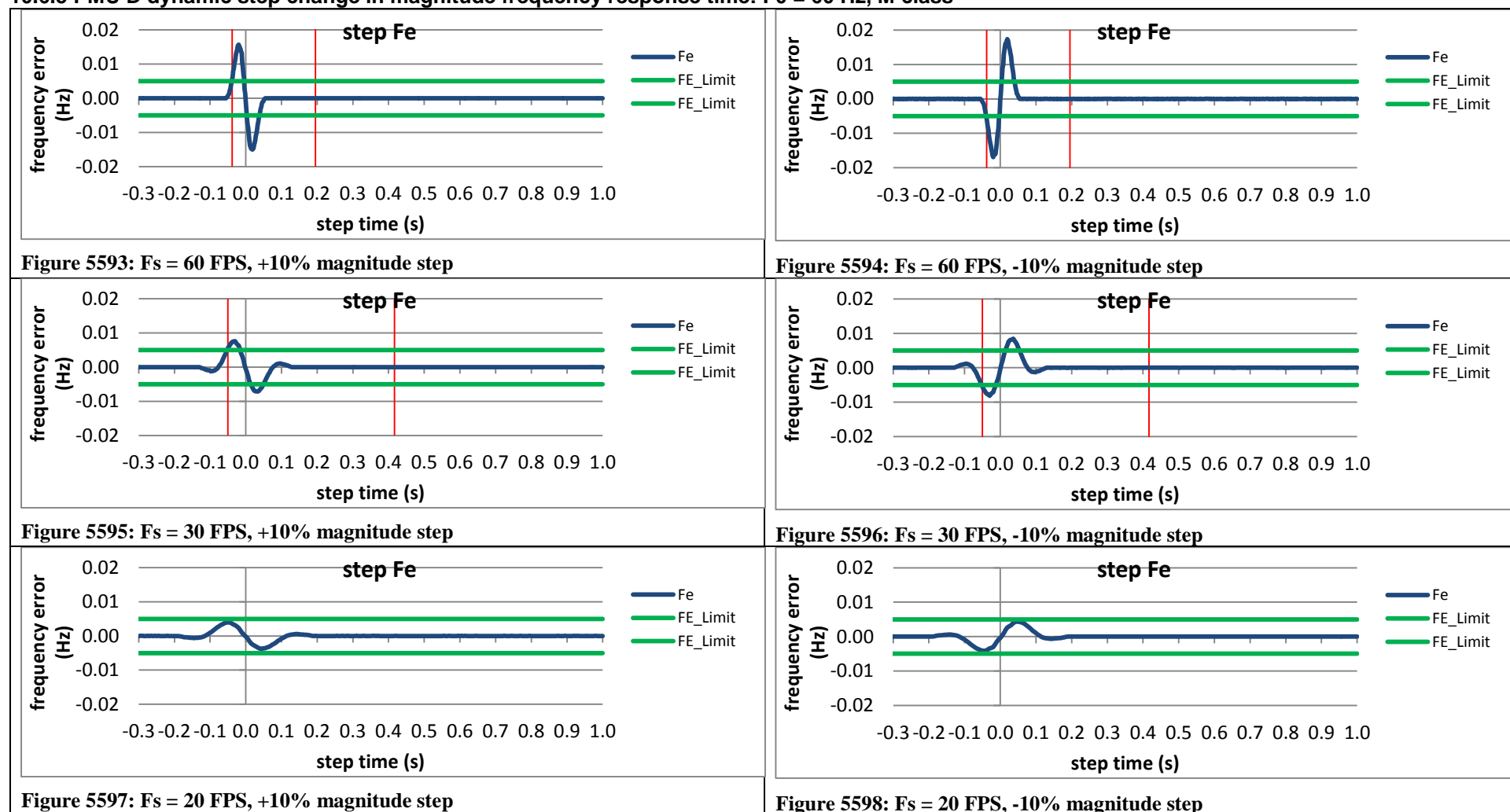
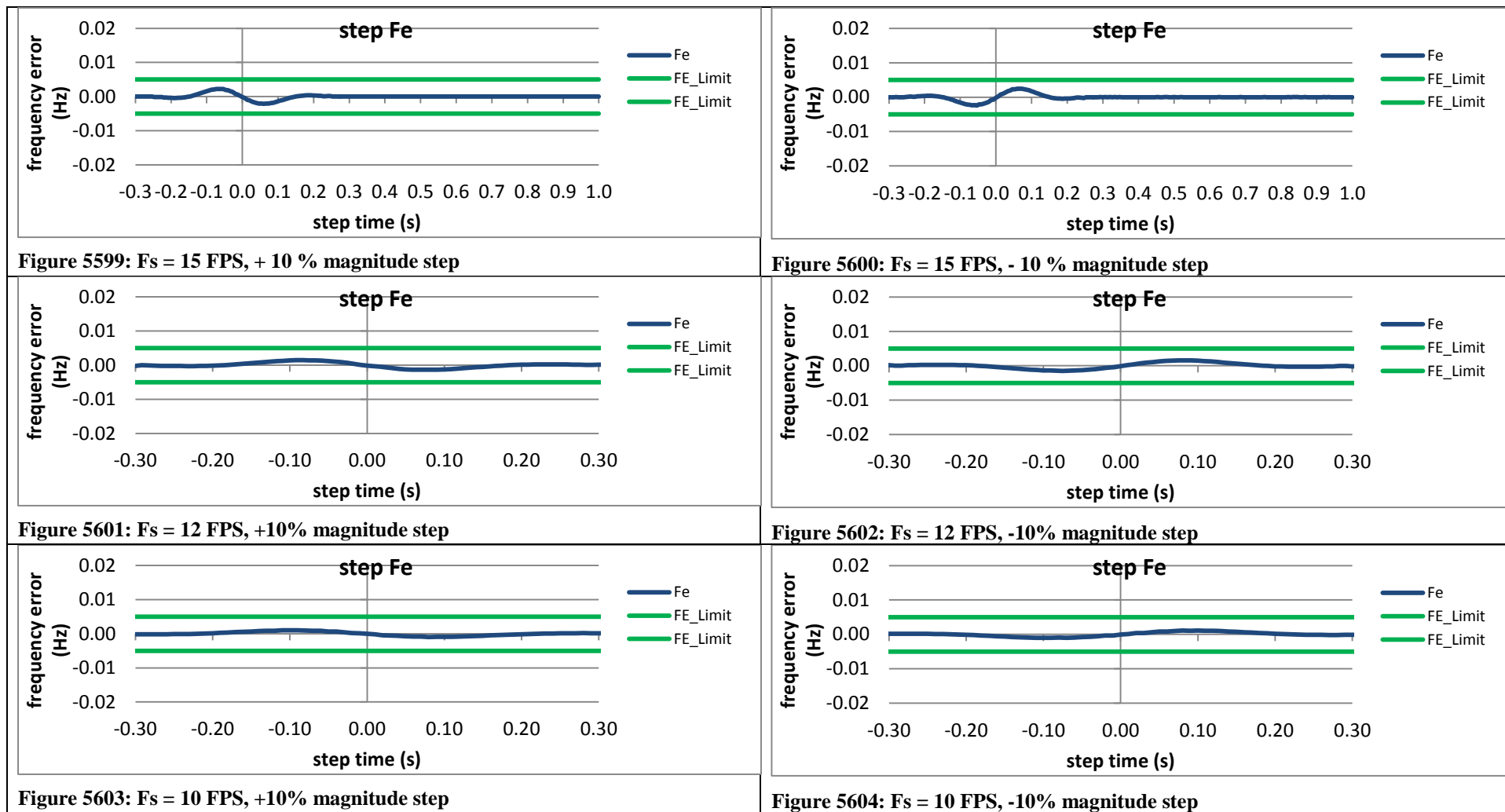


Figure 5592:  $F_s = 10$  FPS, -10% magnitude step

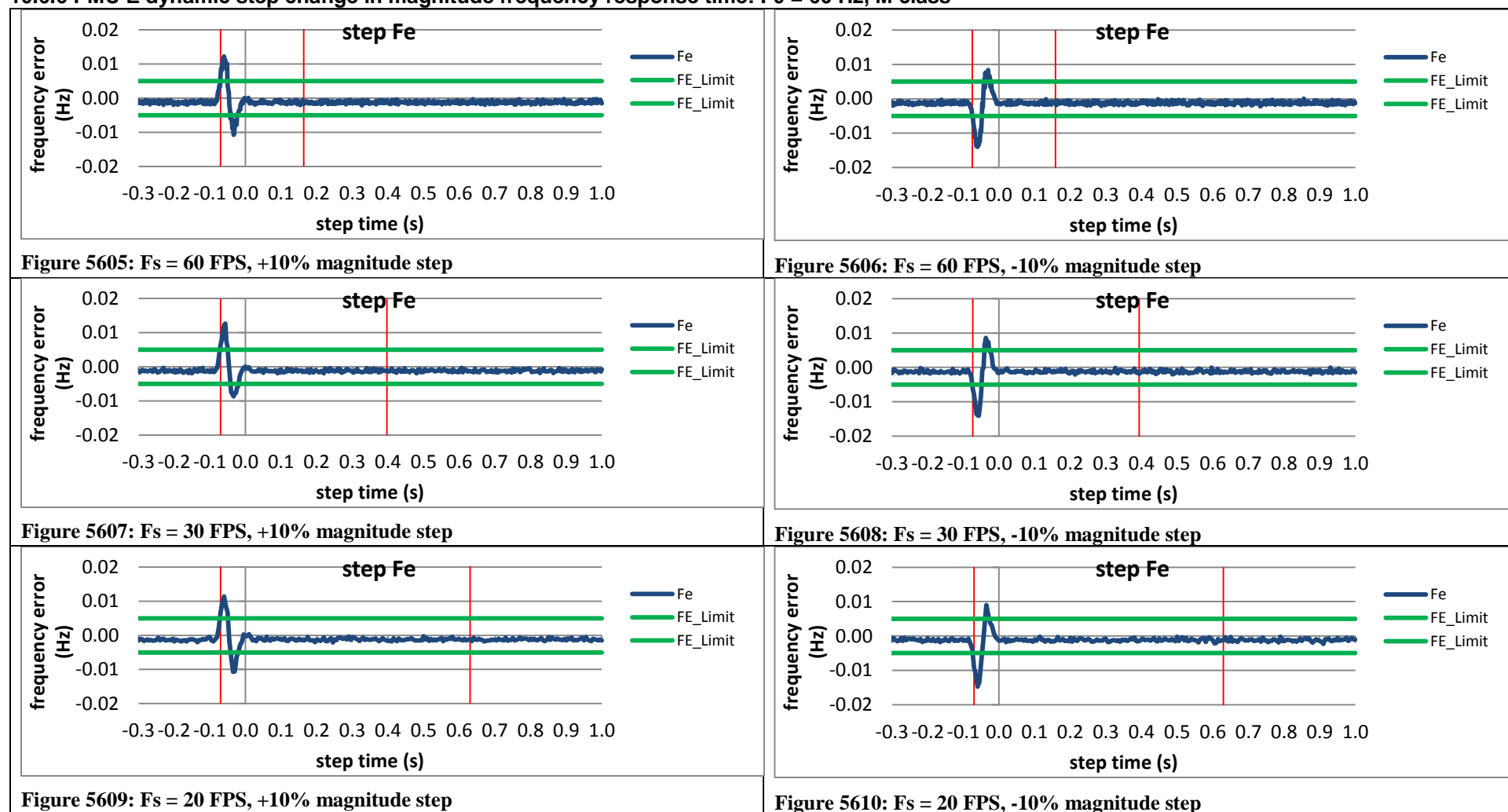
### 10.6.5 PMU D dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, M class







# 10.6.6 PMU E dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, M class



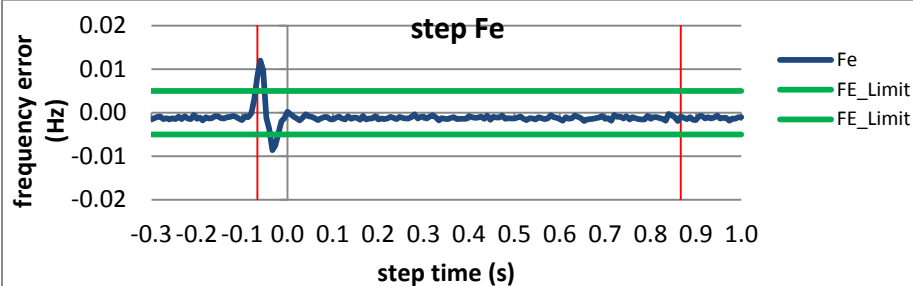


Figure 5611:  $F_s = 15$  FPS, + 10 % magnitude step

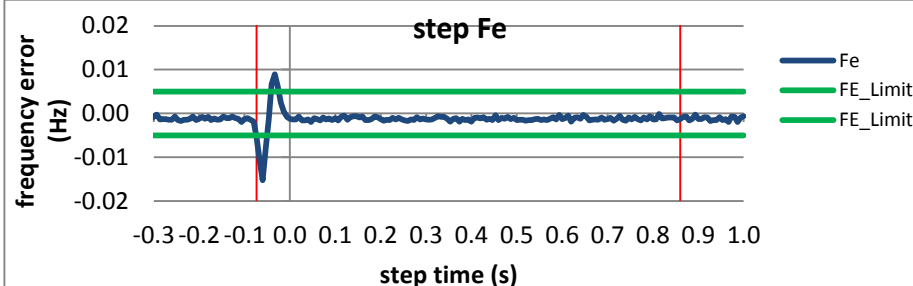


Figure 5612:  $F_s = 15$  FPS, - 10 % magnitude step

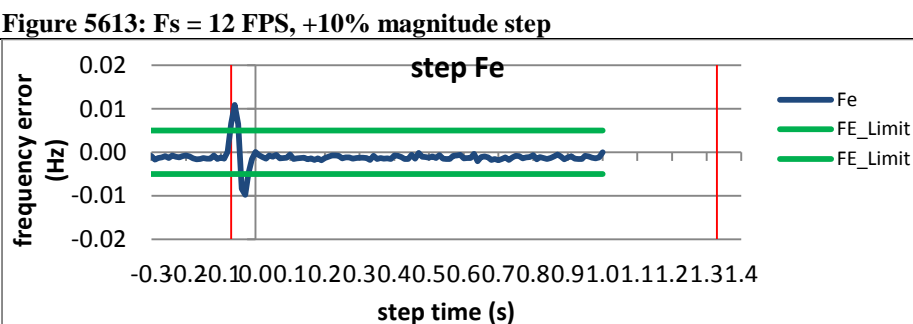


Figure 5615:  $F_s = 10$  FPS, +10% magnitude step

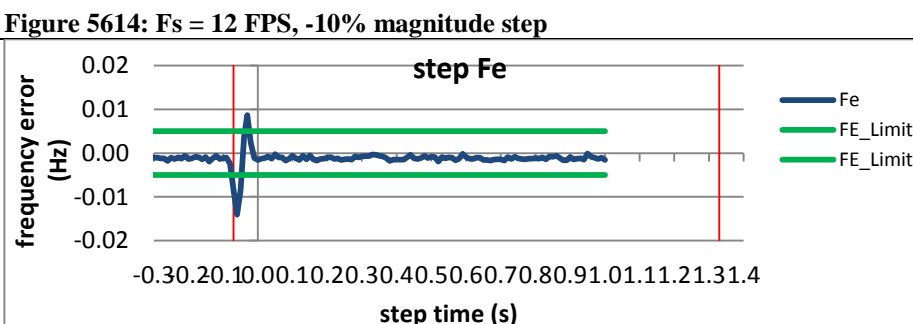
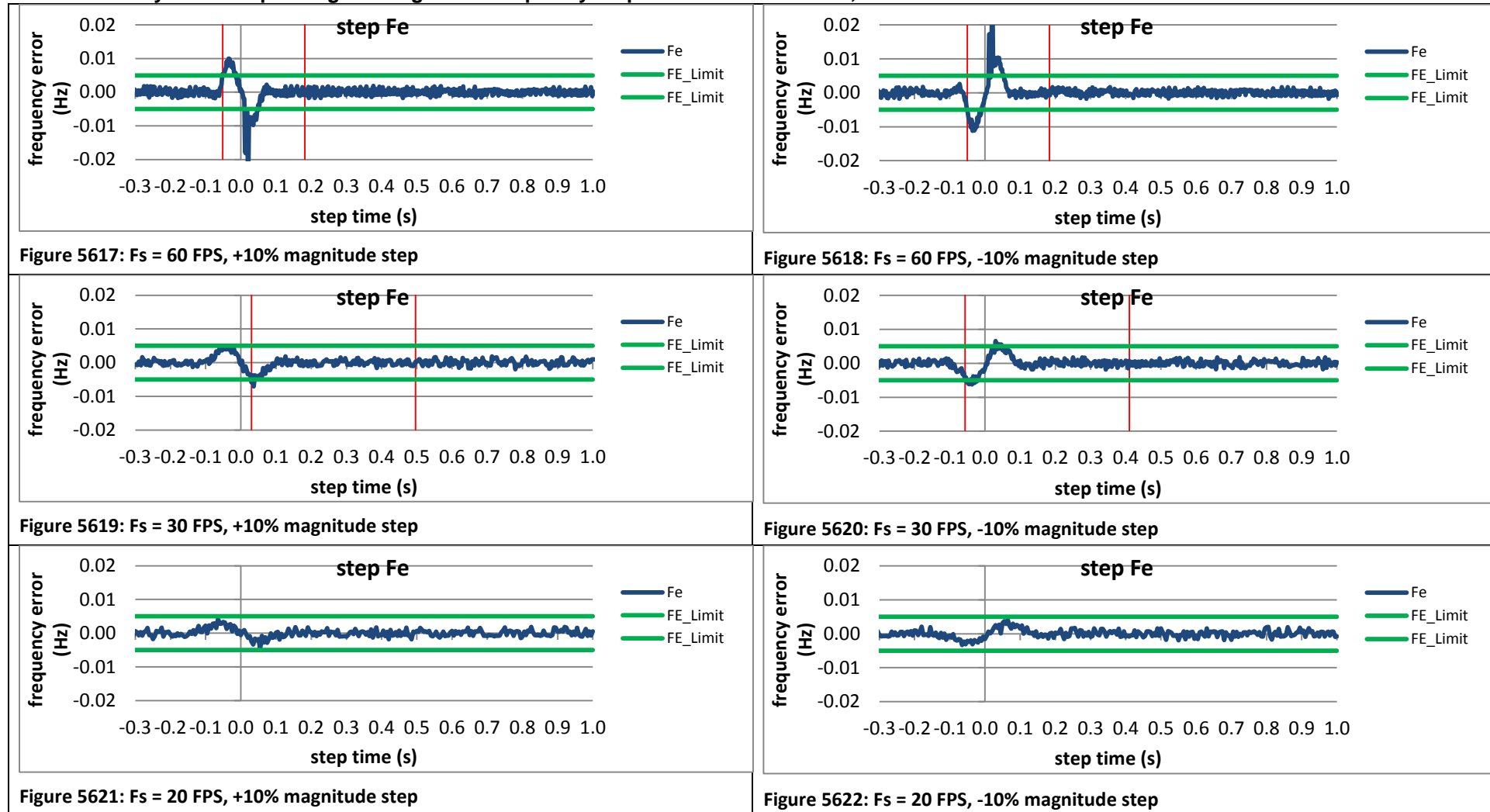
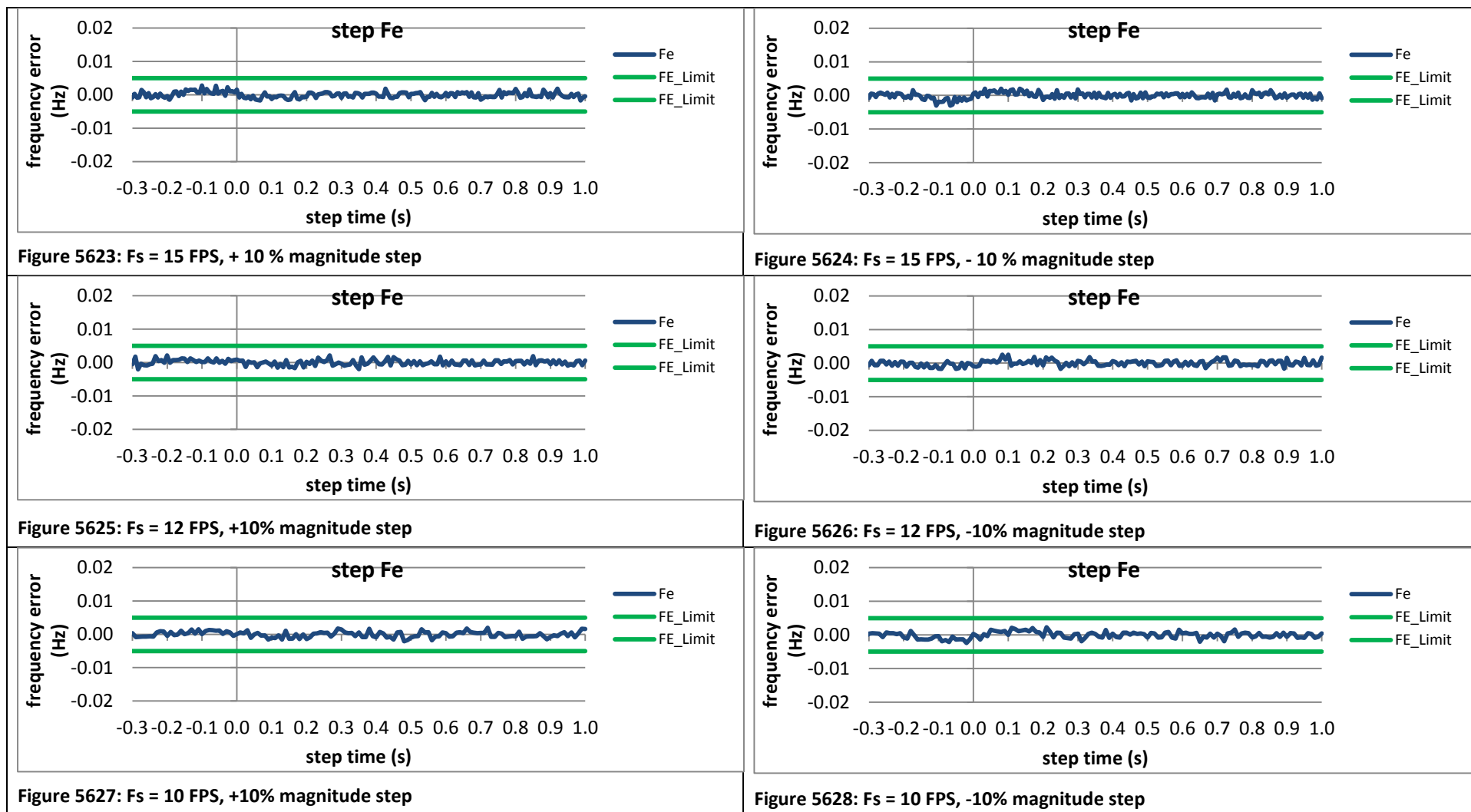


Figure 5616:  $F_s = 10$  FPS, -10% magnitude step

# 10.6.7 PMU F dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class





# 10.6.8 PMU G dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class

Figure 5629: Fs = 60 FPS is not supported by this PMU

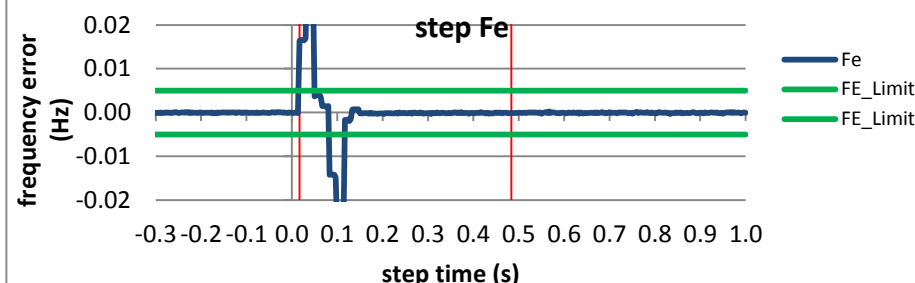
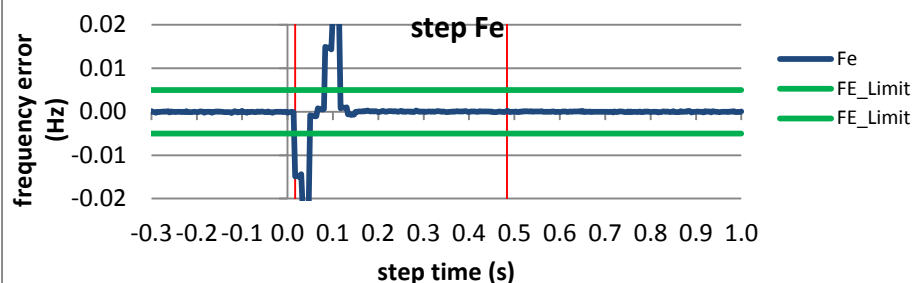


Figure 5630: Fs = 30 FPS, +10% magnitude step

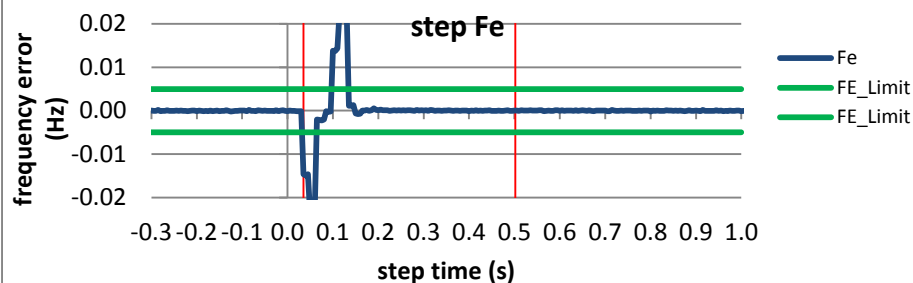


Figure 5631: Fs = 30 FPS, -10% magnitude step

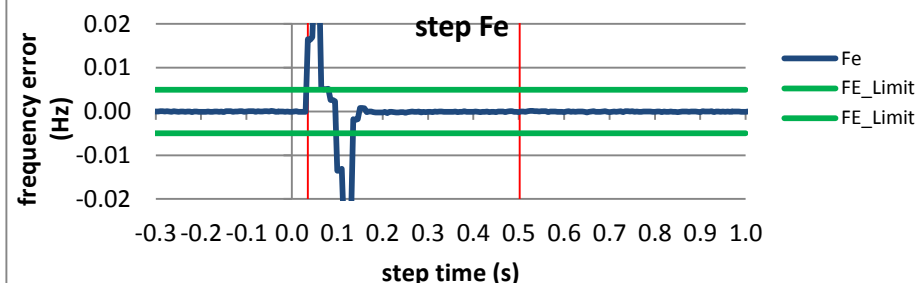


Figure 5632: Fs = 20 FPS, +10% magnitude step

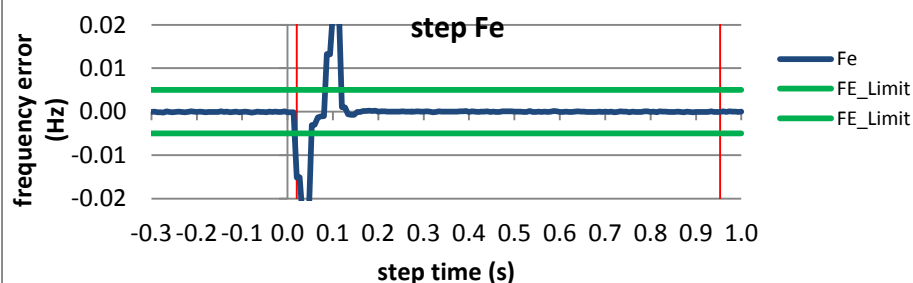


Figure 5633: Fs = 20 FPS, -10% magnitude step

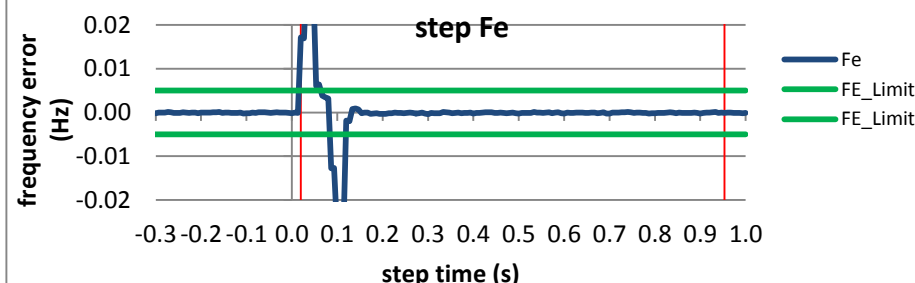


Figure 5634: Fs = 15 FPS, +10% magnitude step



Figure 5635: Fs = 15 FPS, -10% magnitude step



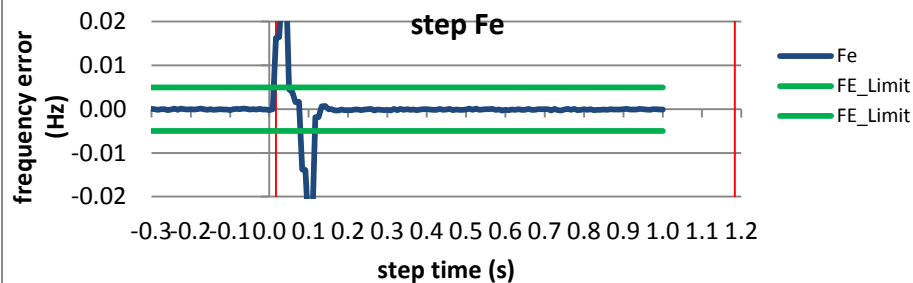


Figure 5636:  $F_s = 15$  FPS, +10% magnitude step

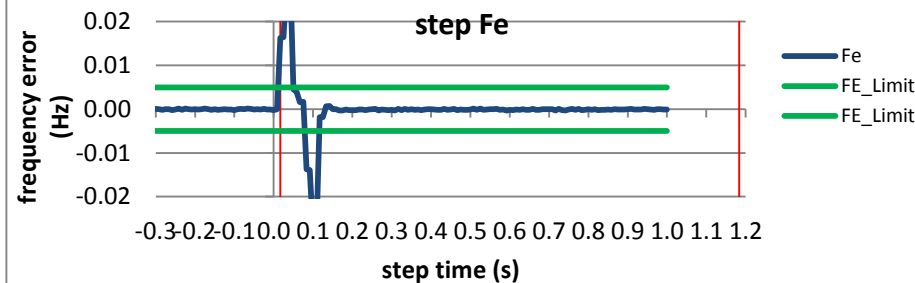


Figure 5637:  $F_s = 15$  FPS, -10% magnitude step

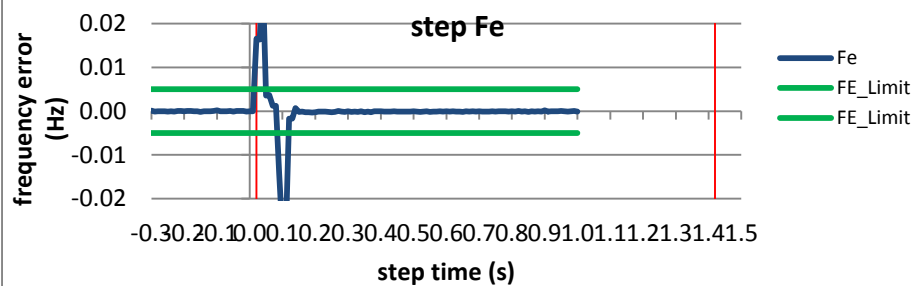


Figure 5638:  $F_s = 10$  FPS, +10% magnitude step

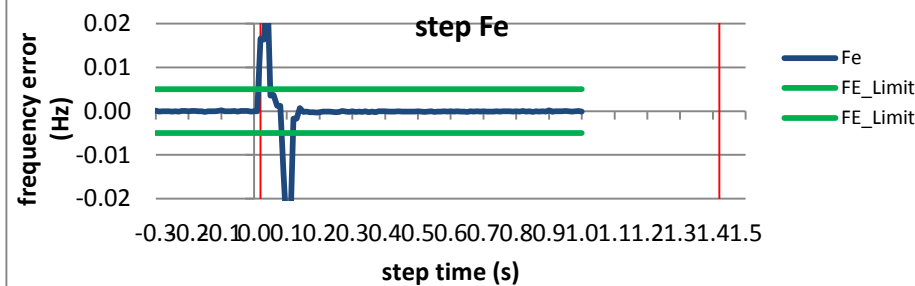
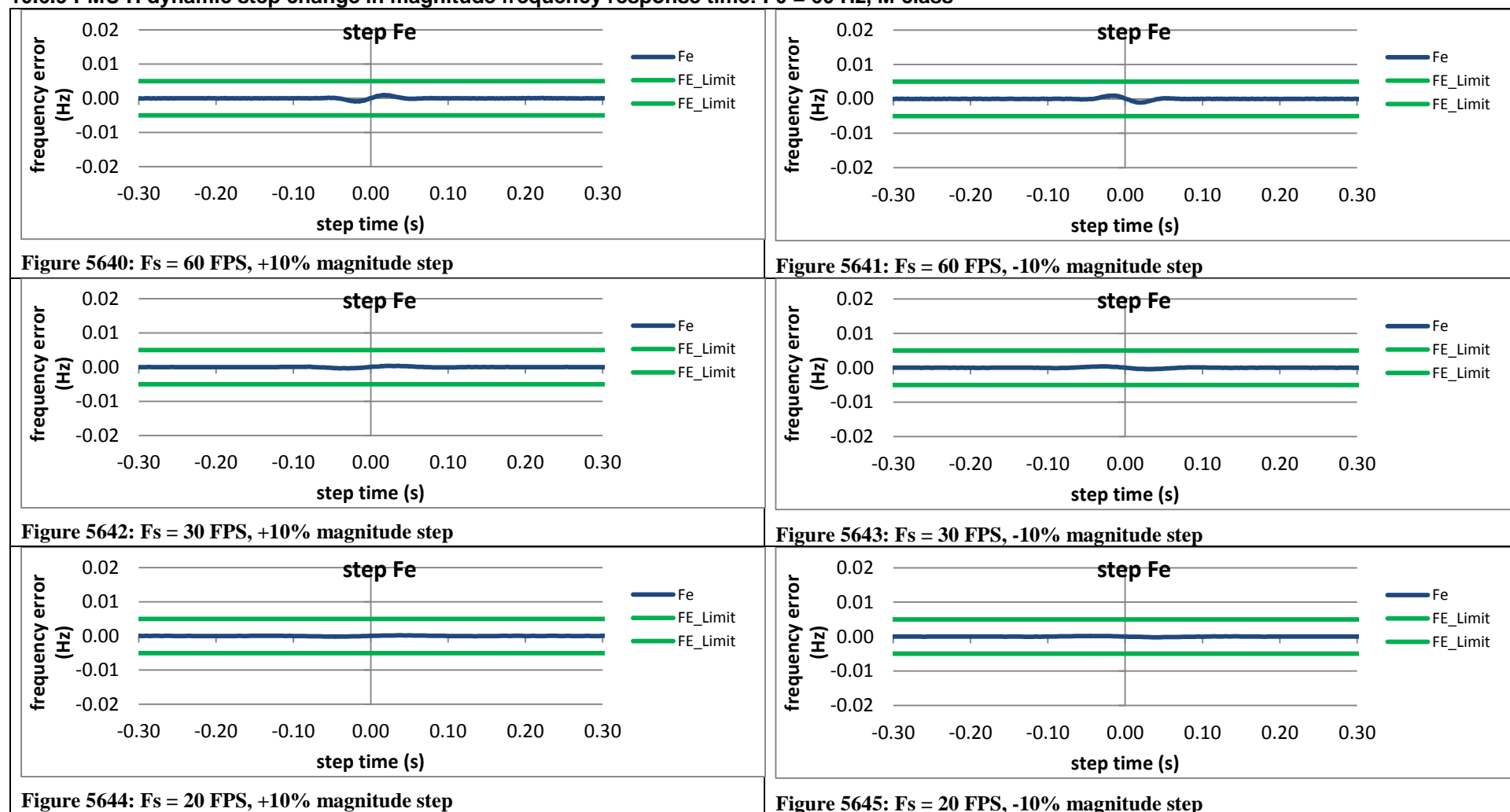
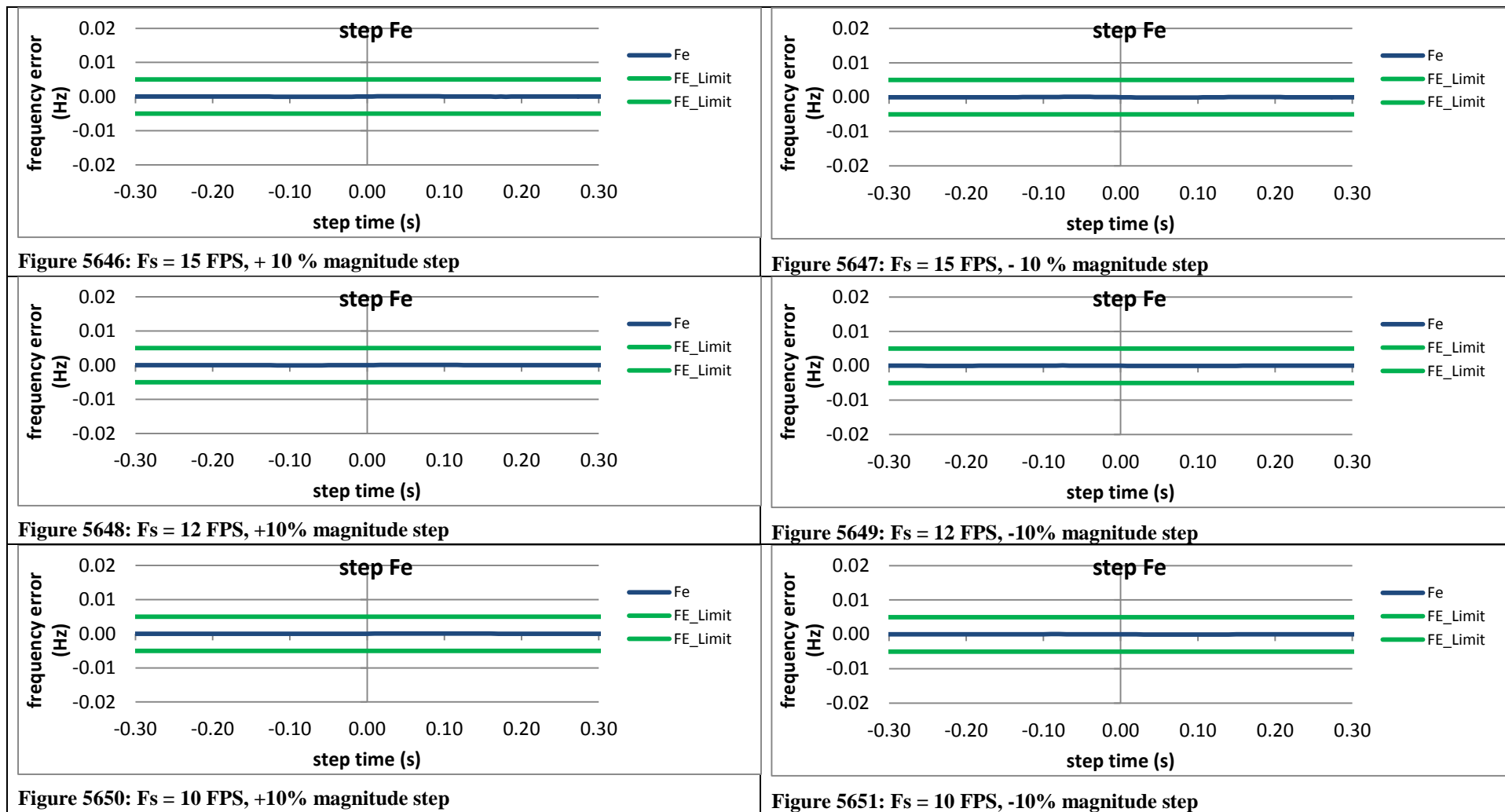


Figure 5639:  $F_s = 10$  FPS, -10% magnitude step

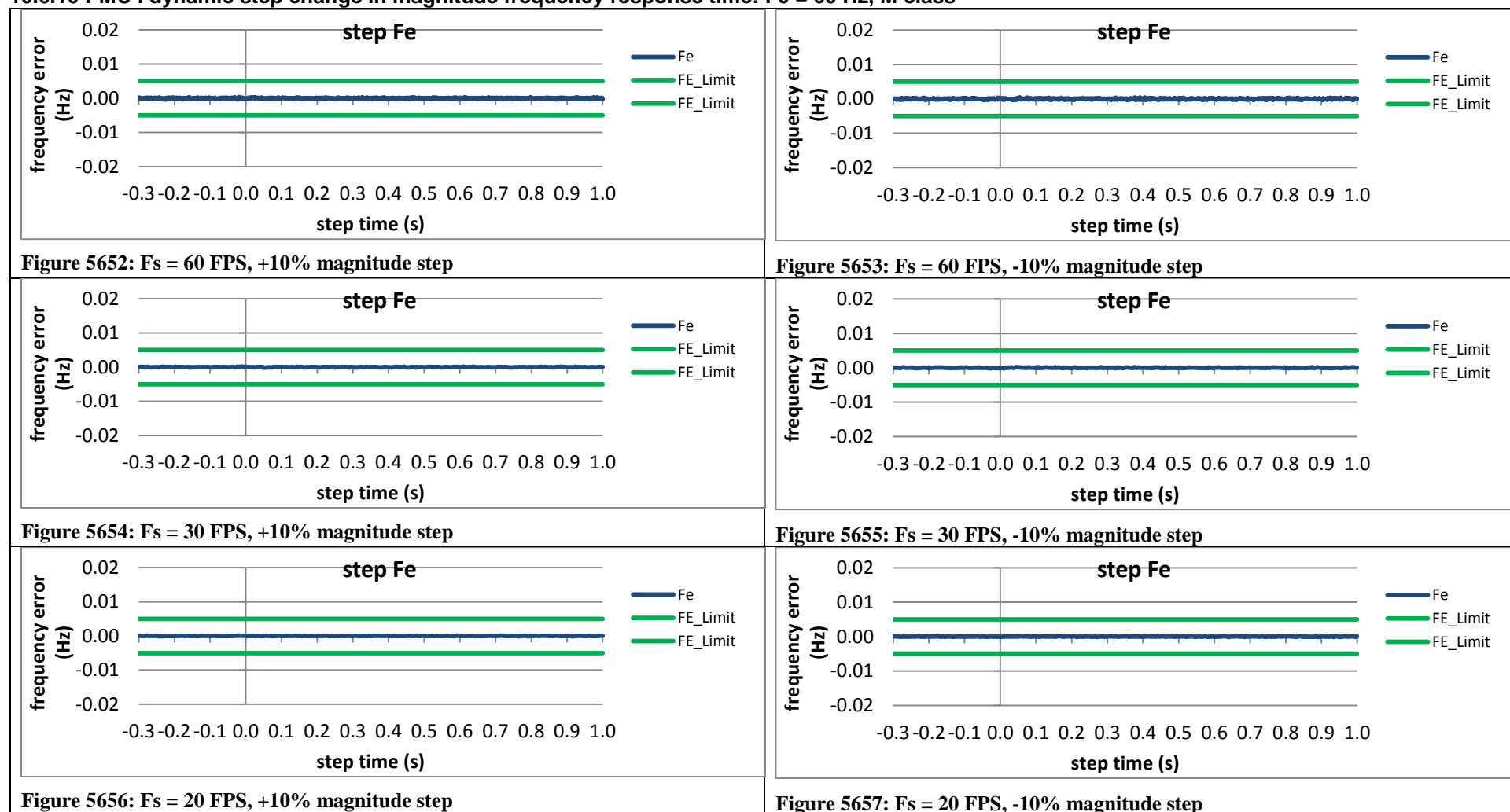
### 10.6.9 PMU H dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, M class

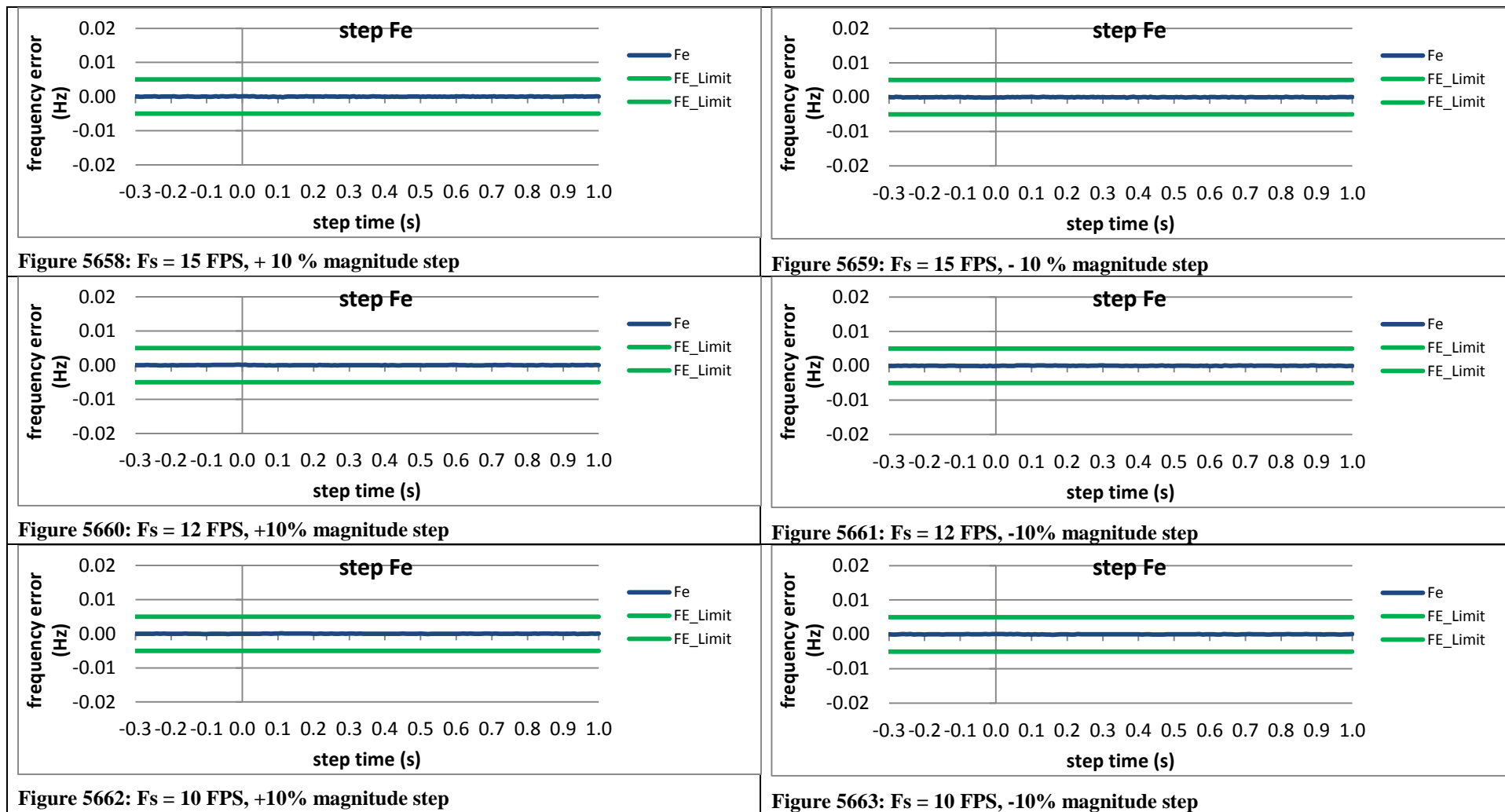




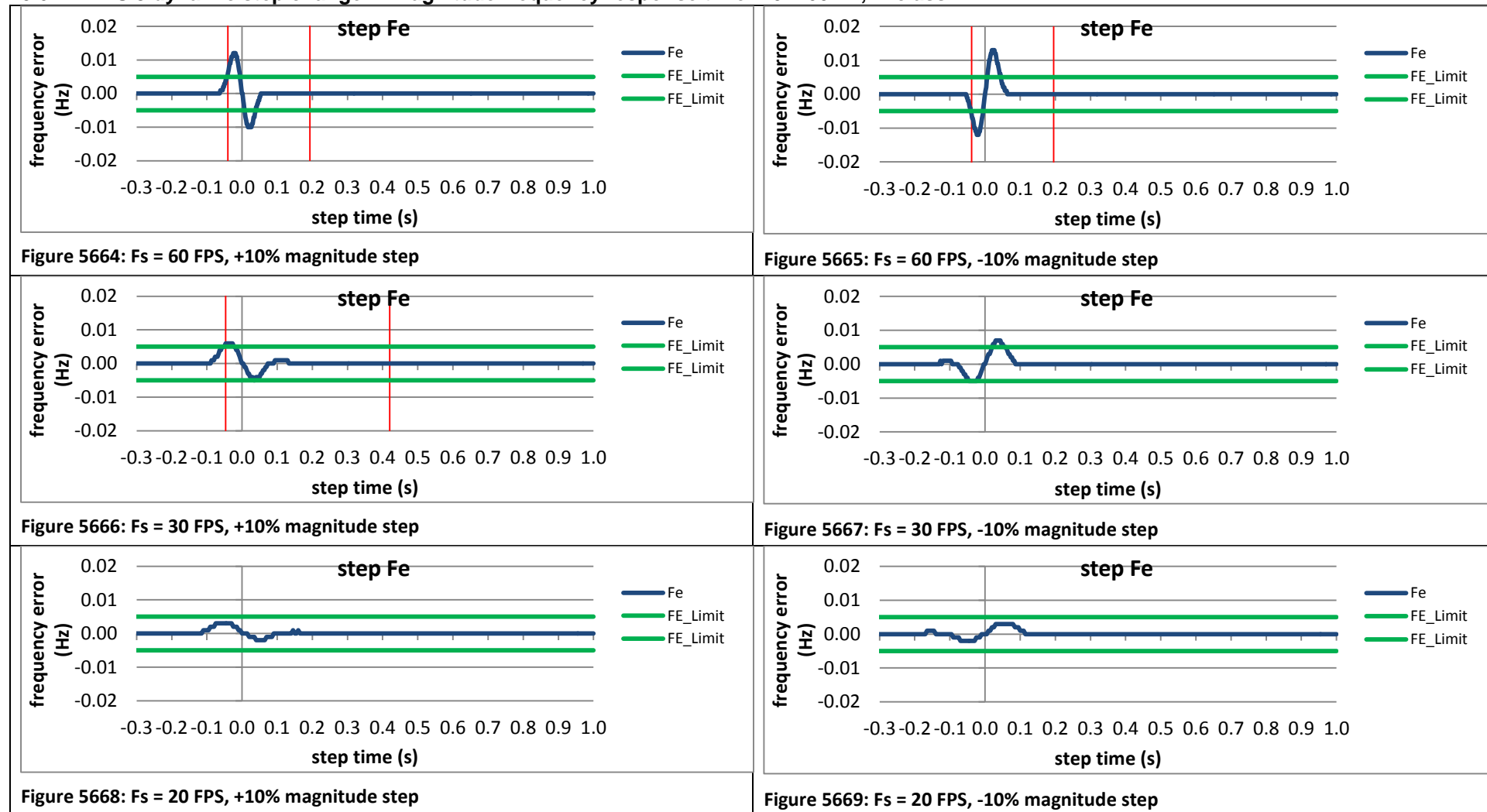


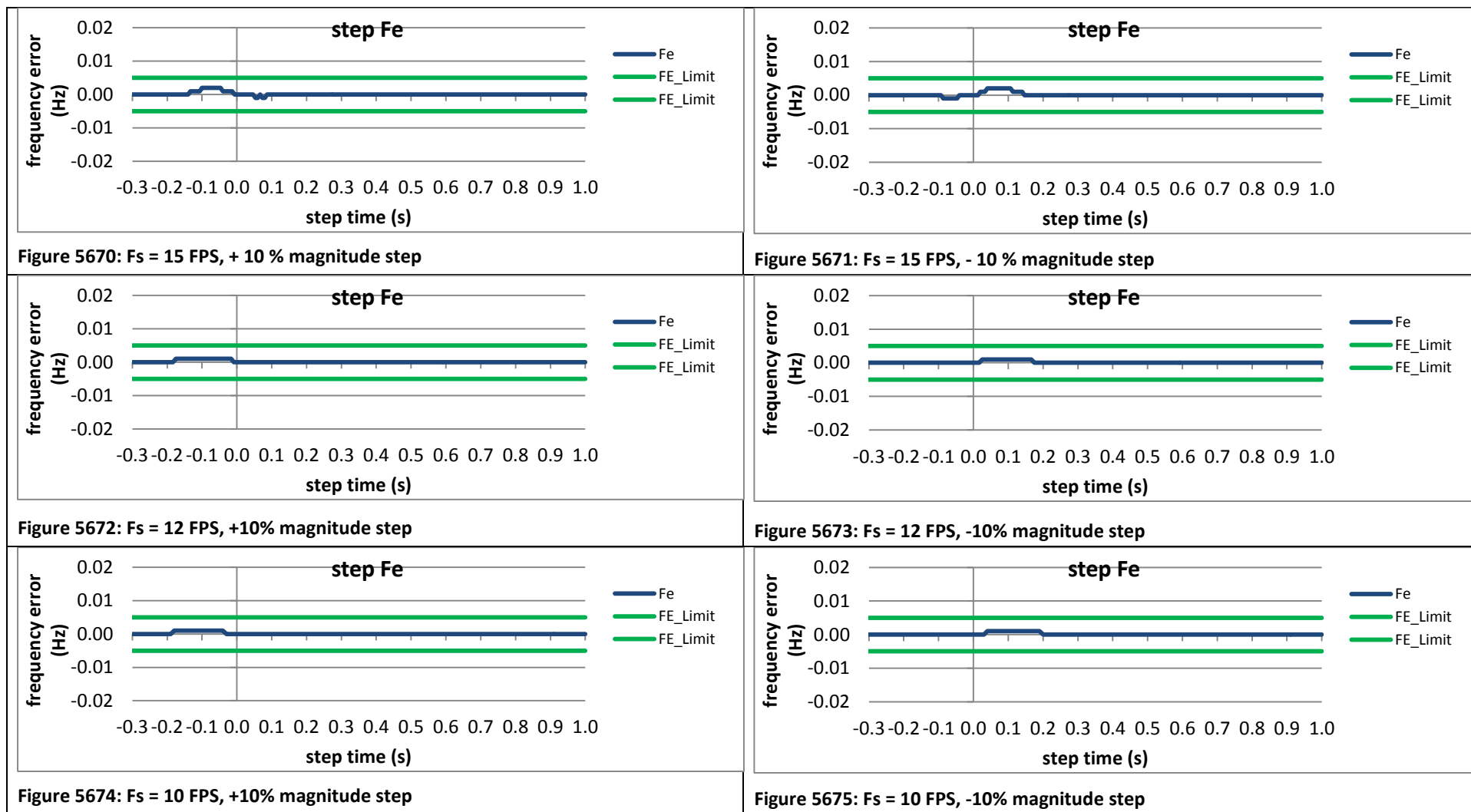
# 10.6.10 PMU I dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class





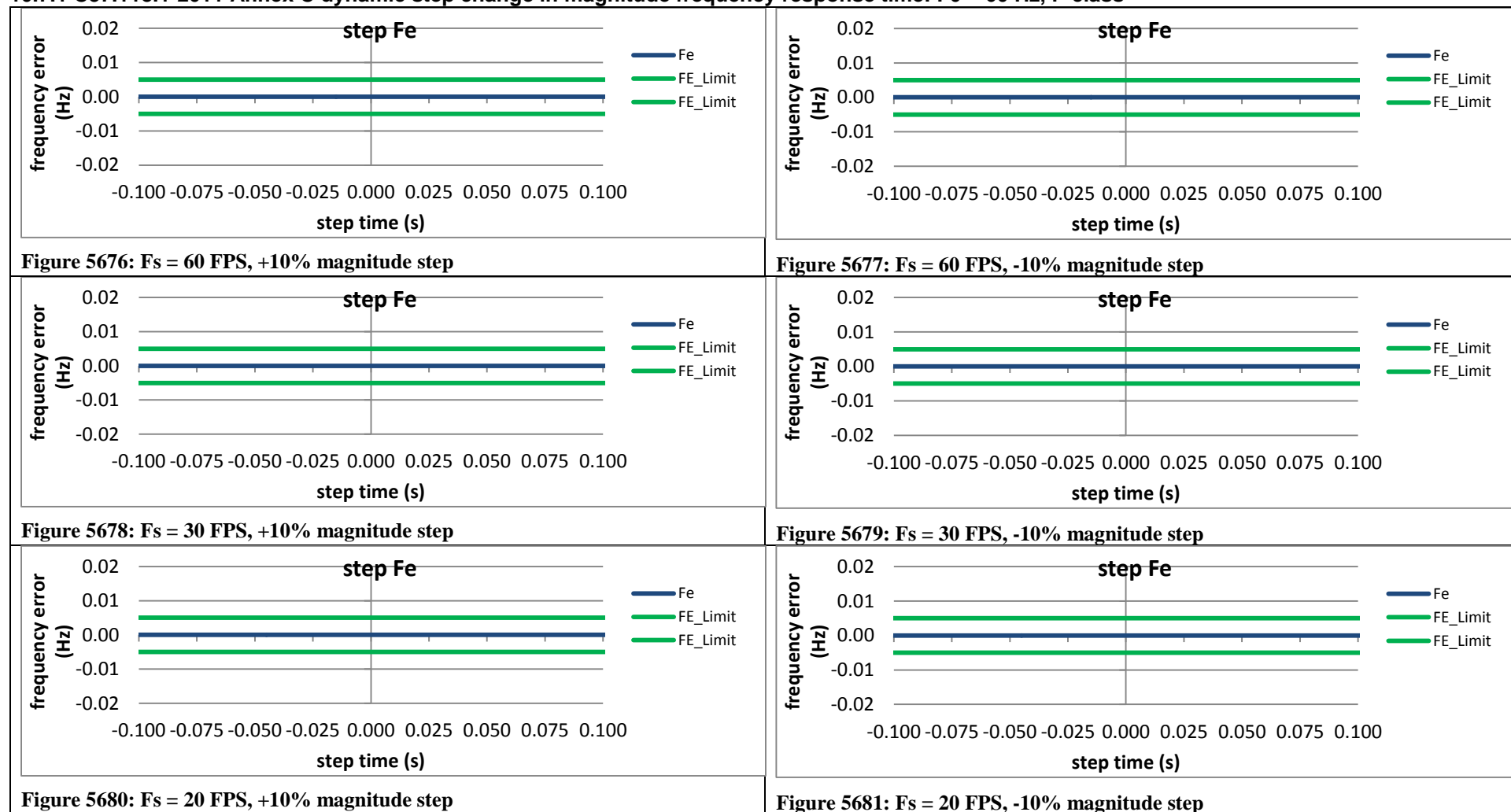
# 10.6.11 PMU J dynamic step change in magnitude frequency response time: F0 = 60 Hz, M class

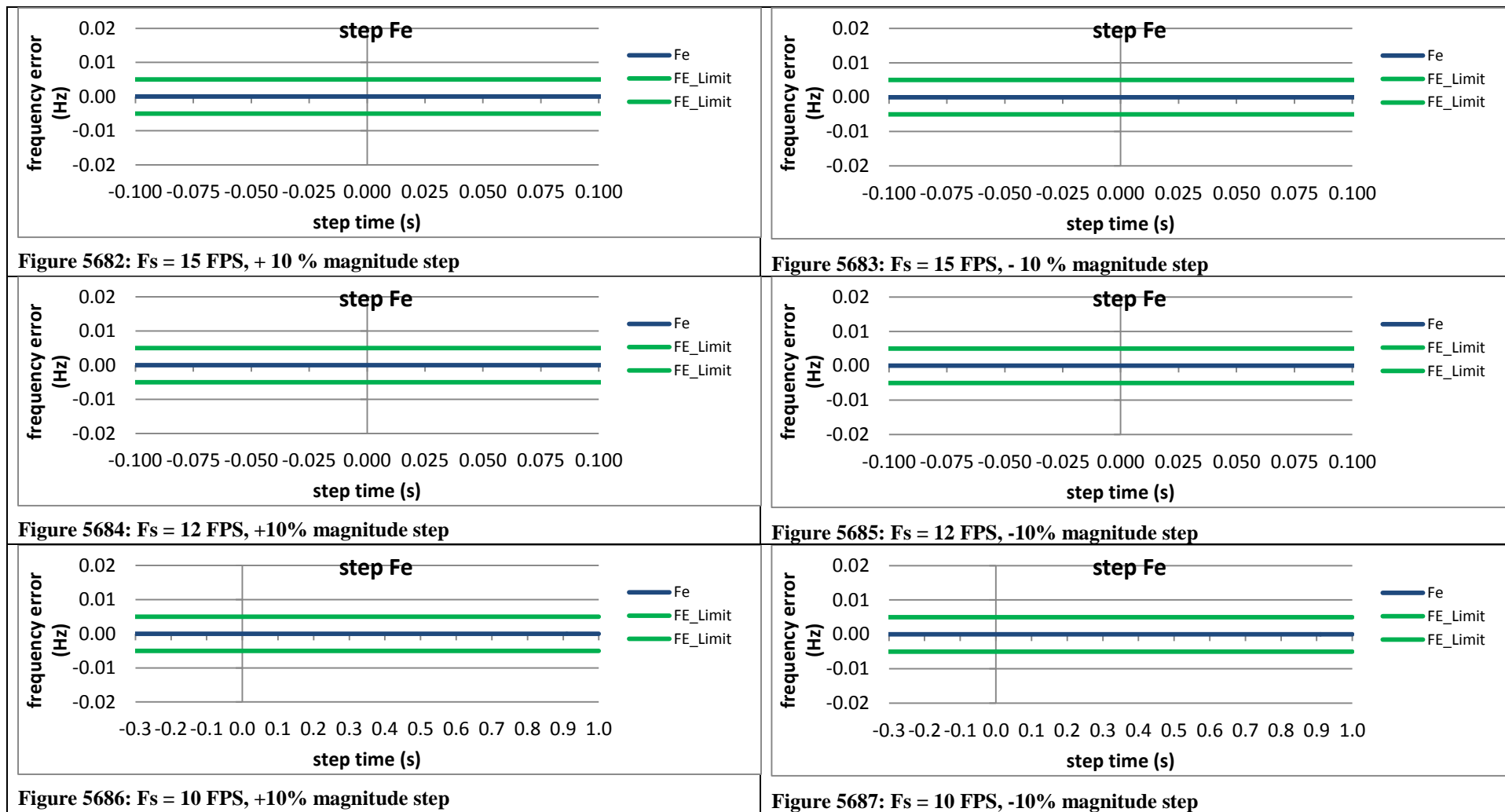




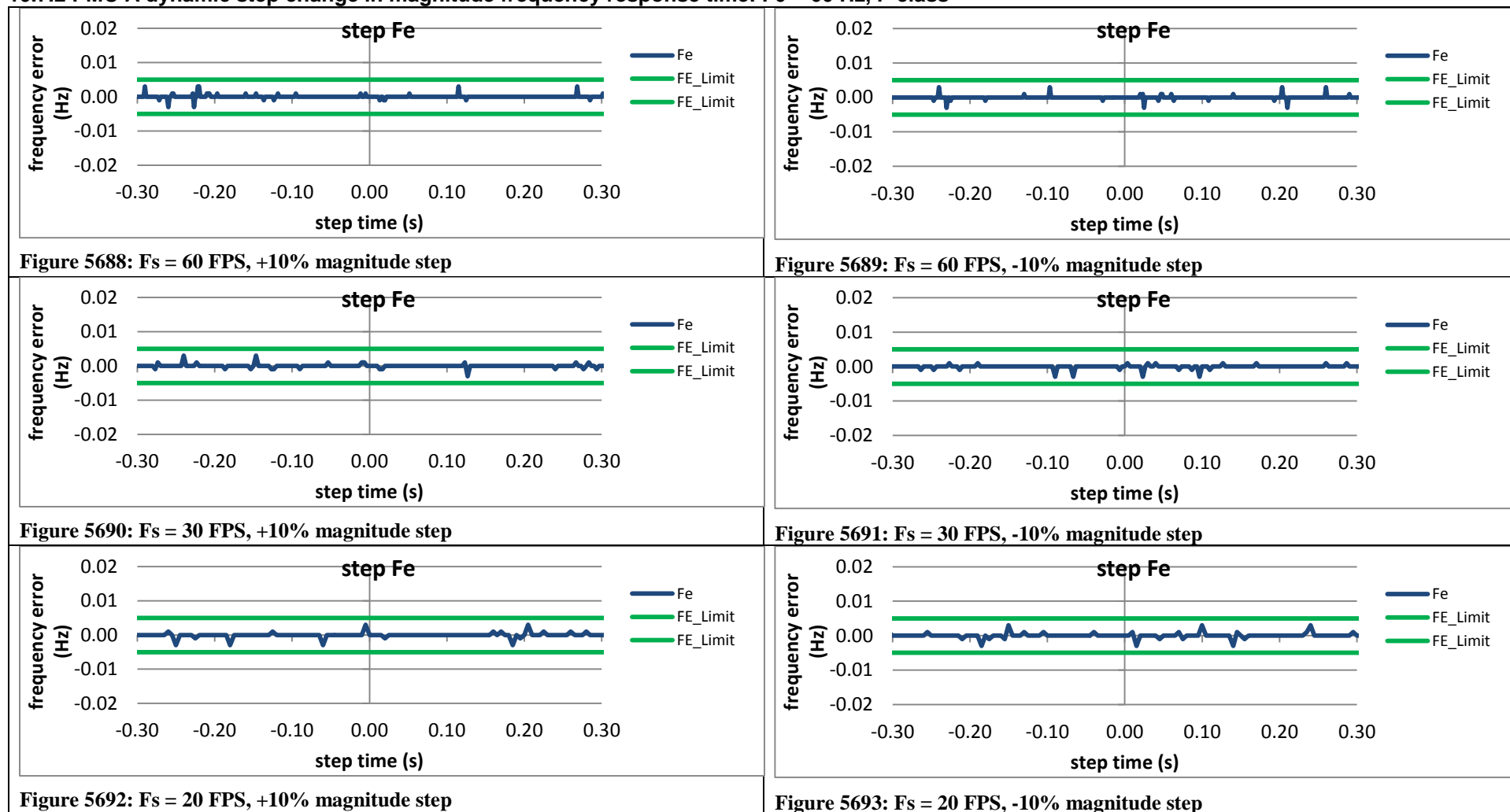
## 10.7 Dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class

### 10.7.1 C37.118.1-2011 Annex C dynamic step change in magnitude frequency response time: F0 = 60 Hz, P class





### 10.7.2 PMU A dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, P class





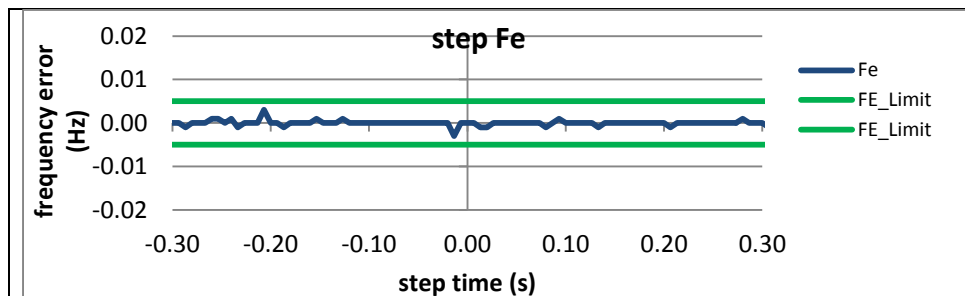


Figure 5694:  $F_s = 15$  FPS, +10% magnitude step

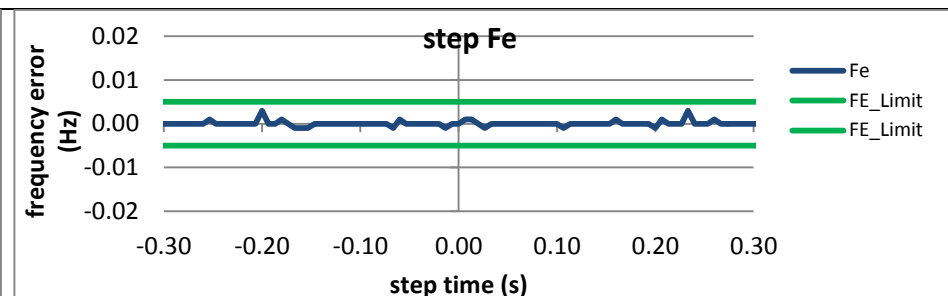


Figure 5695:  $F_s = 15$  FPS, -10% magnitude step

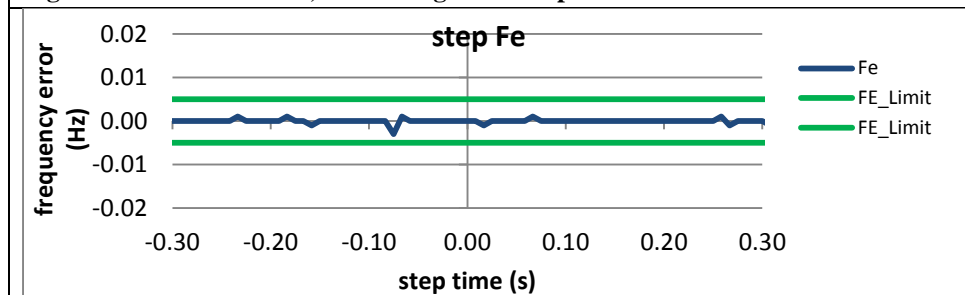


Figure 5696:  $F_s = 12$  FPS, +10% magnitude step

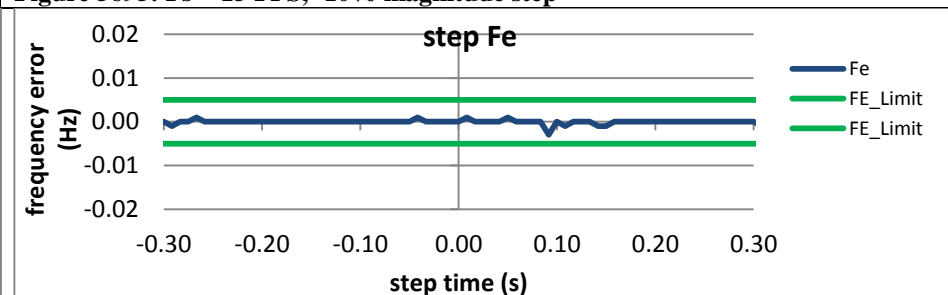


Figure 5697:  $F_s = 12$  FPS, -10% magnitude step

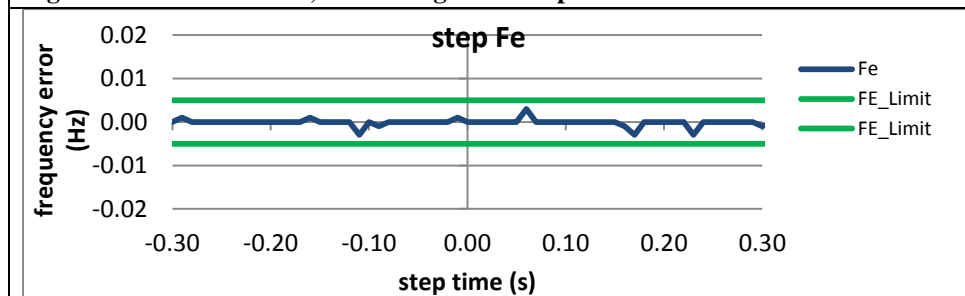


Figure 5698:  $F_s = 10$  FPS, +10% magnitude step

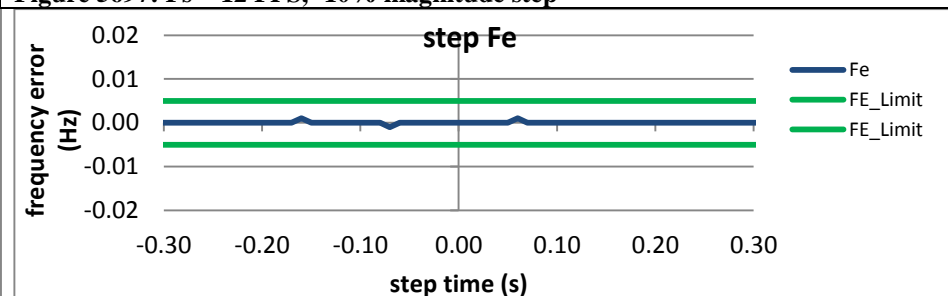
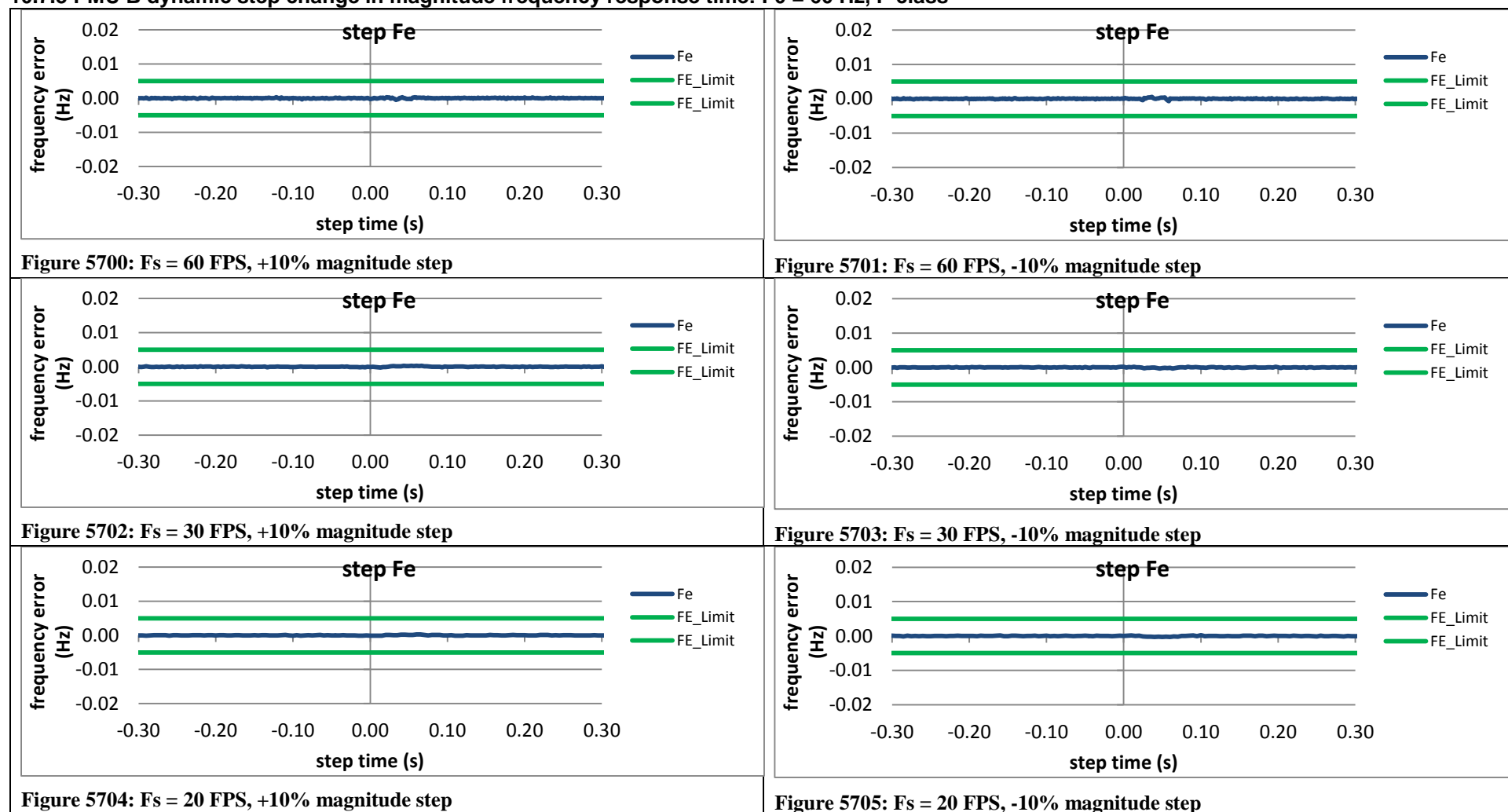
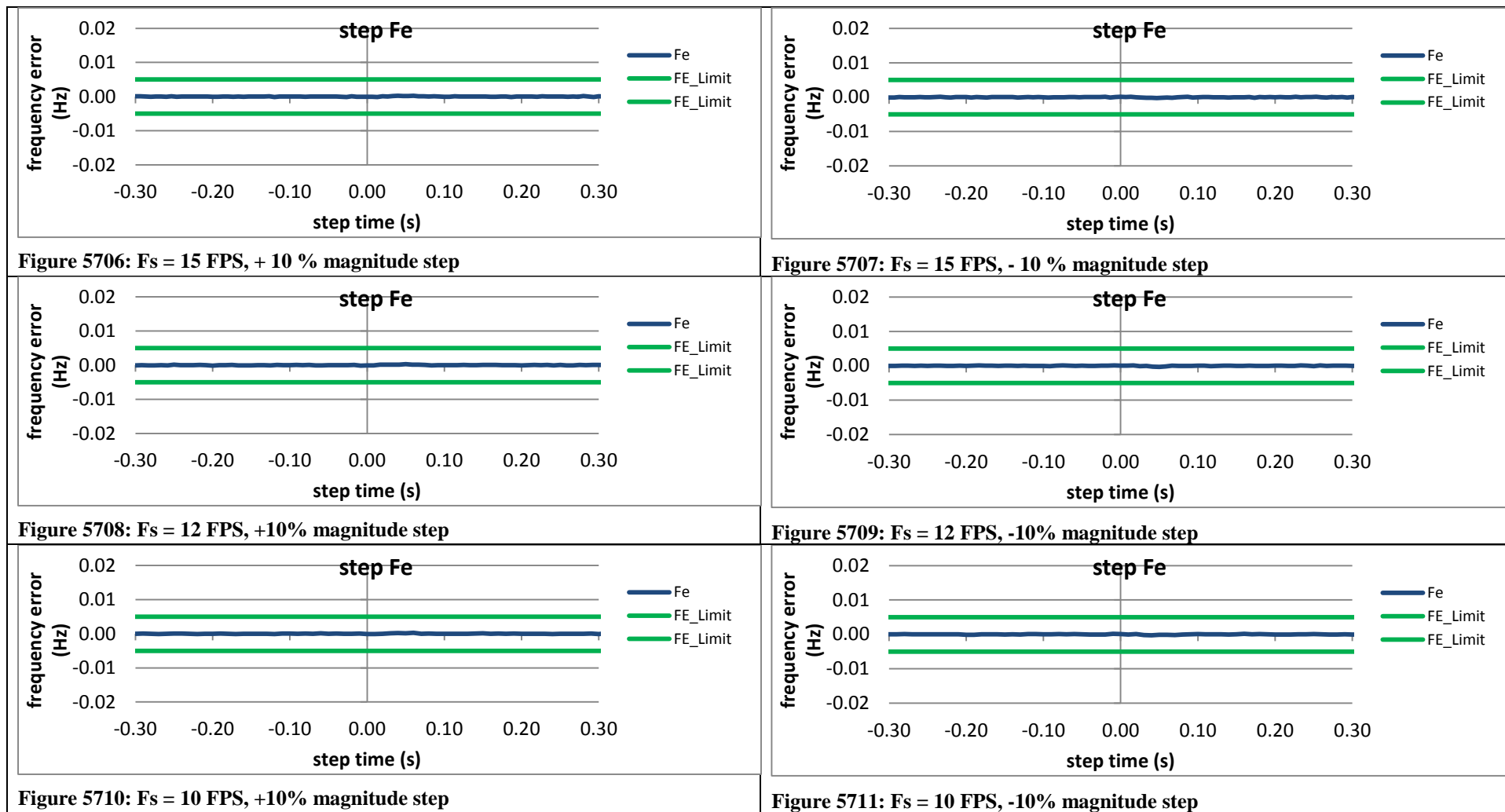


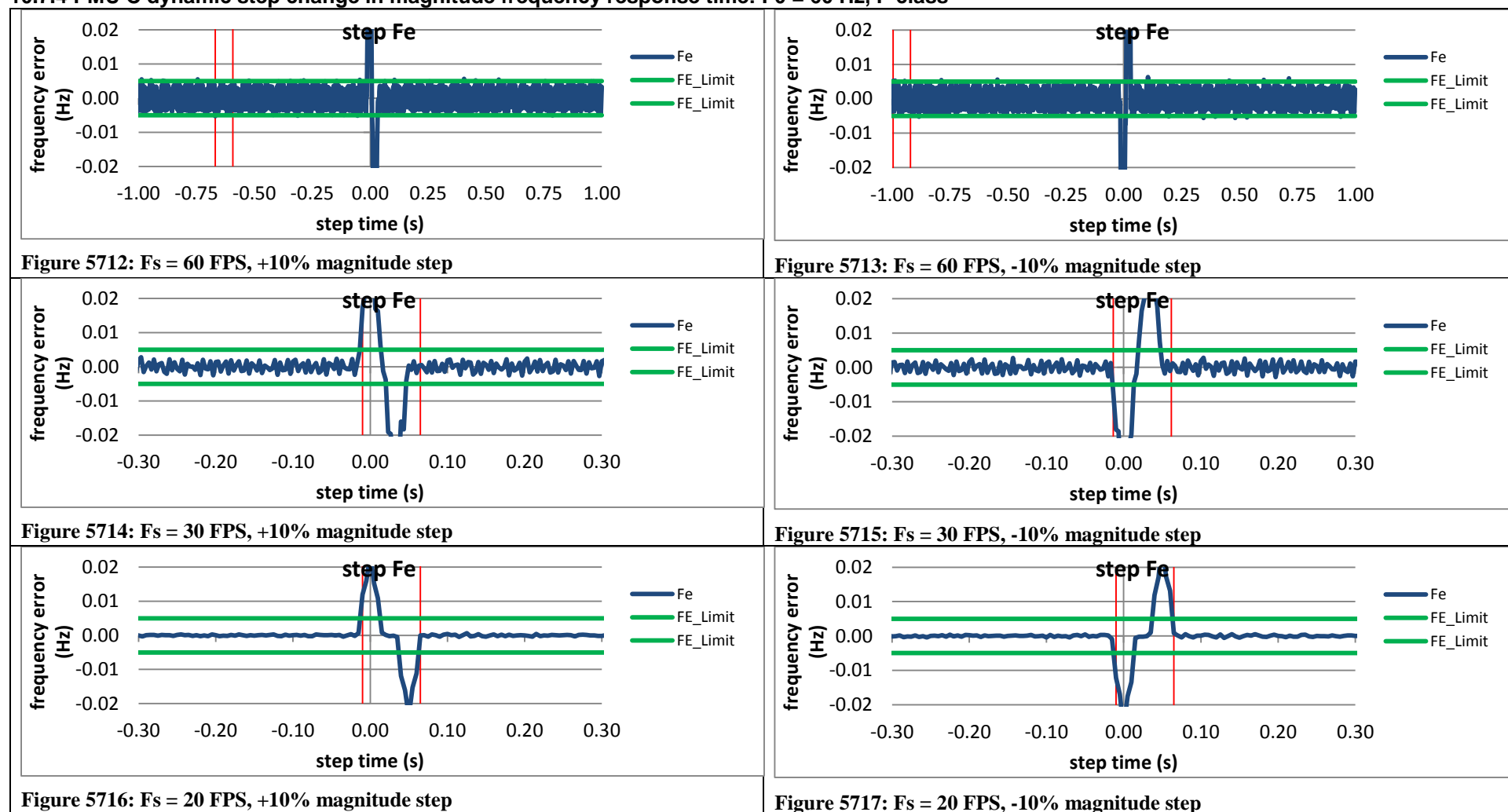
Figure 5699:  $F_s = 10$  FPS, +10% magnitude step

### 10.7.3 PMU B dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, P class





#### 10.7.4 PMU C dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, P class



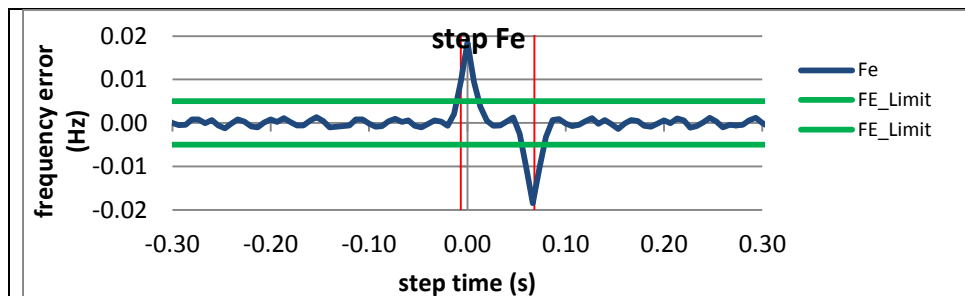


Figure 5718:  $F_s = 15$  FPS, + 10 % magnitude step

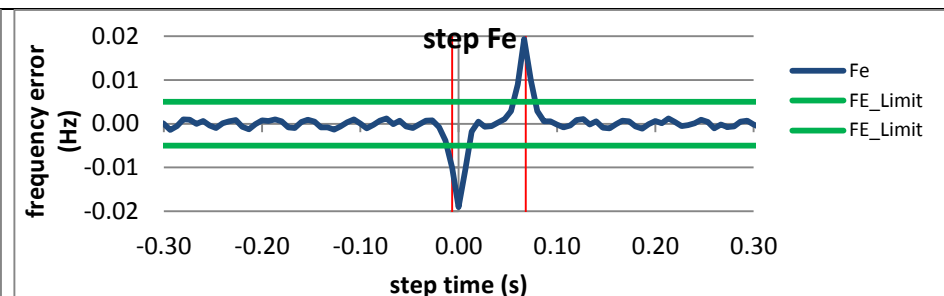


Figure 5719:  $F_s = 15$  FPS, - 10 % magnitude step

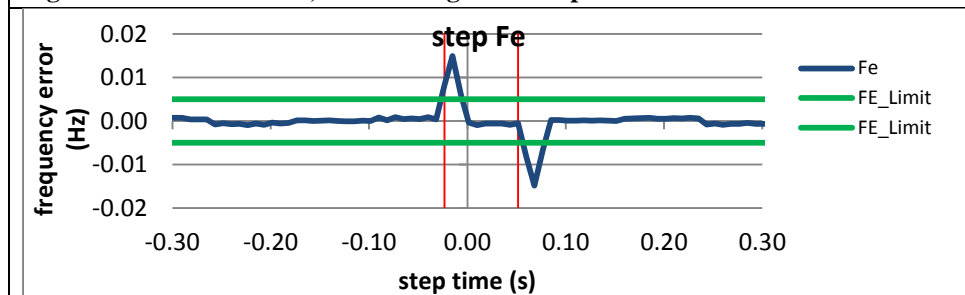


Figure 5720:  $F_s = 12$  FPS, +10% magnitude step

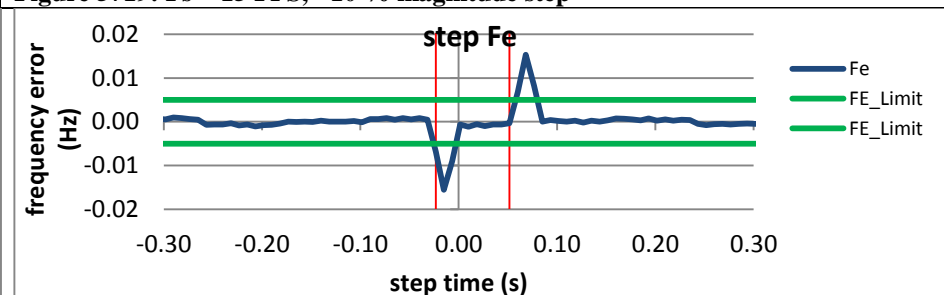


Figure 5721:  $F_s = 12$  FPS, -10% magnitude step

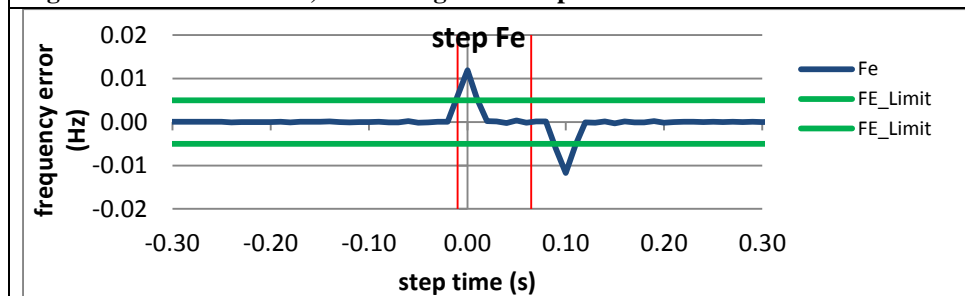


Figure 5722:  $F_s = 10$  FPS, +10% magnitude step

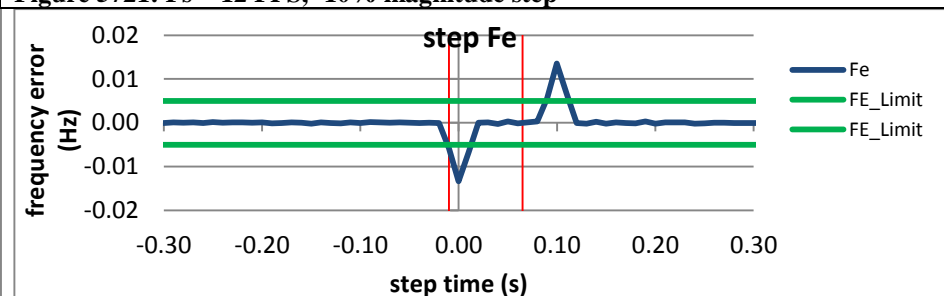
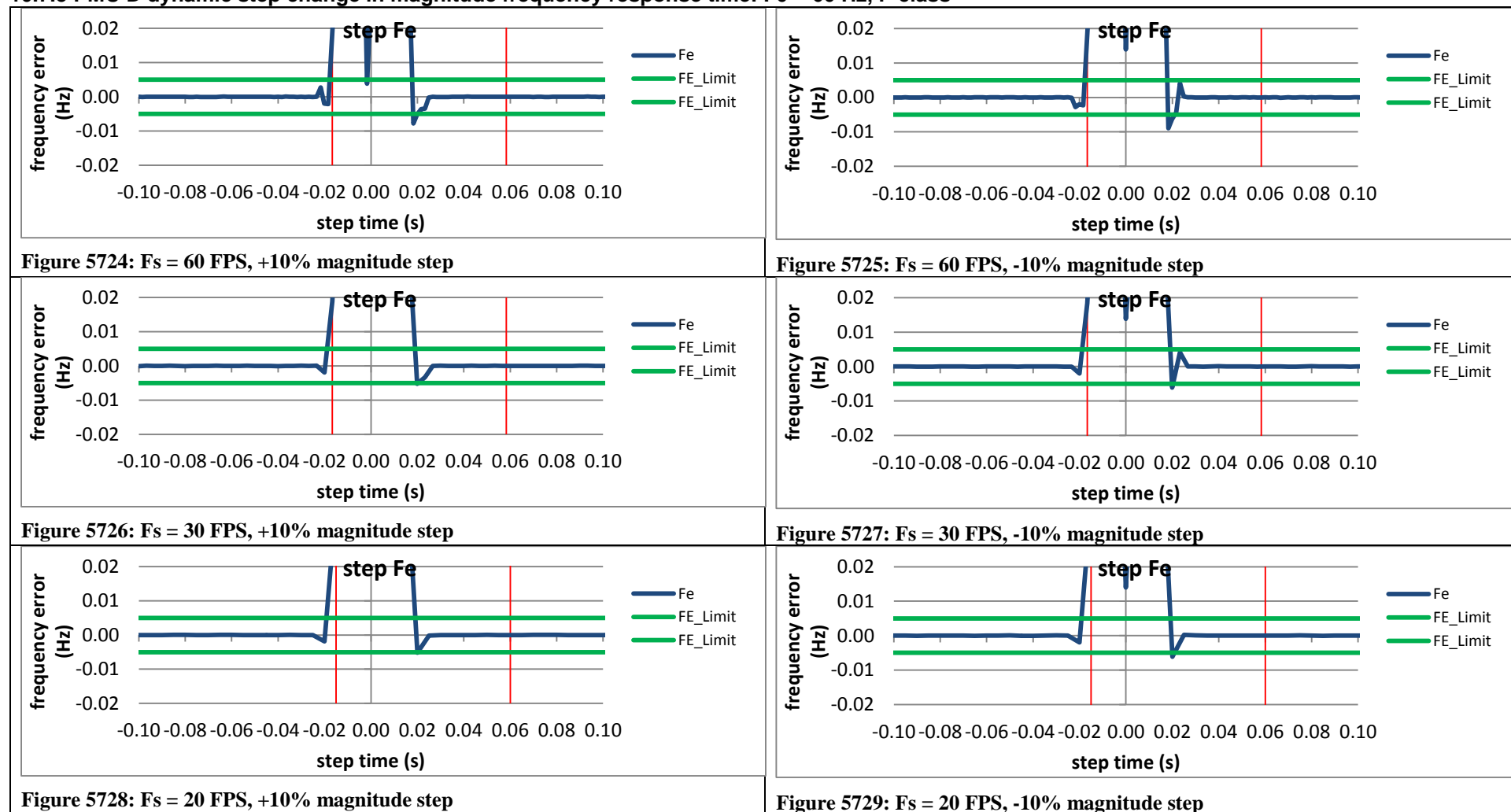


Figure 5723:  $F_s = 10$  FPS, -10% magnitude step

### 10.7.5 PMU D dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, P class



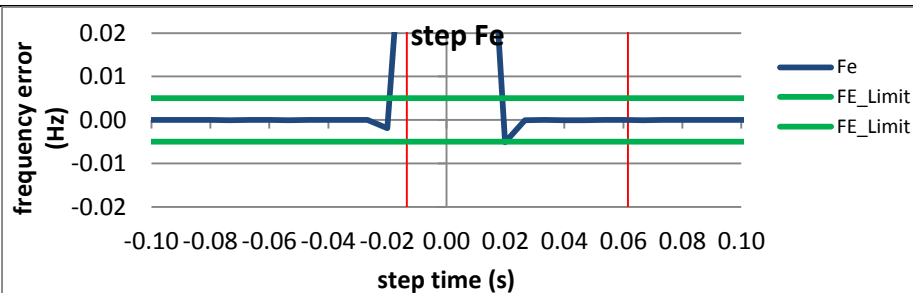


Figure 5730:  $F_s = 15$  FPS, + 10 % magnitude step

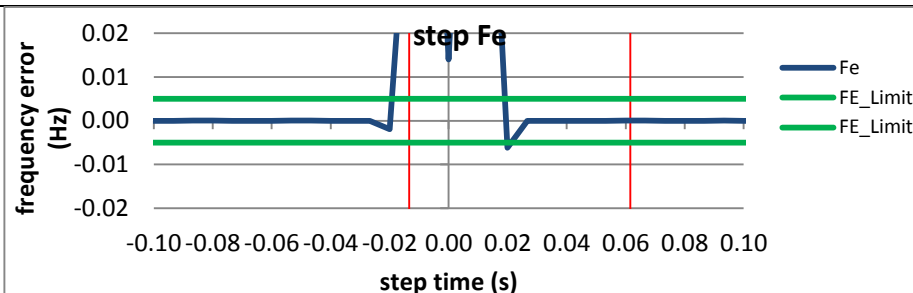


Figure 5731:  $F_s = 15$  FPS, - 10 % magnitude step

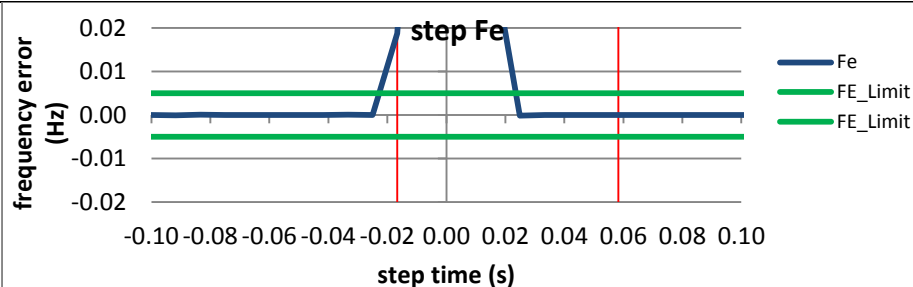


Figure 5732:  $F_s = 12$  FPS, +10% magnitude step

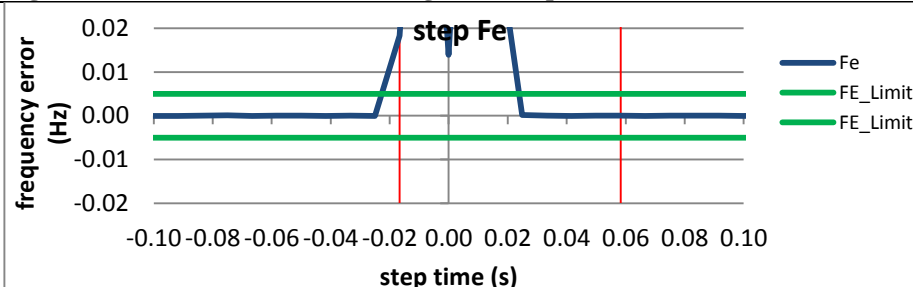


Figure 5733:  $F_s = 12$  FPS, -10% magnitude step

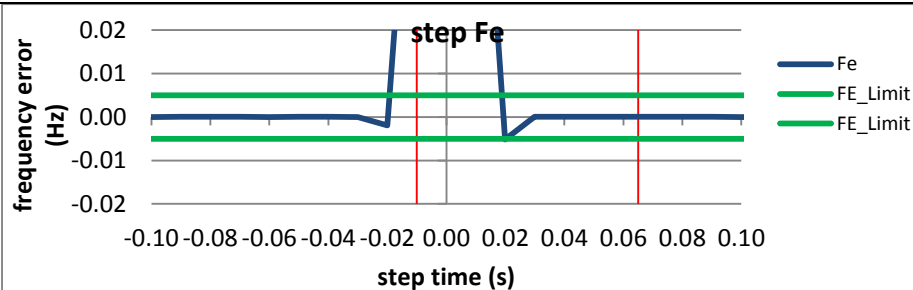


Figure 5734:  $F_s = 10$  FPS, +10% magnitude step

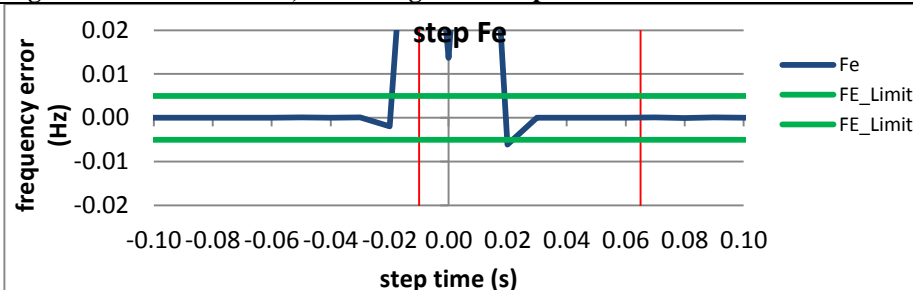
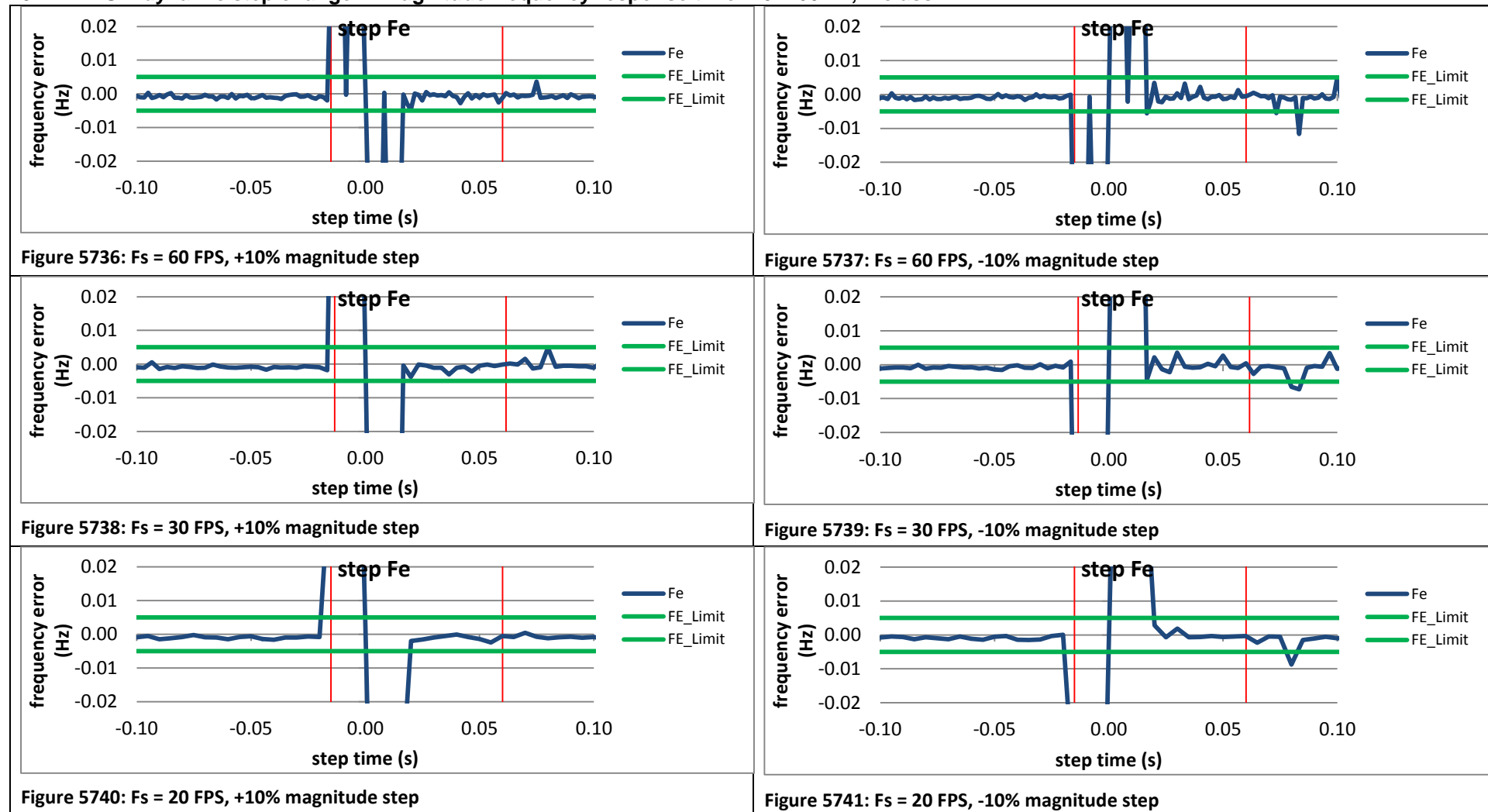


Figure 5735:  $F_s = 10$  FPS, -10% magnitude step

### 10.7.6 PMU E dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, P class

PMU E does not support P class

### 10.7.7 PMU F dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, P class





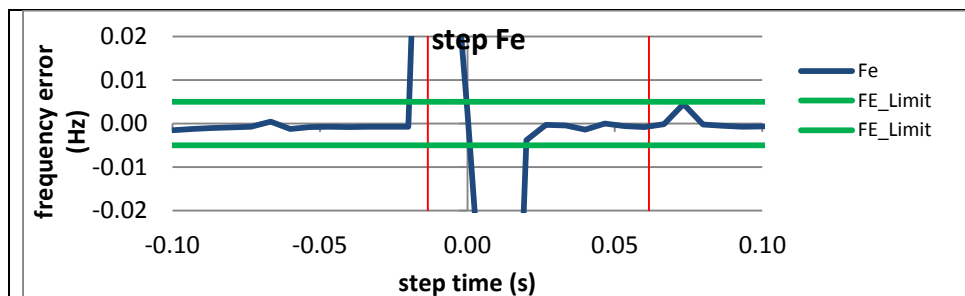


Figure 5742:  $F_s = 15$  FPS, + 10 % magnitude step

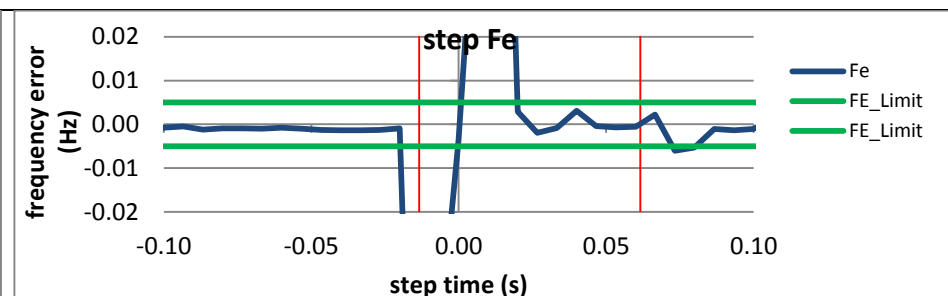


Figure 5743:  $F_s = 15$  FPS, - 10 % magnitude step

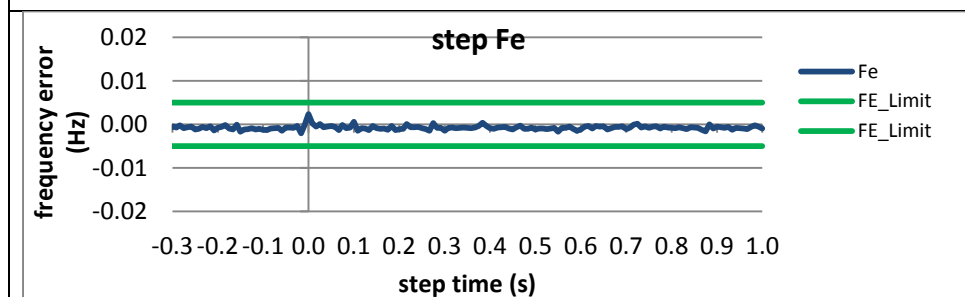


Figure 5744:  $F_s = 12$  FPS, +10% magnitude step

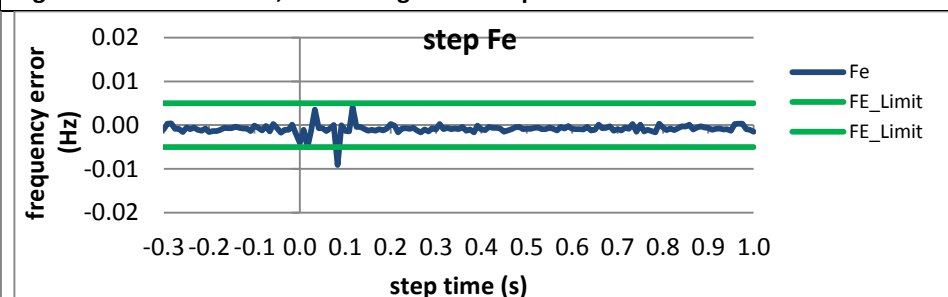


Figure 5745:  $F_s = 12$  FPS, -10% magnitude step

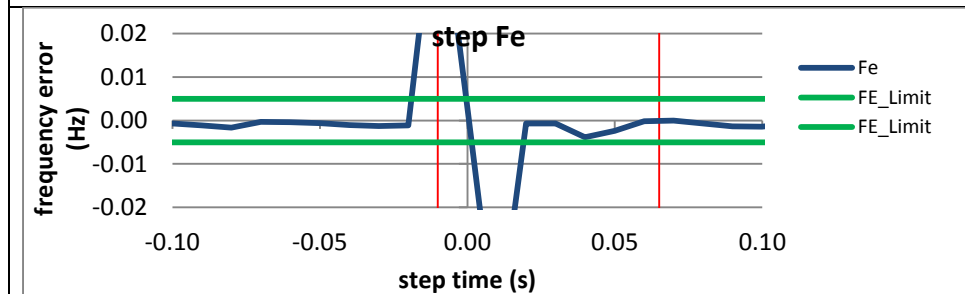


Figure 5746:  $F_s = 10$  FPS, +10% magnitude step

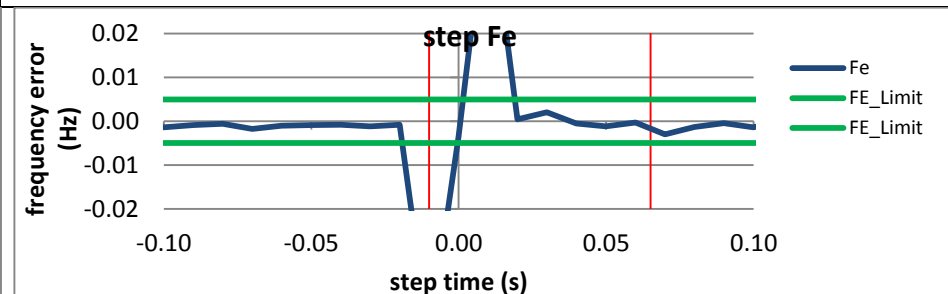
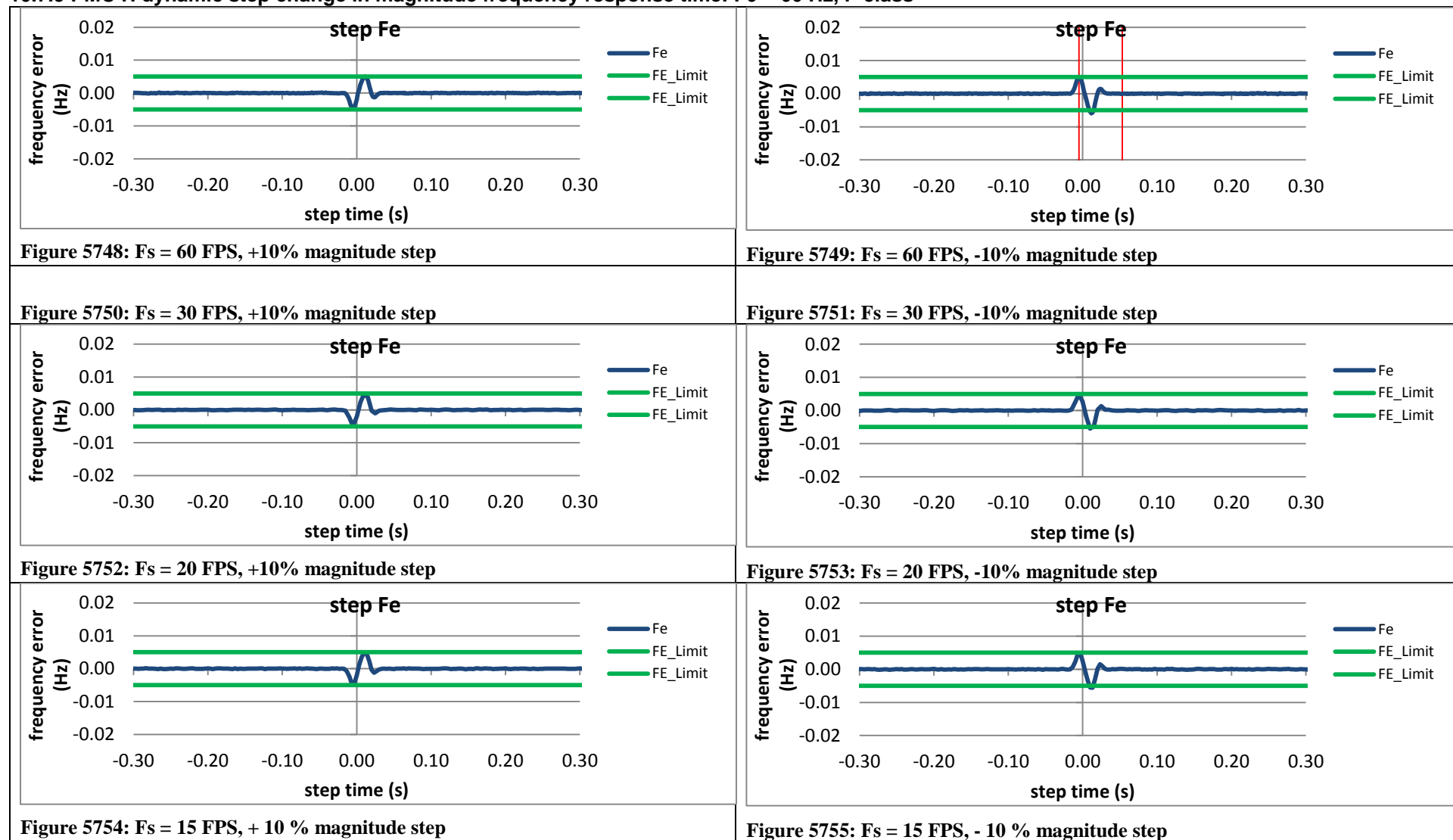


Figure 5747:  $F_s = 10$  FPS, -10% magnitude step

### 10.7.8 PMU G dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, P class

PMU G does not support P class

### 10.7.9 PMU H dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, P class



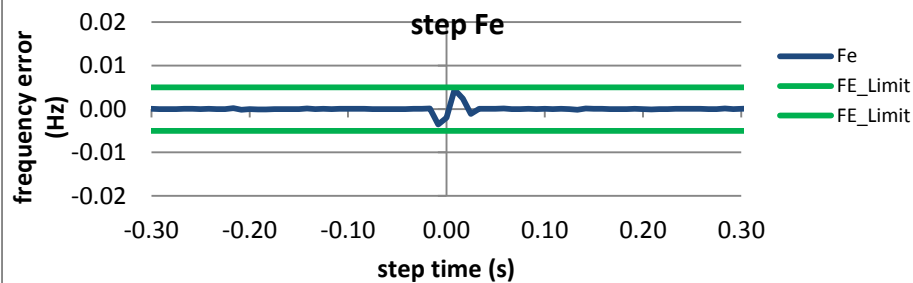


Figure 5756:  $F_s = 12$  FPS, +10% magnitude step

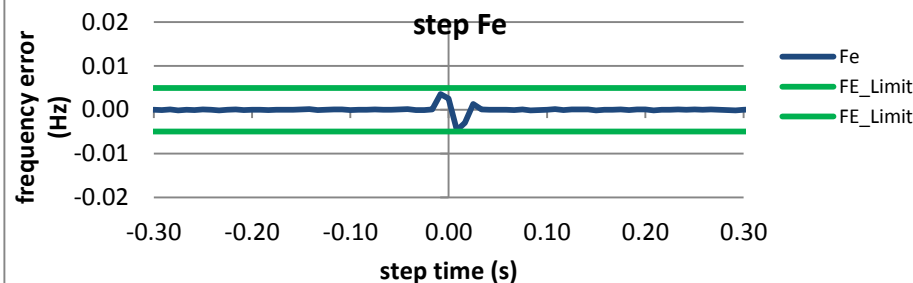


Figure 5757:  $F_s = 12$  FPS, -10% magnitude step

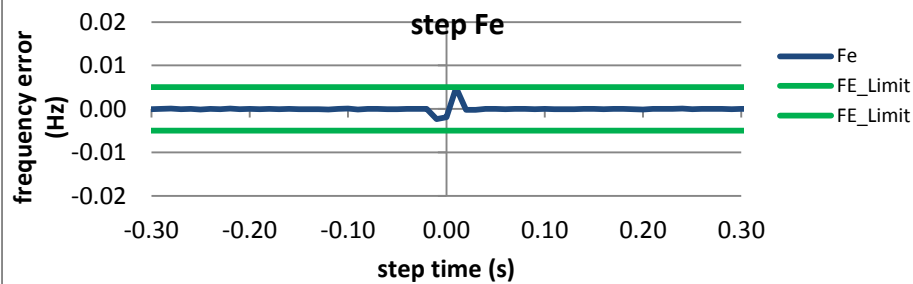


Figure 5758:  $F_s = 10$  FPS, +10% magnitude step

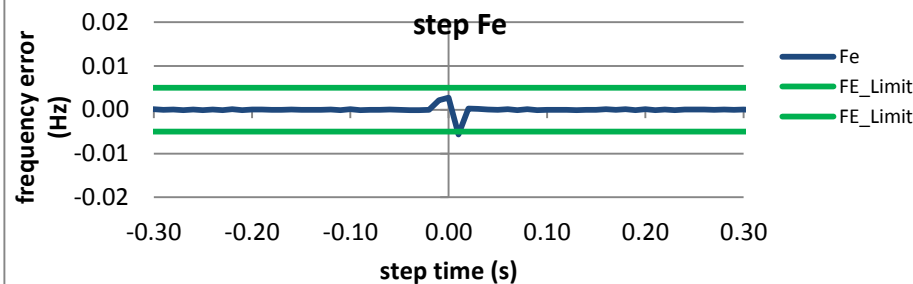
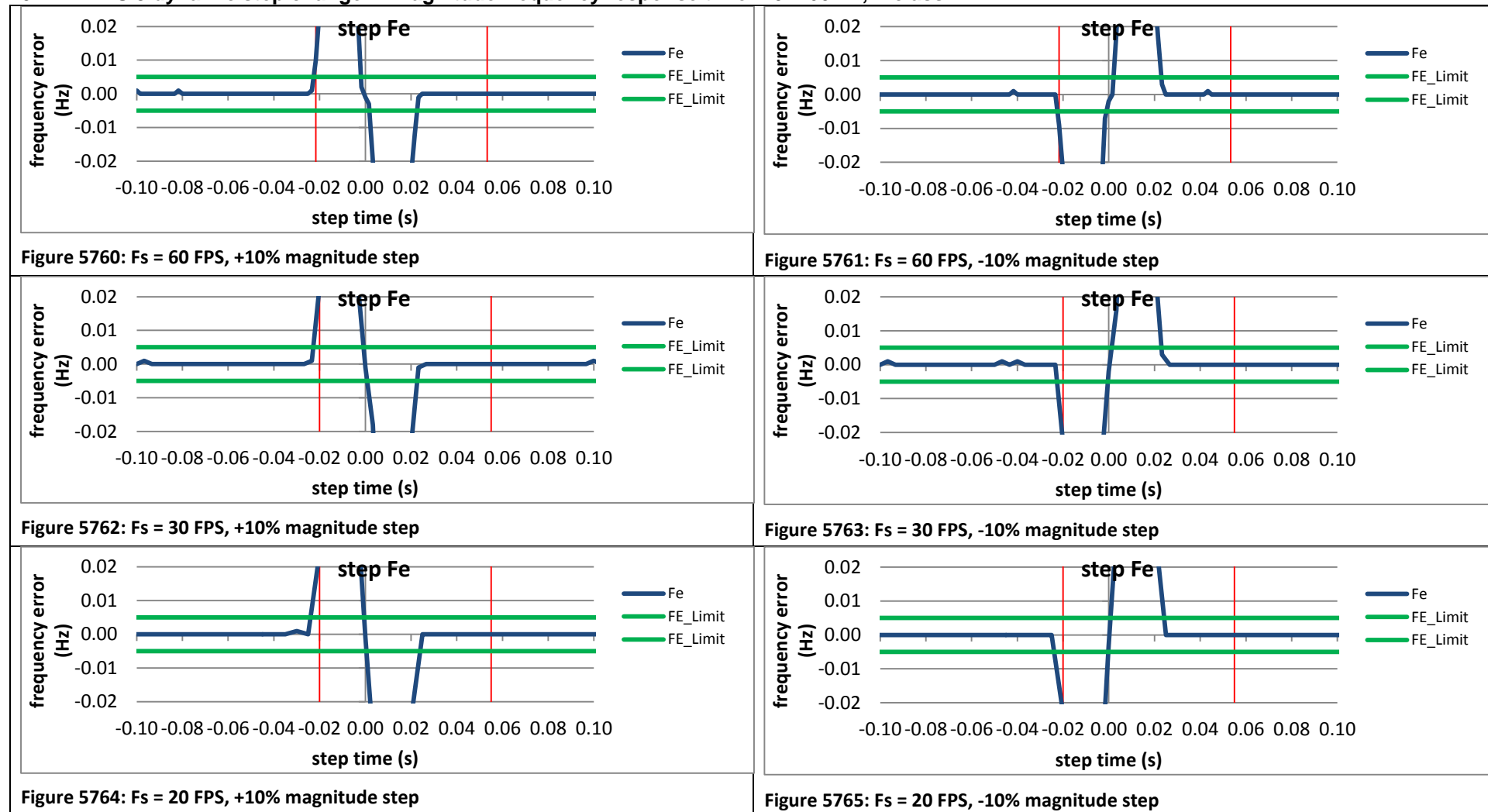


Figure 5759:  $F_s = 10$  FPS, -10% magnitude step

### 10.7.10 PMU I dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, P class

PMU I does not support P class

### 10.7.11 PMU J dynamic step change in magnitude frequency response time: $F_0 = 60$ Hz, P class



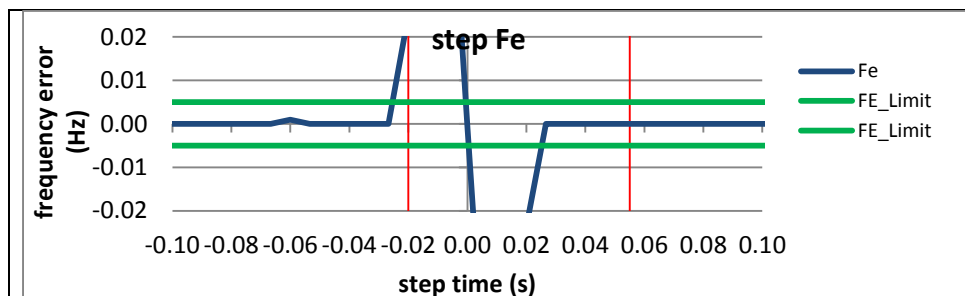


Figure 5766:  $F_s = 15$  FPS, + 10 % magnitude step

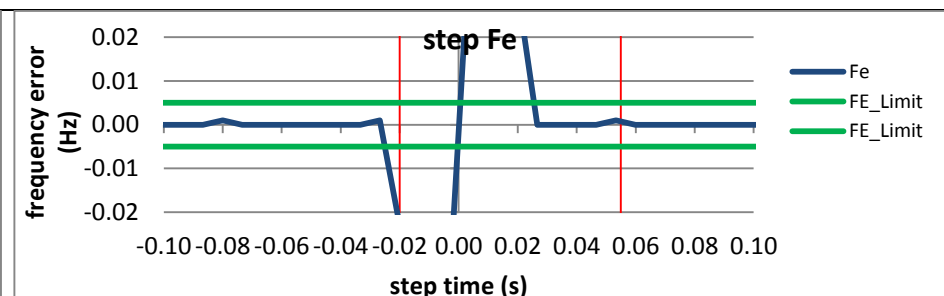


Figure 5767:  $F_s = 15$  FPS, - 10 % magnitude step

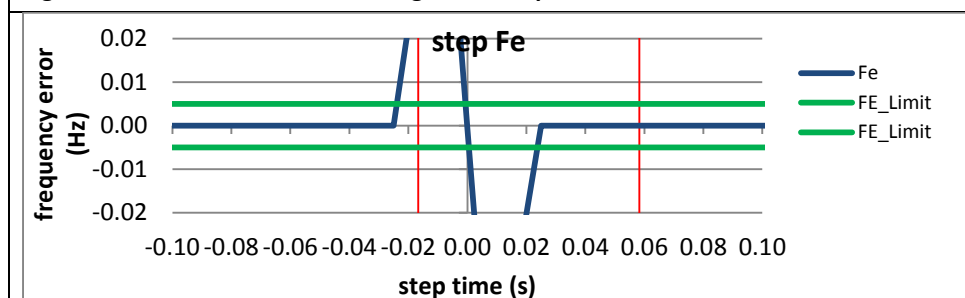


Figure 5768:  $F_s = 12$  FPS, +10% magnitude step

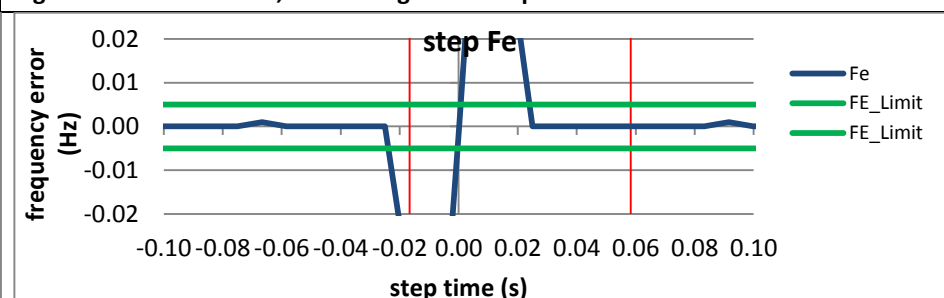


Figure 5769:  $F_s = 12$  FPS, -10% magnitude step

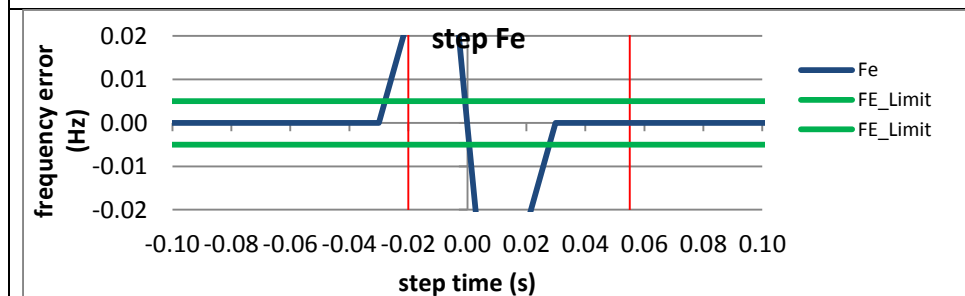


Figure 5770:  $F_s = 10$  FPS, +10% magnitude step

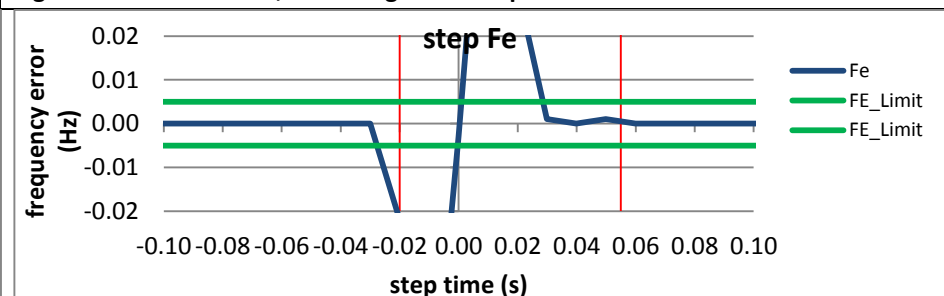


Figure 5771:  $F_s = 10$  FPS, -10% magnitude step

## 10.8 Dynamic step change in magnitude: ROCOF response time

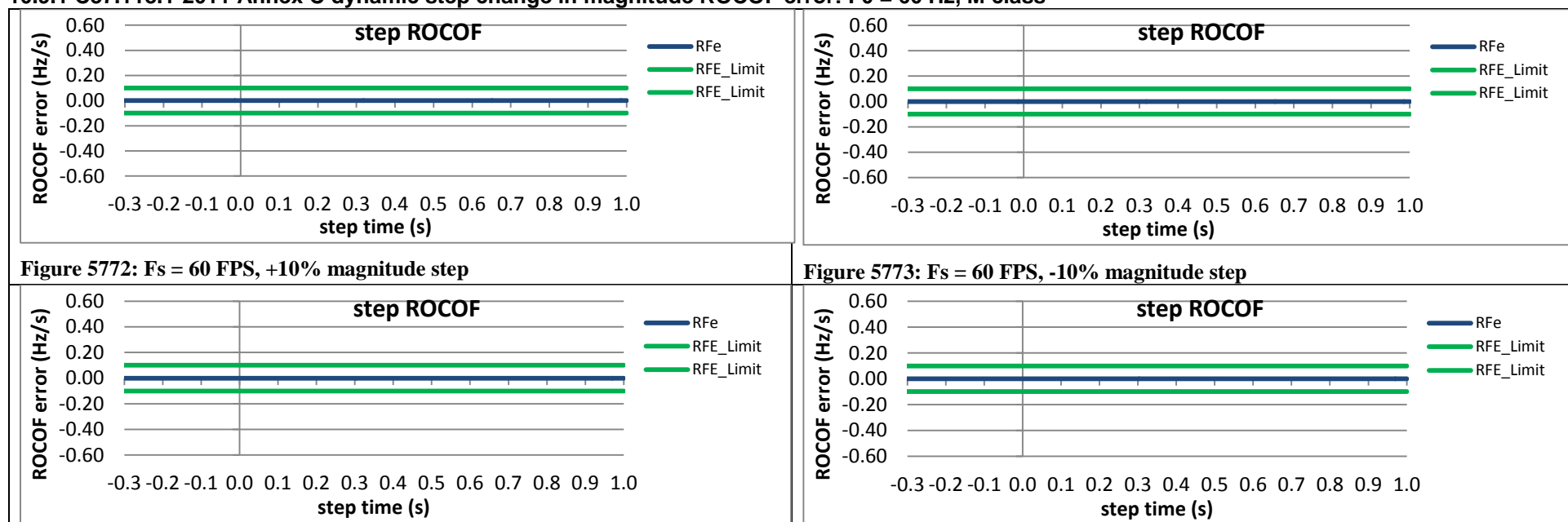
Fs (FPS)	10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P
PMU A	P	F	P	F	P	F	P	F	P	F	F	F
PMU B	P	P	P	P	P	P	P	P	P	P	P	P
PMU C	P	P	P	P	P	P	P	I	P	P	P	P
PMU D	P	P	P	P	P	P	P	P	P	P	P	P
PMU E	P	-	-	-	P	-	P	-	P	-	P	-
PMU F	P	P	P	P	P	P	P	P	P	P	P	P
PMU G*	P	-	P	-	P	-	P	-	P	-	-	-
PMU H	P	P	P	P	P	P	P	P	P	P	P	P
PMU I	P	-	P	-	P	-	P	-	P	-	P	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P

P = Pass, F = Fail, I = Indeterminate

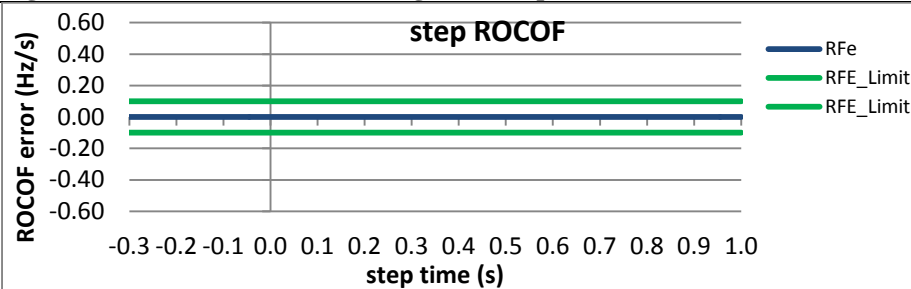
\* PMU G always outputs ROCOF = 0.

## 10.9 Dynamic step change in magnitude ROCOF error: F0 = 60 Hz, M class

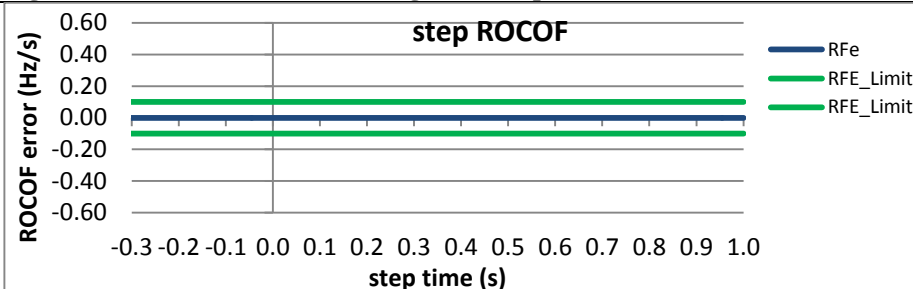
### 10.9.1 C37.118.1-2011 Annex C dynamic step change in magnitude ROCOF error: F0 = 60 Hz, M class



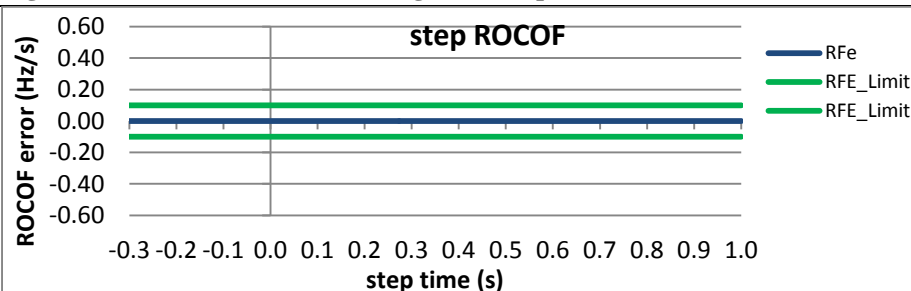
**Figure 5774:  $F_s = 30$  FPS, +10% magnitude step**



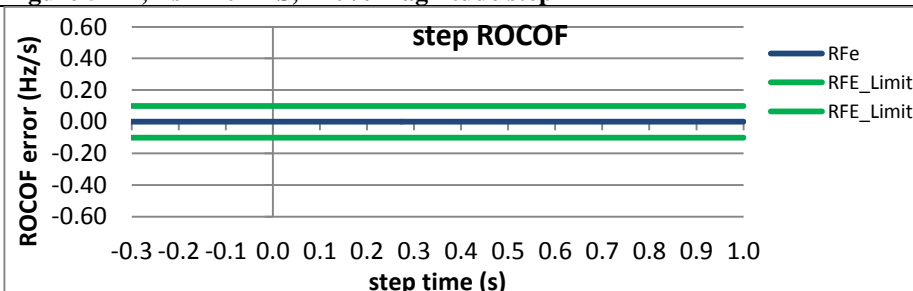
**Figure 5775:  $F_s = 30$  FPS, -10% magnitude step**



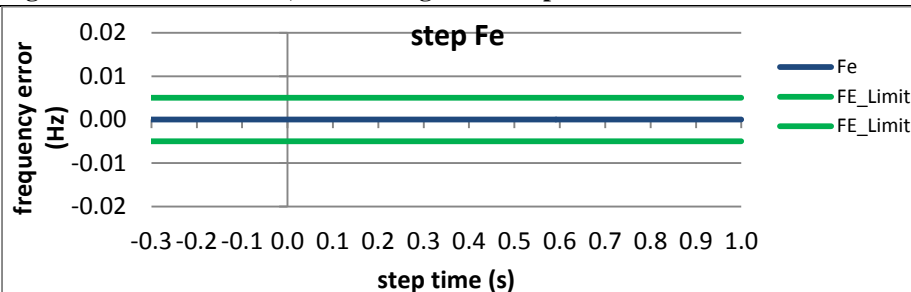
**Figure 5776:  $F_s = 20$  FPS, +10% magnitude step**



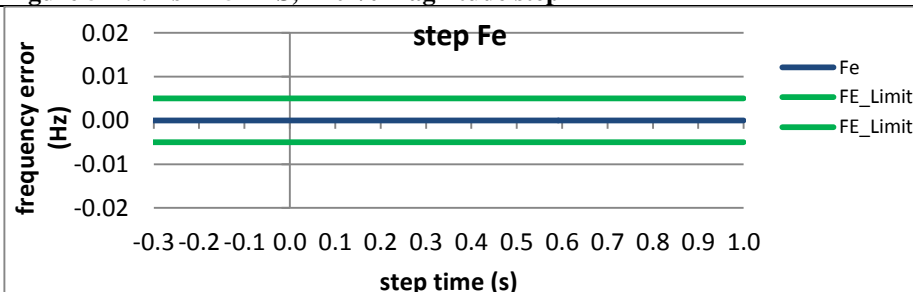
**Figure 5777:  $F_s = 20$  FPS, -10% magnitude step**



**Figure 5778:  $F_s = 15$  FPS, + 10% magnitude step**



**Figure 5779:  $F_s = 15$  FPS, - 10 % magnitude step**



**Figure 5780:  $F_s = 12$  FPS, +10% magnitude step**

**Figure 5781:  $F_s = 12$  FPS, -10% magnitude step**

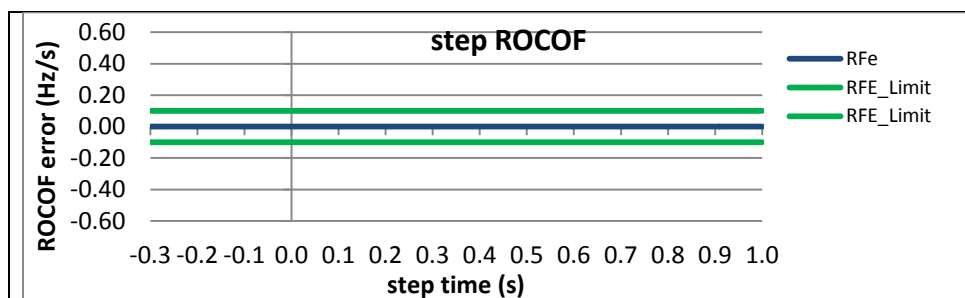


Figure 5782:  $F_s = 10$  FPS, +10% magnitude step

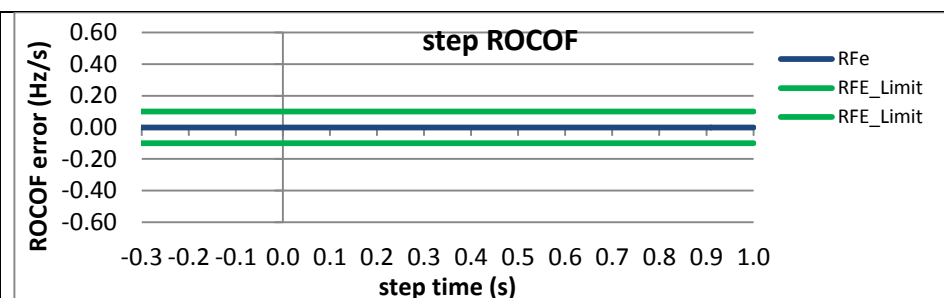


Figure 5783:  $F_s = 10$  FPS, -10% magnitude step

### 10.9.2 PMU A dynamic step change in magnitude ROCOF response time: $F_0 = 60$ Hz, M class

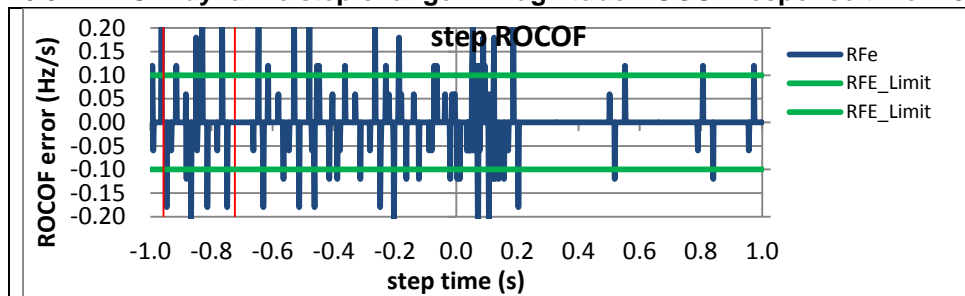


Figure 5784:  $F_s = 60$  FPS, +10% magnitude step

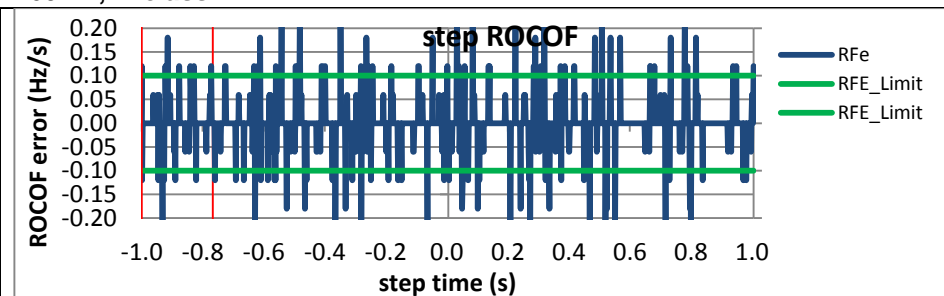


Figure 5785:  $F_s = 60$  FPS, -10% magnitude step

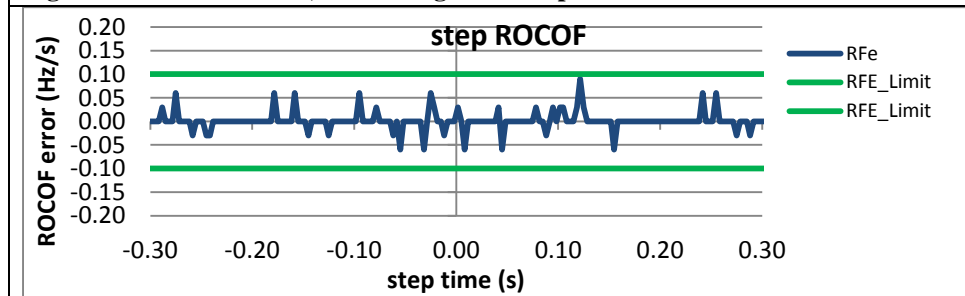


Figure 5786:  $F_s = 30$  FPS, +10% magnitude step

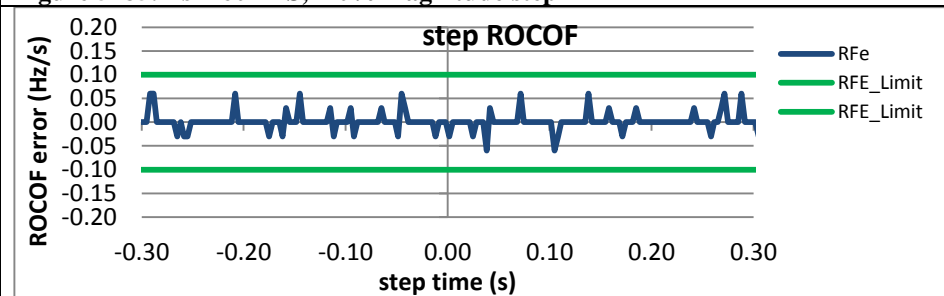


Figure 5787:  $F_s = 30$  FPS, -10% magnitude step



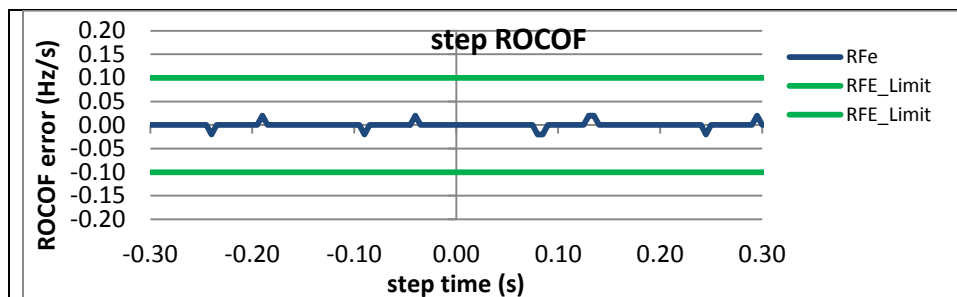


Figure 5788:  $F_s = 20$  FPS, +10% magnitude step

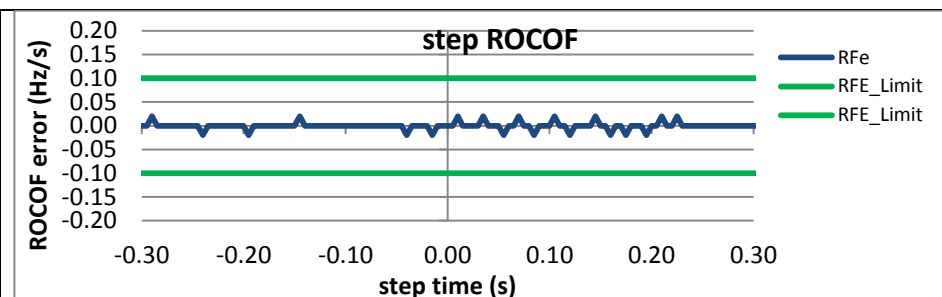


Figure 5789:  $F_s = 20$  FPS, -10% magnitude step

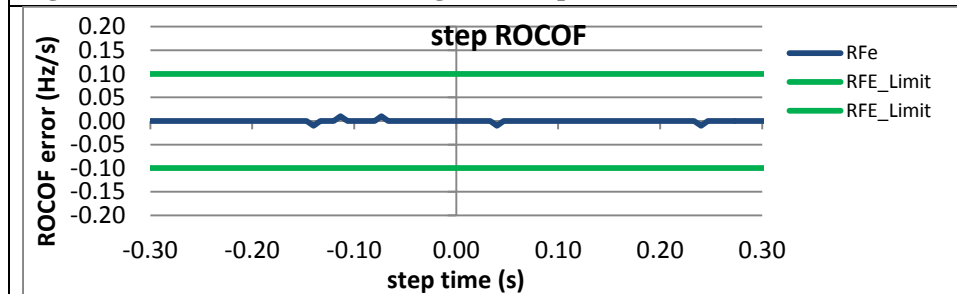


Figure 5790:  $F_s = 15$  FPS, + 10% magnitude step

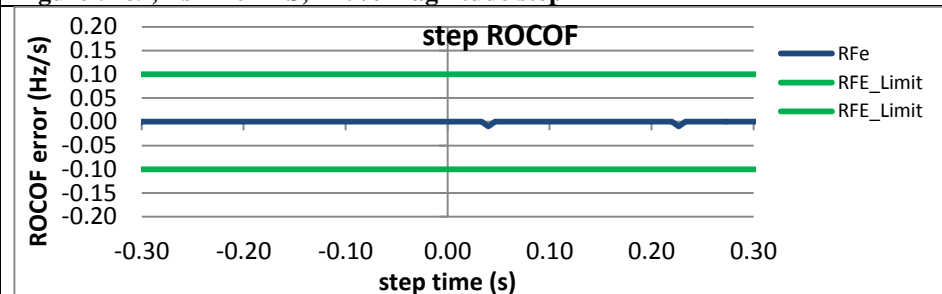


Figure 5791:  $F_s = 15$  FPS, - 10 % magnitude step

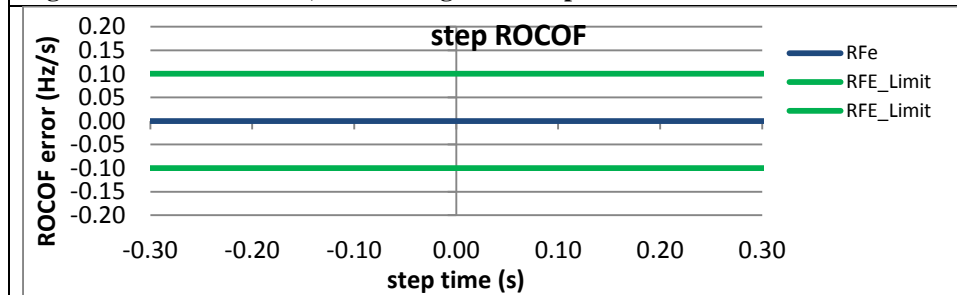


Figure 5792:  $F_s = 12$  FPS, +10% magnitude step

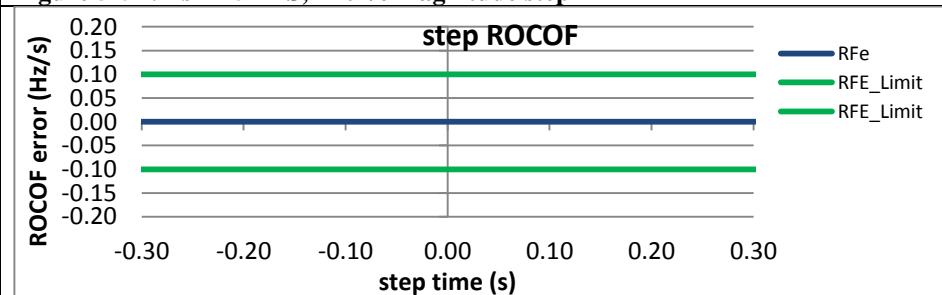


Figure 5793:  $F_s = 12$  FPS, -10% magnitude step

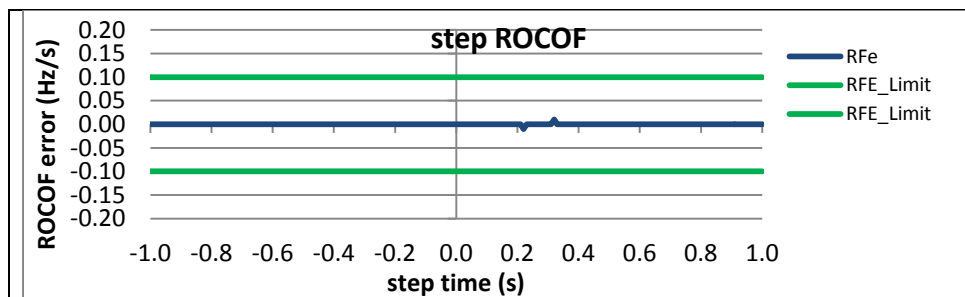


Figure 5794:  $F_s = 10$  FPS, +10% magnitude step

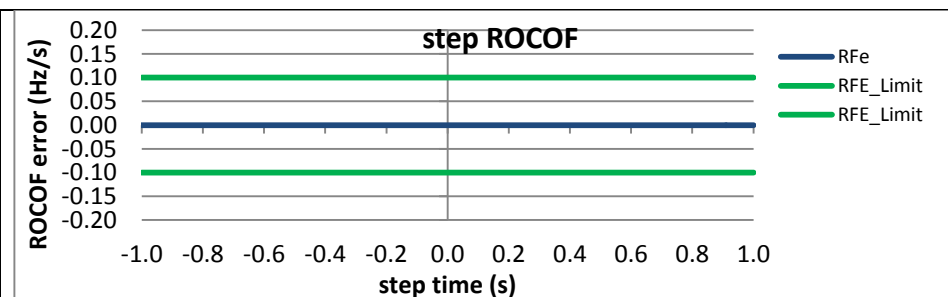
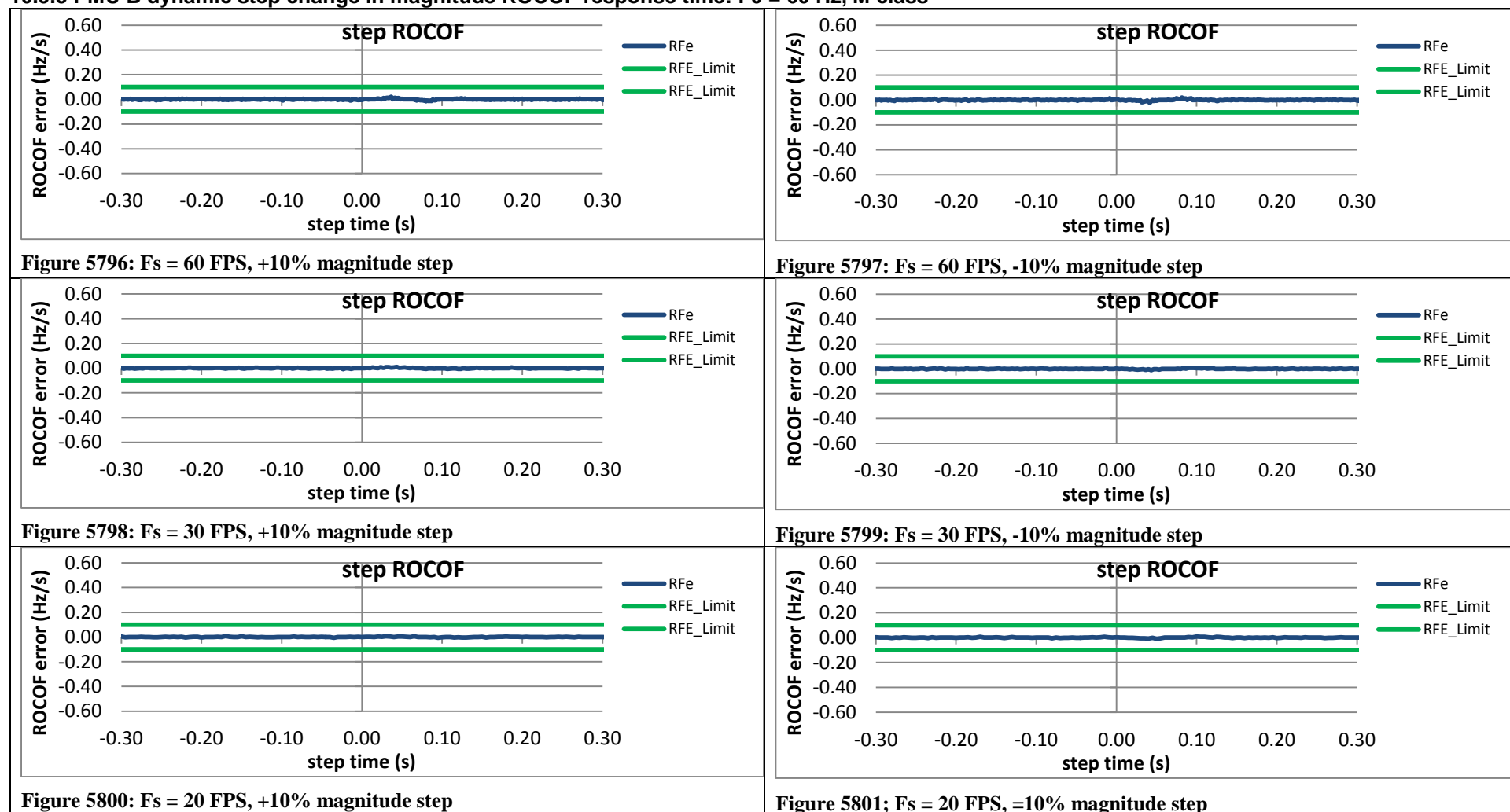
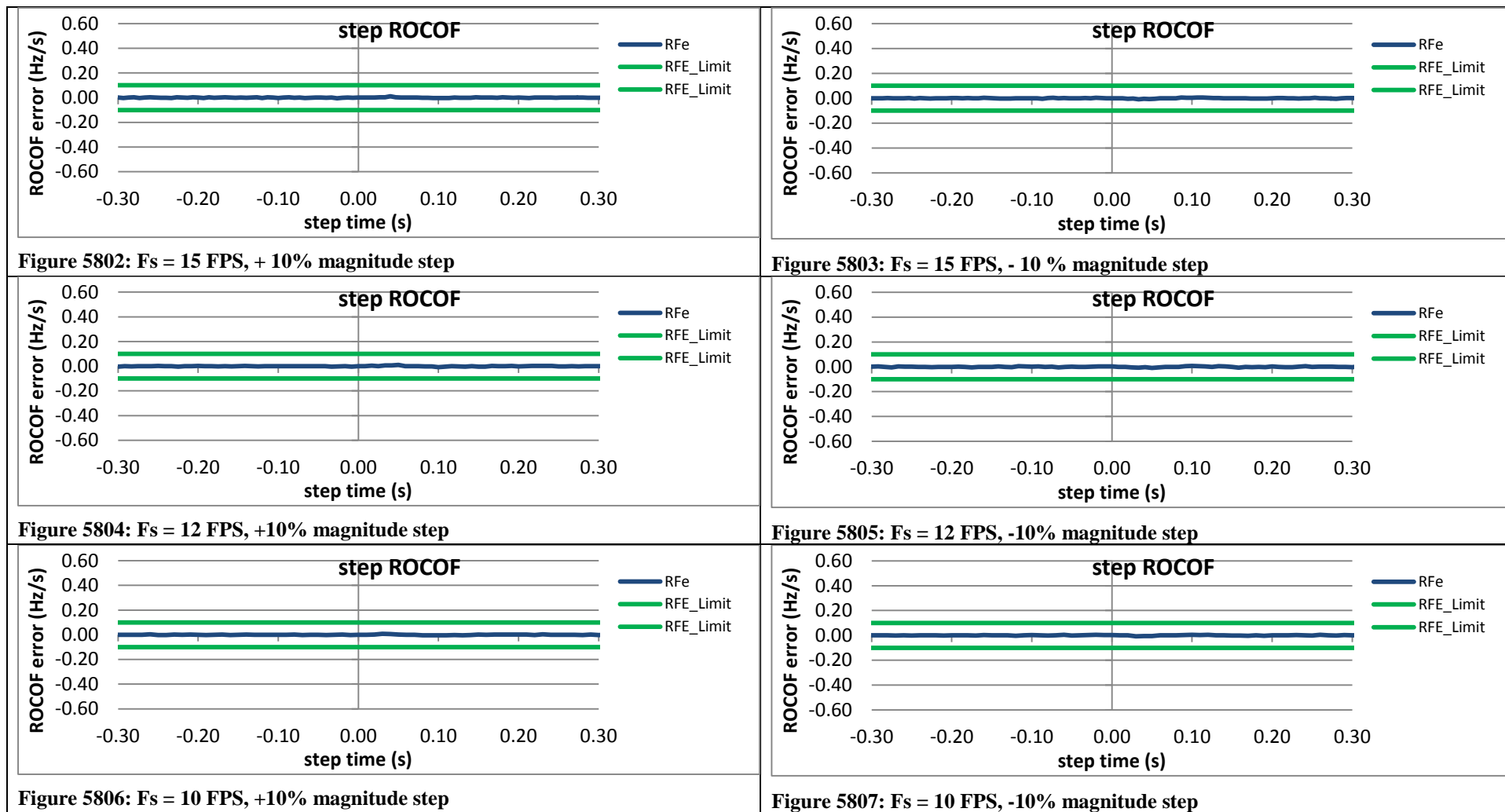


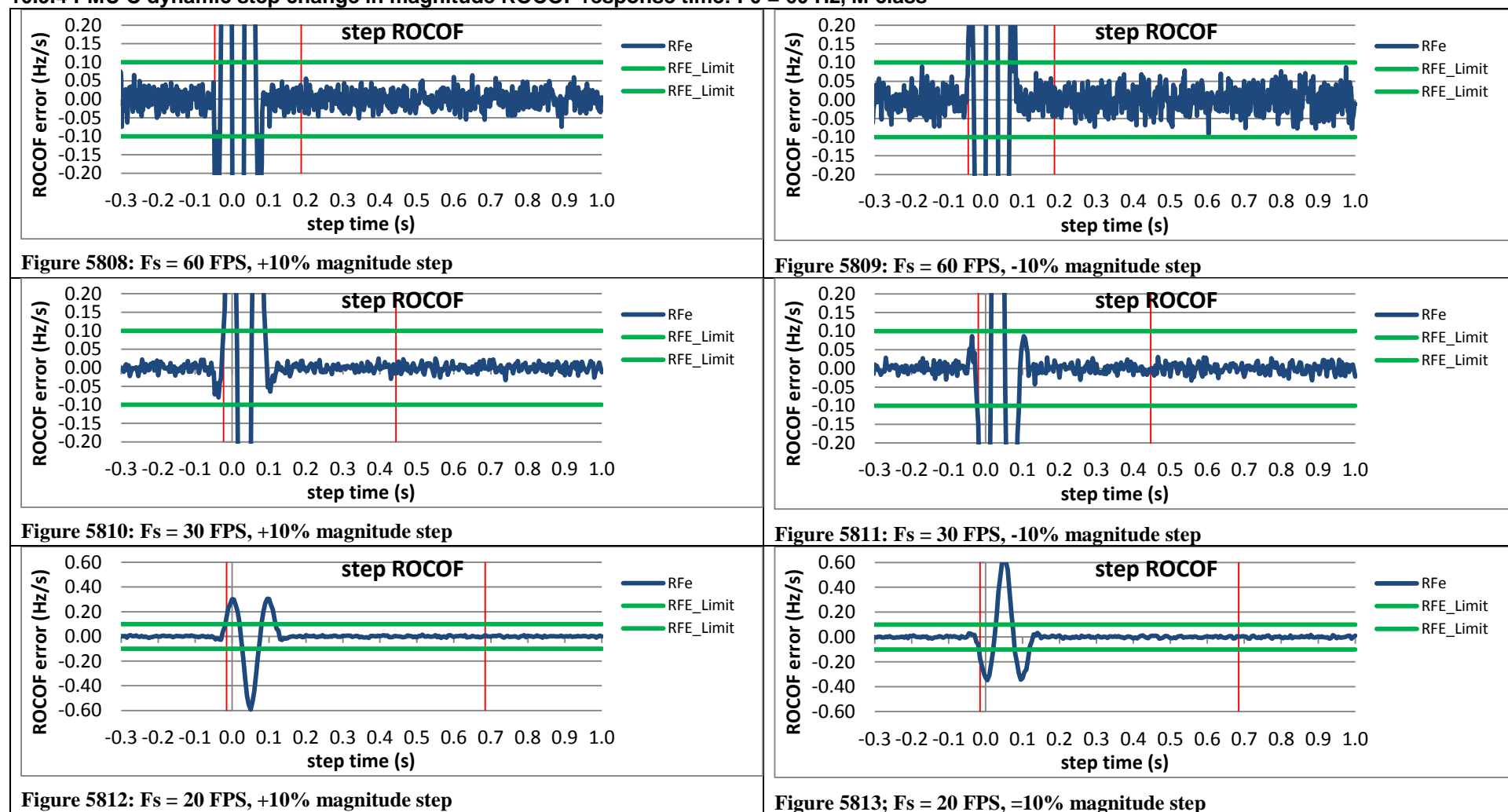
Figure 5795:  $F_s = 10$  FPS, -10% magnitude step

### 10.9.3 PMU B dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class





#### 10.9.4 PMU C dynamic step change in magnitude ROCOF response time: $F_0 = 60$ Hz, M class



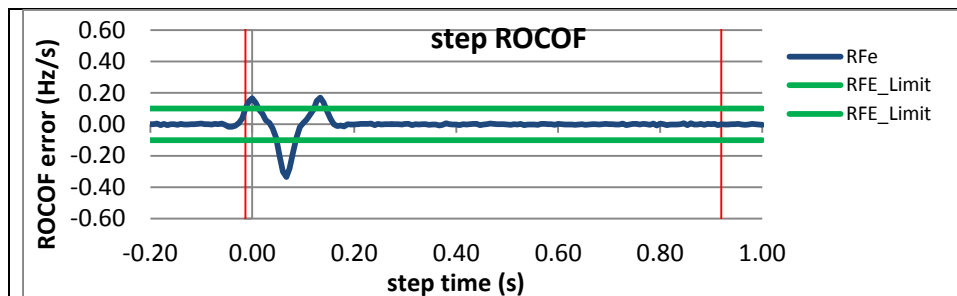


Figure 5814:  $F_s = 15$  FPS, + 10% magnitude step

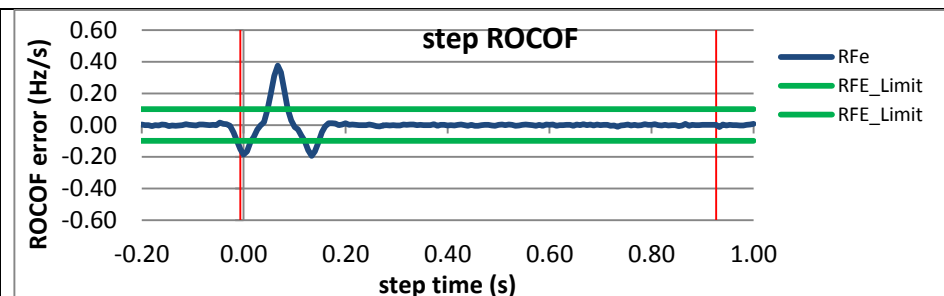


Figure 5815:  $F_s = 15$  FPS, - 10 % magnitude step

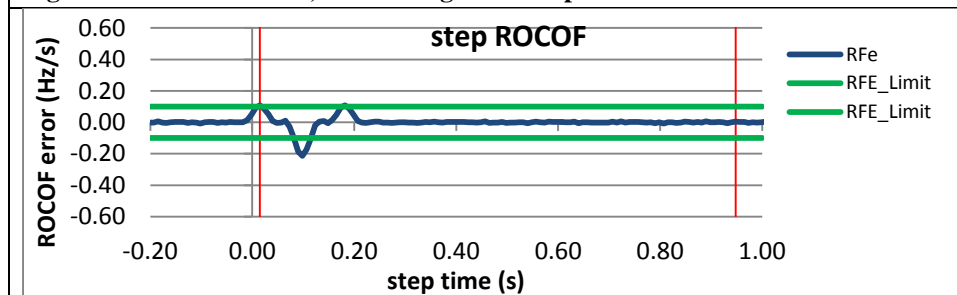


Figure 5816:  $F_s = 12$  FPS, +10% magnitude step

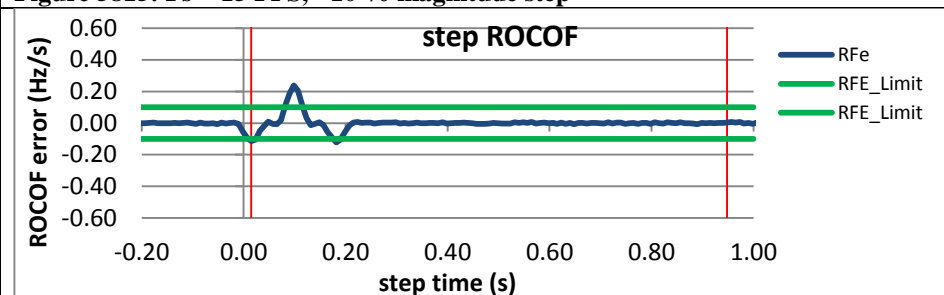


Figure 5817:  $F_s = 12$  FPS, -10% magnitude step

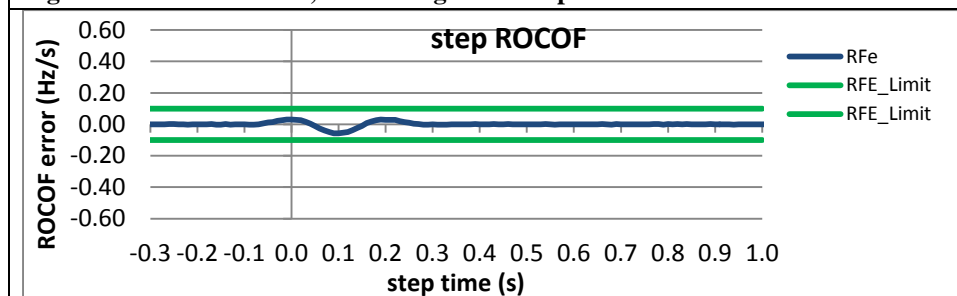


Figure 5818:  $F_s = 10$  FPS, +10% magnitude step

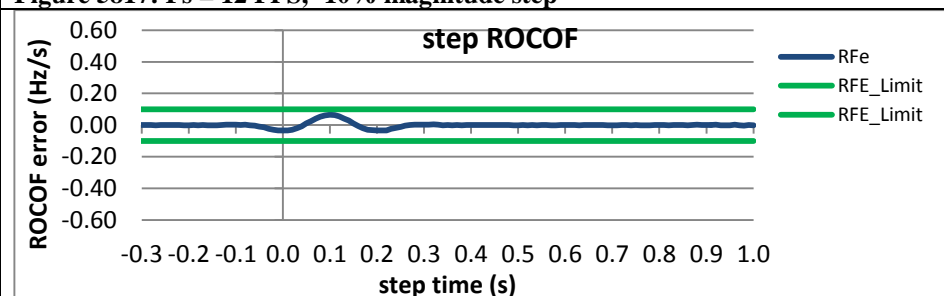
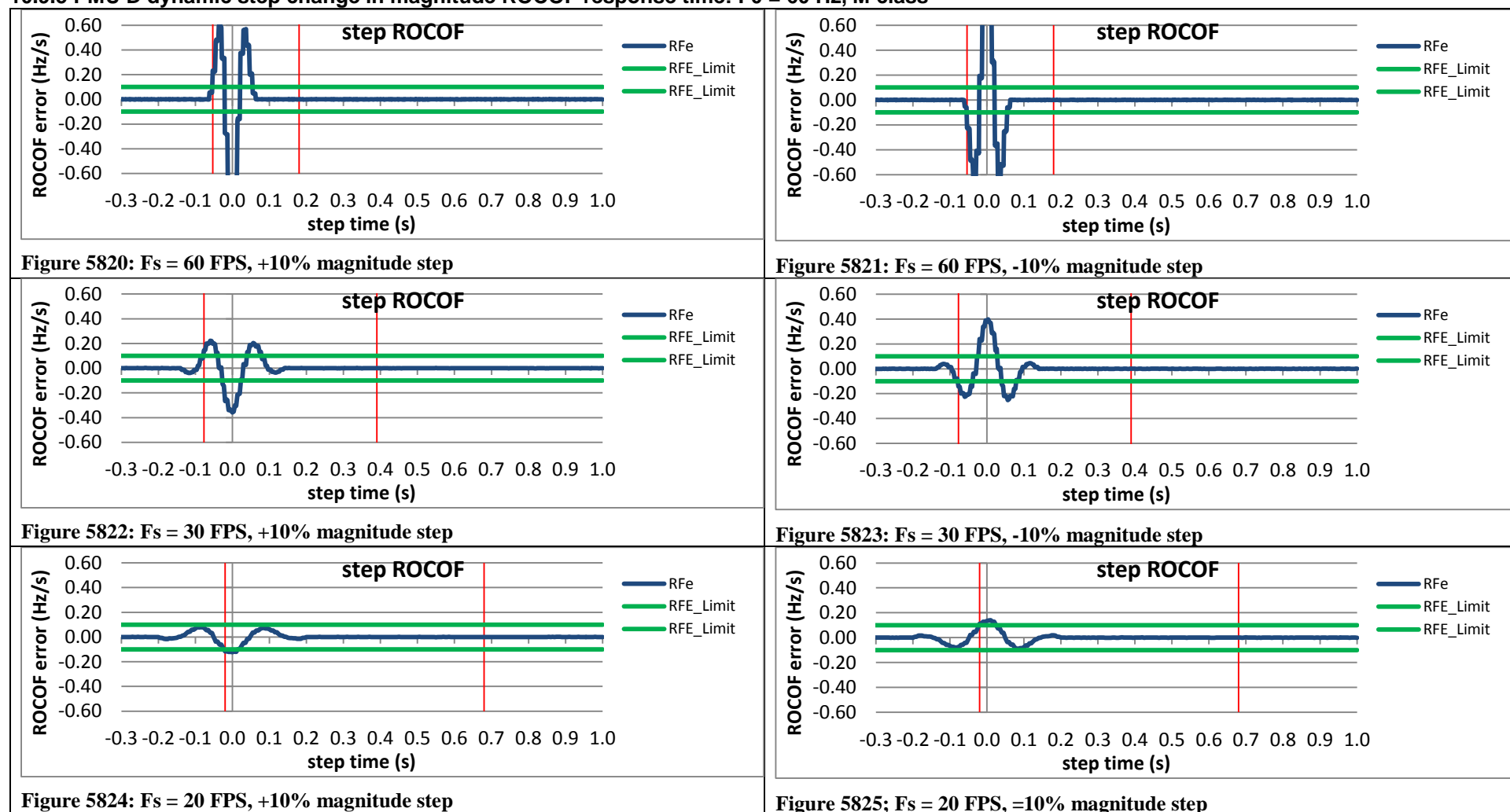


Figure 5819:  $F_s = 10$  FPS, -10% magnitude step

### 10.9.5 PMU D dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class



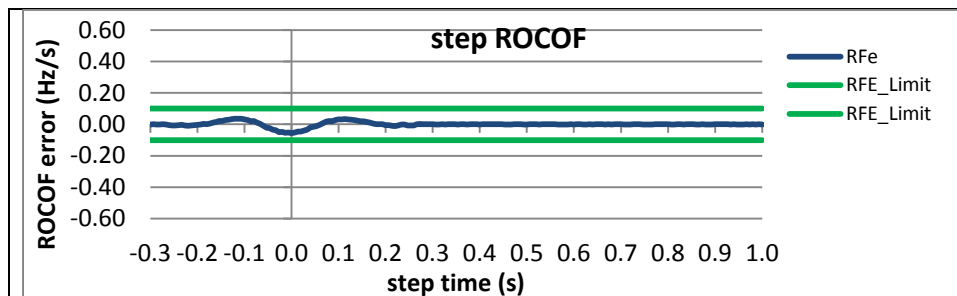


Figure 5826:  $F_s = 15$  FPS, + 10% magnitude step

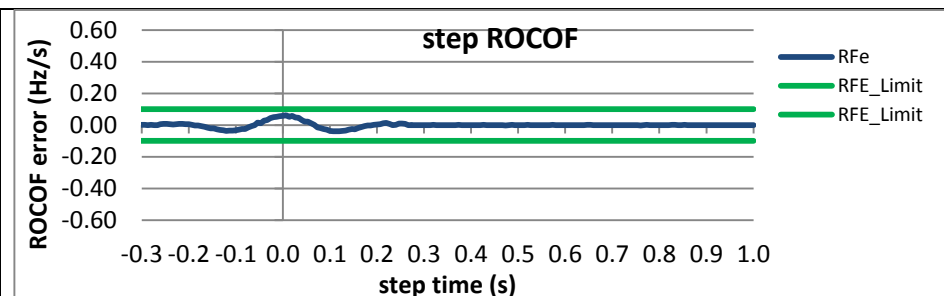


Figure 5827:  $F_s = 15$  FPS, - 10 % magnitude step

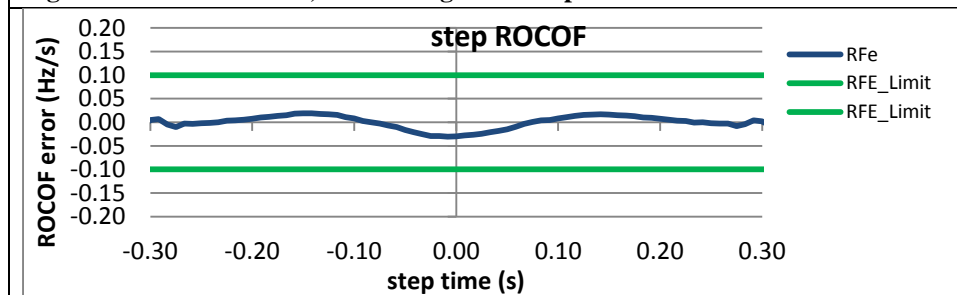


Figure 5828:  $F_s = 12$  FPS, +10% magnitude step

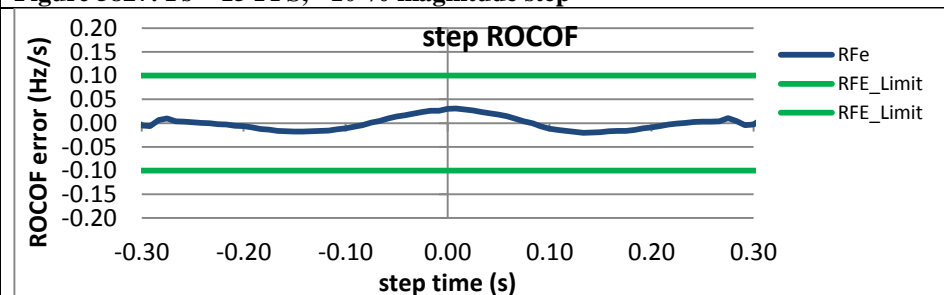


Figure 5829:  $F_s = 12$  FPS, -10% magnitude step

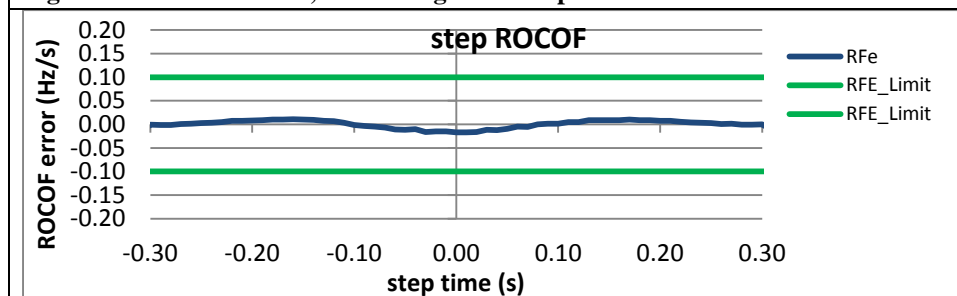


Figure 5830:  $F_s = 10$  FPS, +10% magnitude step

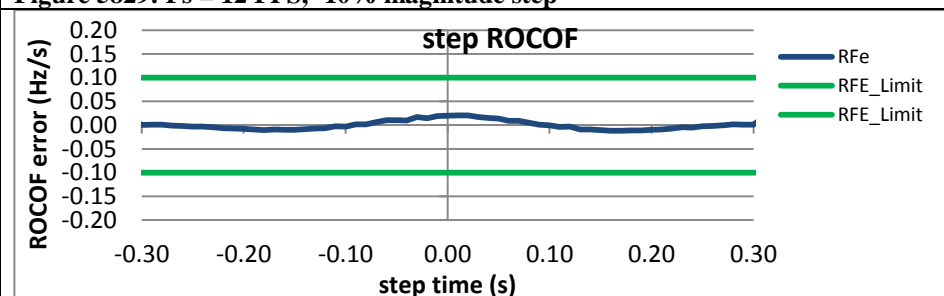
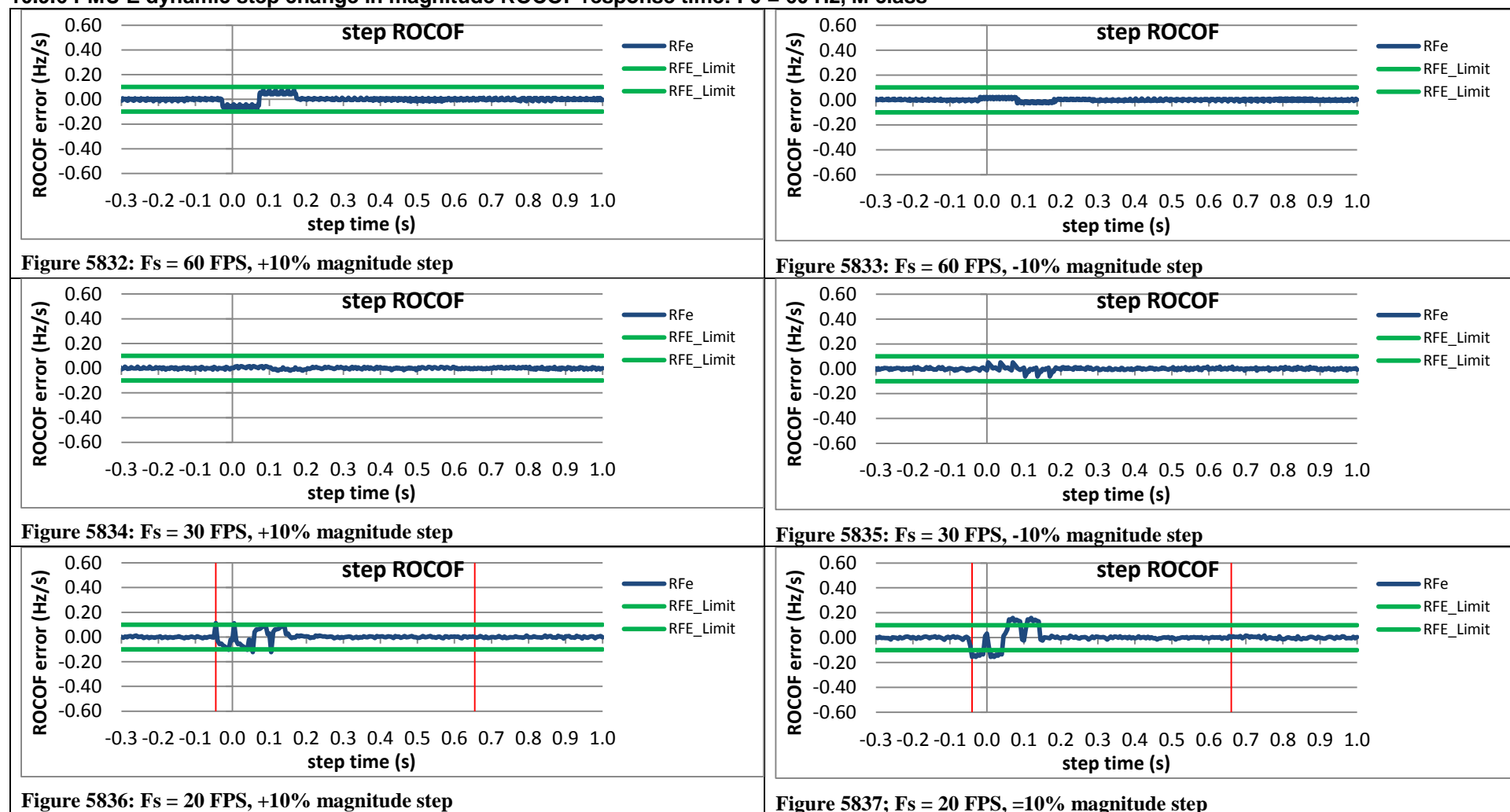
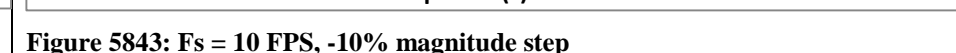
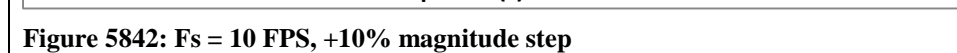
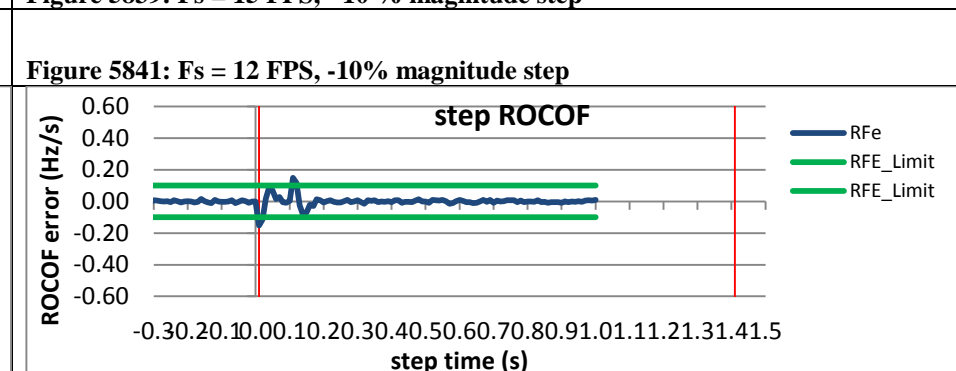
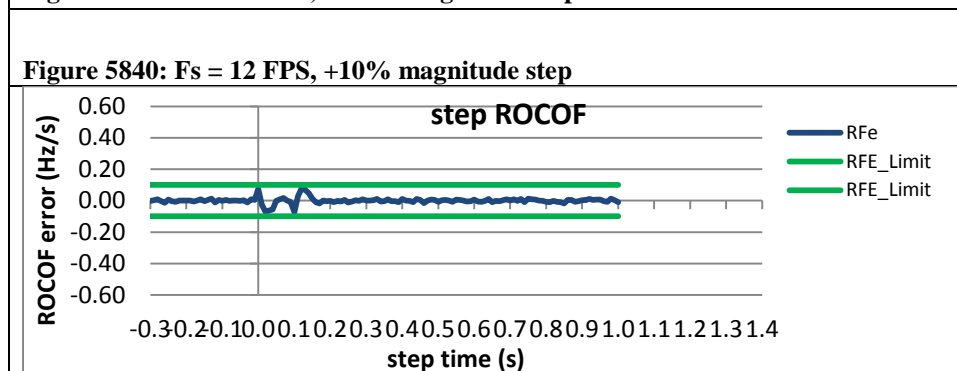
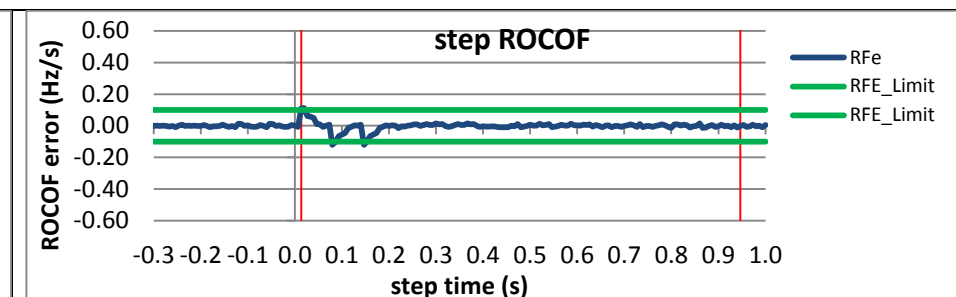
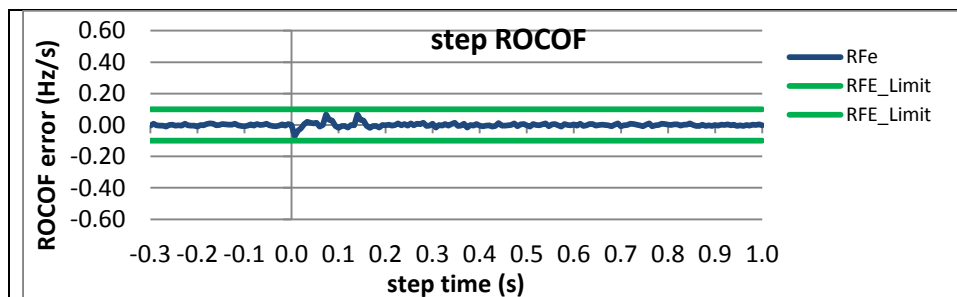


Figure 5831:  $F_s = 10$  FPS, -10% magnitude step

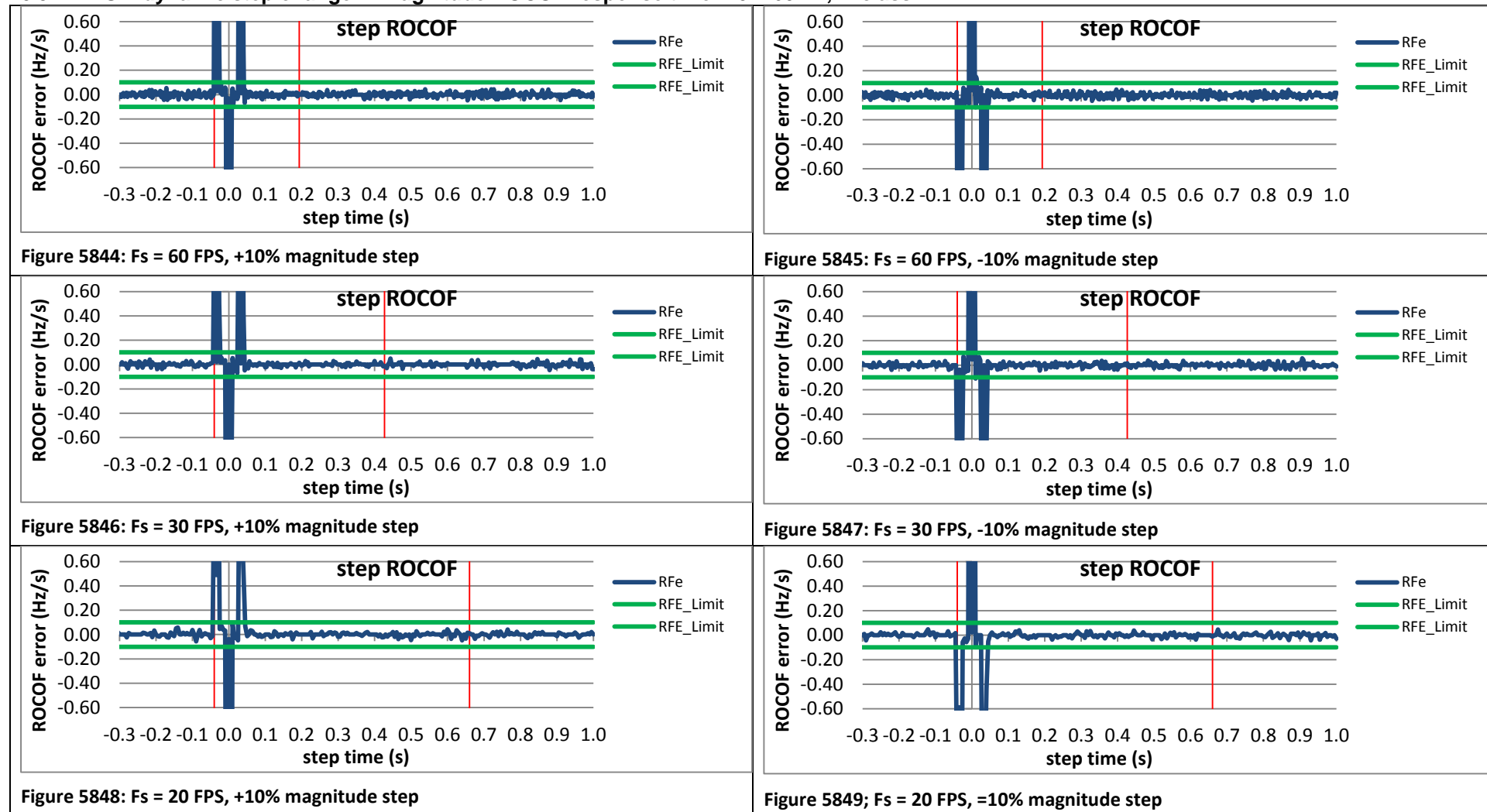


# 10.9.6 PMU E dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class





### 10.9.7 PMU F dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class



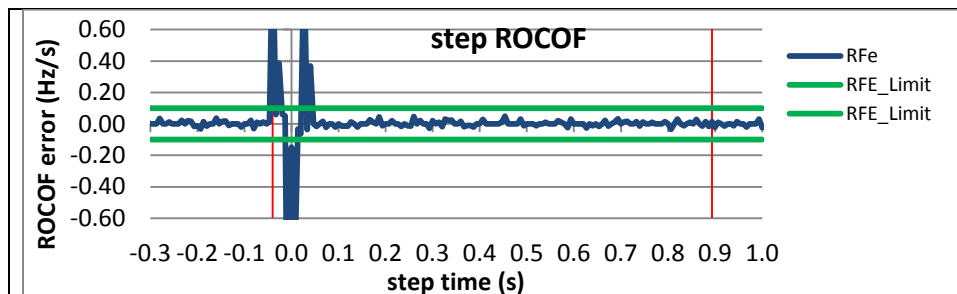


Figure 5850:  $F_s = 15$  FPS, +10% magnitude step

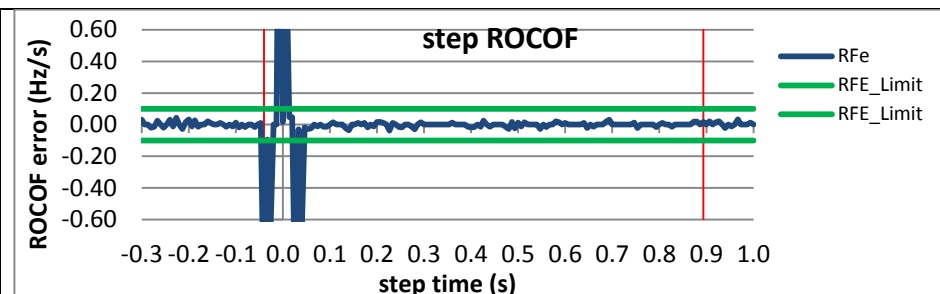


Figure 5851:  $F_s = 15$  FPS, -10% magnitude step

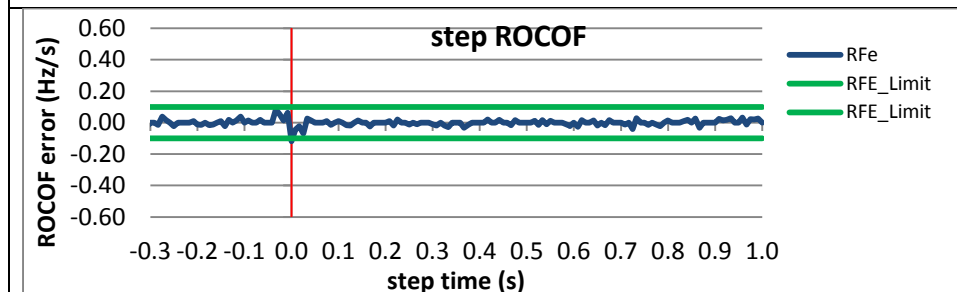


Figure 5852:  $F_s = 12$  FPS, +10% magnitude step

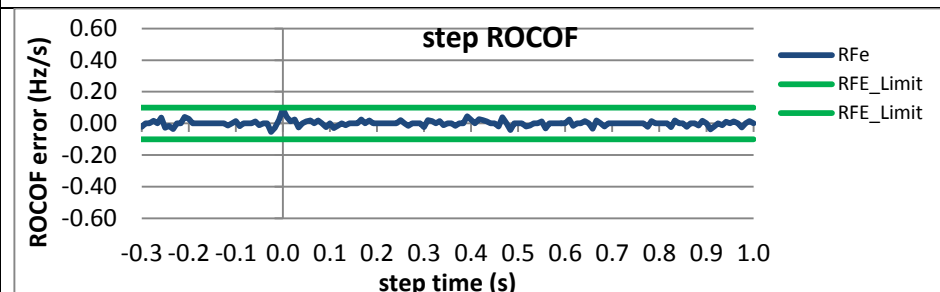


Figure 5853:  $F_s = 12$  FPS, -10% magnitude step

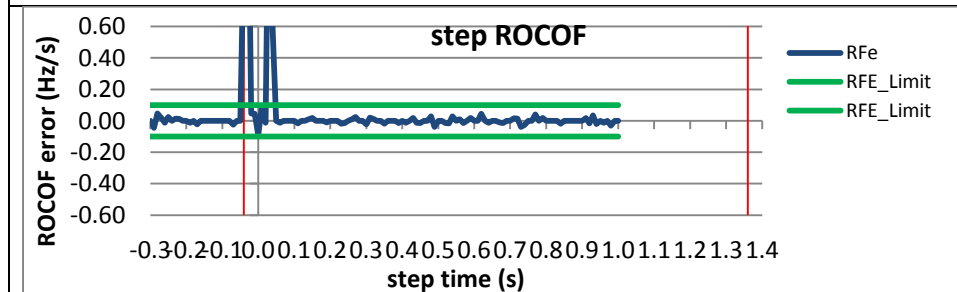


Figure 5854:  $F_s = 10$  FPS, +10% magnitude step

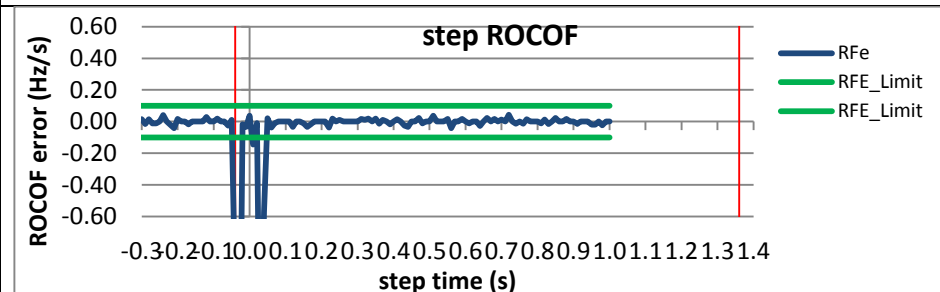


Figure 5855:  $F_s = 10$  FPS, -10% magnitude step

### 10.9.8 PMU G \* dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class

Figure 5856: Fs = 60 FPS is not supported by this PMU

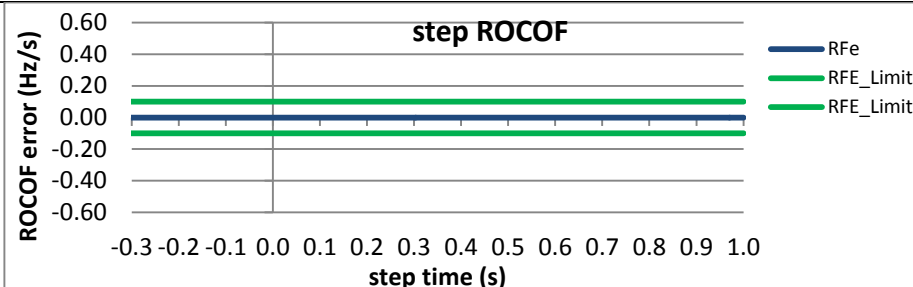
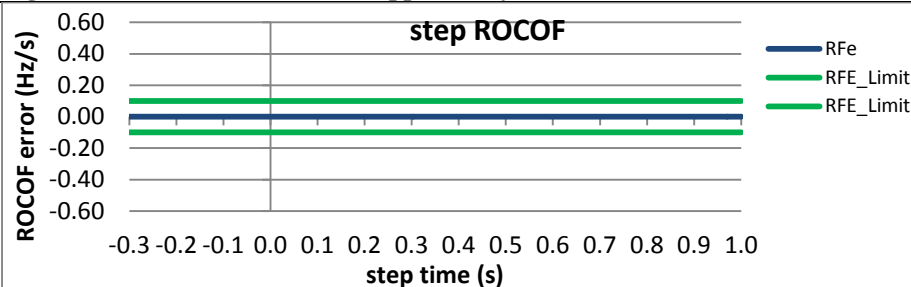


Figure 5857: Fs = 30 FPS, +10% magnitude step

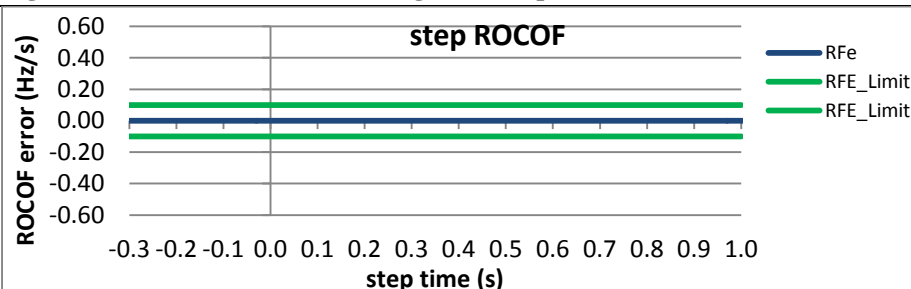


Figure 5858: Fs = 30 FPS, -10% magnitude step

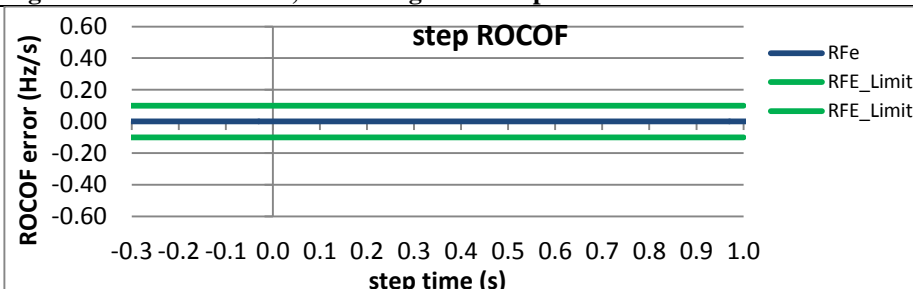


Figure 5859: Fs = 20 FPS, +10% magnitude step

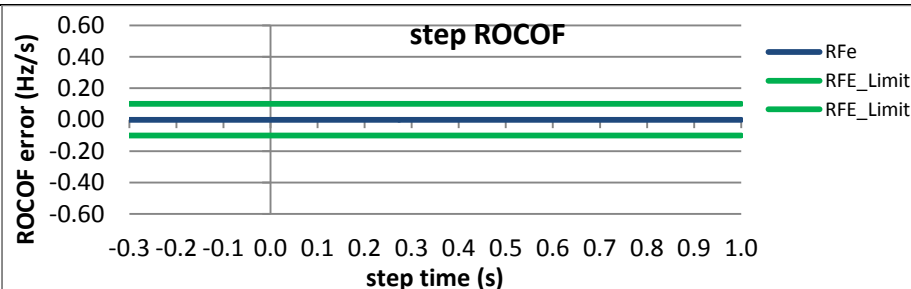


Figure 5860: Fs = 20 FPS, -10% magnitude step

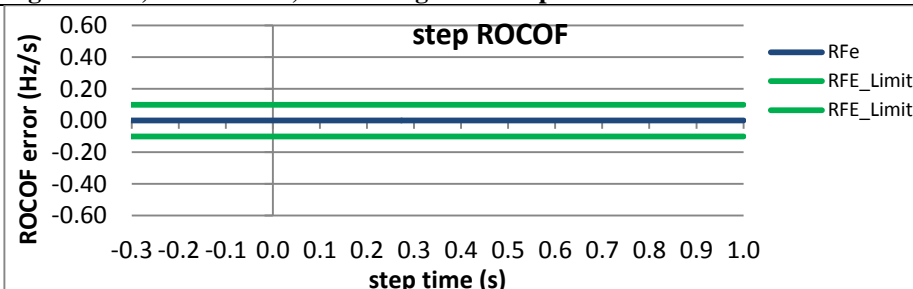
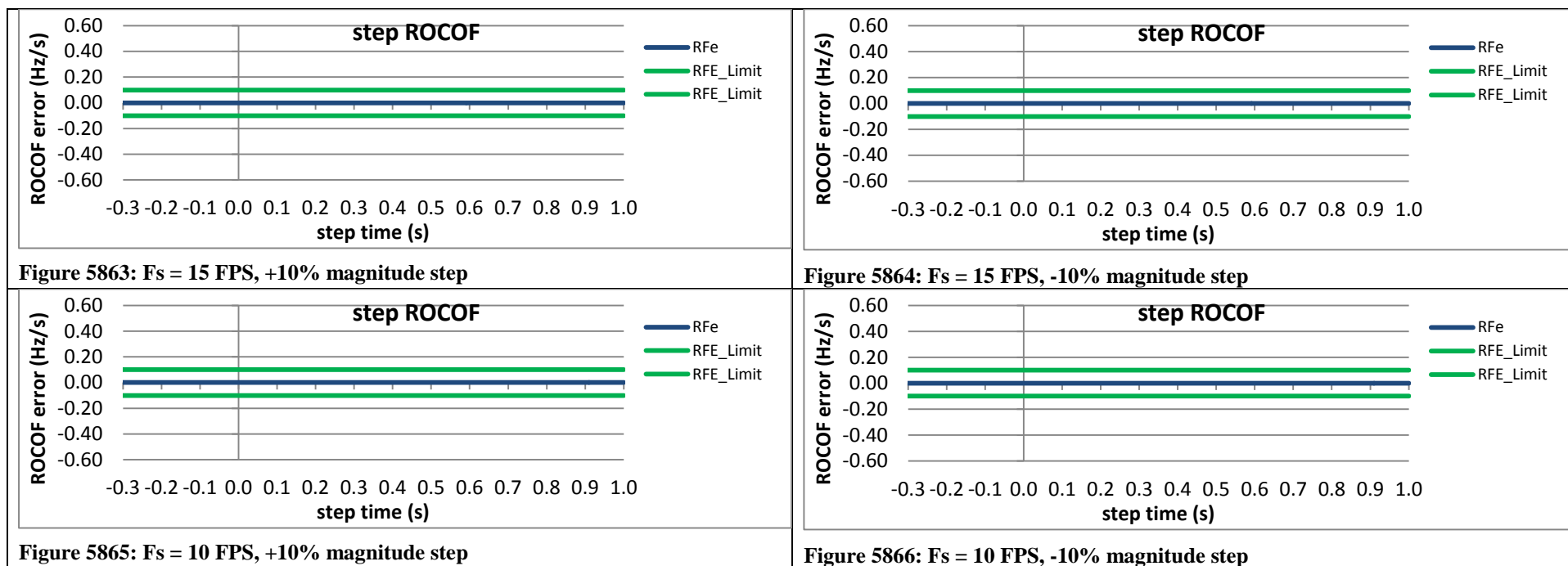


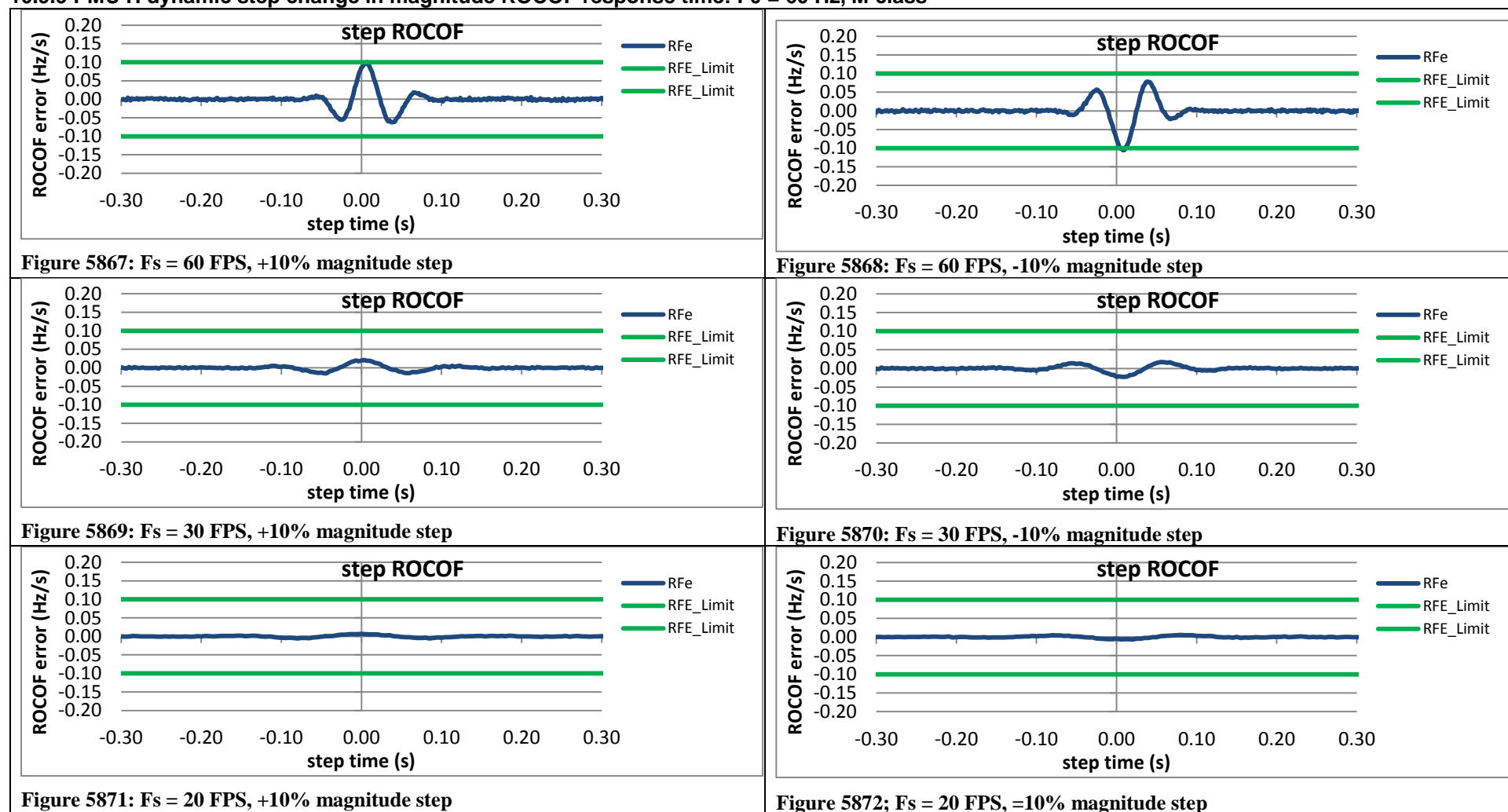
Figure 5861: Fs = 15 FPS, +10% magnitude step

Figure 5862: Fs = 15 FPS, -10% magnitude step



\* PMU G always outputs ROCOF = 0

### 10.9.9 PMU H dynamic step change in magnitude ROCOF response time: F<sub>0</sub> = 60 Hz, M class



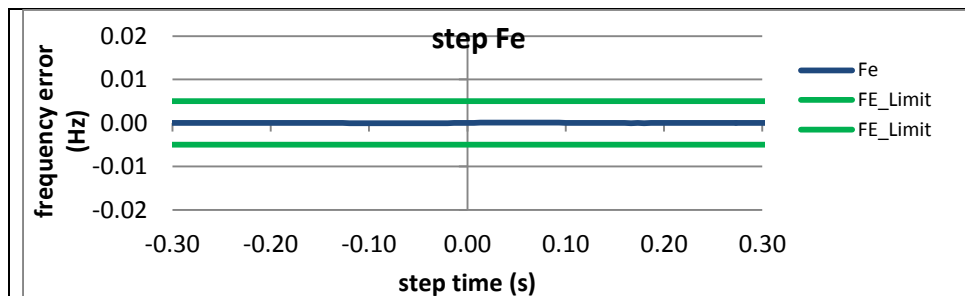


Figure 5873:  $F_s = 15$  FPS, + 10% magnitude step

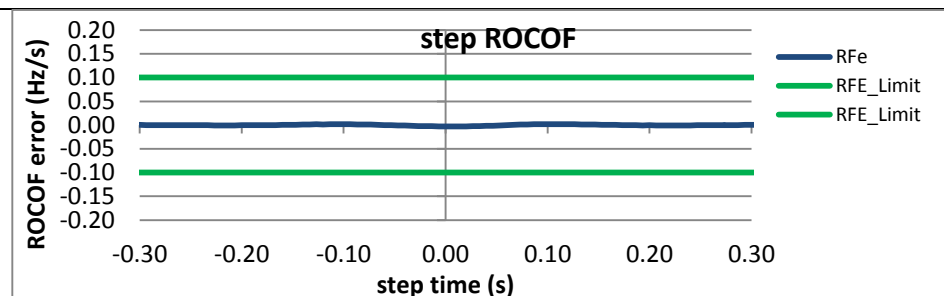


Figure 5874:  $F_s = 15$  FPS, - 10 % magnitude step

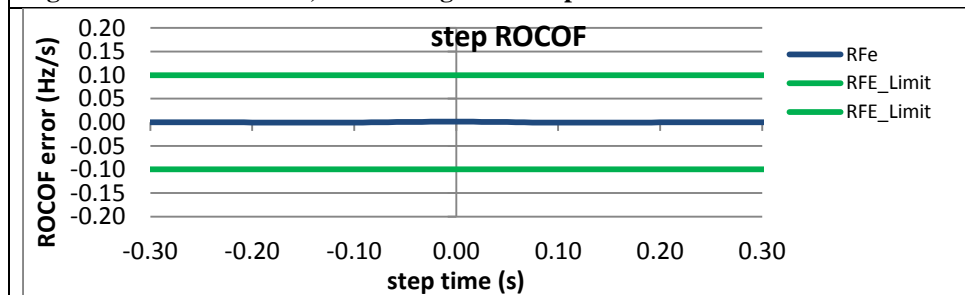


Figure 5875:  $F_s = 12$  FPS, +10% magnitude step

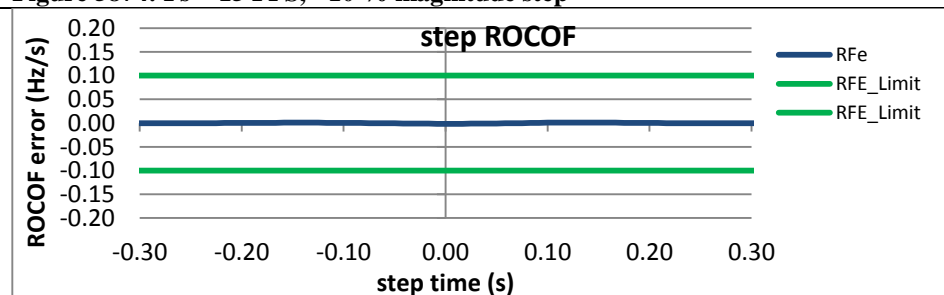


Figure 5876:  $F_s = 12$  FPS, -10% magnitude step

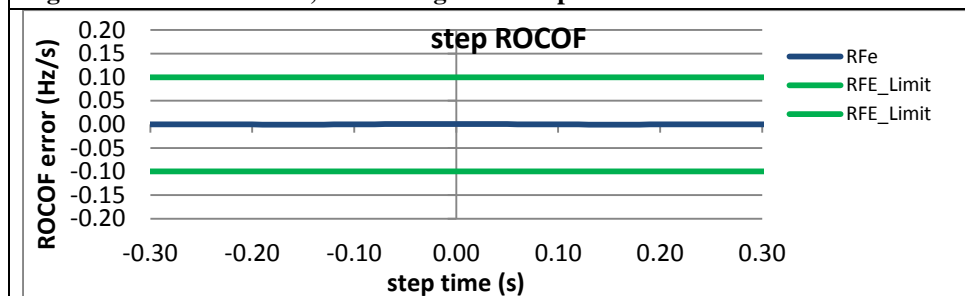


Figure 5877:  $F_s = 10$  FPS, +10% magnitude step

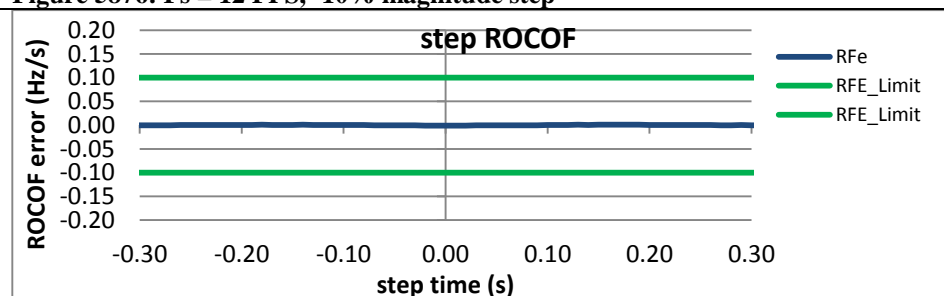
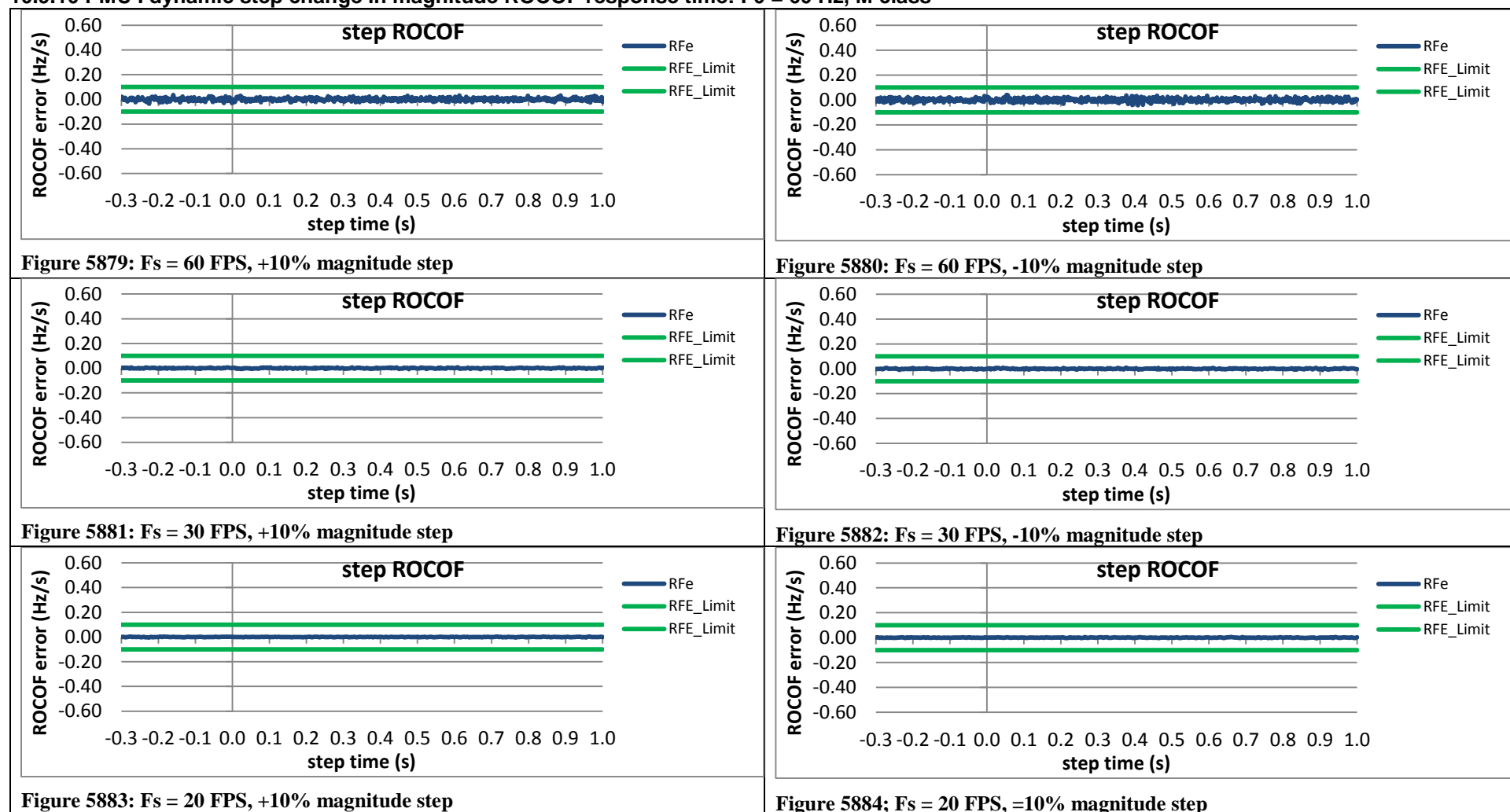


Figure 5878:  $F_s = 10$  FPS, -10% magnitude step



# 10.9.10 PMU I dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class



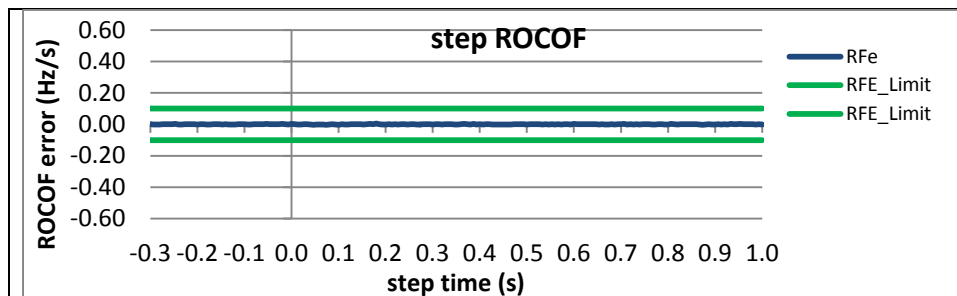


Figure 5885:  $F_s = 15$  FPS, + 10% magnitude step

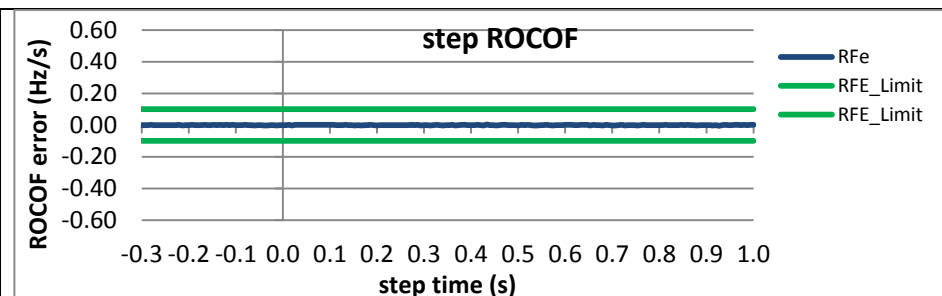


Figure 5886:  $F_s = 15$  FPS, - 10 % magnitude step

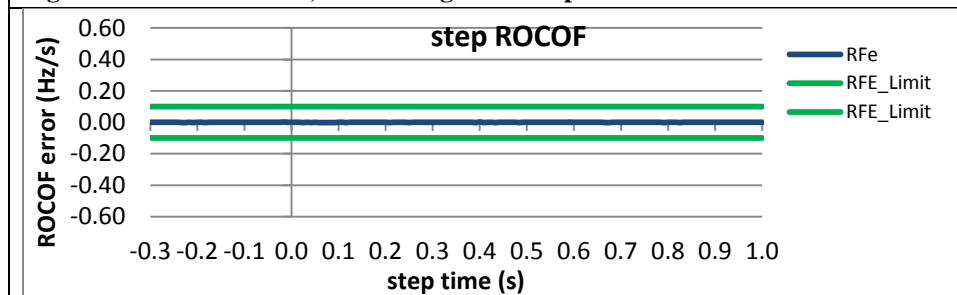


Figure 5887:  $F_s = 12$  FPS, +10% magnitude step

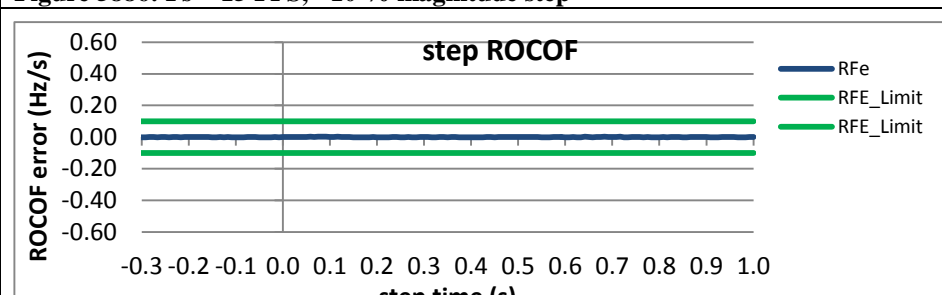


Figure 5888:  $F_s = 12$  FPS, -10% magnitude step

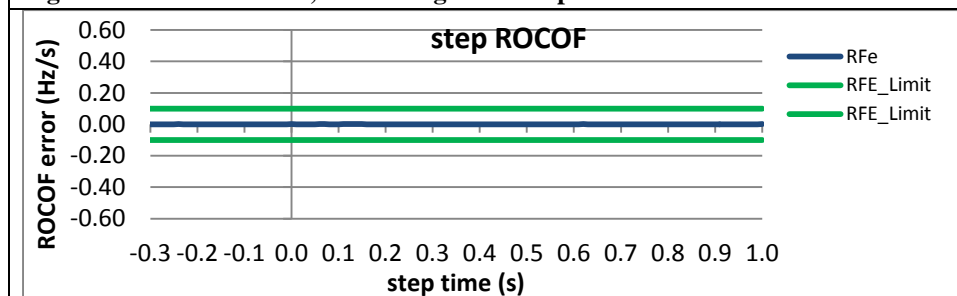


Figure 5889:  $F_s = 10$  FPS, +10% magnitude step

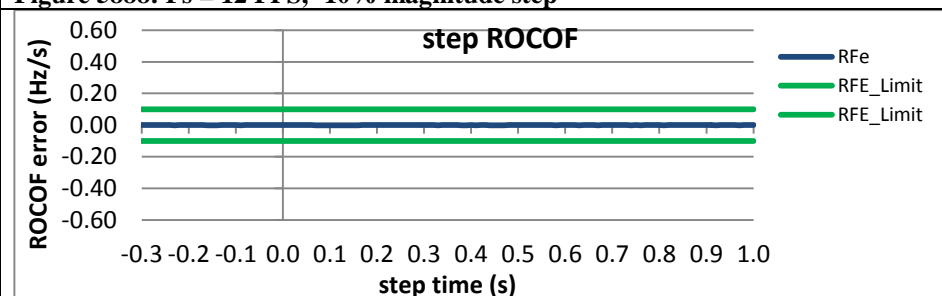
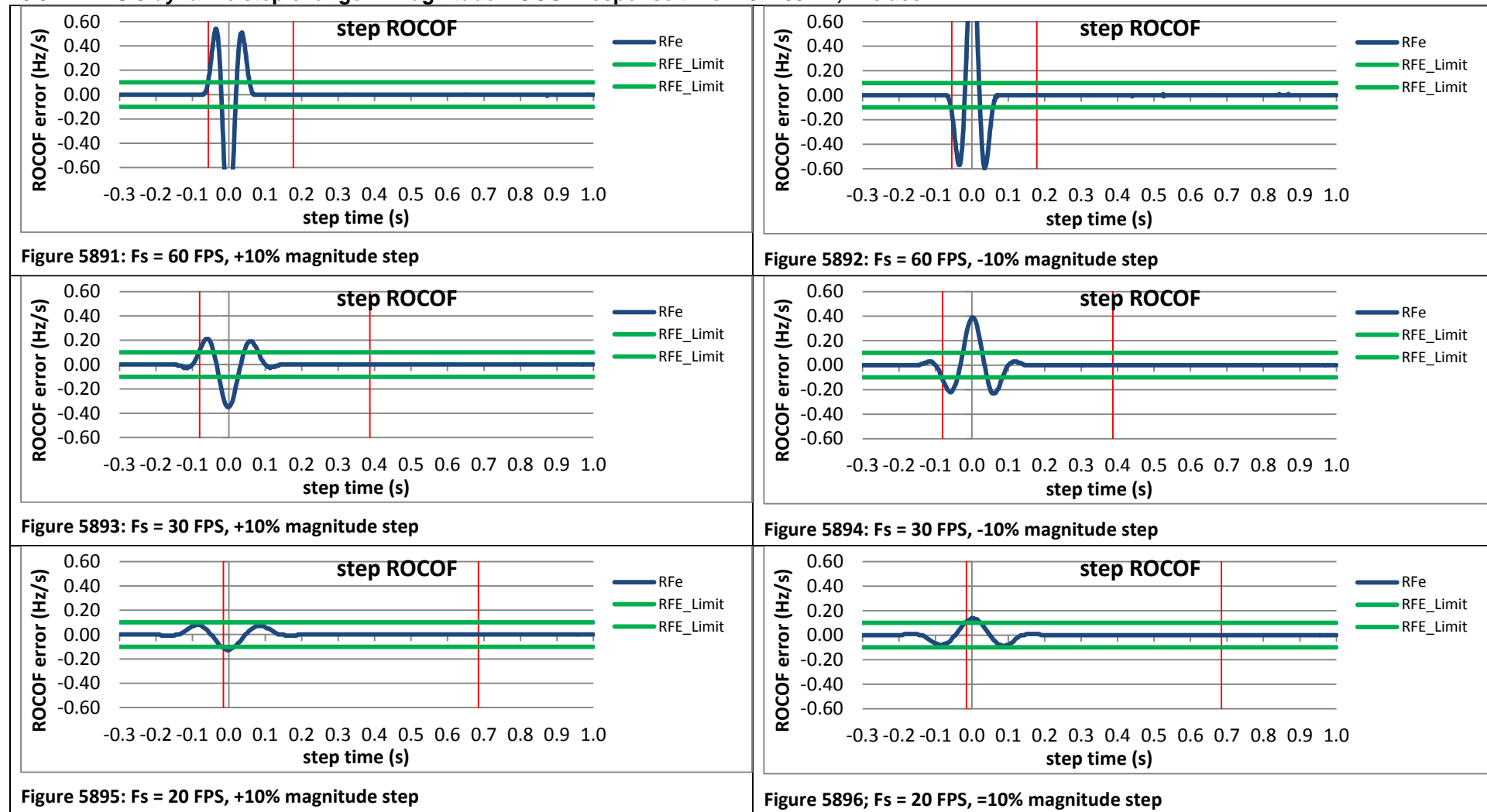


Figure 5890:  $F_s = 10$  FPS, -10% magnitude step

# 10.9.11 PMU J dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, M class



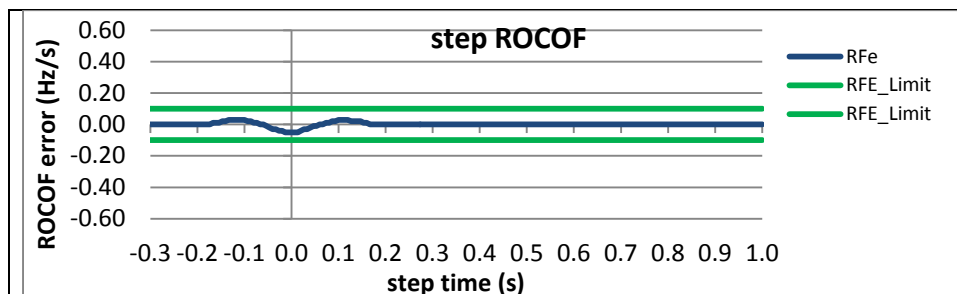


Figure 5897:  $F_s = 15$  FPS, +10% magnitude step

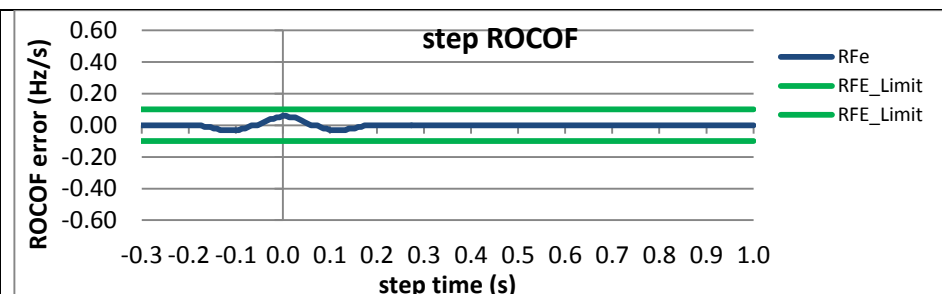


Figure 5898:  $F_s = 15$  FPS, -10% magnitude step

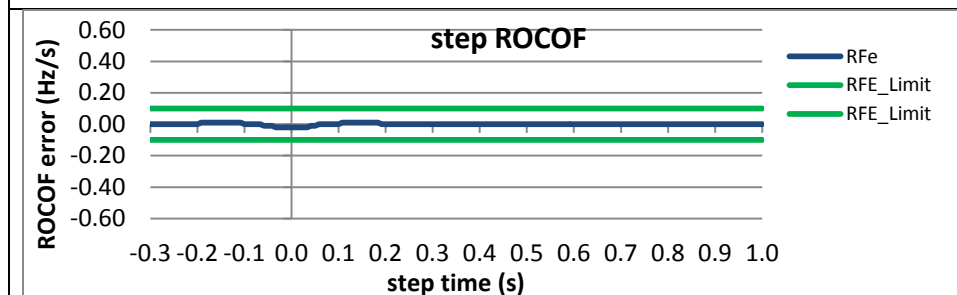


Figure 5899:  $F_s = 12$  FPS, +10% magnitude step

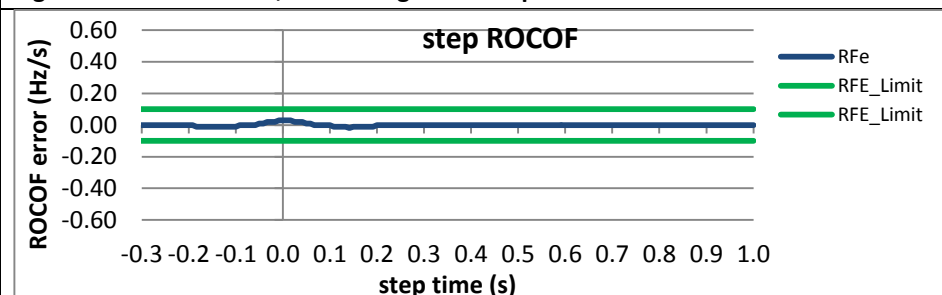


Figure 5900:  $F_s = 12$  FPS, -10% magnitude step

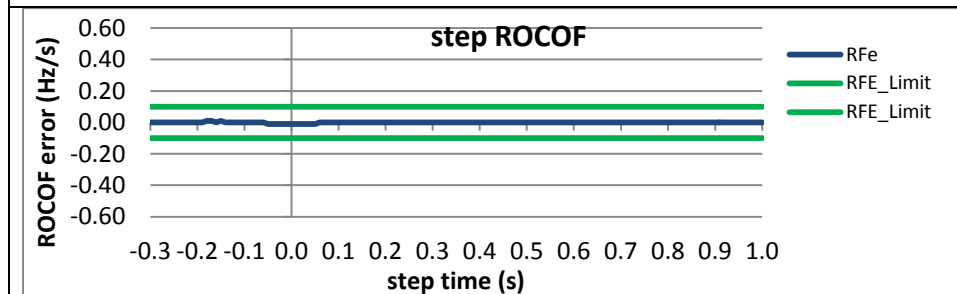


Figure 5901:  $F_s = 10$  FPS, +10% magnitude step

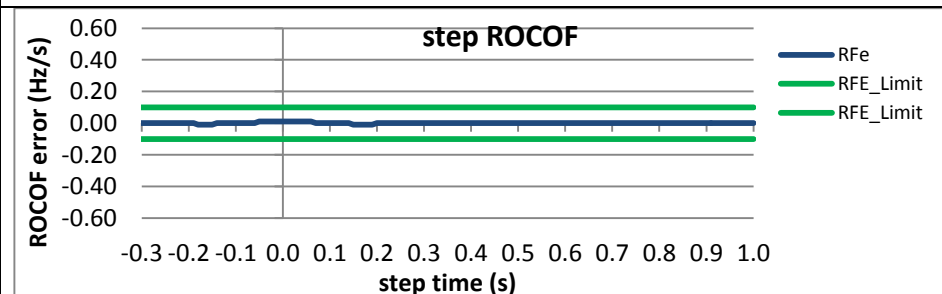
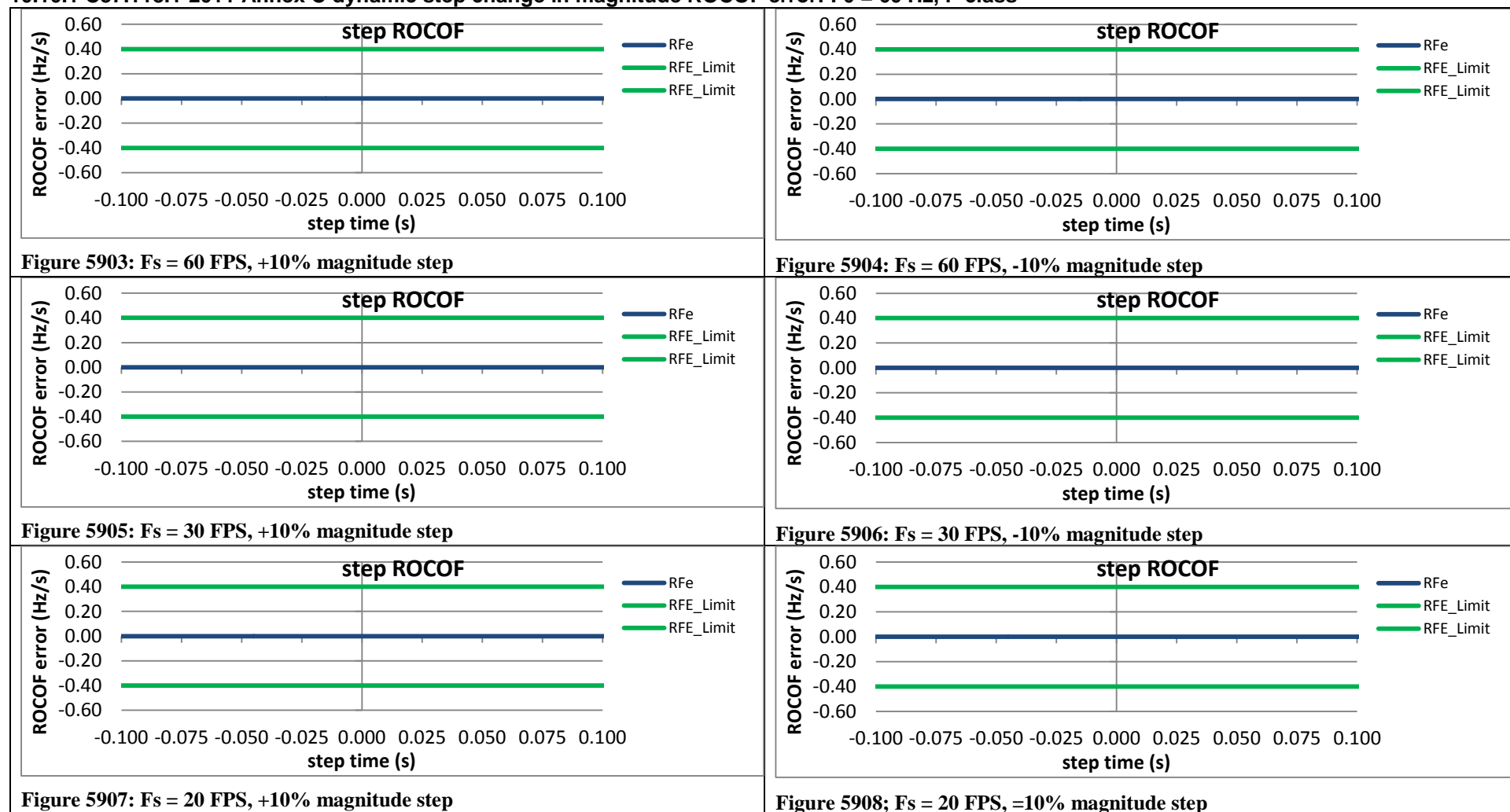
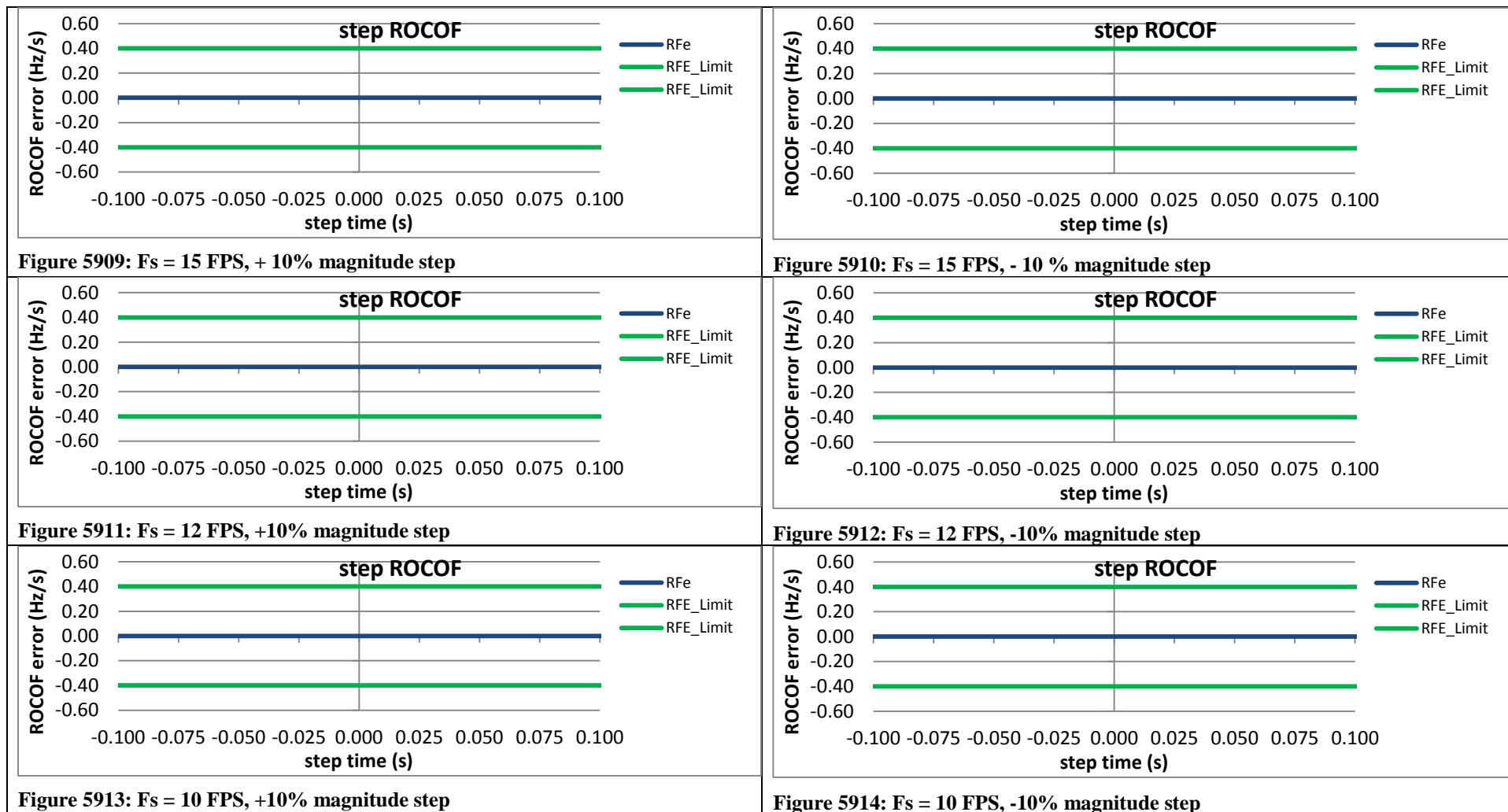


Figure 5902:  $F_s = 10$  FPS, -10% magnitude step

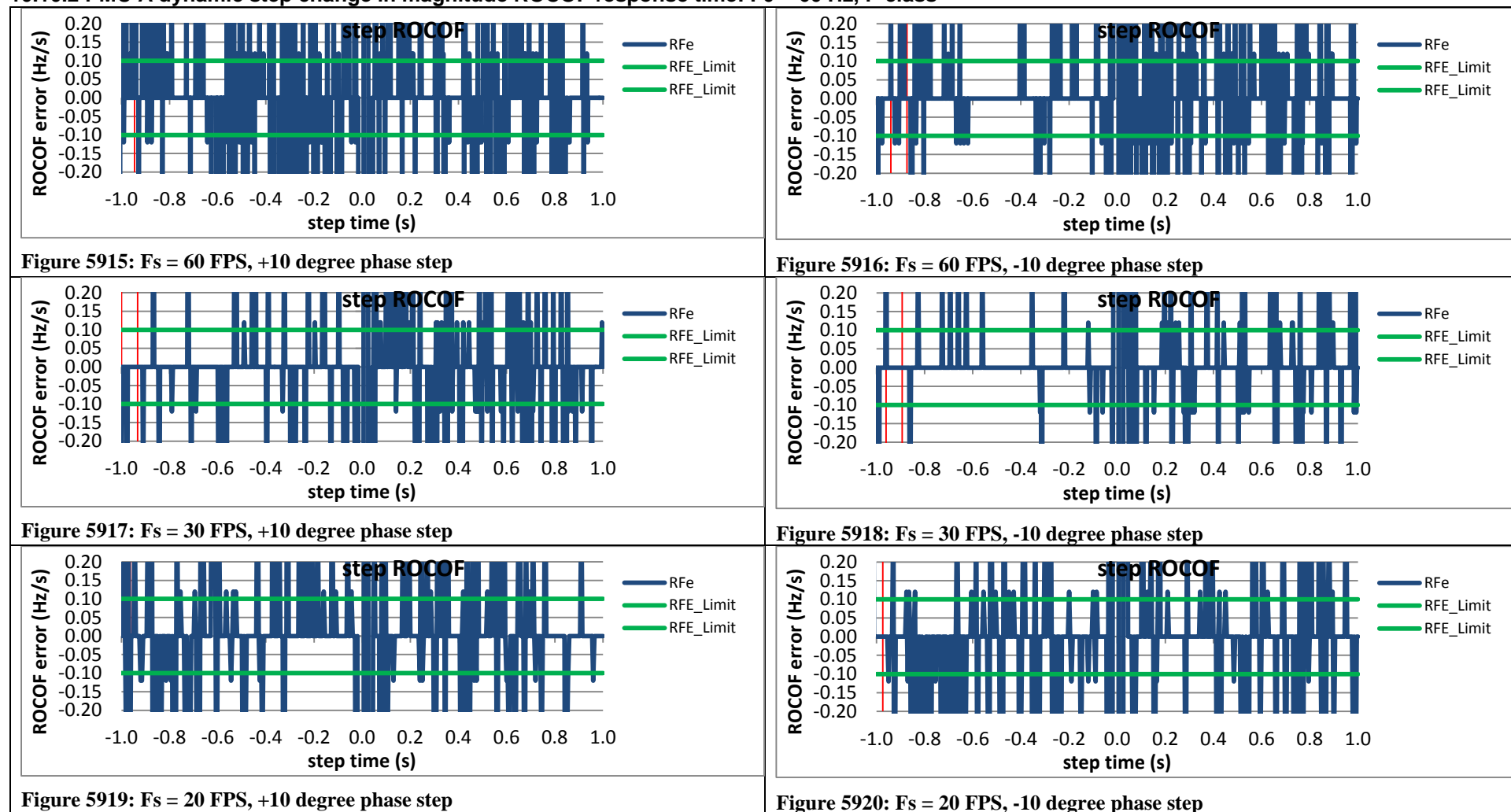
## 10.10 Dynamic step change in magnitude ROCOF error: F0 = 60 Hz, P class

### 10.10.1 C37.118.1-2011 Annex C dynamic step change in magnitude ROCOF error: F0 = 60 Hz, P class





### 10.10.2 PMU A dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class



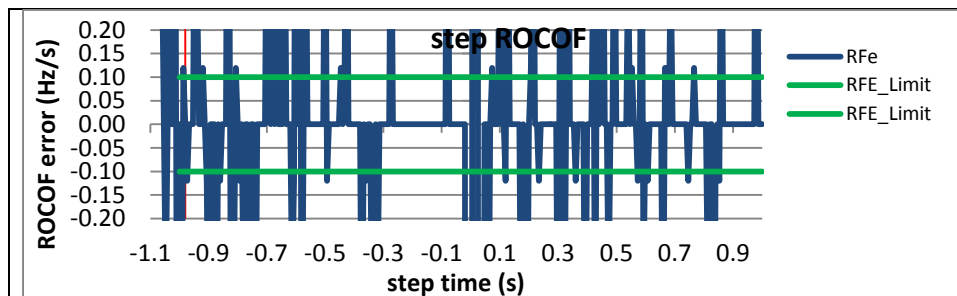


Figure 5921:  $F_s = 15$  FPS, +10 degree phase step

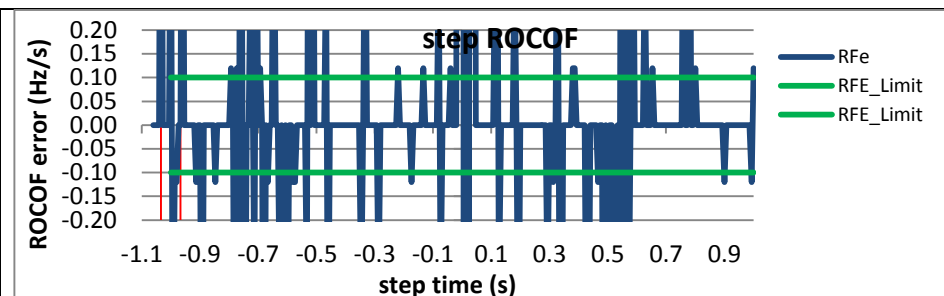


Figure 5922:  $F_s = 15$  FPS, -10 degree phase step

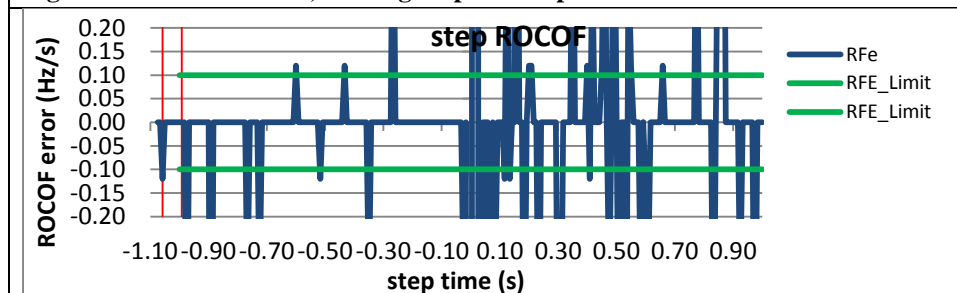


Figure 5923:  $F_s = 12$  FPS, +10 degree phase step

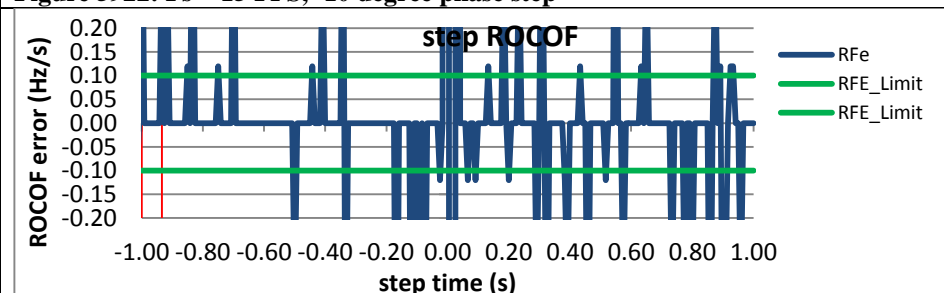


Figure 5924:  $F_s = 12$  FPS, -10 degree phase step

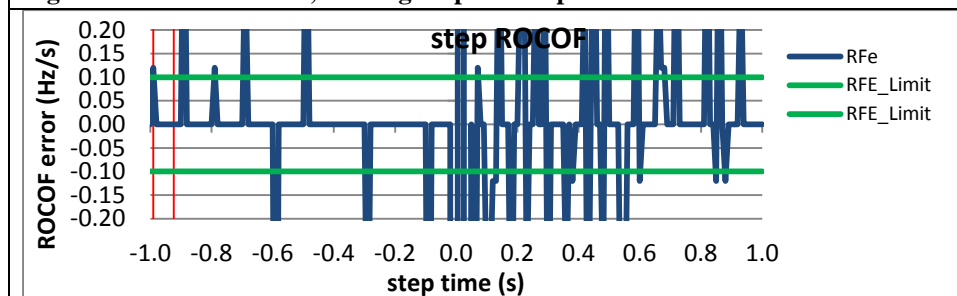


Figure 5925:  $F_s = 10$  FPS, +10 degree phase step

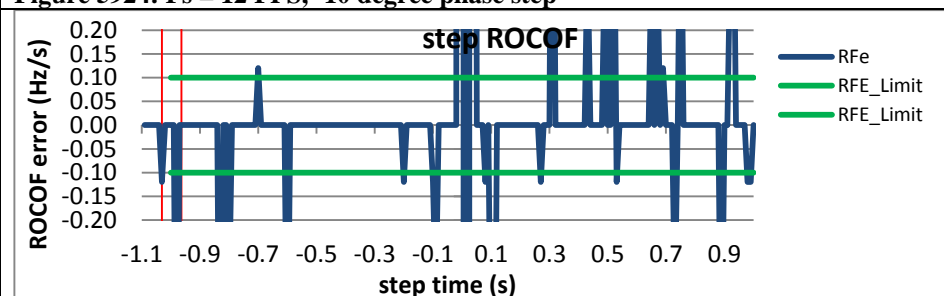
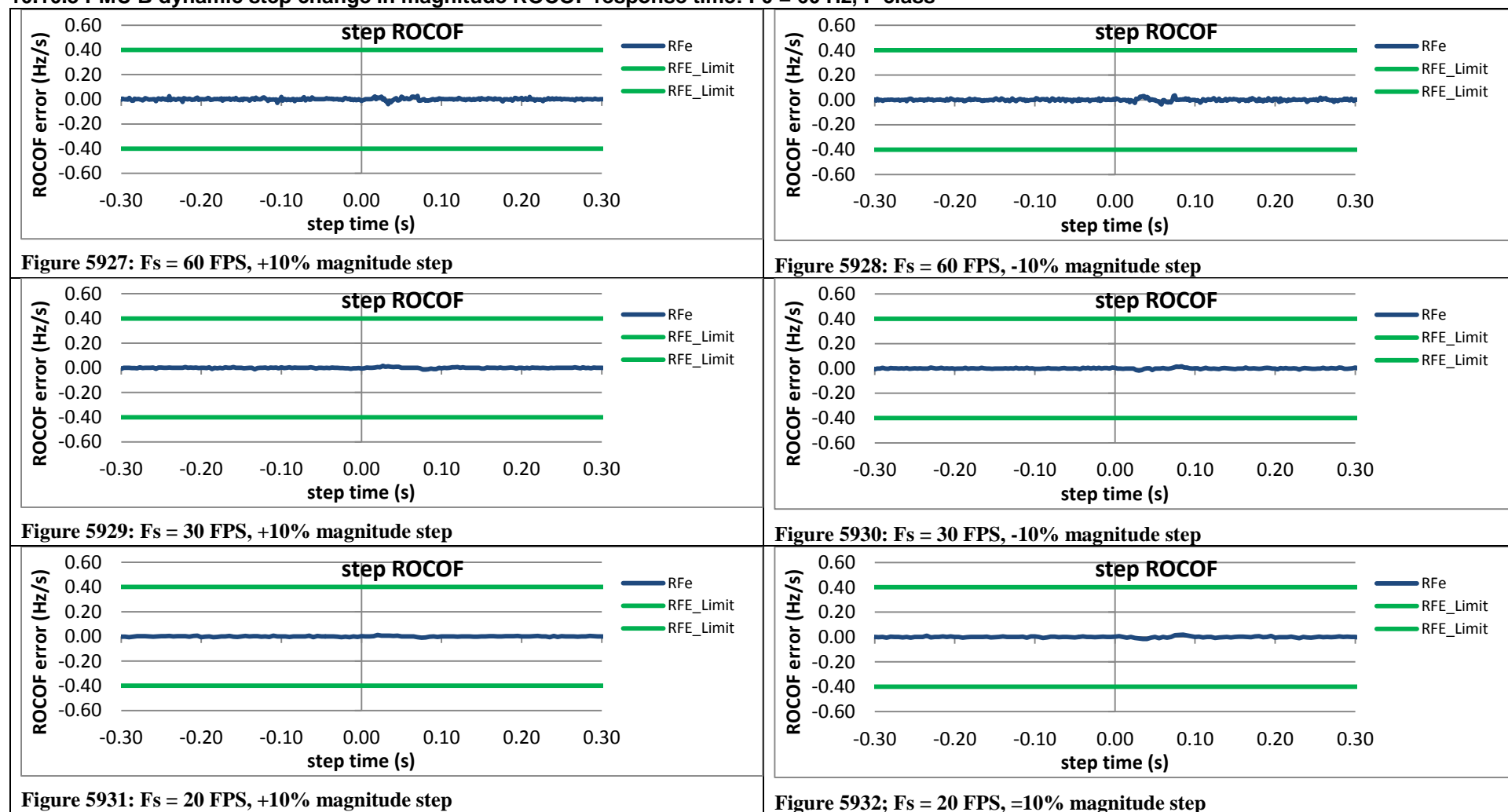


Figure 5926:  $F_s = 10$  FPS, -10 degree phase step



### 10.10.3 PMU B dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class



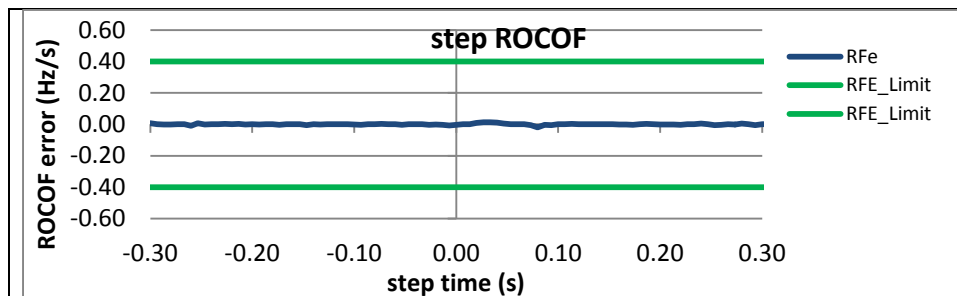


Figure 5933: Fs = 15 FPS, + 10% magnitude step

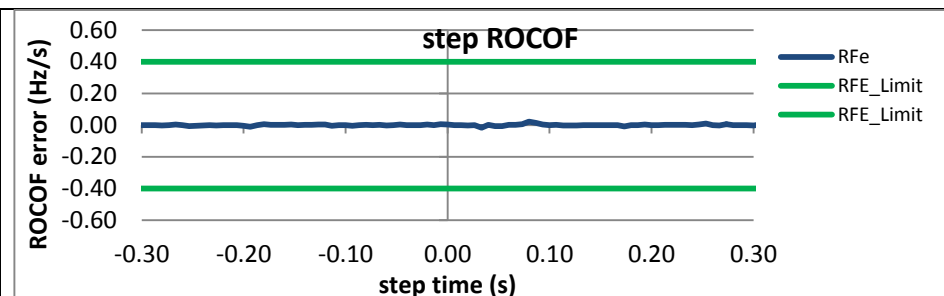


Figure 5934: Fs = 15 FPS, - 10 % magnitude step

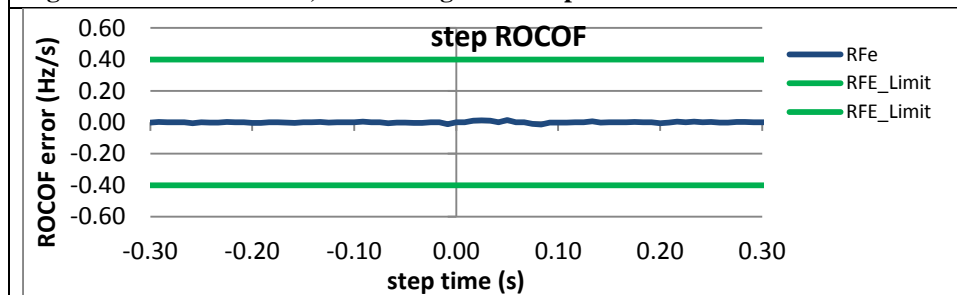


Figure 5935: Fs = 12 FPS, +10% magnitude step

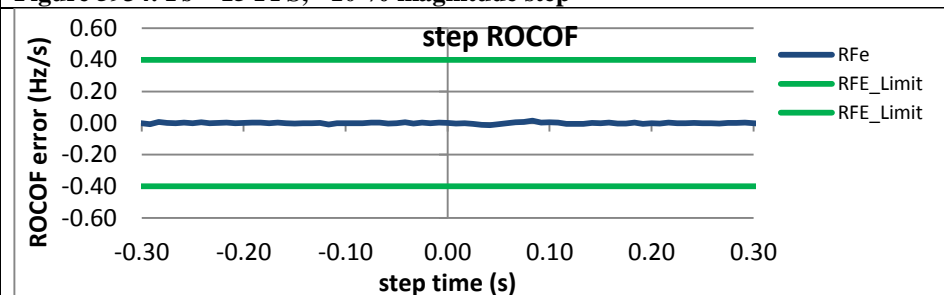


Figure 5936: Fs = 12 FPS, -10% magnitude step

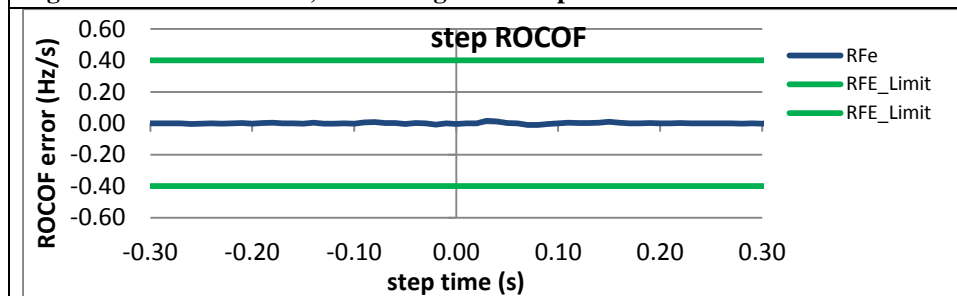


Figure 5937: Fs = 10 FPS, +10% magnitude step

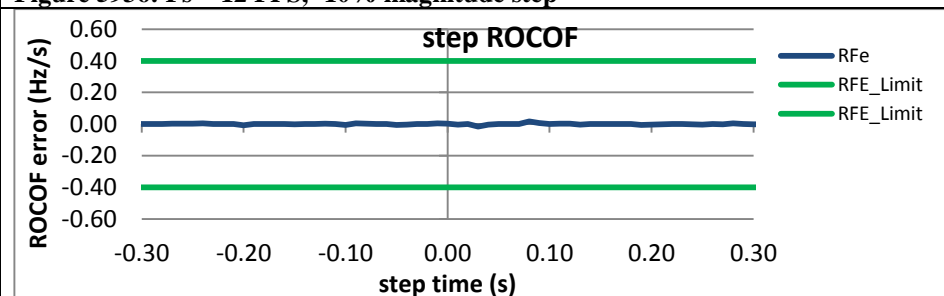
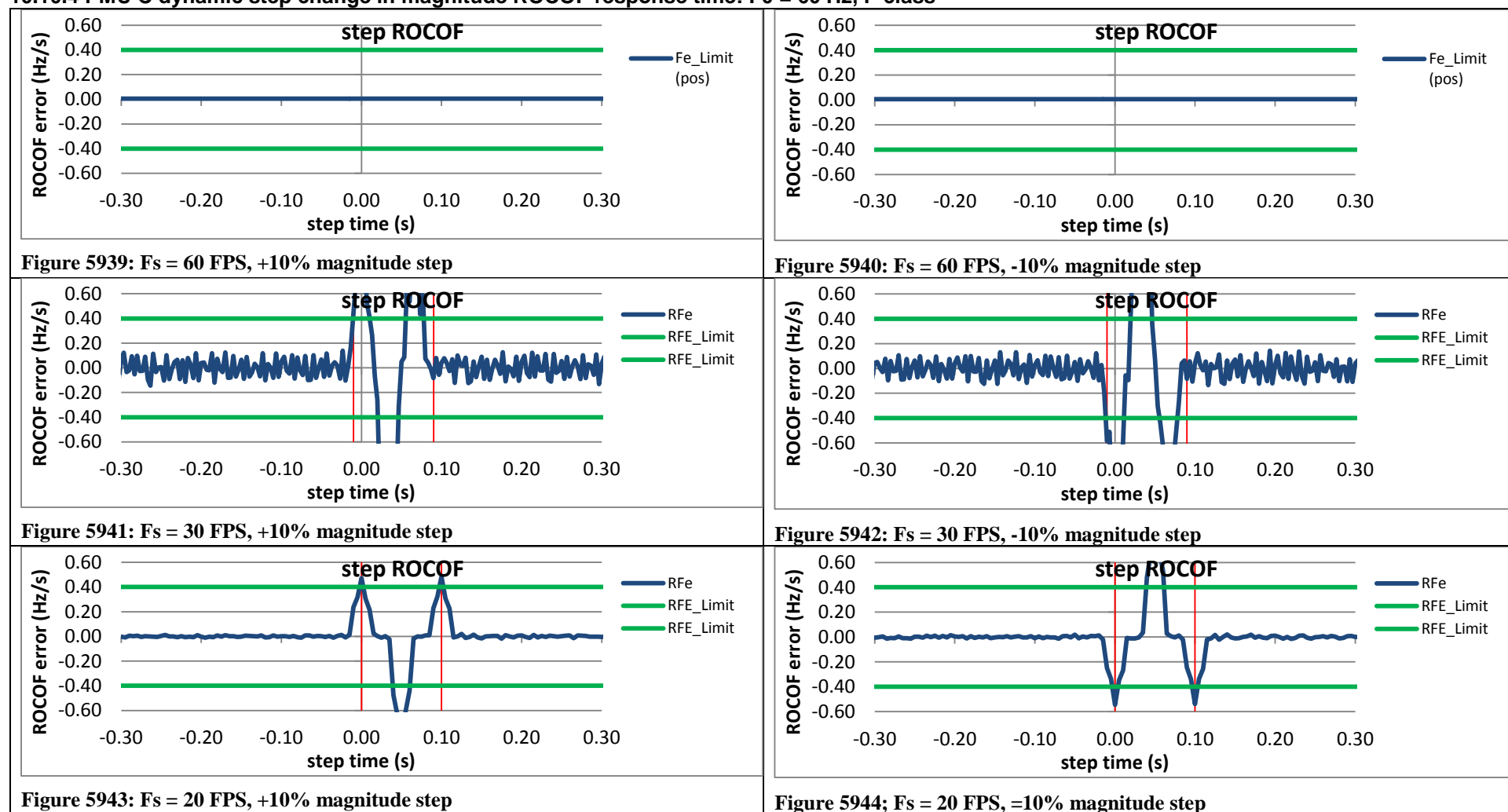


Figure 5938: Fs = 10 FPS, -10% magnitude step

#### 10.10.4 PMU C dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class



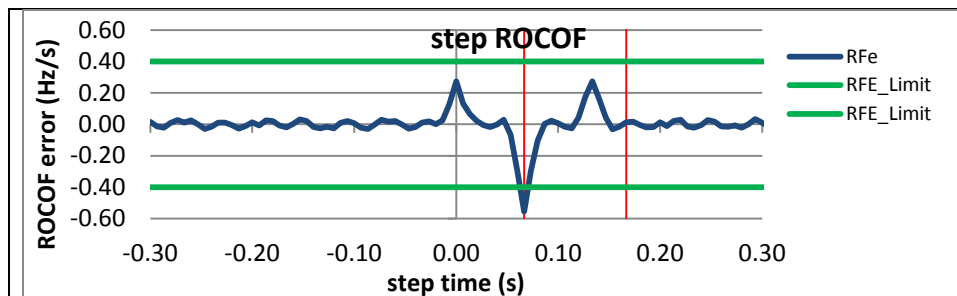


Figure 5945:  $F_s = 15$  FPS, +10% magnitude step

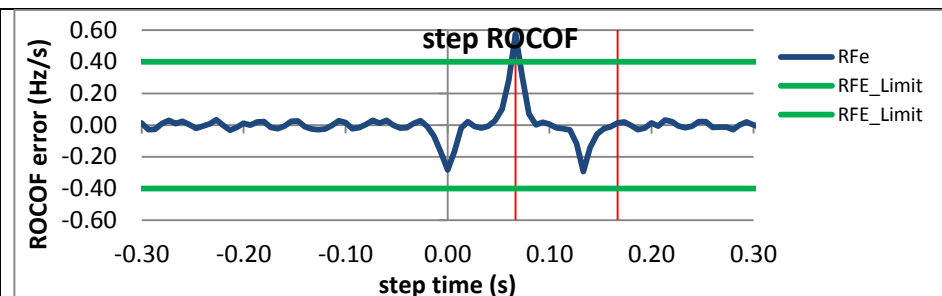


Figure 5946:  $F_s = 15$  FPS, -10% magnitude step

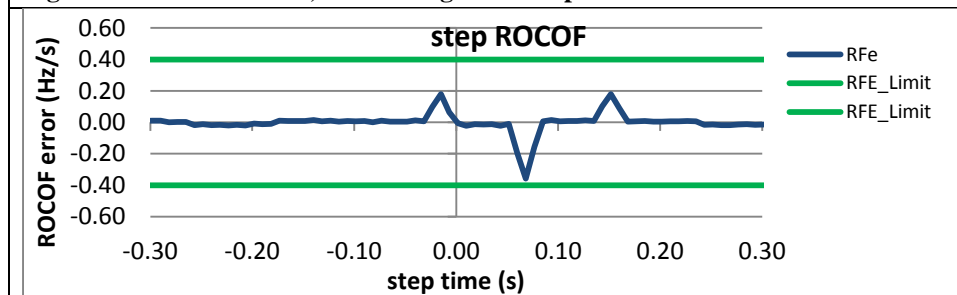


Figure 5947:  $F_s = 12$  FPS, +10% magnitude step

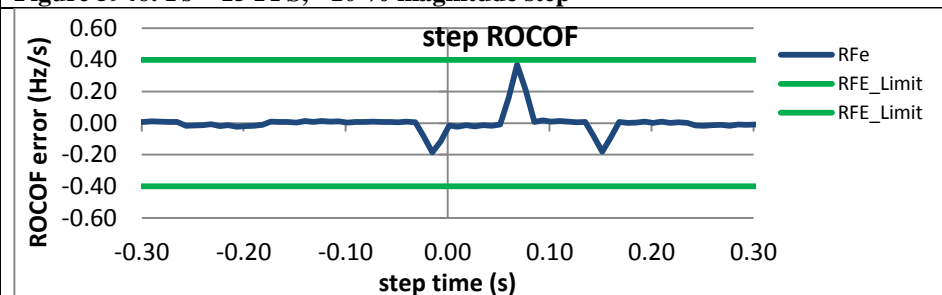


Figure 5948:  $F_s = 12$  FPS, -10% magnitude step

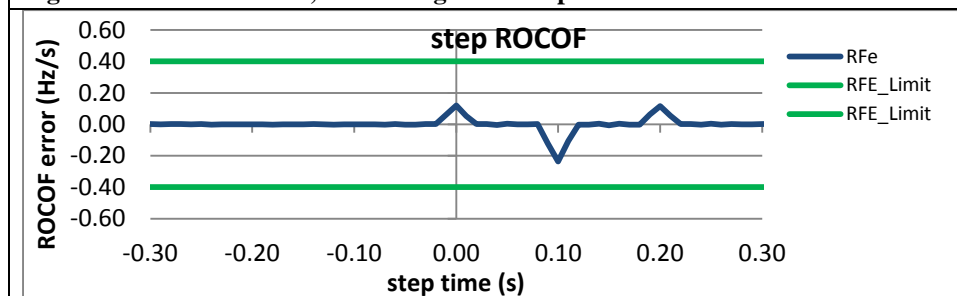


Figure 5949:  $F_s = 10$  FPS, +10% magnitude step

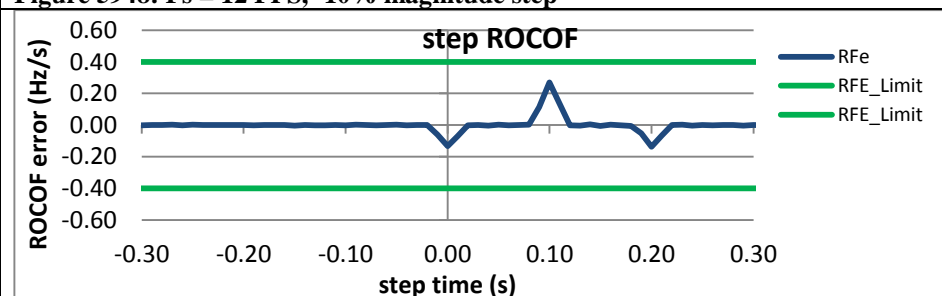
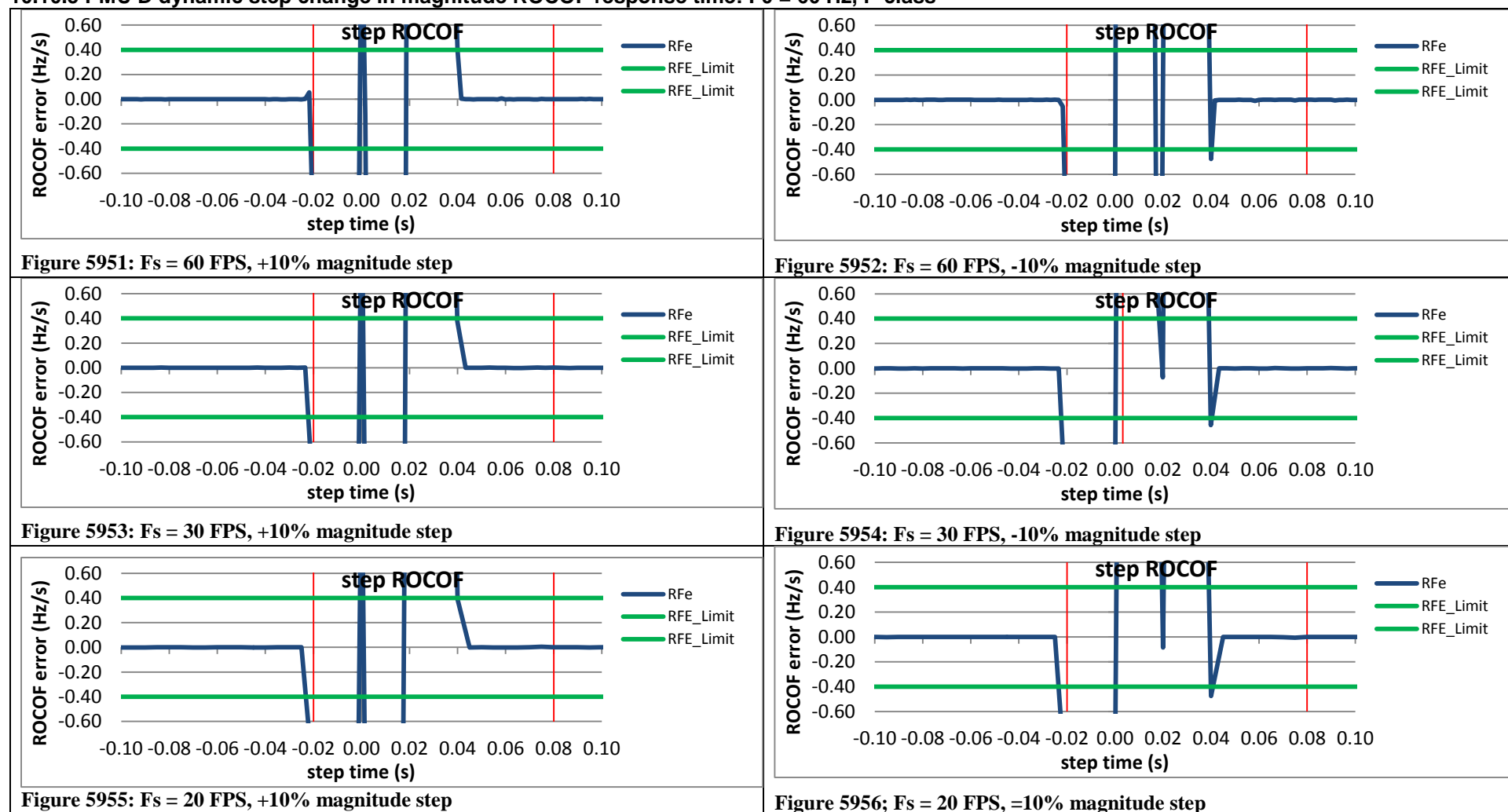
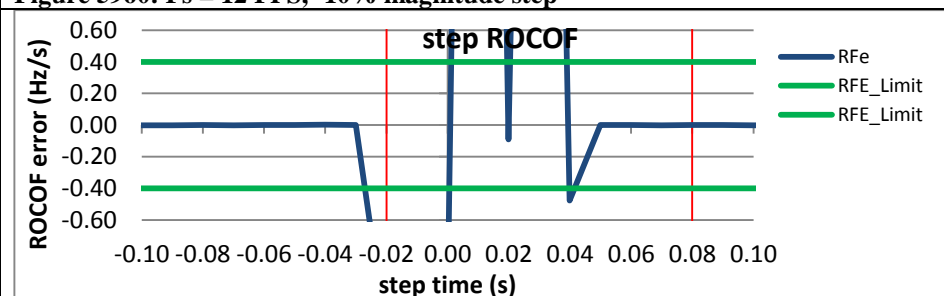
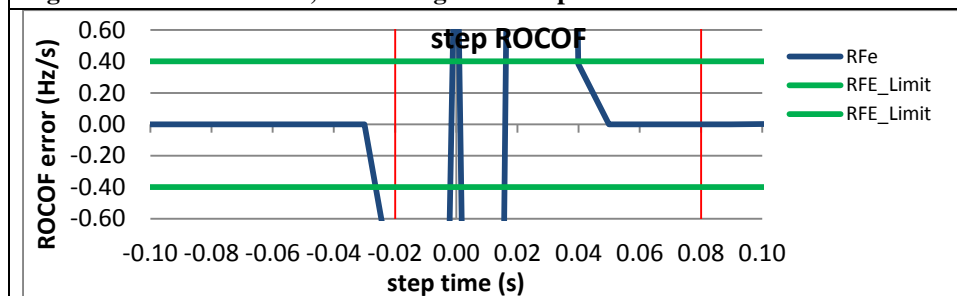
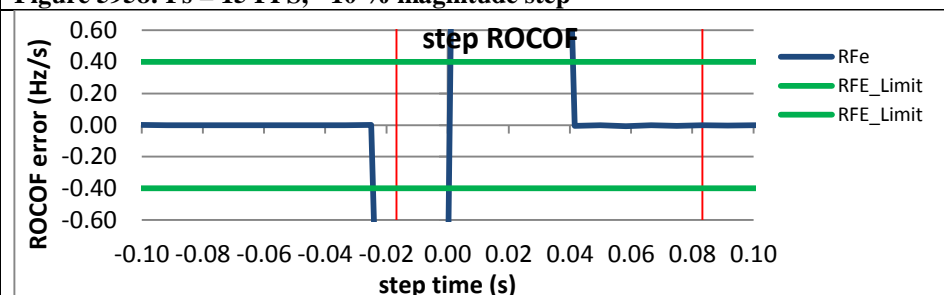
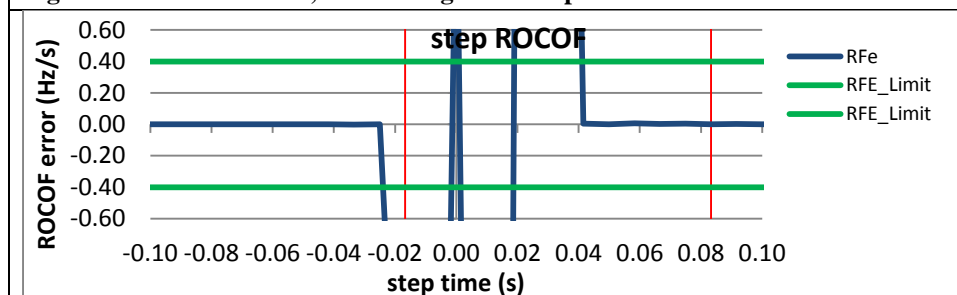
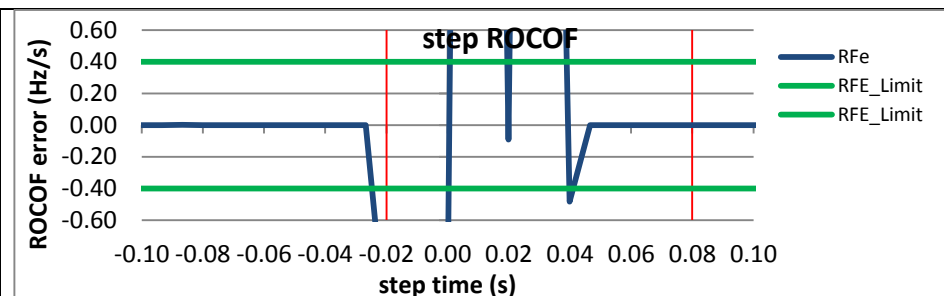
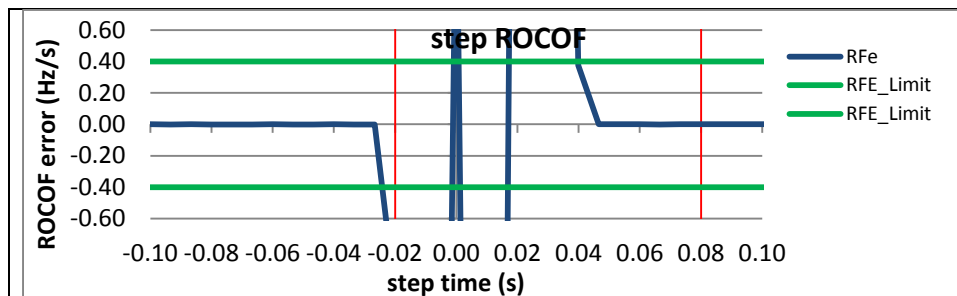


Figure 5950:  $F_s = 10$  FPS, -10% magnitude step

### 10.10.5 PMU D dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class

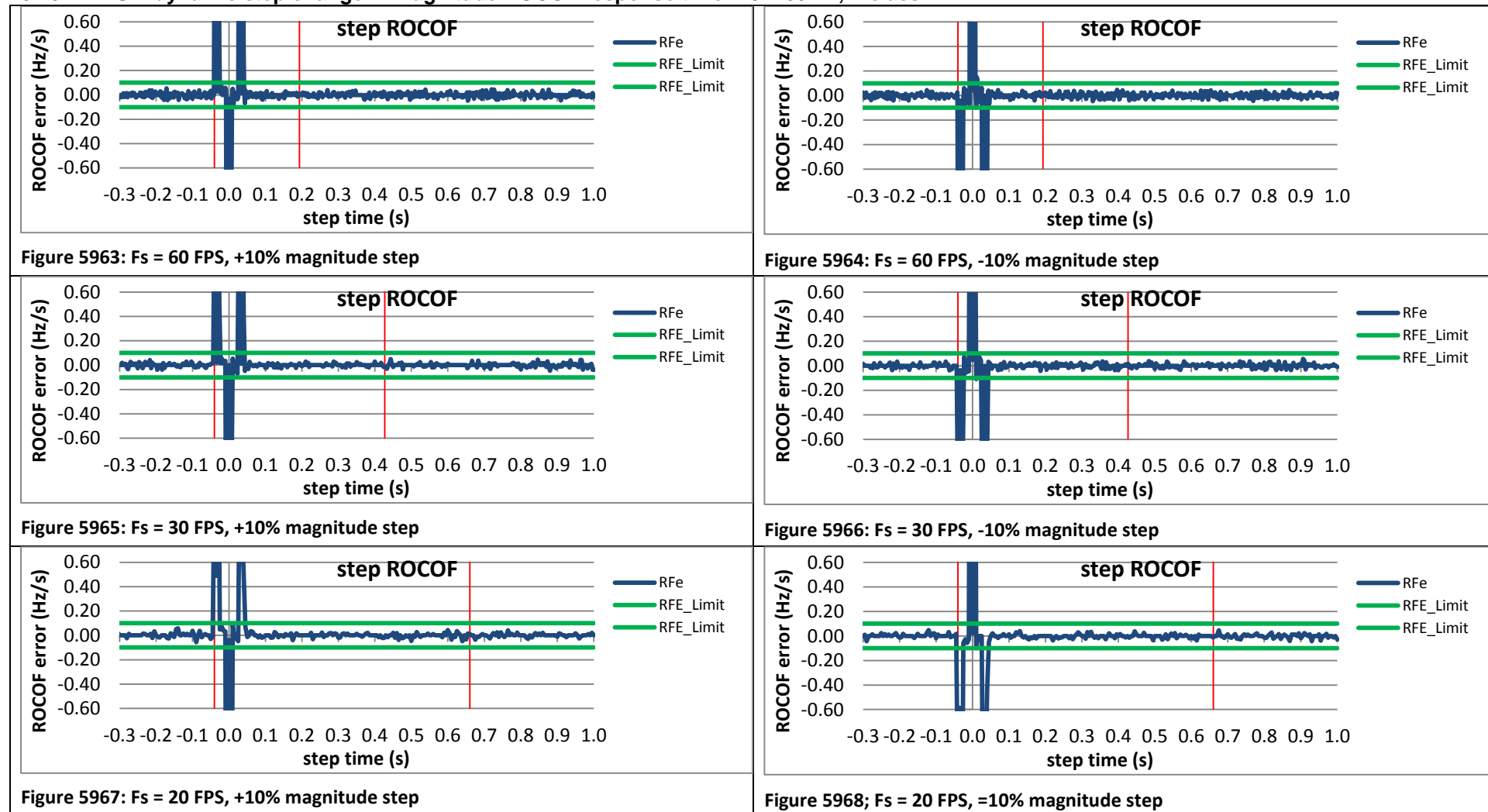




### 10.10.6 PMU E dynamic step change in magnitude ROCOF response time: $F_0 = 60$ Hz, P class

PMU E does not support P class.

### 10.10.7 PMU F dynamic step change in magnitude ROCOF response time: $F_0 = 60$ Hz, P class



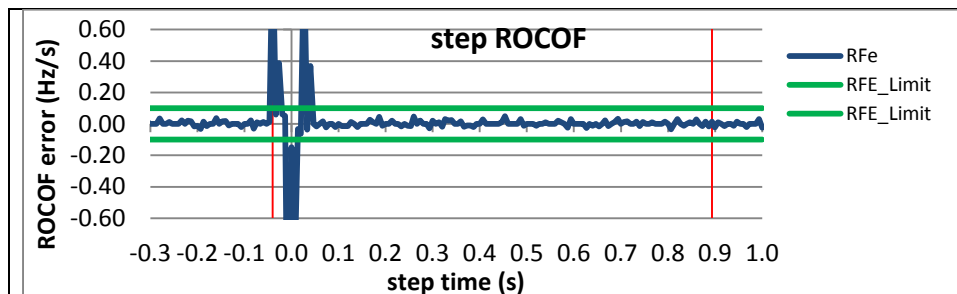


Figure 5969:  $F_s = 15$  FPS, +10% magnitude step

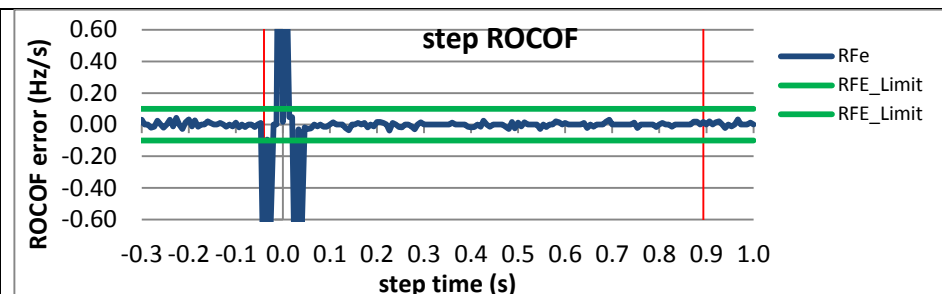


Figure 5970:  $F_s = 15$  FPS, -10% magnitude step

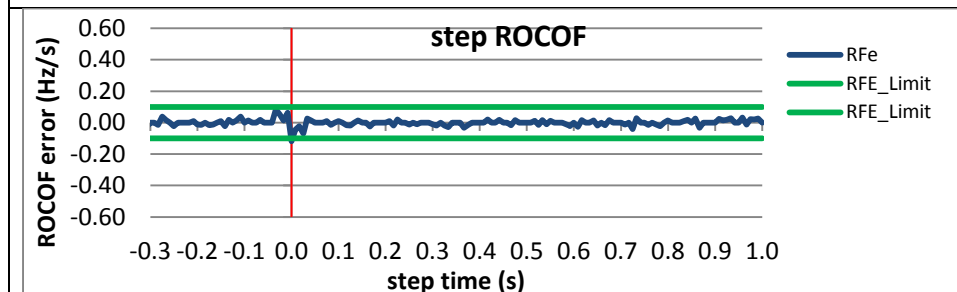


Figure 5971:  $F_s = 12$  FPS, +10% magnitude step

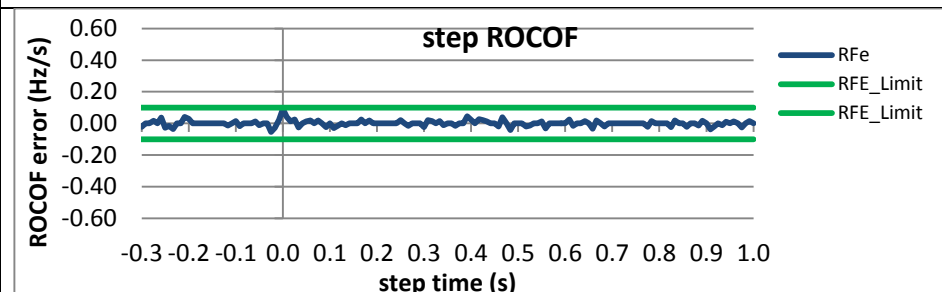


Figure 5972:  $F_s = 12$  FPS, -10% magnitude step

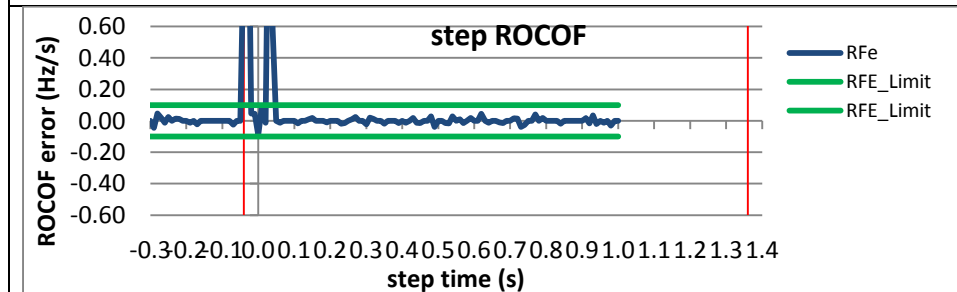


Figure 5973:  $F_s = 10$  FPS, +10% magnitude step

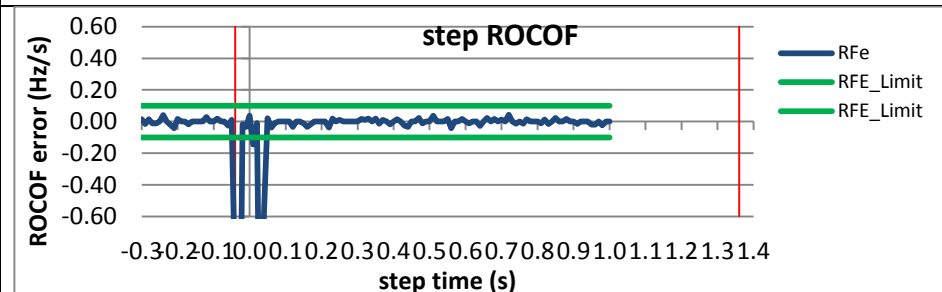


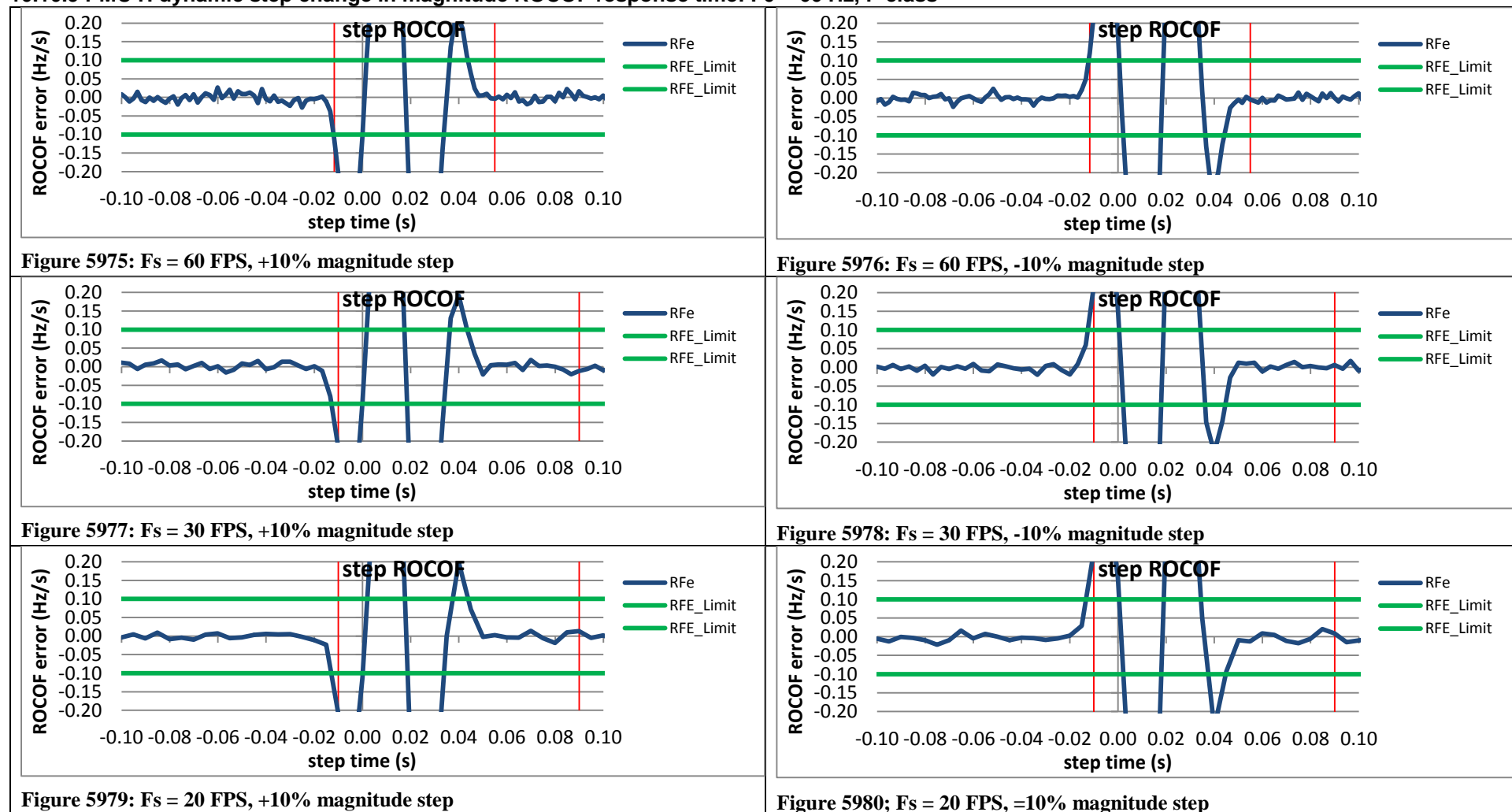
Figure 5974:  $F_s = 10$  FPS, -10% magnitude step



### 10.10.8 PMU G \* dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class

PMU G does not support P class.

### 10.10.9 PMU H dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class



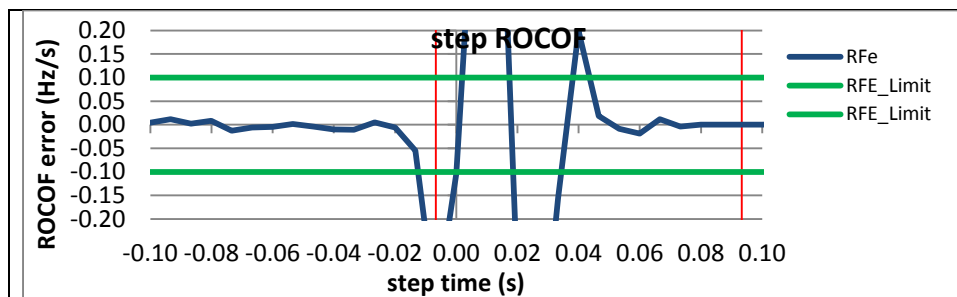


Figure 5981:  $F_s = 15$  FPS, +10% magnitude step

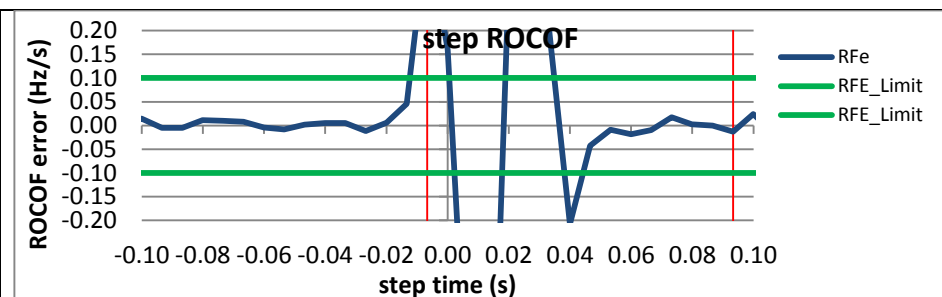


Figure 5982:  $F_s = 15$  FPS, -10% magnitude step

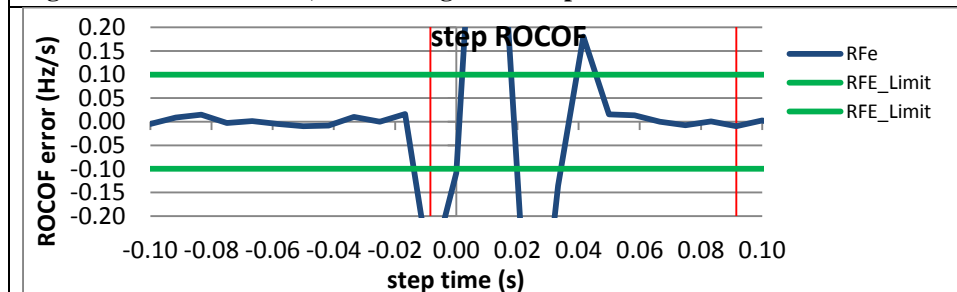


Figure 5983:  $F_s = 12$  FPS, +10% magnitude step

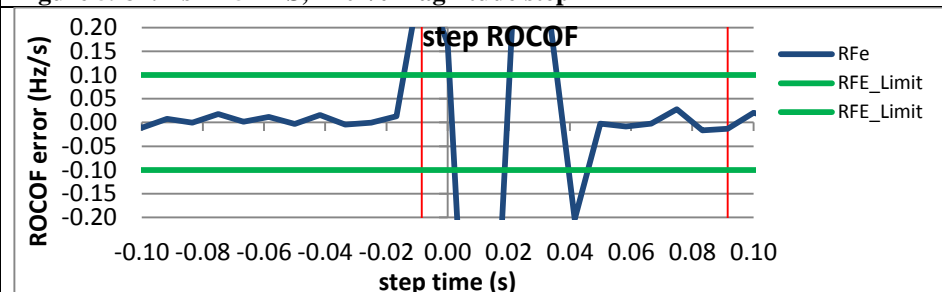


Figure 5984:  $F_s = 12$  FPS, -10% magnitude step

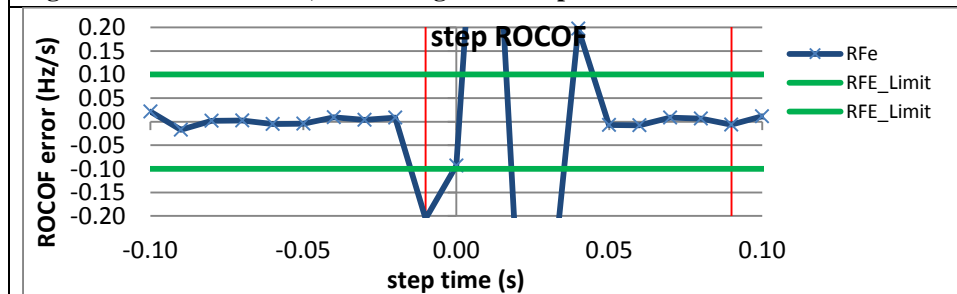


Figure 5985:  $F_s = 10$  FPS, +10% magnitude step

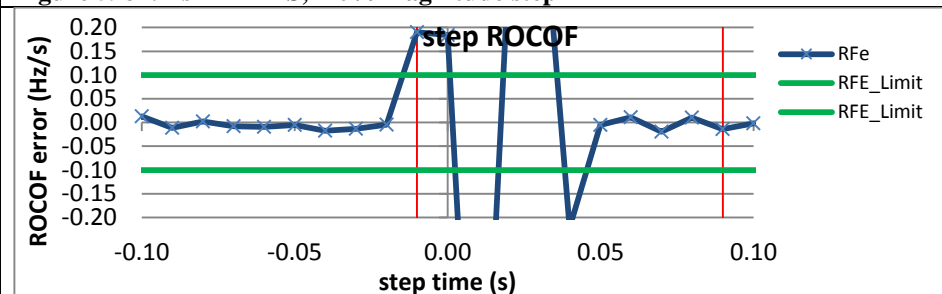
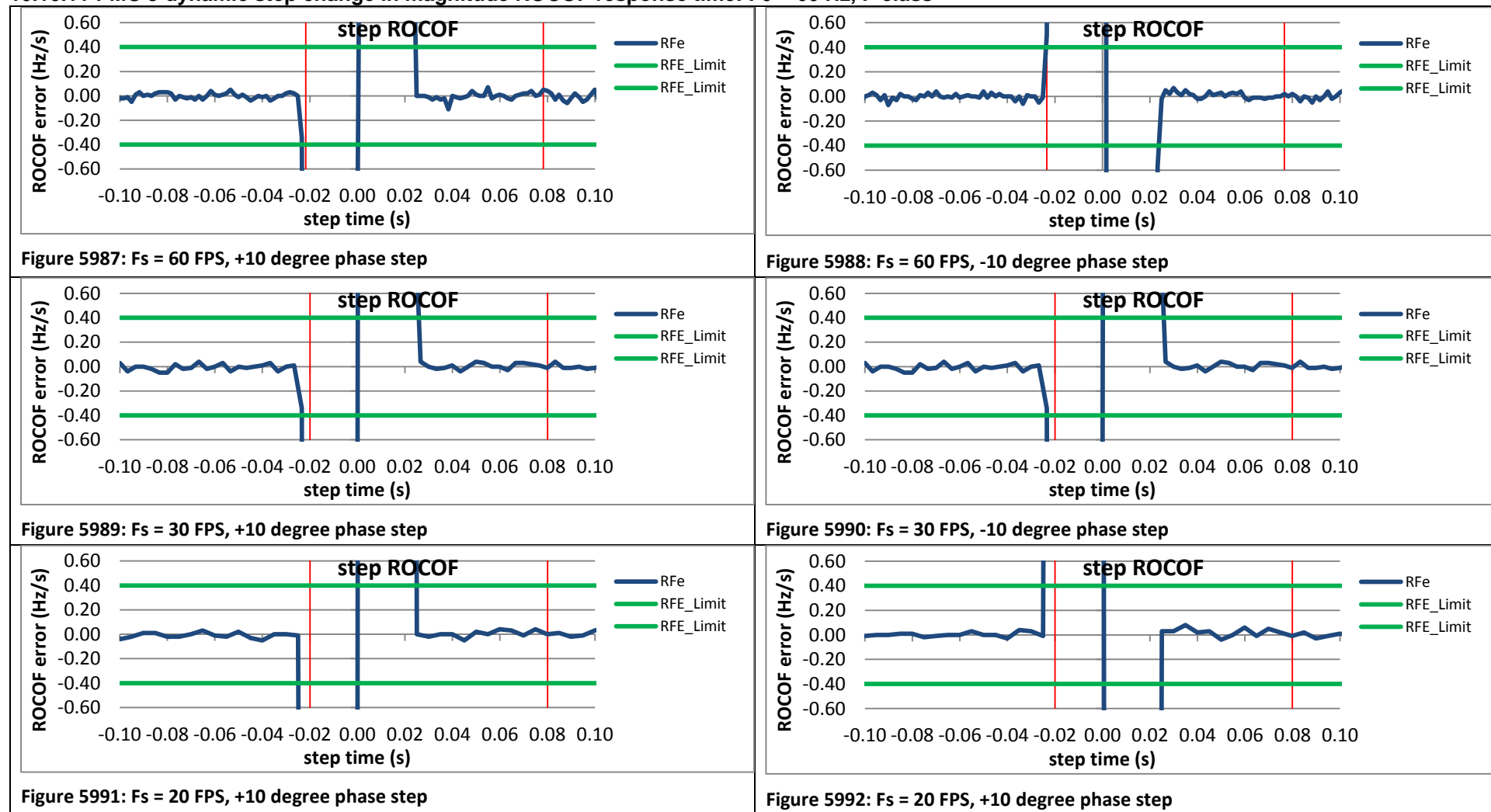


Figure 5986:  $F_s = 10$  FPS, -10% magnitude step

### 10.10.10 PMU I dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class

PMU I does not support P class

### 10.10.11 PMU J dynamic step change in magnitude ROCOF response time: F0 = 60 Hz, P class



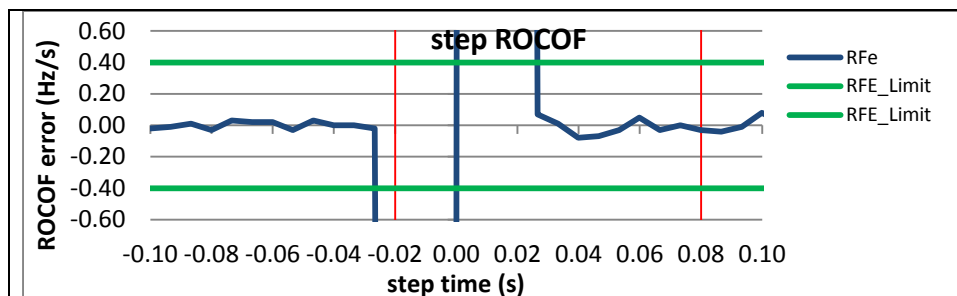


Figure 5993:  $F_s = 15$  FPS, +10 degree phase step

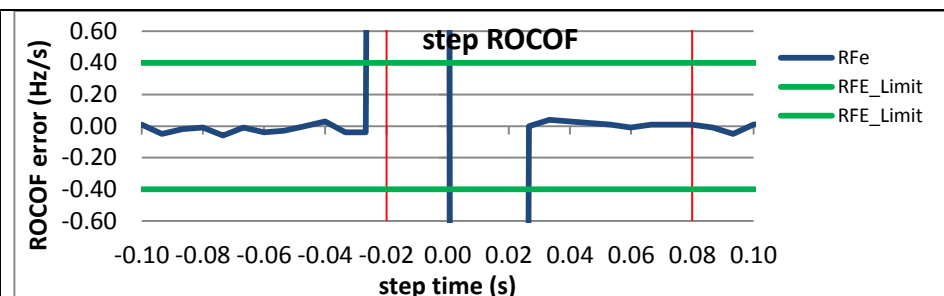


Figure 5994:  $F_s = 15$  FPS, -10 degree phase step

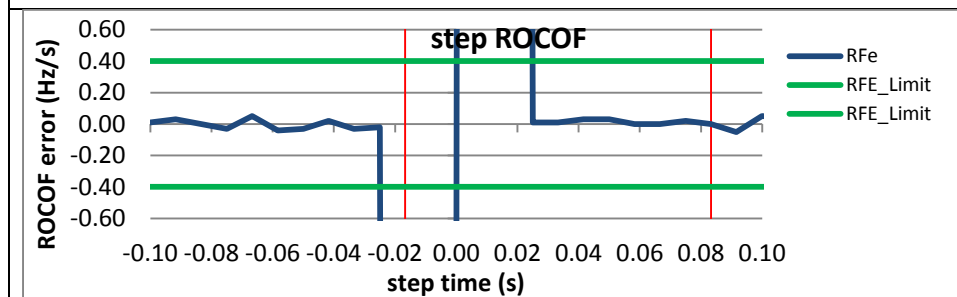


Figure 5995:  $F_s = 12$  FPS, +10 degree phase step

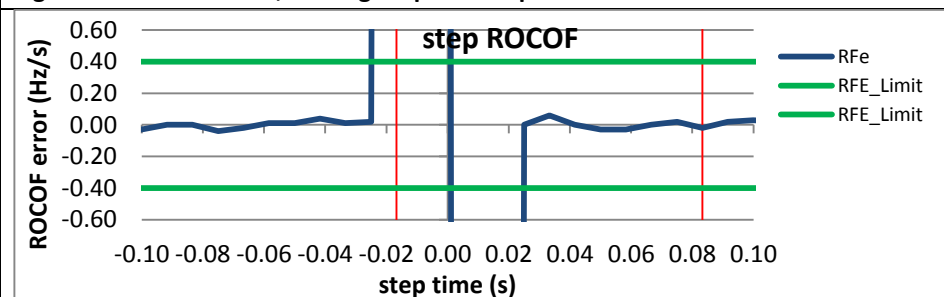


Figure 5996:  $F_s = 12$  FPS, -10 degree phase step

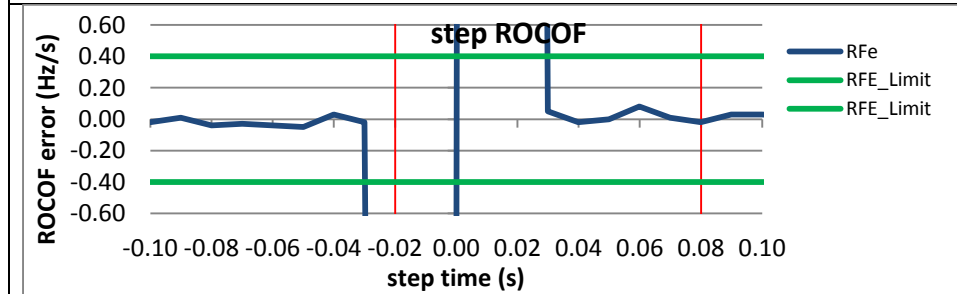


Figure 5997:  $F_s = 10$  FPS, +10 degree phase step

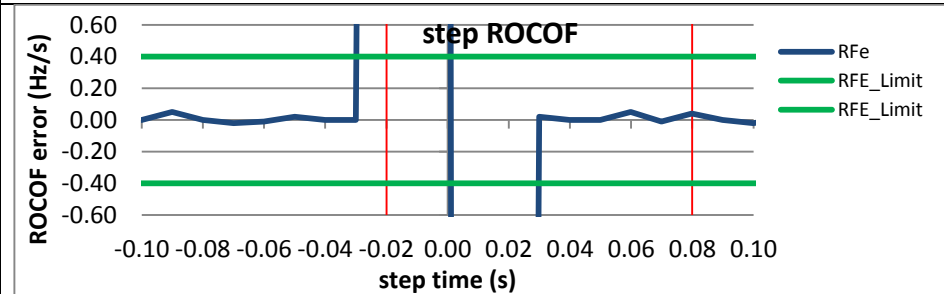


Figure 5998:  $F_s = 10$  FPS, -10 degree phase step

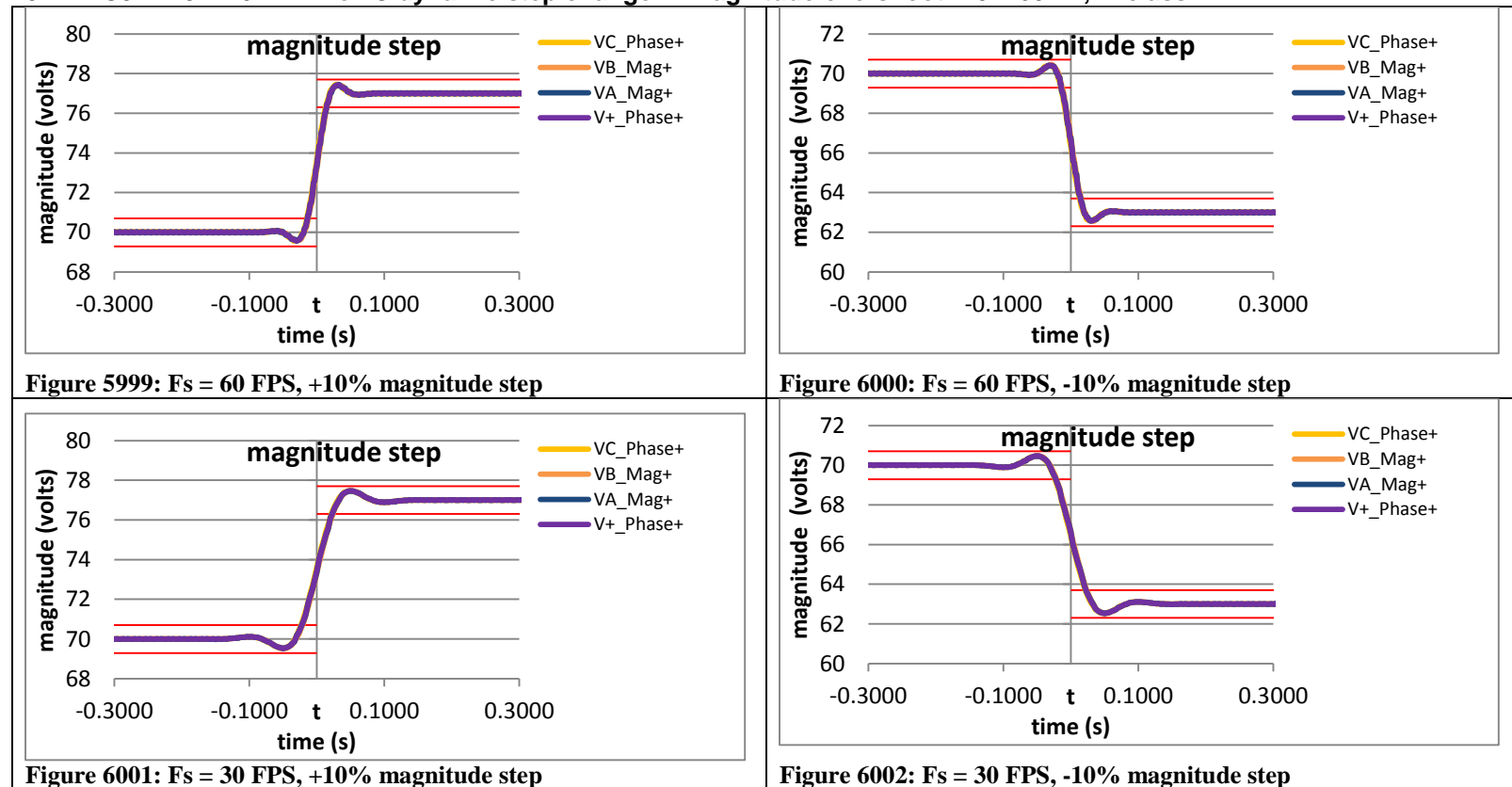
### 10.11 Dynamic step change in magnitude: phasor overshoot

Fs (FPS)	10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P
PMU A	P	P	P	P	P	P	P	P	P	P	P	P
PMU B	F	F	F	F	F	F	F	F	F	F	F	F
PMU C	P	P	P	P	P	P	P	P	P	P	P	P
PMU D	P	P	P	P	P	P	P	P	P	P	P	P
PMU E	P	-	-	-	P	-	P	-	P	-	P	-
PMU F	P	P	P	P	P	P	P	P	P	P	P	P
PMU G	I	-	I	-	I	-	I	-	I	-	-	-
PMU H	P	P	P	P	P	P	P	P	P	P	P	P
PMU I	P	-	P	-	P	-	P	-	P	-	P	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P

### 10.12 Dynamic step change in magnitude: phasor delay time

Fs (FPS)	10M	10P	12M	12P	15M	15P	20M	20P	30M	30P	60M	60P
C37.118.1 Annex C	P	P	P	P	P	P	P	P	P	P	P	P
PMU A	P	P	P	P	P	P	P	P	P	P	P	P
PMU B	P	P	P	P	P	P	P	P	P	P	P	P
PMU C	P	P	P	P	P	P	P	P	P	P	P	P
PMU D	P	P	P	P	P	P	P	P	P	P	P	P
PMU E	P	-	-	-	P	-	P	-	P	-	P	-
PMU F	P	P	P	P	P	P	P	P	P	P	P	P
PMU G	F	-	F	-	F	-	F	-	F	-	-	-
PMU H	P	P	P	P	P	P	P	P	P	P	P	P
PMU I	P	-	P	-	P	-	P	-	P	-	P	-
PMU J	P	P	P	P	P	P	P	P	P	P	P	P

# 10.12.1 C37.118.1-2011 Annex C dynamic step change in magnitude overshoot: F0 = 60 Hz, M class



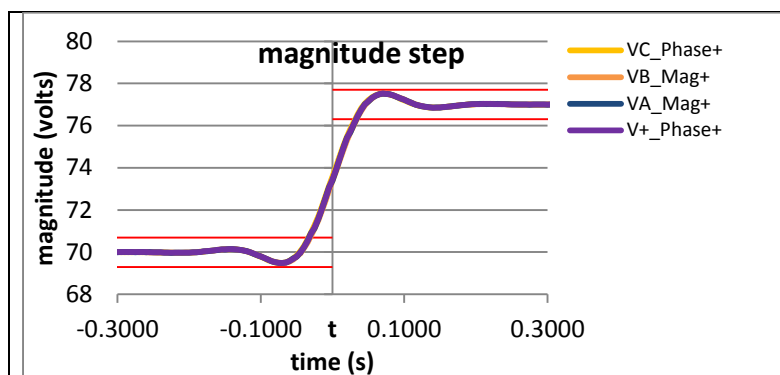


Figure 6003: Fs = 20 FPS, +10% magnitude step

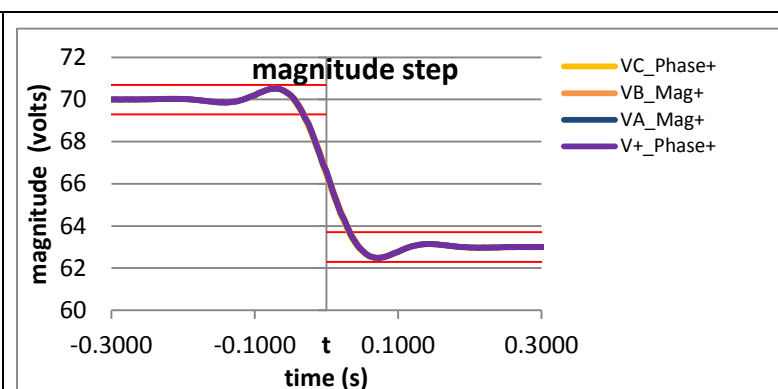


Figure 6004: Fs = 20 FPS, -10% magnitude step

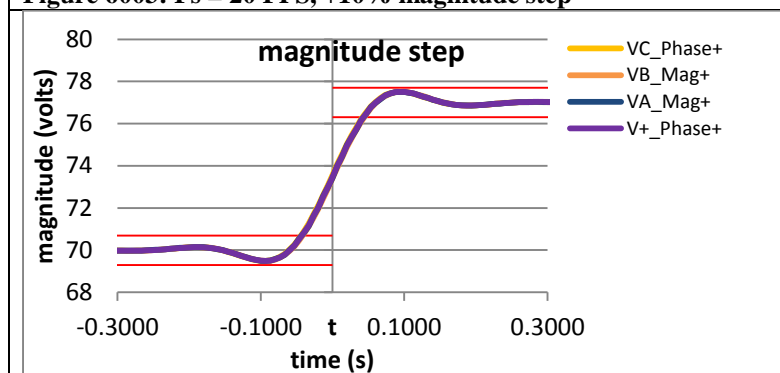


Figure 6005: Fs = 15 FPS, + 10% magnitude step

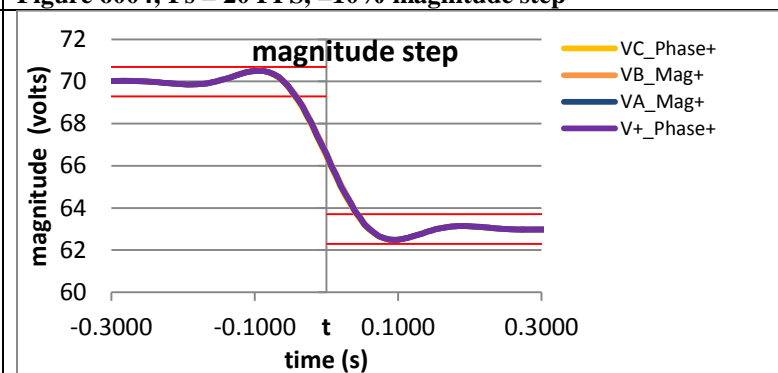


Figure 6006: Fs = 15 FPS, - 10 % magnitude step

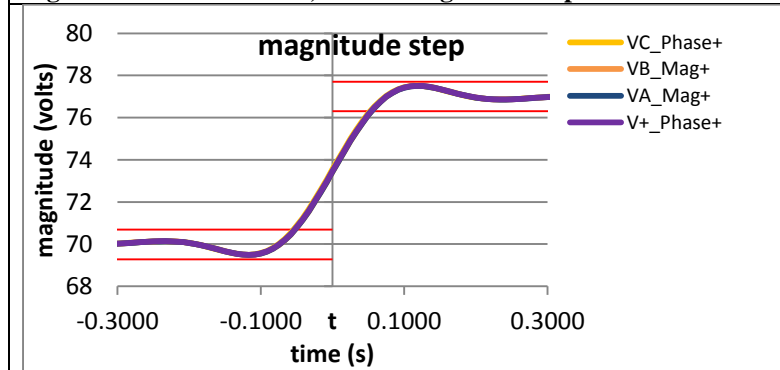


Figure 6007: Fs = 12 FPS, +10% magnitude step

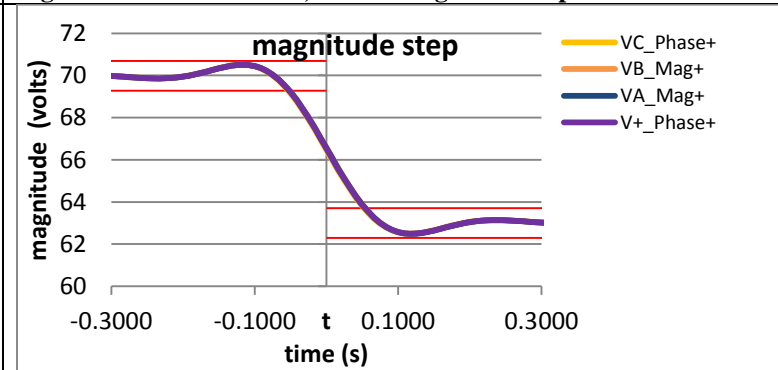


Figure 6008: Fs = 12 FPS, -10% magnitude step

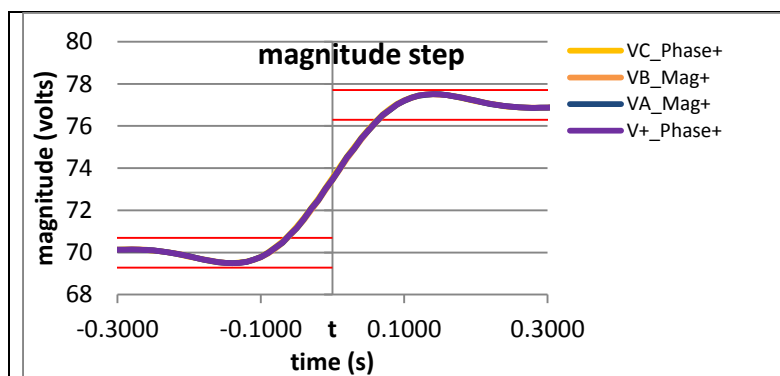


Figure 6009:  $F_s = 10$  FPS, +10% magnitude step

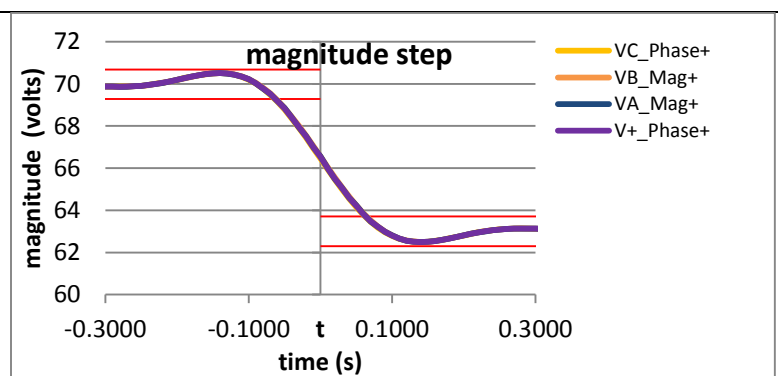


Figure 6010:  $F_s = 10$  FPS, -10% magnitude step



### 10.12.2 PMU A dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, M class

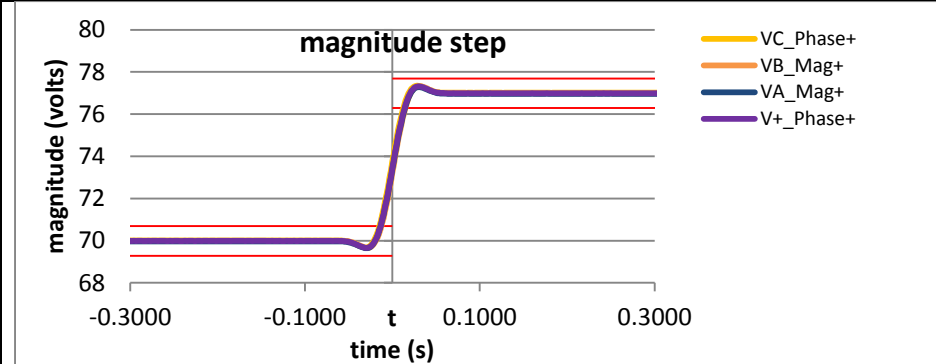


Figure 6011: Fs = 60 FPS, +10% magnitude step

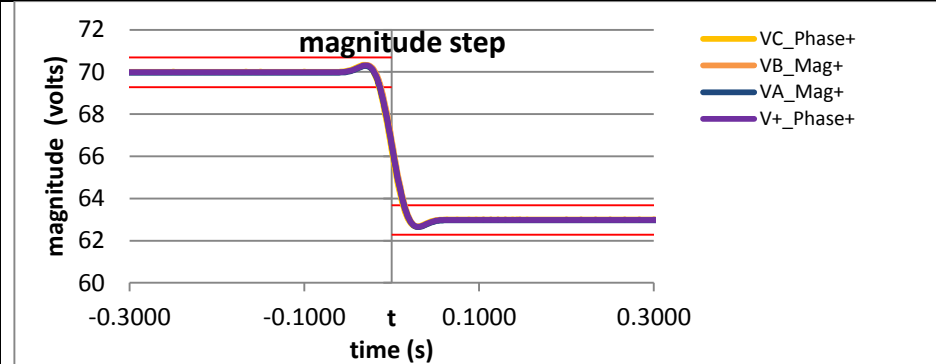


Figure 6012: Fs = 60 FPS, -10% magnitude step

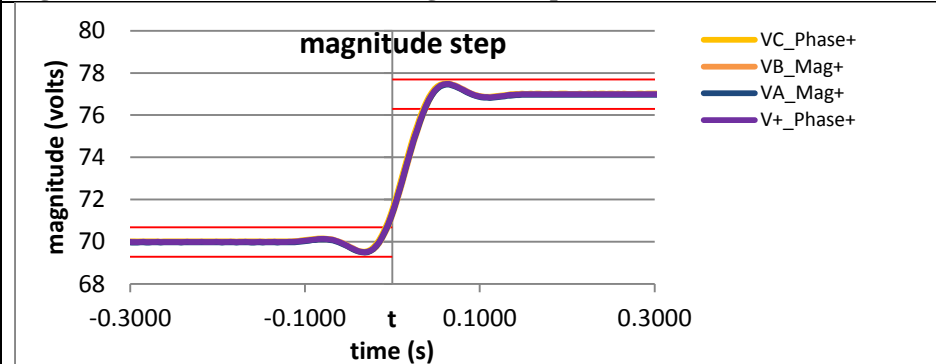


Figure 6013: Fs = 30 FPS, +10% magnitude step

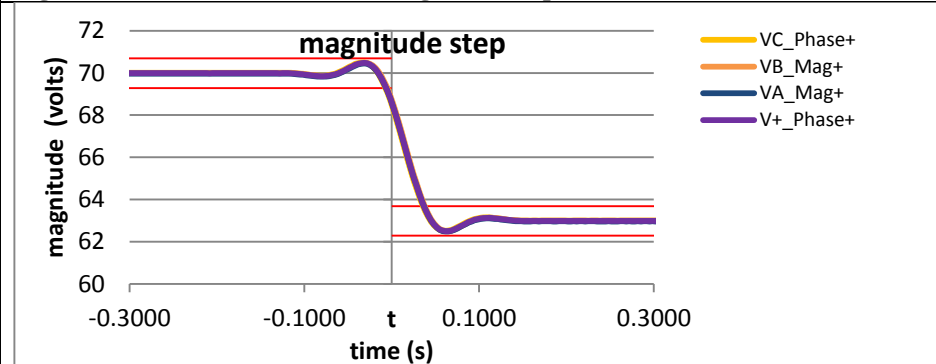


Figure 6014: Fs = 30 FPS, -10% magnitude step

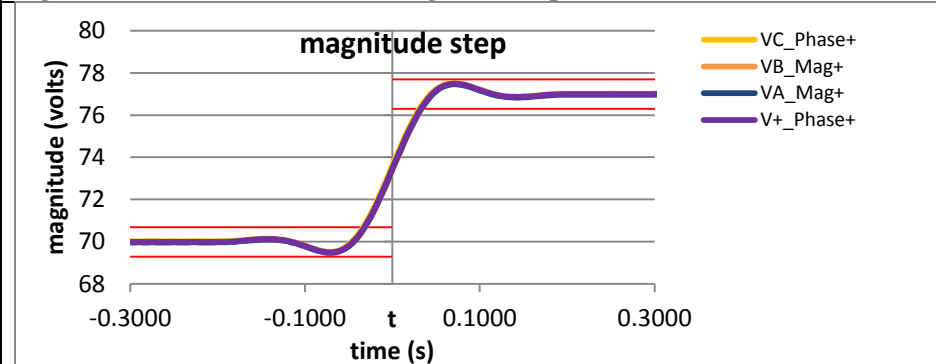


Figure 6015: Fs = 20 FPS, +10% magnitude step

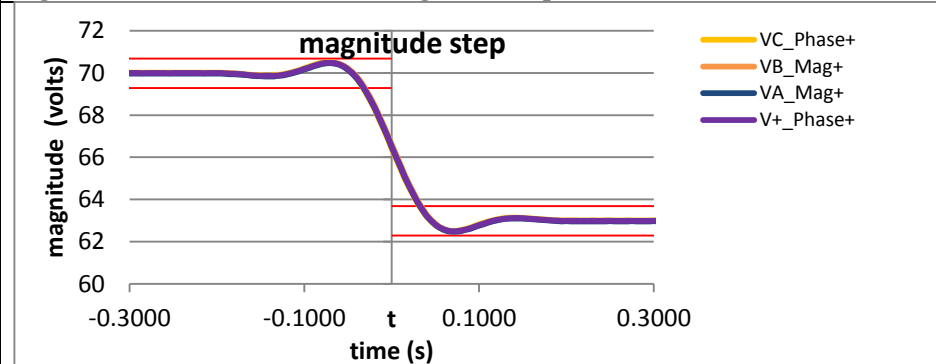


Figure 6016: Fs = 20 FPS, -10% magnitude step

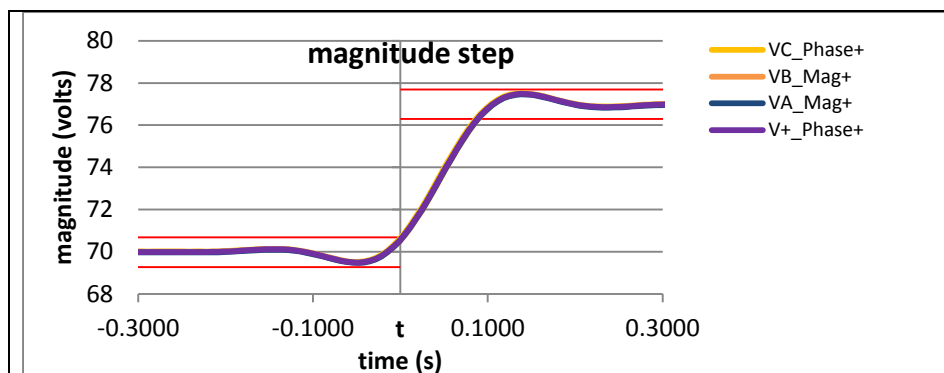


Figure 6017: Fs = 15 FPS, + 10% magnitude step

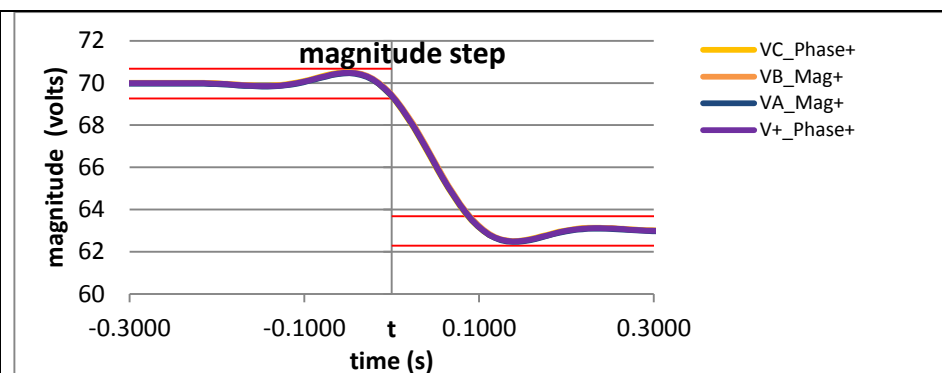


Figure 6018: Fs = 15 FPS, - 10 % magnitude step

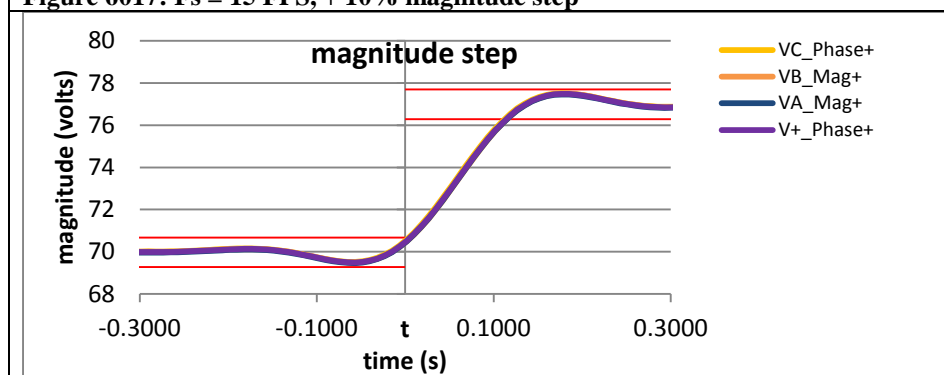


Figure 6019: Fs = 12 FPS, +10% magnitude step

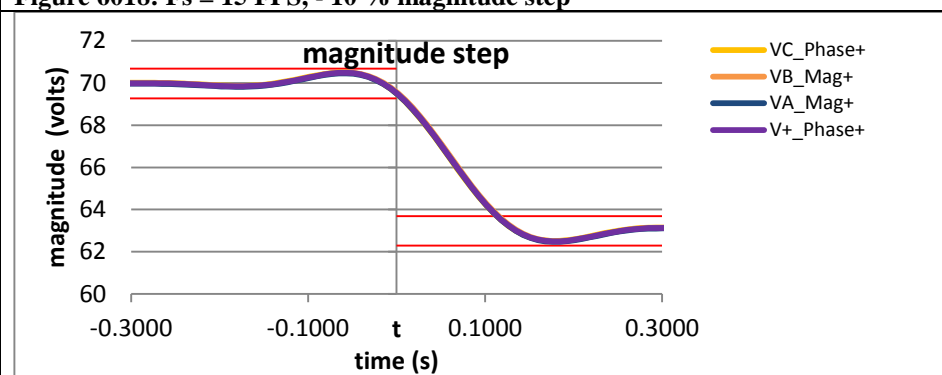


Figure 6020: Fs = 12 FPS, -10% magnitude step

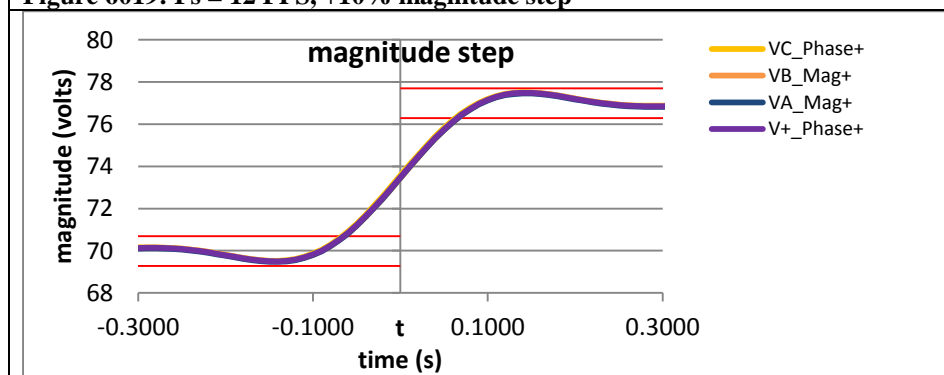


Figure 6021: Fs = 10 FPS, +10% magnitude step

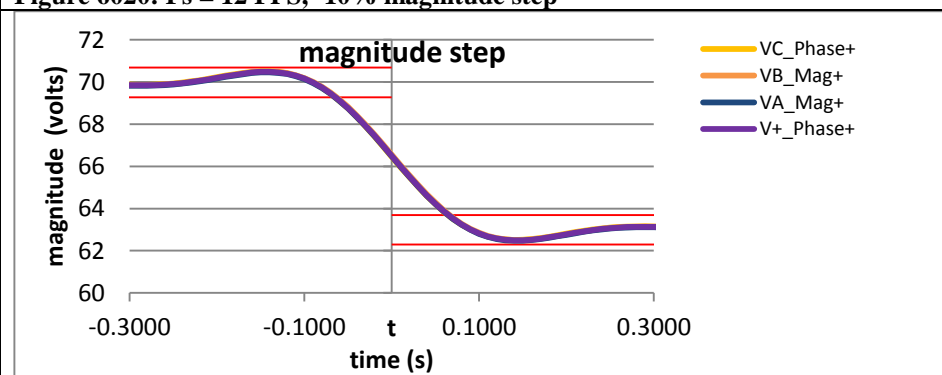


Figure 6022: Fs = 10 FPS, -10% magnitude step

### 10.12.3 PMU B dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, M class

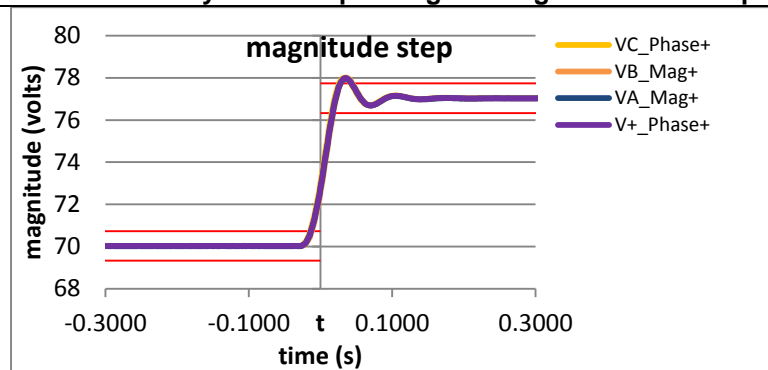


Figure 6023: Fs = 60 FPS, +10% magnitude step

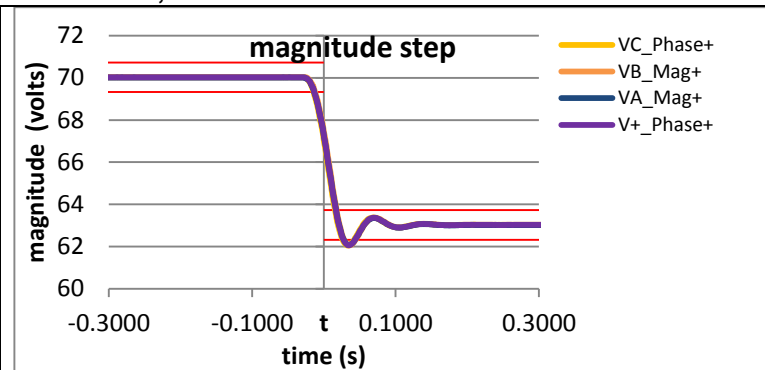


Figure 6024: Fs = 60 FPS, -10% magnitude step

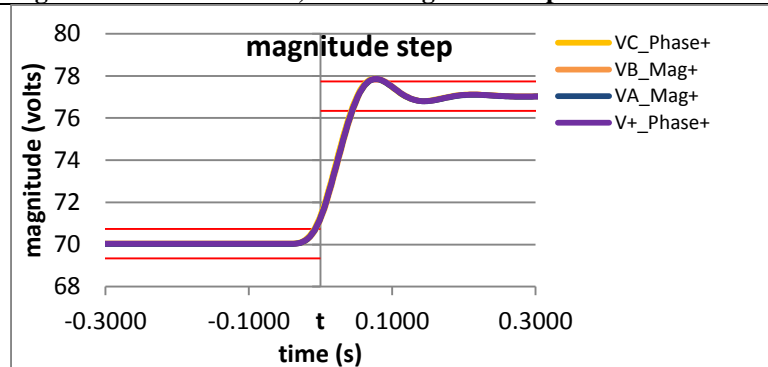


Figure 6025: Fs = 30 FPS, +10% magnitude step

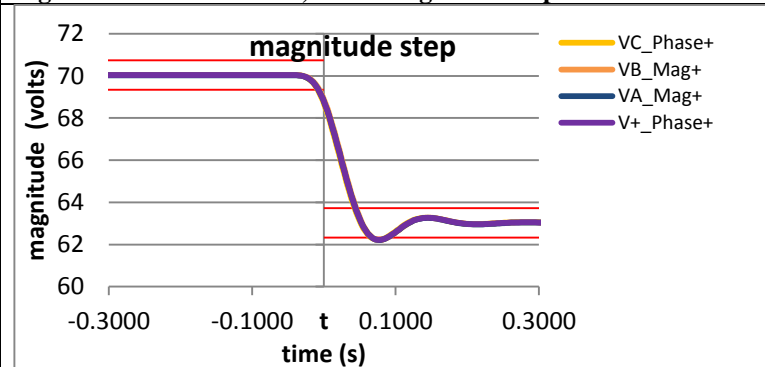


Figure 6026: Fs = 30 FPS, -10% magnitude step

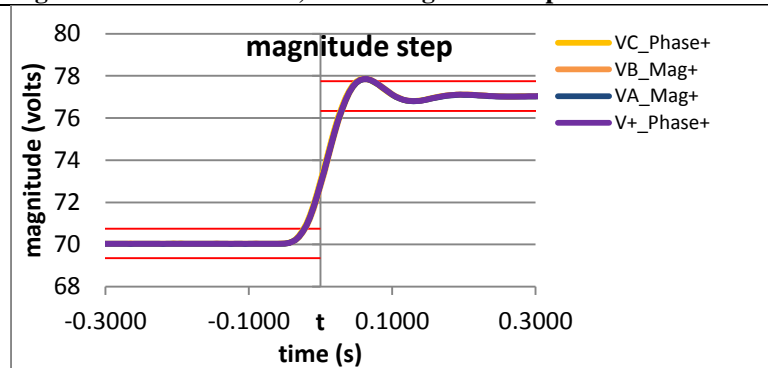


Figure 6027: Fs = 20 FPS, +10% magnitude step

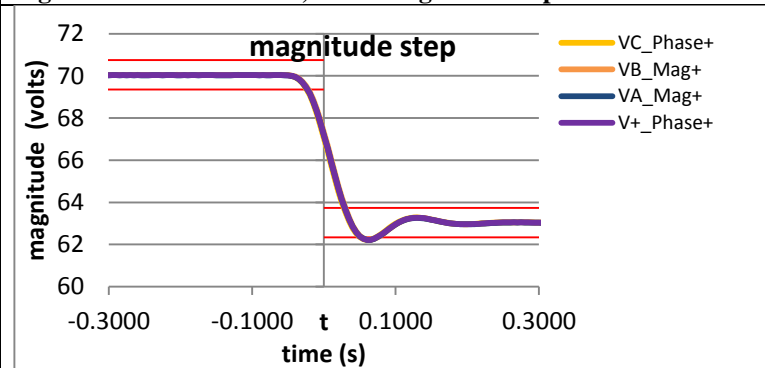


Figure 6028: Fs = 20 FPS, -10% magnitude step

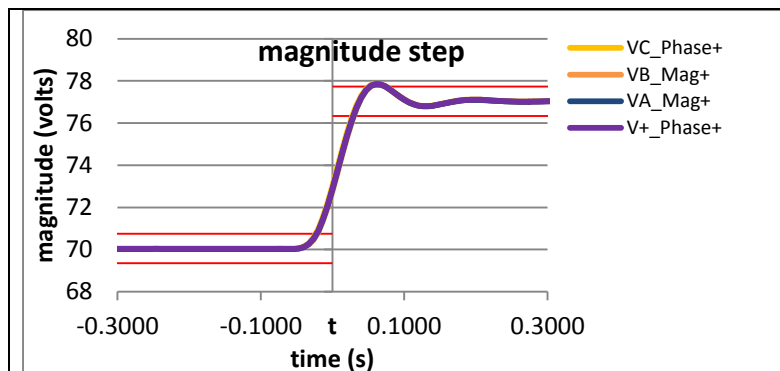


Figure 6029:  $F_s = 15$  FPS, + 10% magnitude step

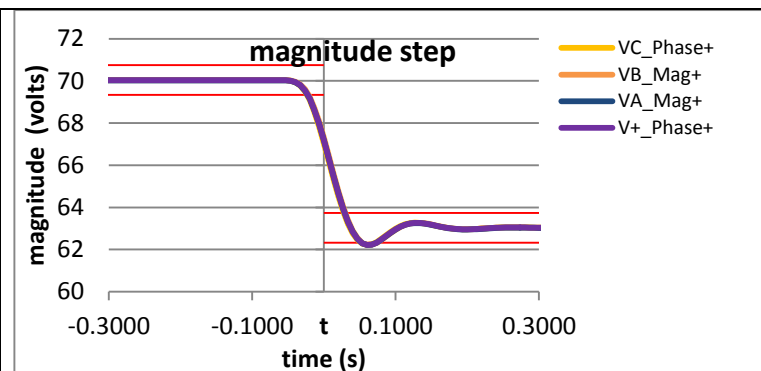


Figure 6030:  $F_s = 15$  FPS, - 10 % magnitude step

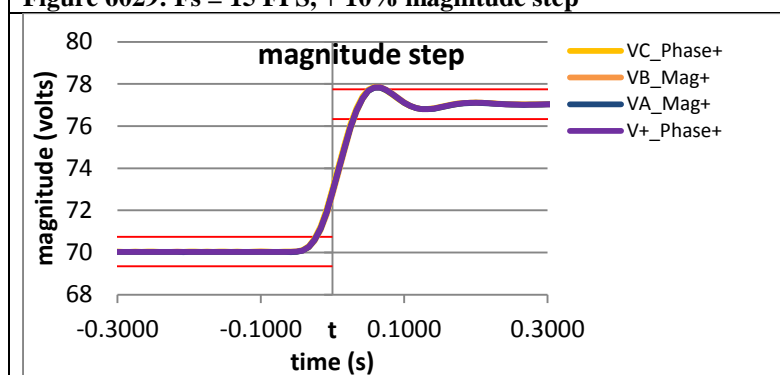


Figure 6031:  $F_s = 12$  FPS, +10% magnitude step

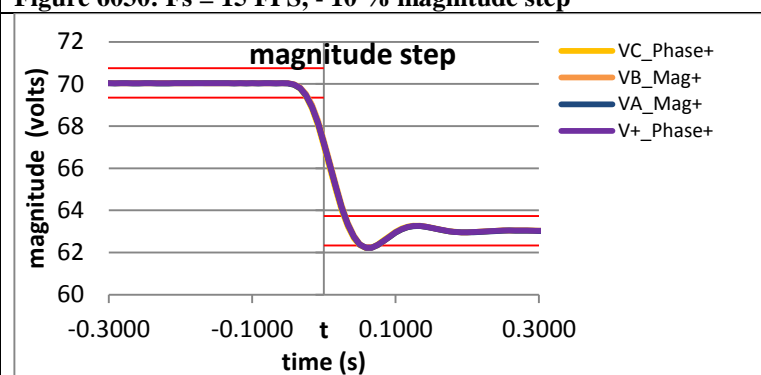


Figure 6032:  $F_s = 12$  FPS, -10% magnitude step

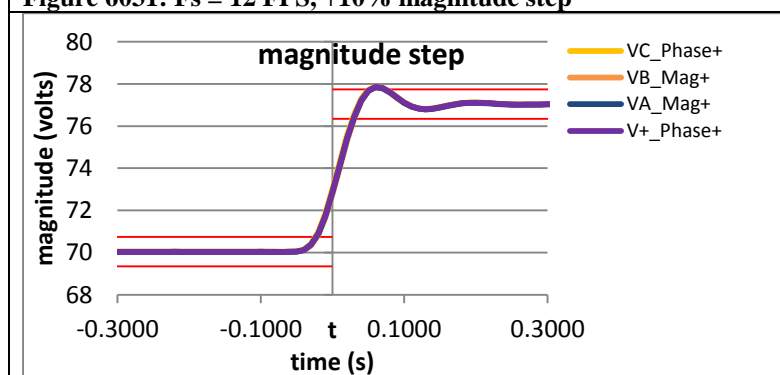


Figure 6033:  $F_s = 10$  FPS, +10% magnitude step

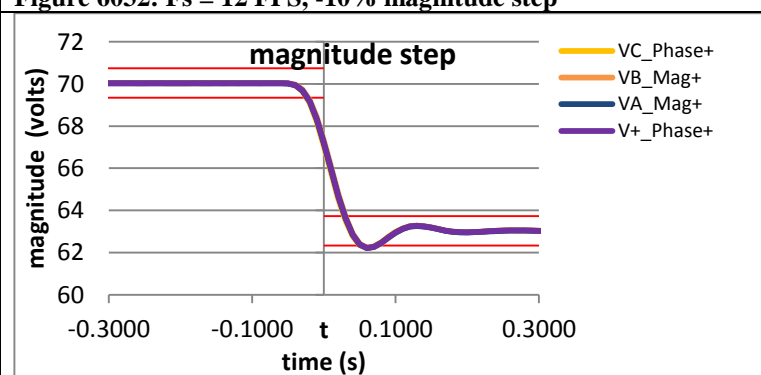


Figure 6034:  $F_s = 10$  FPS, -10% magnitude step

#### 10.12.4 PMU C dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, M class

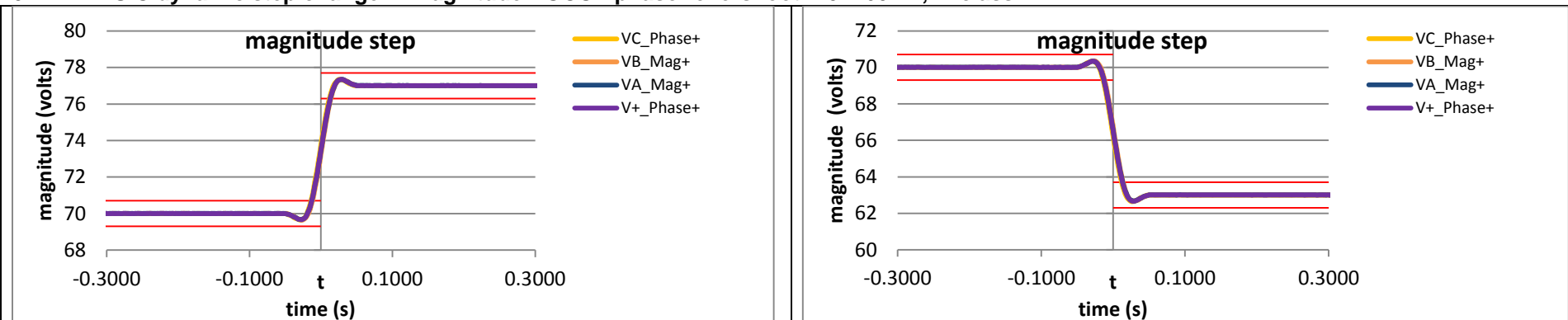


Figure 6035: Fs = 60 FPS, +10% magnitude step

Figure 6036: Fs = 60 FPS, -10% magnitude step

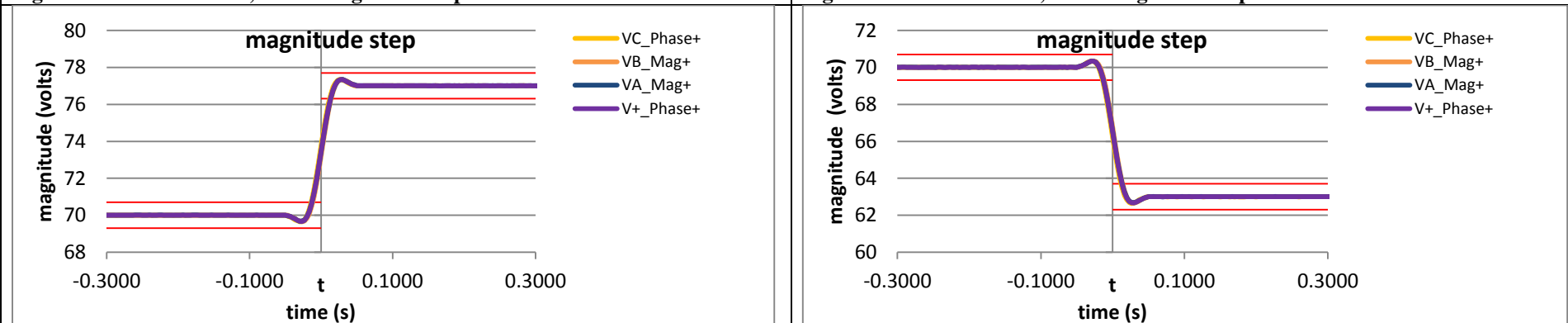


Figure 6037: Fs = 30 FPS, +10% magnitude step

Figure 6038: Fs = 30 FPS, -10% magnitude step

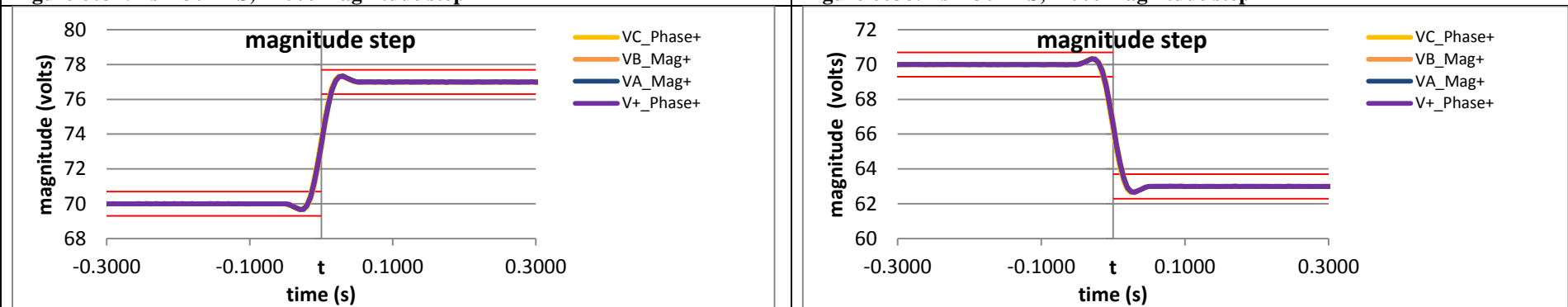


Figure 6039:  $F_s = 20$  FPS, +10% magnitude step

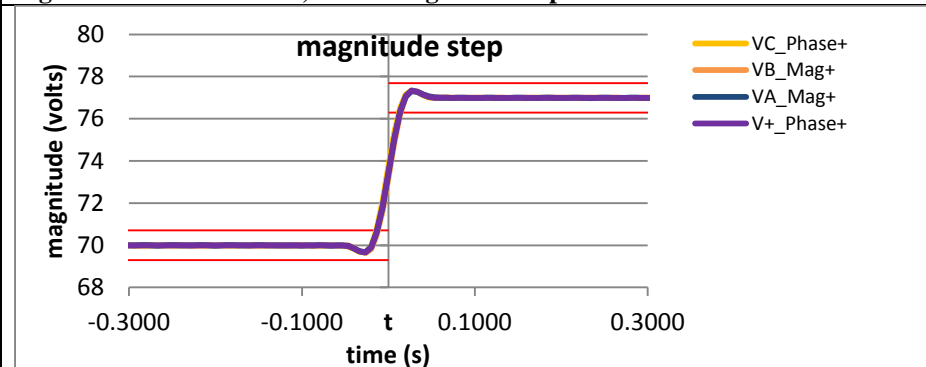


Figure 6040:  $F_s = 20$  FPS, -10% magnitude step

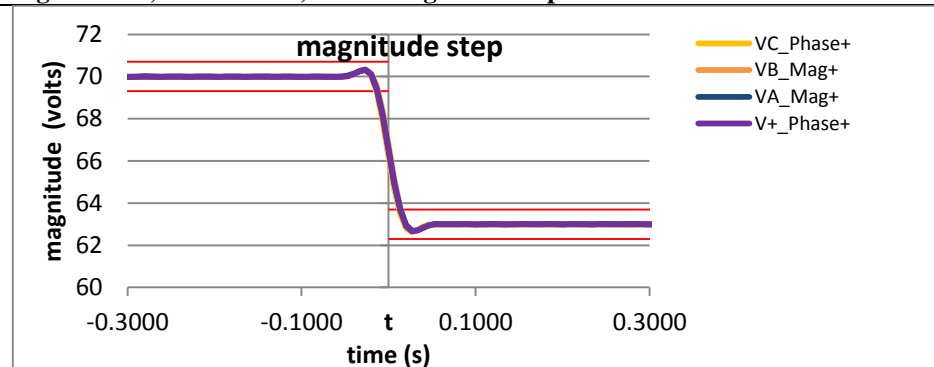


Figure 6041:  $F_s = 15$  FPS, + 10% magnitude step

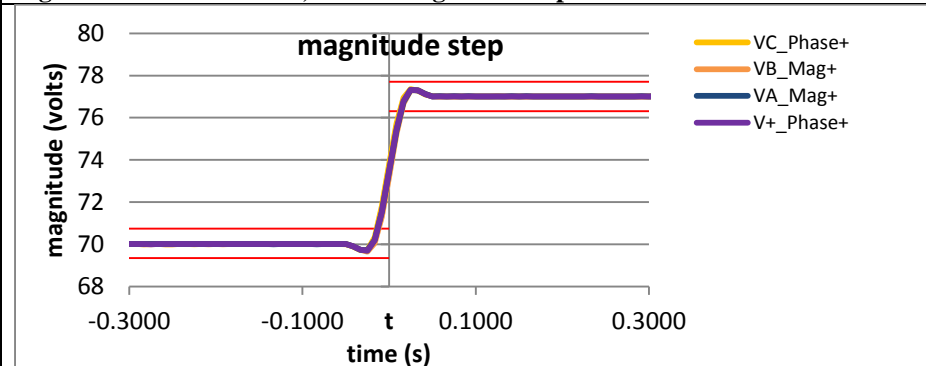


Figure 6042:  $F_s = 15$  FPS, - 10 % magnitude step

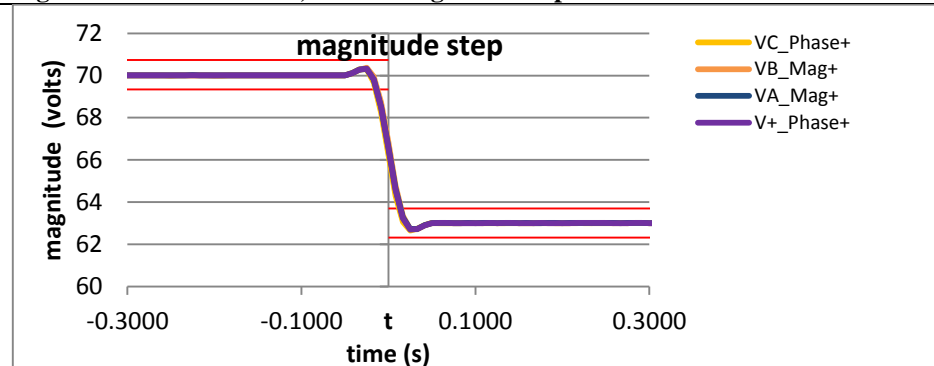


Figure 6043:  $F_s = 12$  FPS, +10% magnitude step

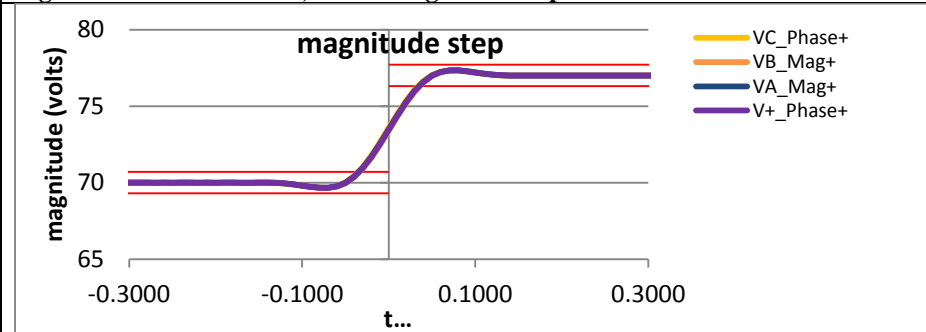


Figure 6044:  $F_s = 12$  FPS, -10% magnitude step

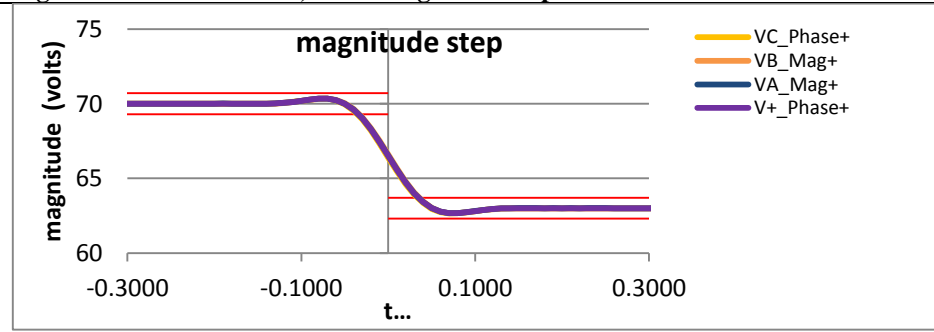


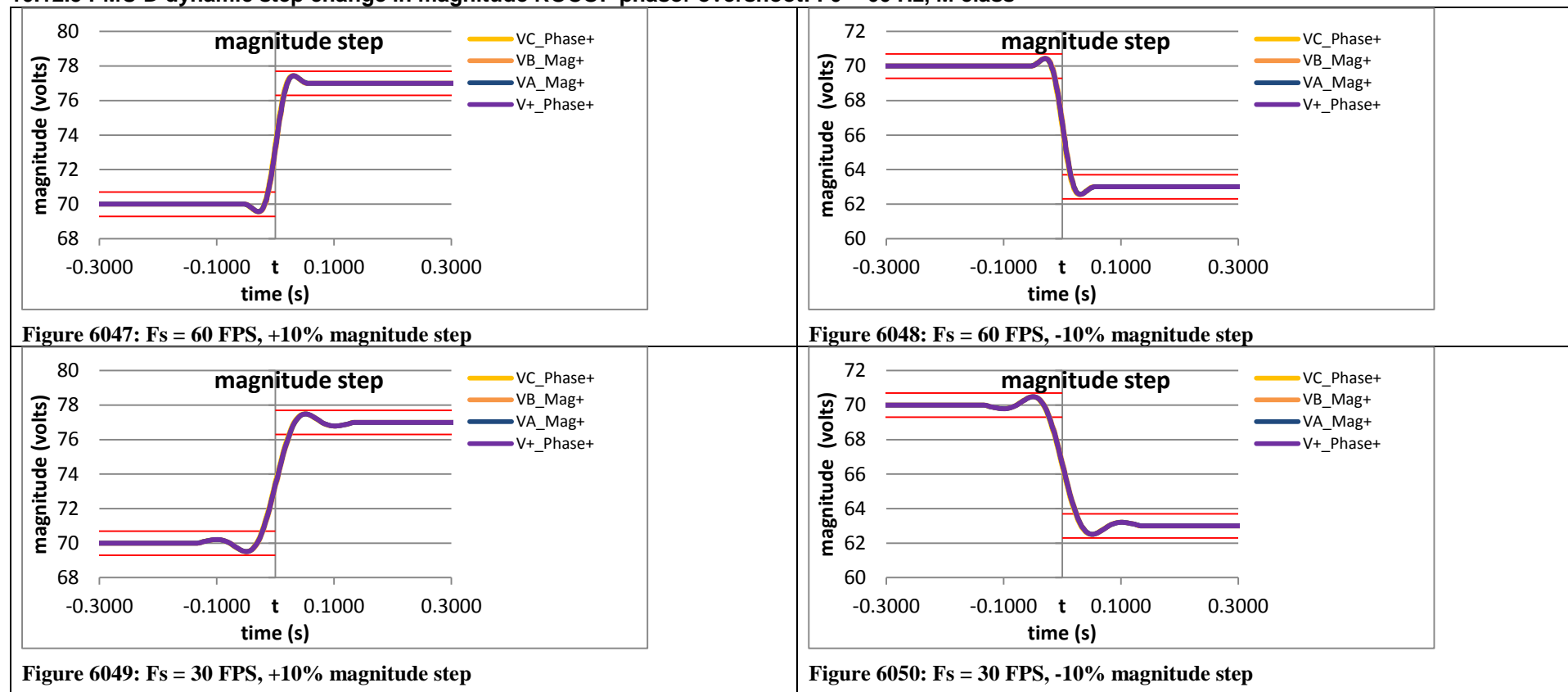
Figure 6045:  $F_s = 10$  FPS, +10% magnitude step



Figure 6046:  $F_s = 10$  FPS, -10% magnitude step



### 10.12.5 PMU D dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, M class



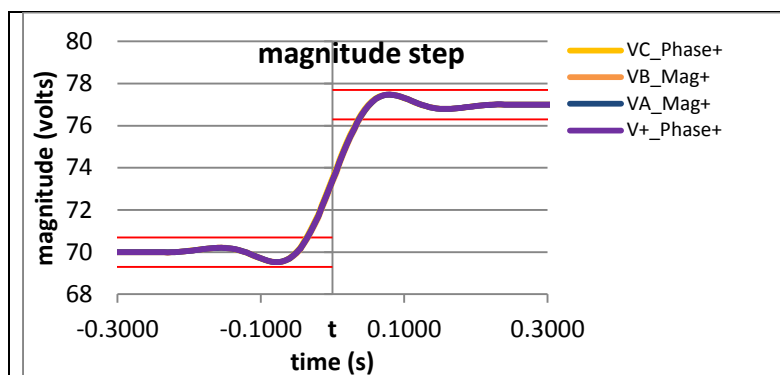


Figure 6051: Fs = 20 FPS, +10% magnitude step

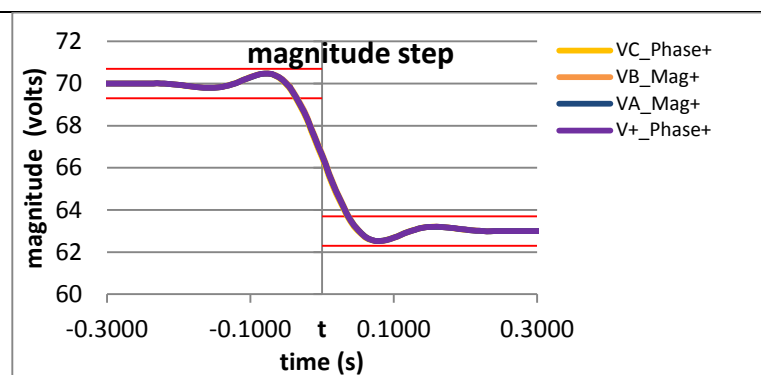


Figure 6052: Fs = 20 FPS, -10% magnitude step

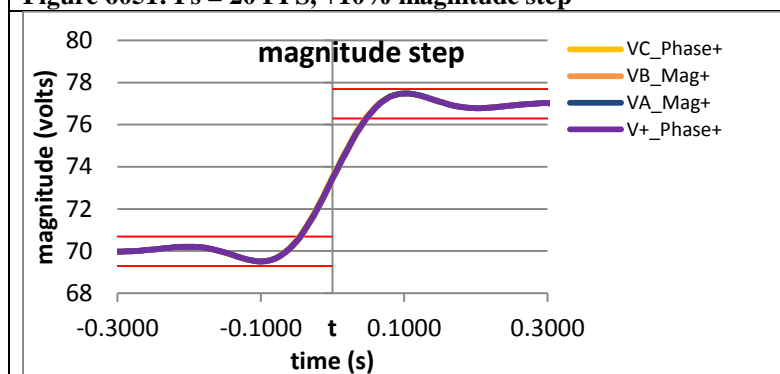


Figure 6053: Fs = 15 FPS, + 10% magnitude step

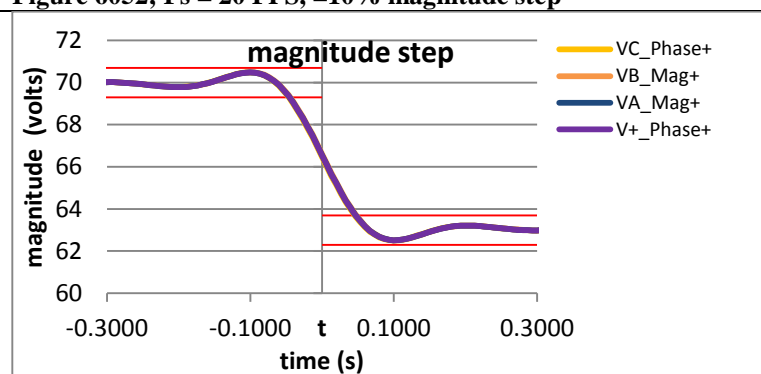


Figure 6054: Fs = 15 FPS, - 10 % magnitude step

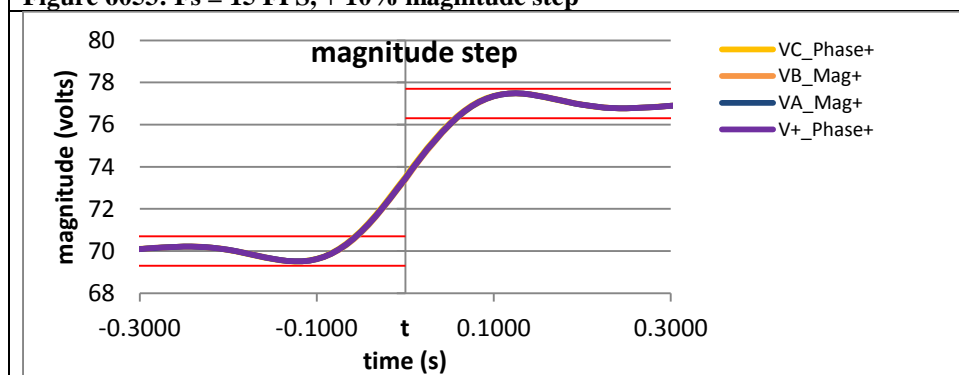


Figure 6055: Fs = 12 FPS, +10% magnitude step

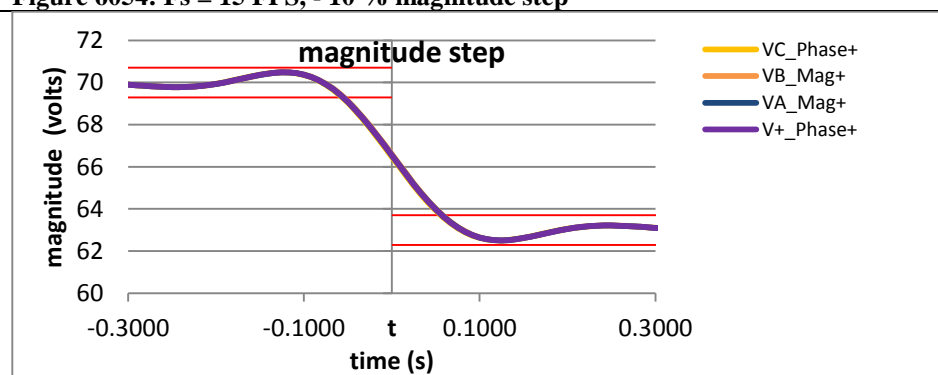
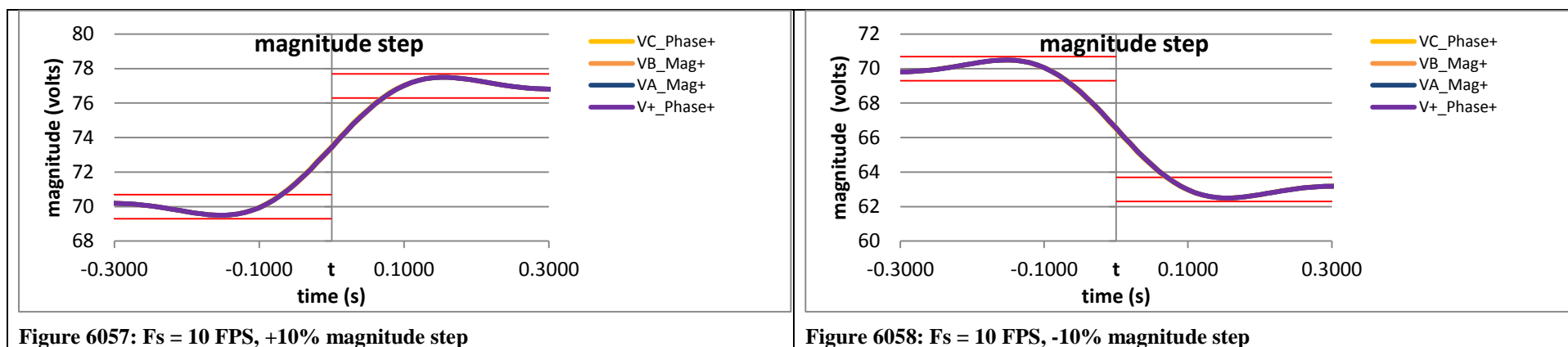


Figure 6056: Fs = 12 FPS, -10% magnitude step





### 10.12.6 PMU E dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, M class

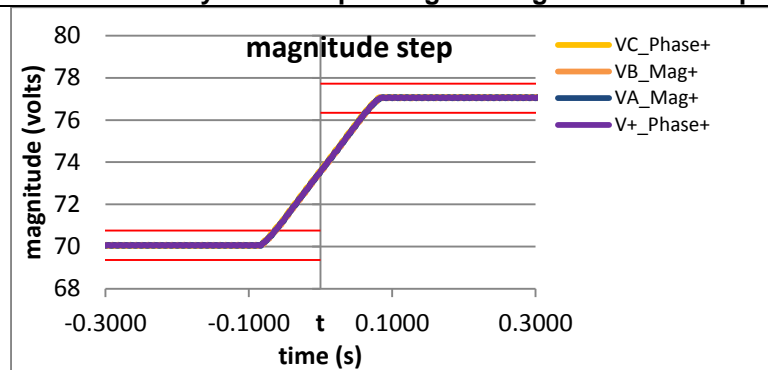


Figure 6059: Fs = 60 FPS, +10% magnitude step

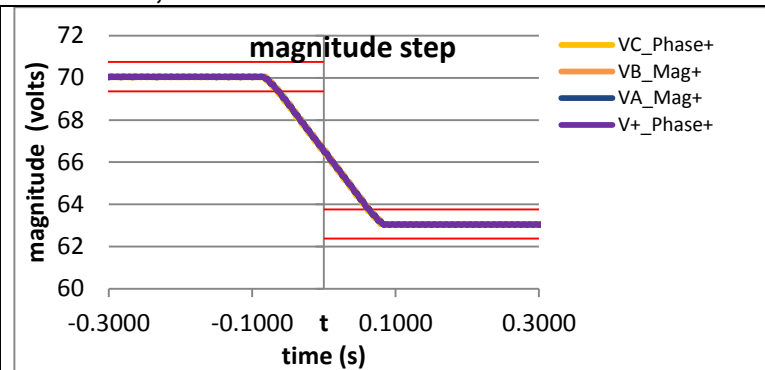


Figure 6060: Fs = 60 FPS, -10% magnitude step

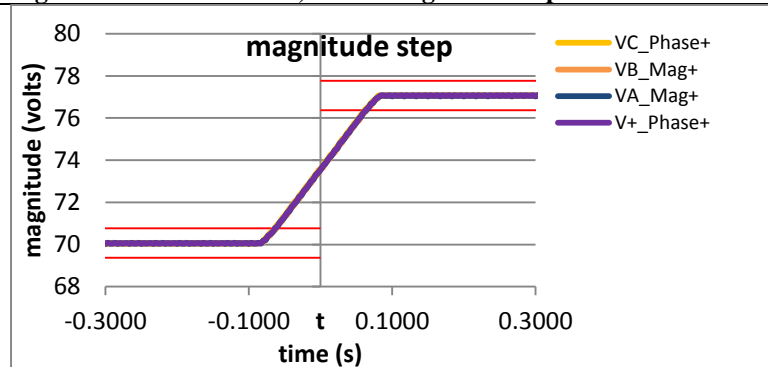


Figure 6061: Fs = 30 FPS, +10% magnitude step

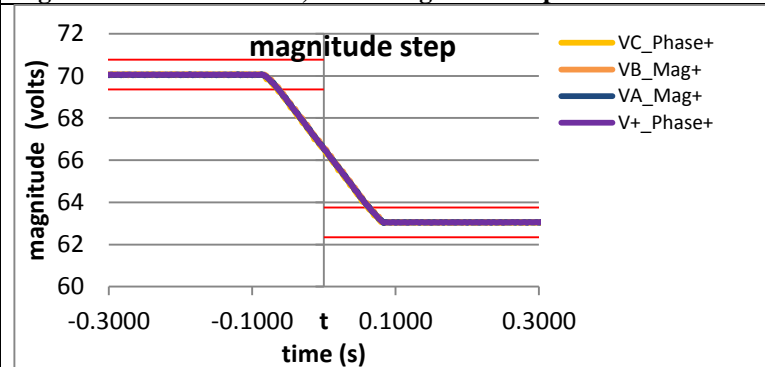


Figure 6062: Fs = 30 FPS, -10% magnitude step

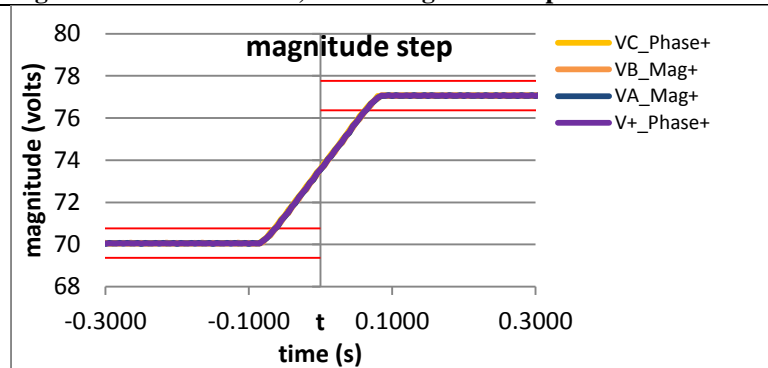


Figure 6063: Fs = 20 FPS, +10% magnitude step

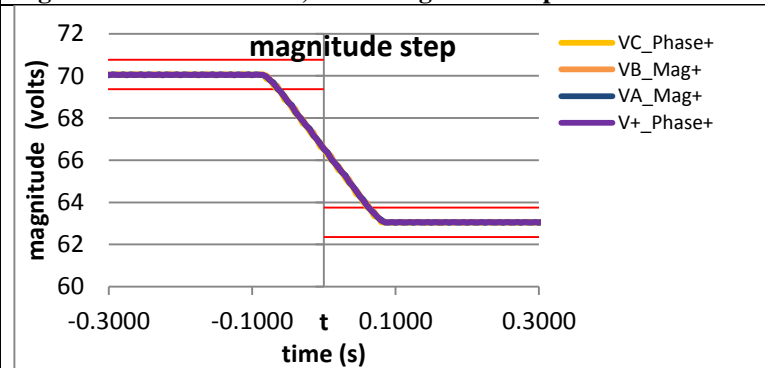


Figure 6064: Fs = 20 FPS, -10% magnitude step

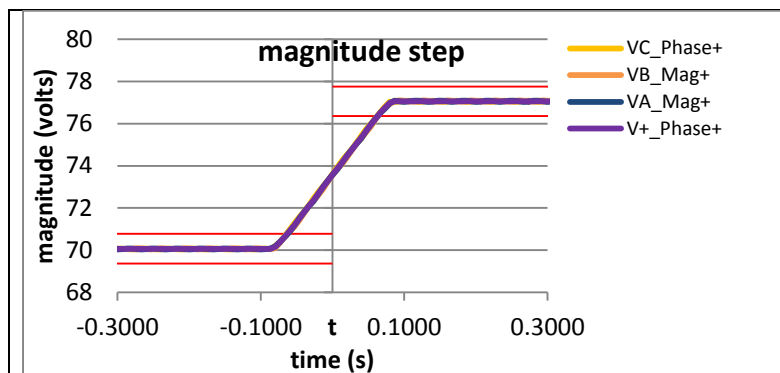


Figure 6065: Fs = 15 FPS, + 10% magnitude step

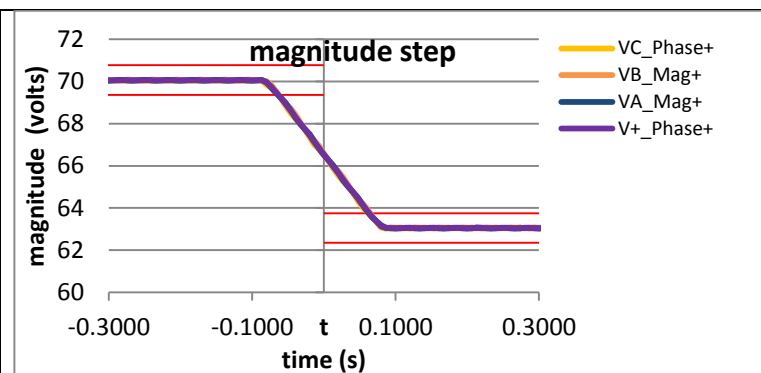


Figure 6066: Fs = 15 FPS, - 10 % magnitude step

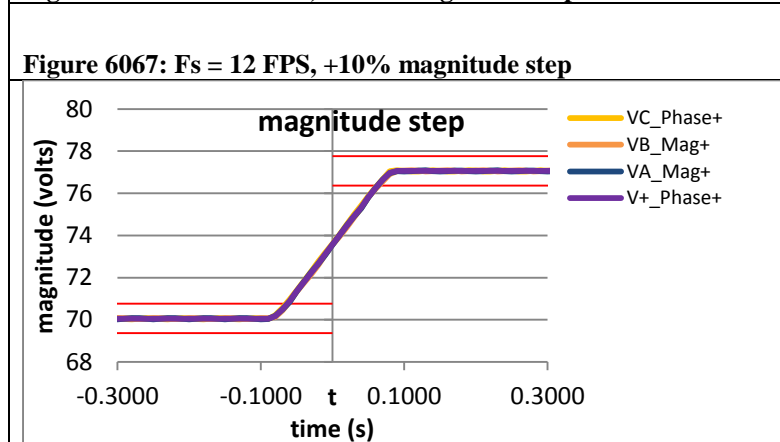


Figure 6067: Fs = 12 FPS, +10% magnitude step

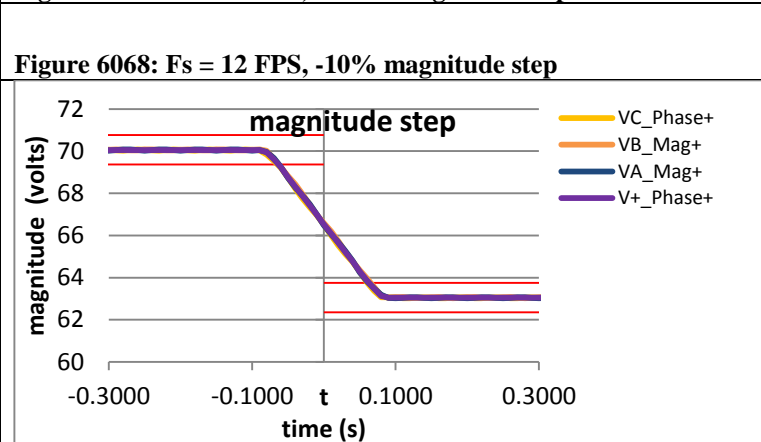


Figure 6068: Fs = 12 FPS, -10% magnitude step

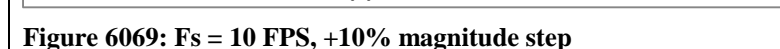


Figure 6069: Fs = 10 FPS, +10% magnitude step

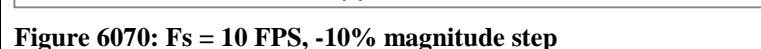
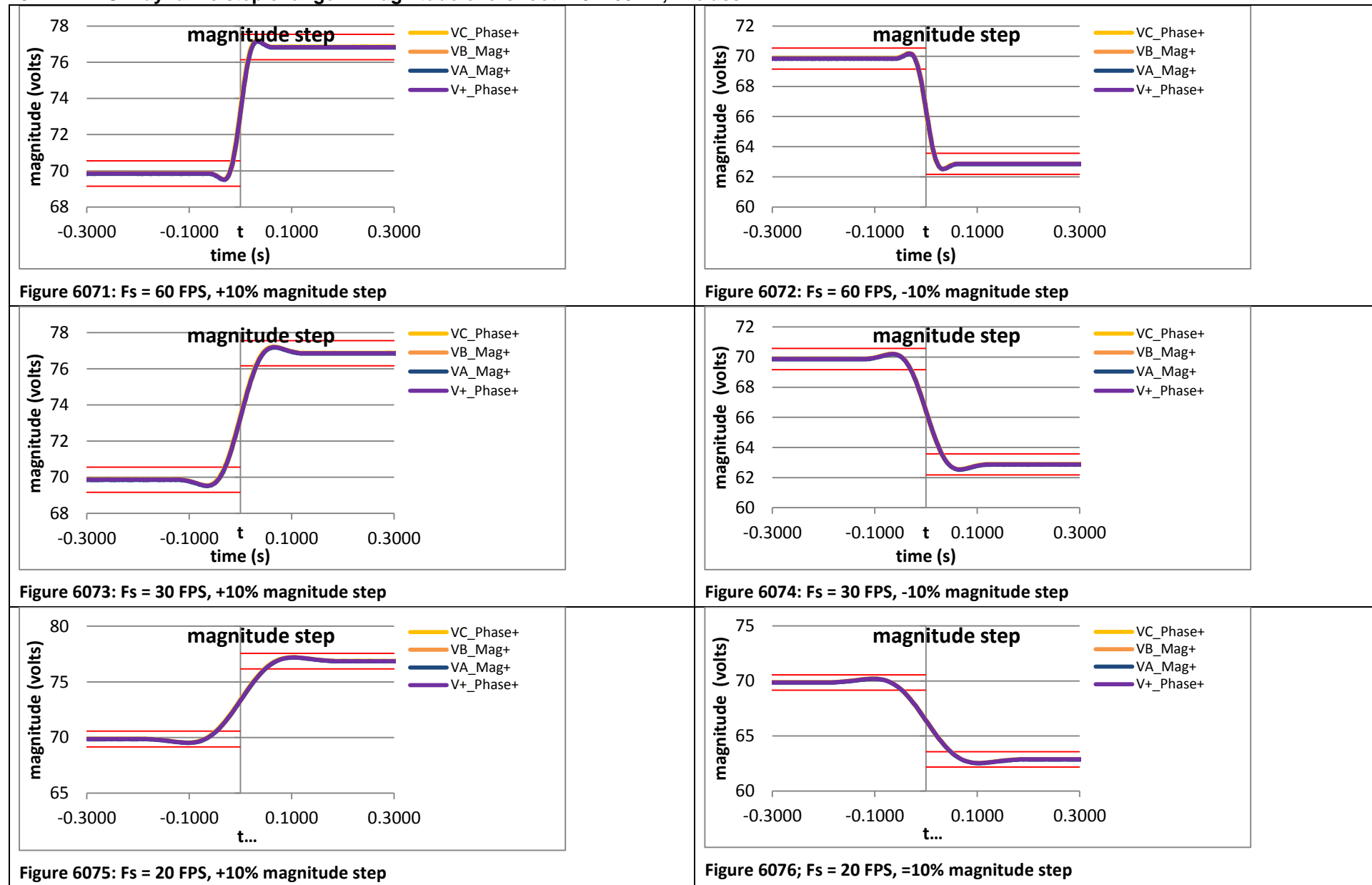


Figure 6070: Fs = 10 FPS, -10% magnitude step

# 10.12.7 PMU F dynamic step change in magnitude overshoot: F0 = 60 Hz, M class



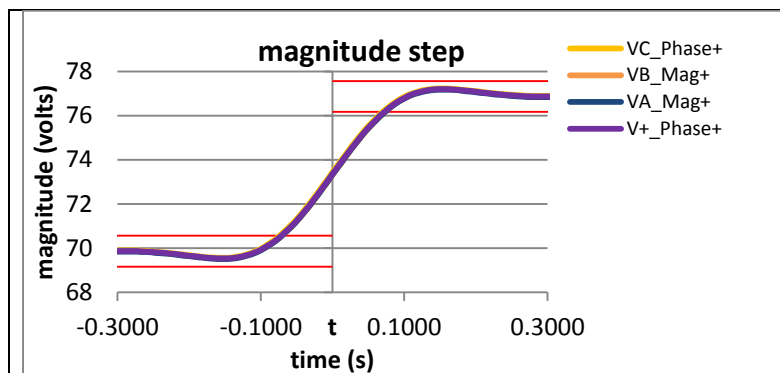


Figure 6077: Fs = 15 FPS, + 10% magnitude step

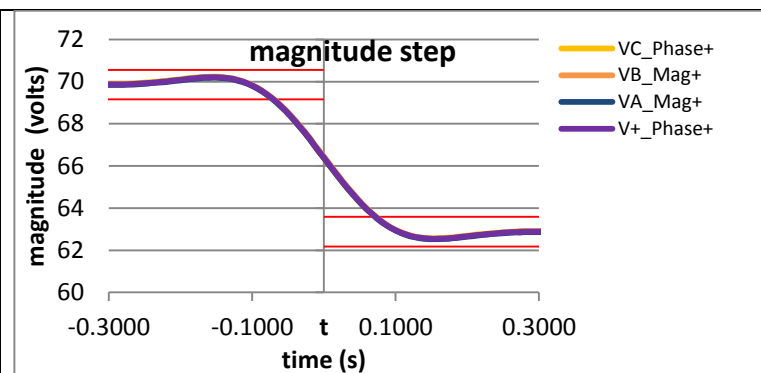


Figure 6078: Fs = 15 FPS, - 10 % magnitude step

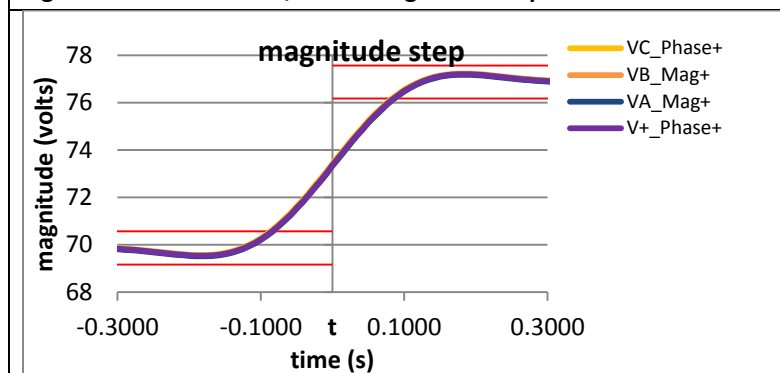


Figure 6079: Fs = 12 FPS, +10% magnitude step

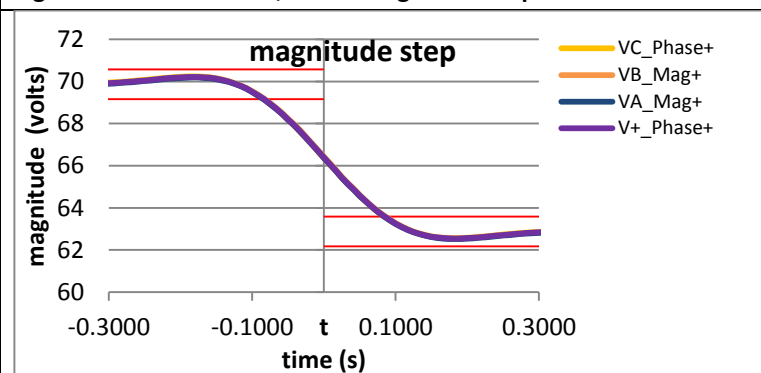


Figure 6080: Fs = 12 FPS, -10% magnitude step

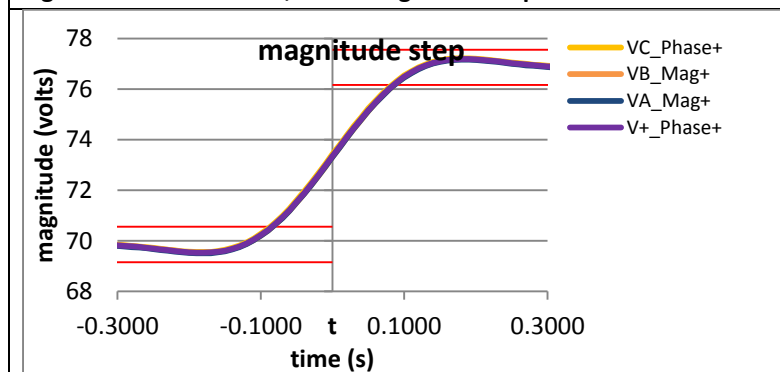


Figure 6081: Fs = 10 FPS, +10% magnitude step

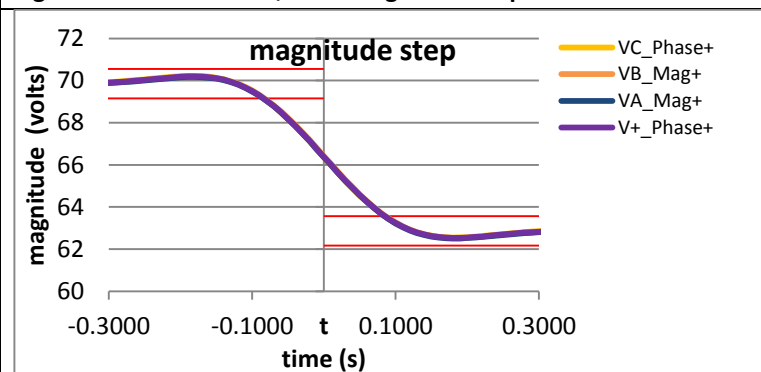


Figure 6082: Fs = 10 FPS, -10% magnitude step

### 10.12.8 PMU G dynamic step change in magnitude overshoot: F0 = 60 Hz, M class

Figure 6083: Fs = 60 FPS is not supported by this PMU

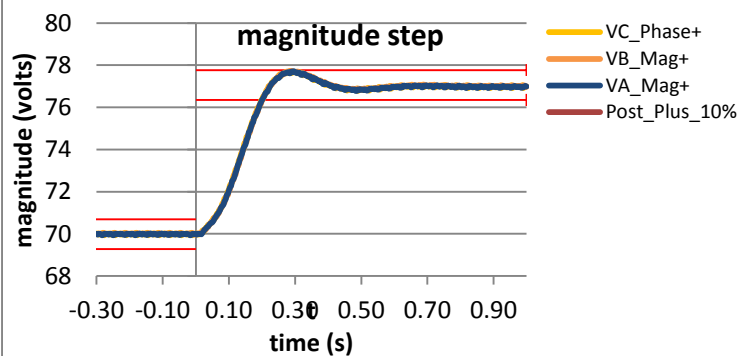


Figure 6084: Fs = 60 FPS is not supported by this PMU

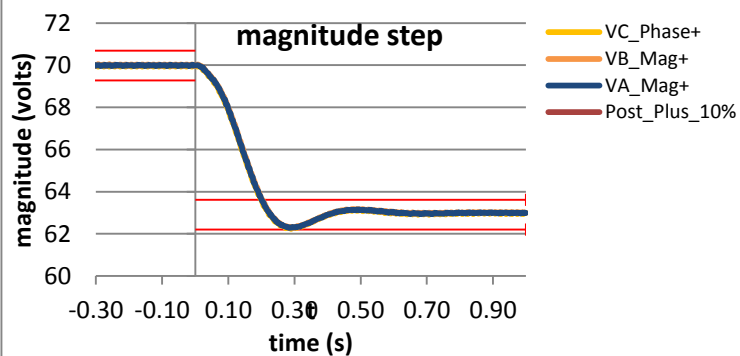


Figure 6085: Fs = 30 FPS, +10% magnitude step

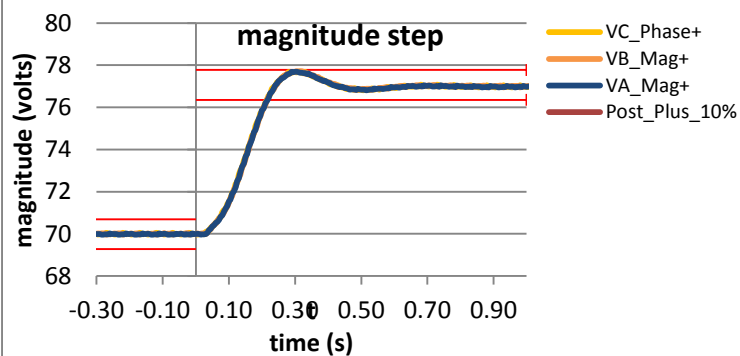


Figure 6086: Fs = 30 FPS, -10% magnitude step

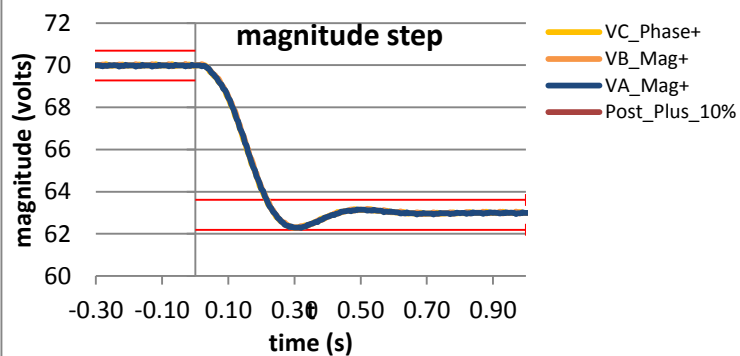


Figure 6087: Fs = 20 FPS, +10% magnitude step



Figure 6088: Fs = 20 FPS, +10% magnitude step



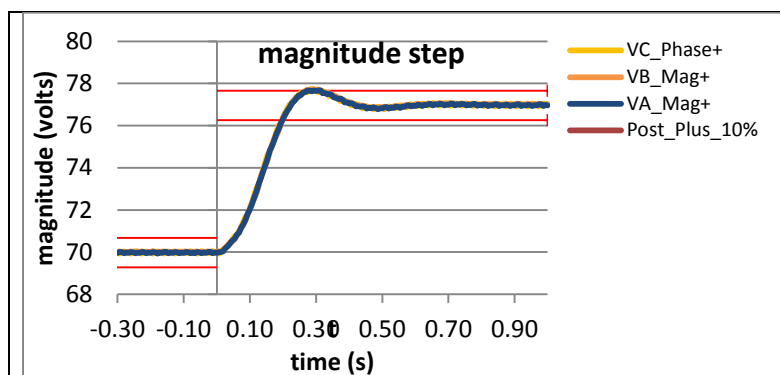


Figure 6089:  $F_s = 15$  FPS, +10% magnitude step

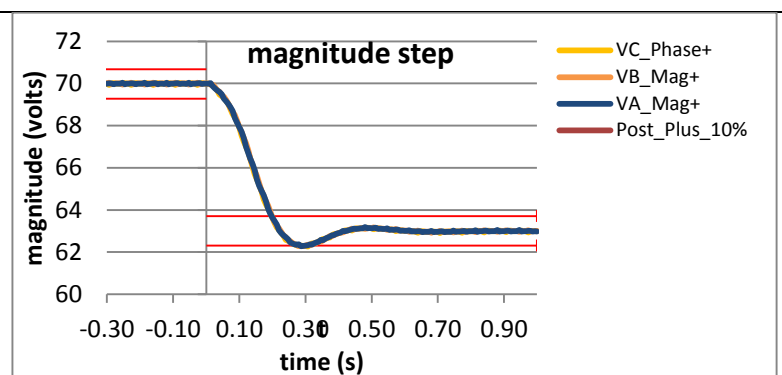


Figure 6090:  $F_s = 15$  FPS, -10% magnitude step

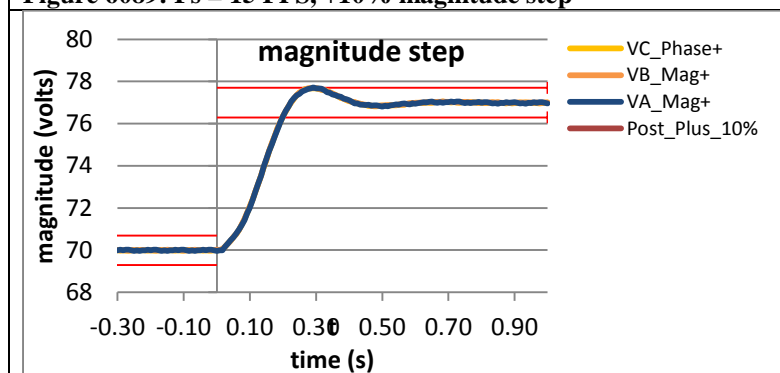


Figure 6091:  $F_s = 12$  FPS, +10% magnitude step

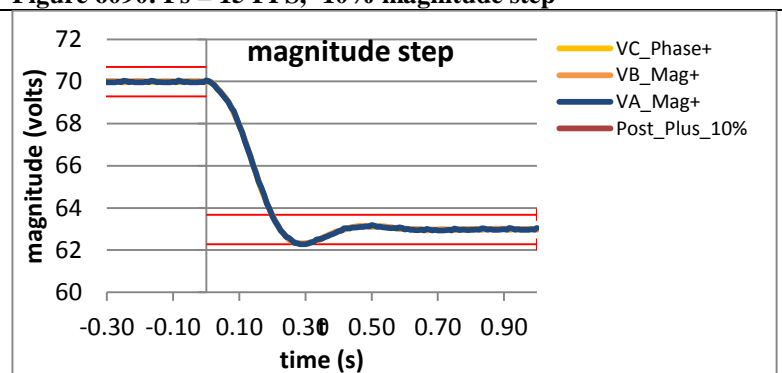


Figure 6092:  $F_s = 12$  FPS, -10% magnitude step

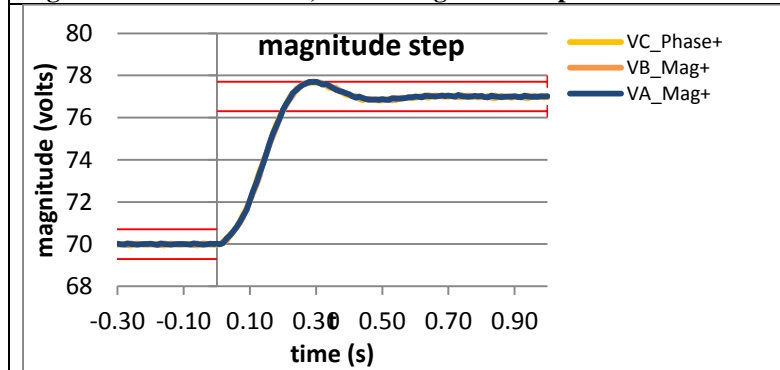


Figure 6093:  $F_s = 10$  FPS, +10% magnitude step

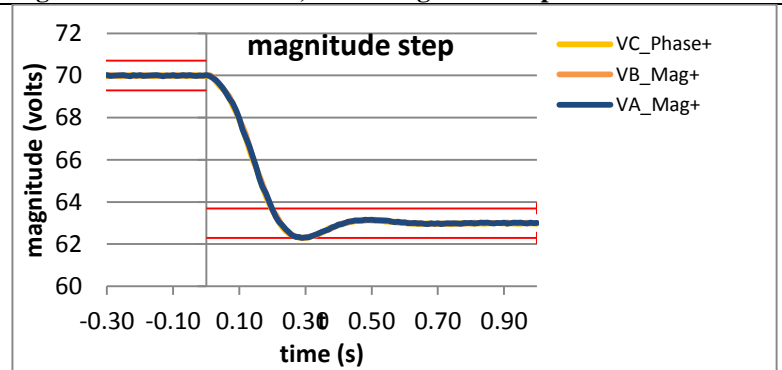


Figure 6094:  $F_s = 10$  FPS, -10% magnitude step

### 10.12.9 PMU H dynamic step change in magnitude overshoot: F0 = 60 Hz, M class

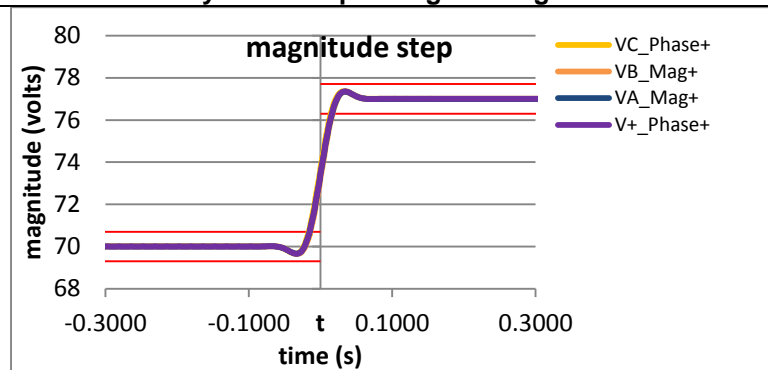


Figure 6095: Fs = 60 FPS, +10% magnitude step

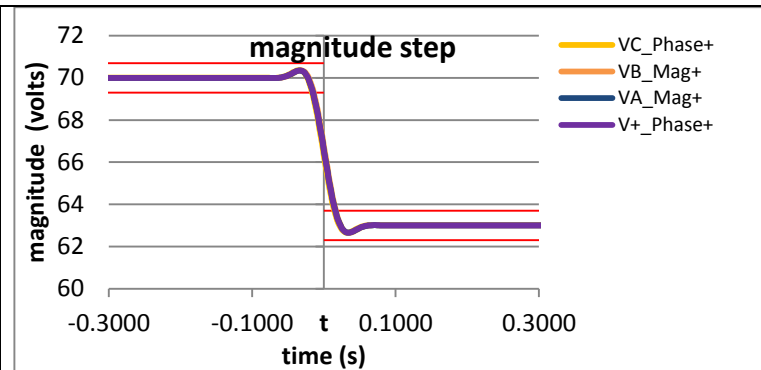


Figure 6096: Fs = 60 FPS, -10% magnitude step

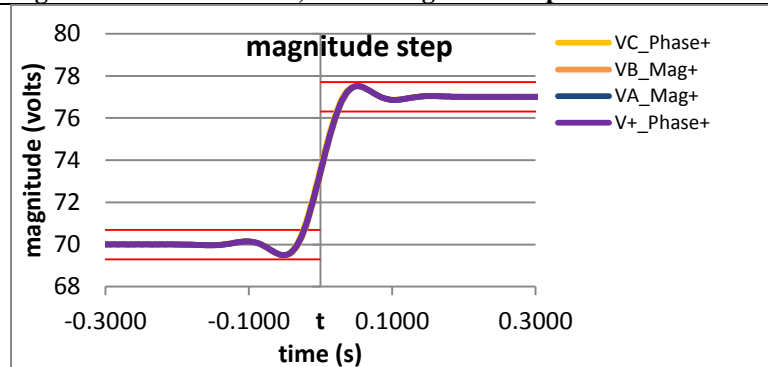


Figure 6097: Fs = 30 FPS, +10% magnitude step

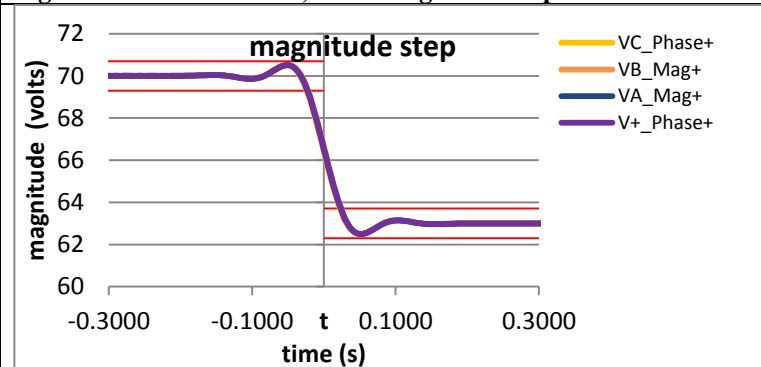


Figure 6098: Fs = 30 FPS, -10% magnitude step

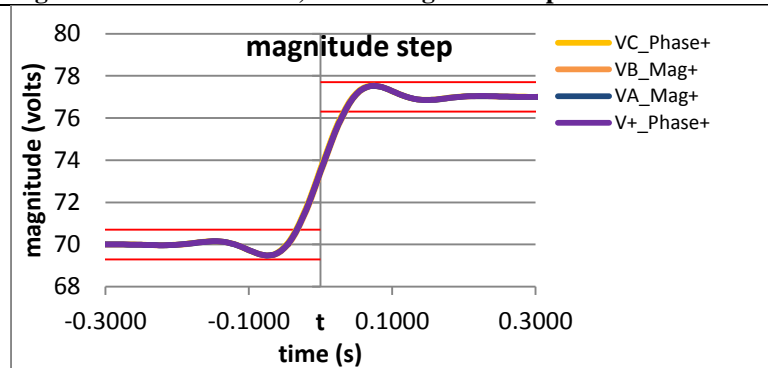


Figure 6099: Fs = 20 FPS, +10% magnitude step

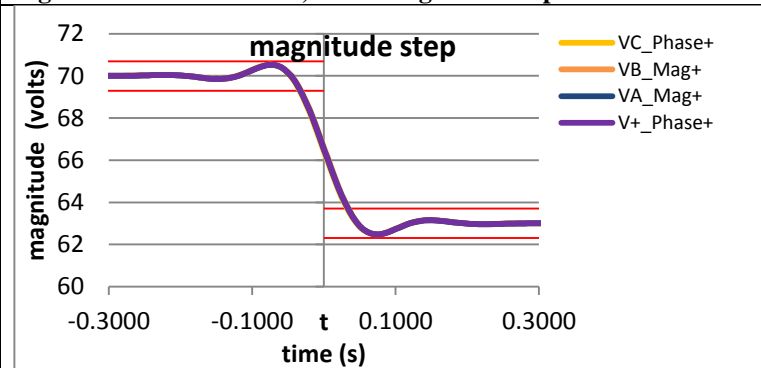


Figure 6100: Fs = 20 FPS, -10% magnitude step



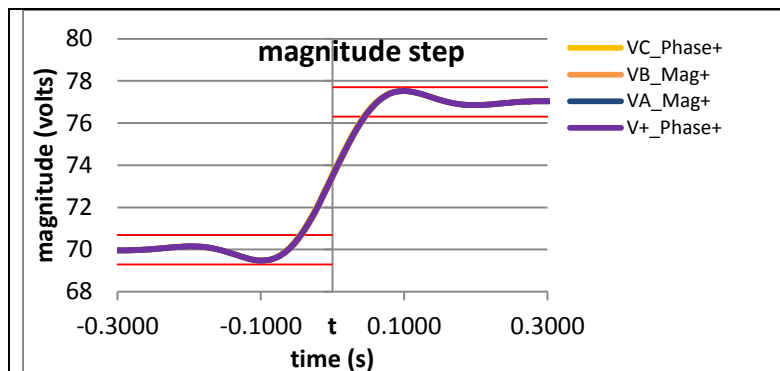


Figure 6101:  $F_s = 15$  FPS, + 10% magnitude step

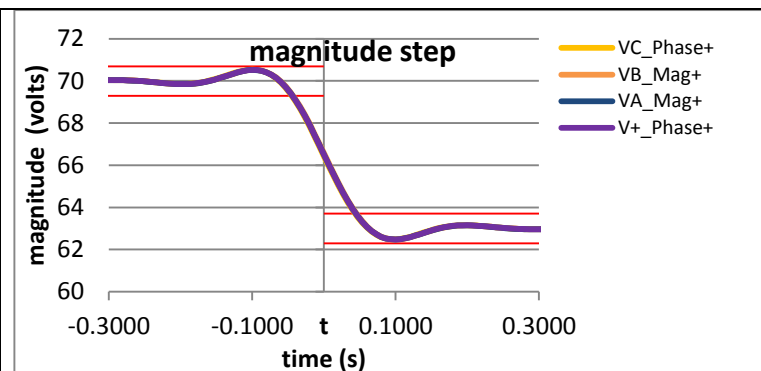


Figure 6102:  $F_s = 15$  FPS, - 10 % magnitude step

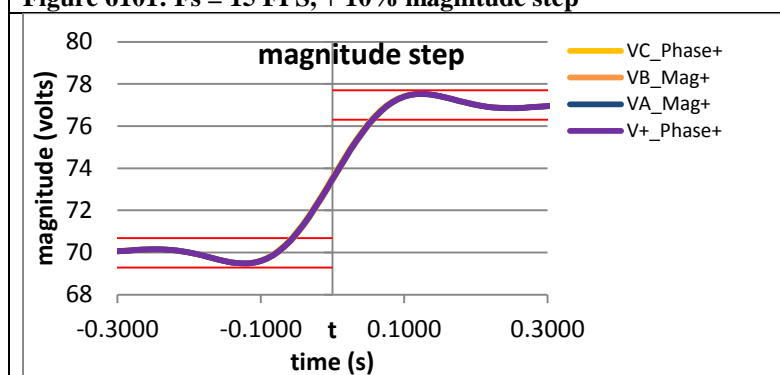


Figure 6103:  $F_s = 12$  FPS, +10% magnitude step

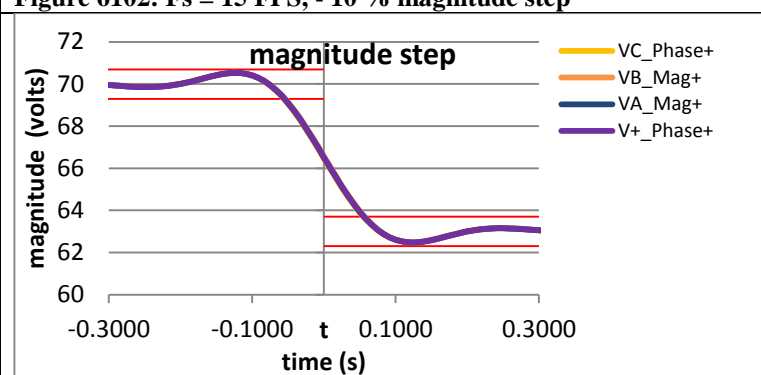


Figure 6104:  $F_s = 12$  FPS, -10% magnitude step

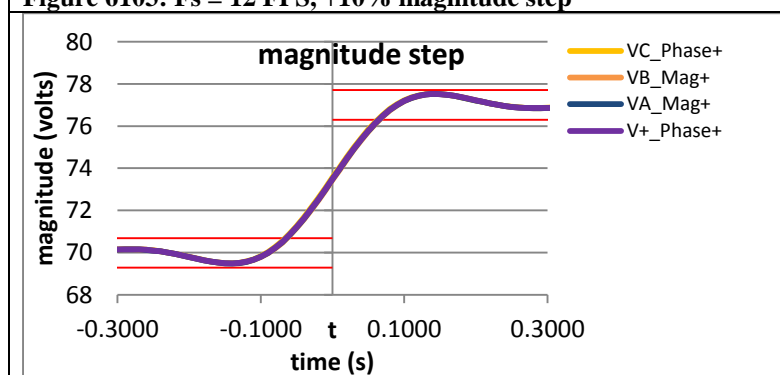


Figure 6105:  $F_s = 10$  FPS, +10% magnitude step

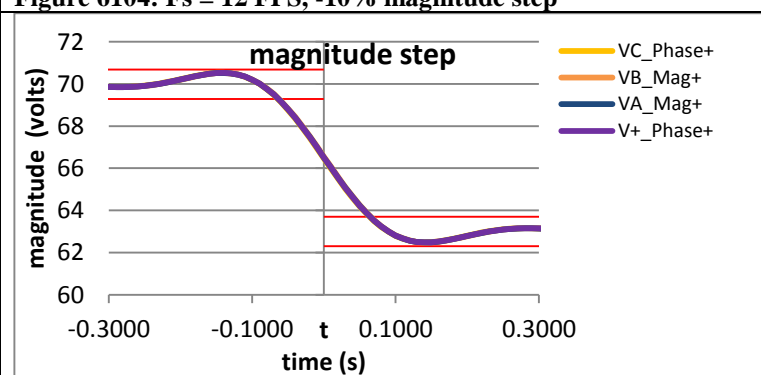


Figure 6106:  $F_s = 10$  FPS, -10% magnitude step

# 10.12.10 PMU I dynamic step change in magnitude overshoot: F0 = 60 Hz, M class

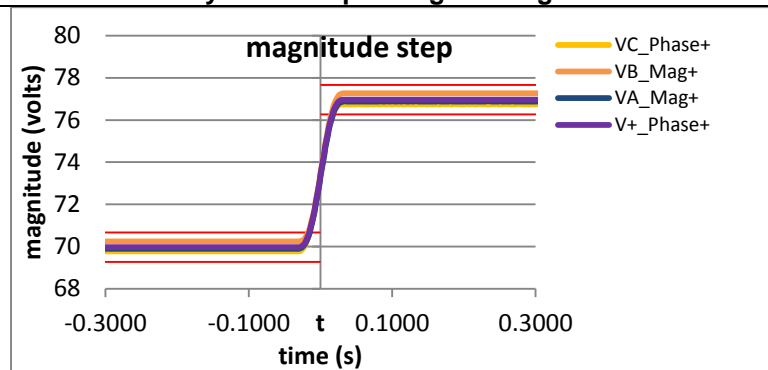


Figure 6107: Fs = 60 FPS, +10% magnitude step

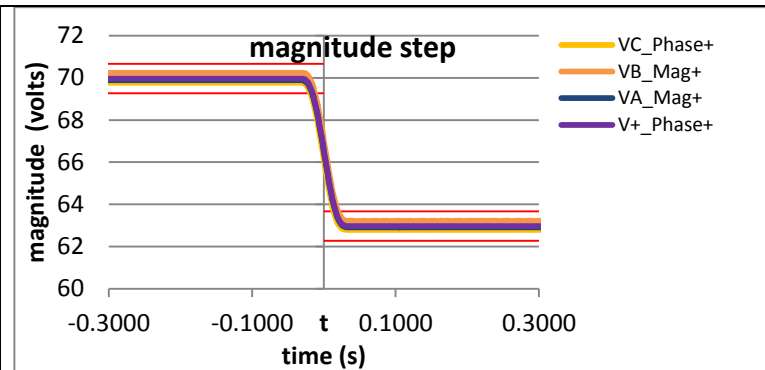


Figure 6108: Fs = 60 FPS, -10% magnitude step

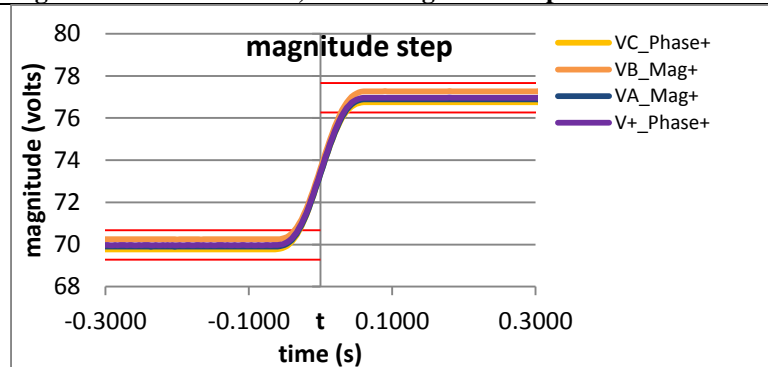


Figure 6109: Fs = 30 FPS, +10% magnitude step

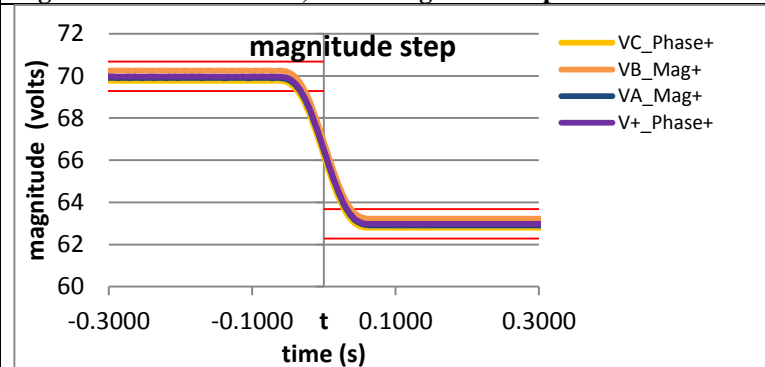


Figure 6110: Fs = 30 FPS, -10% magnitude step

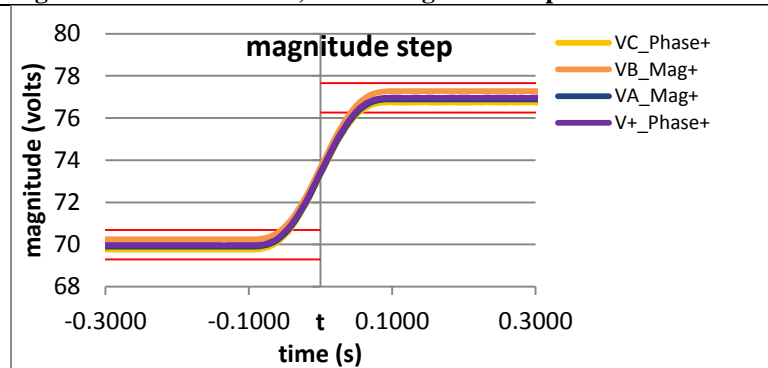


Figure 6111: Fs = 20 FPS, +10% magnitude step

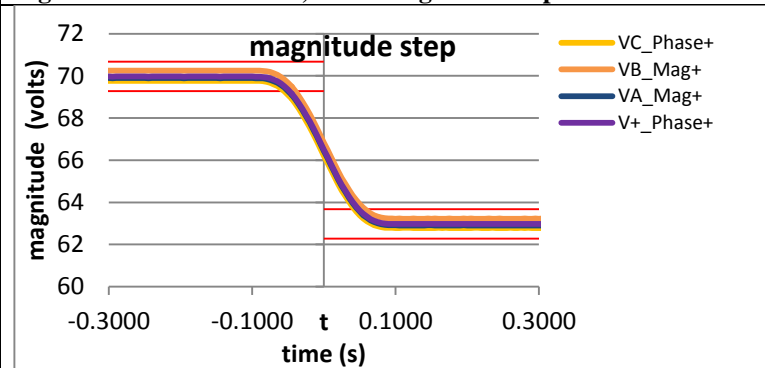


Figure 6112: Fs = 20 FPS, -10% magnitude step

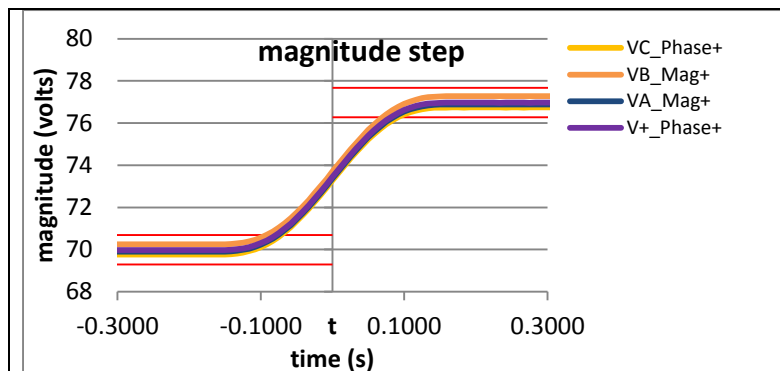


Figure 6113: Fs = 15 FPS, + 10% magnitude step

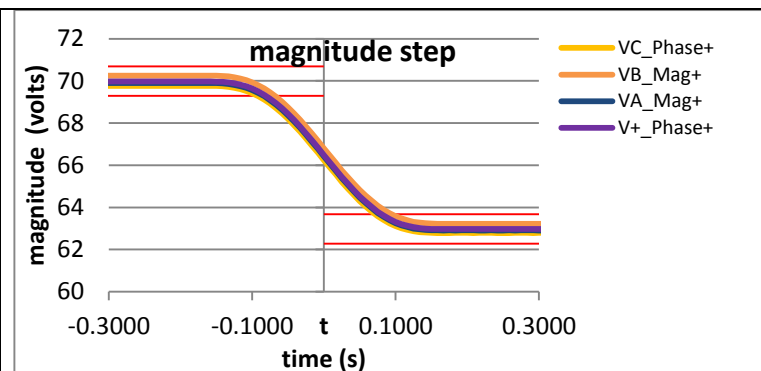


Figure 6114: Fs = 15 FPS, - 10 % magnitude step

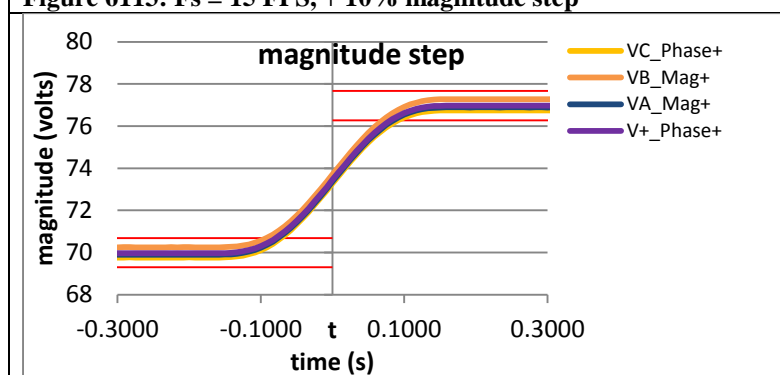


Figure 6115: Fs = 12 FPS, +10% magnitude step

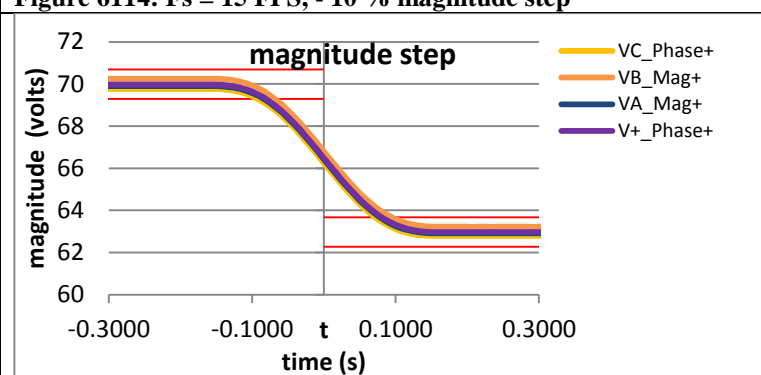


Figure 6116: Fs = 12 FPS, -10% magnitude step

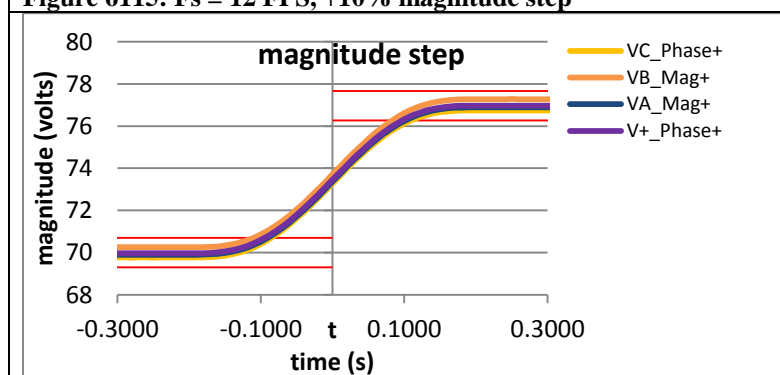


Figure 6117: Fs = 10 FPS, +10% magnitude step

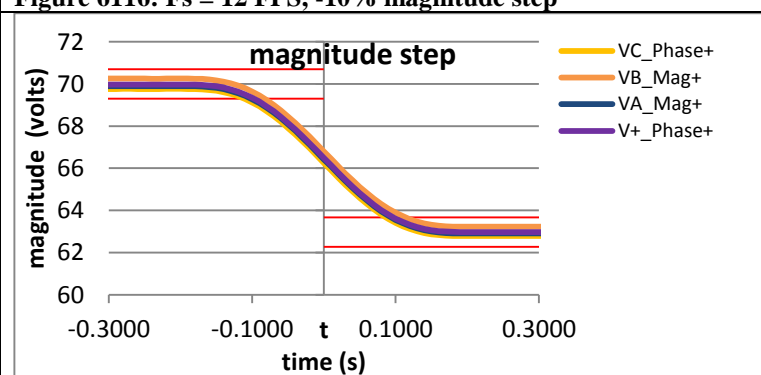


Figure 6118: Fs = 10 FPS, -10% magnitude step

# 10.12.11 PMU J dynamic step change in magnitude overshoot: F0 = 60 Hz, M class

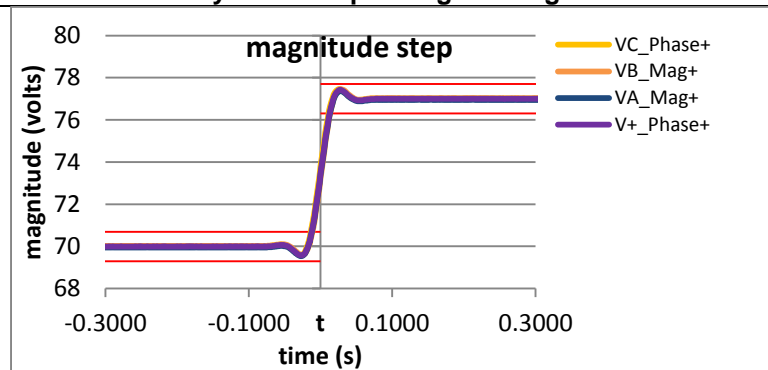


Figure 6119: Fs = 60 FPS, +10% magnitude step

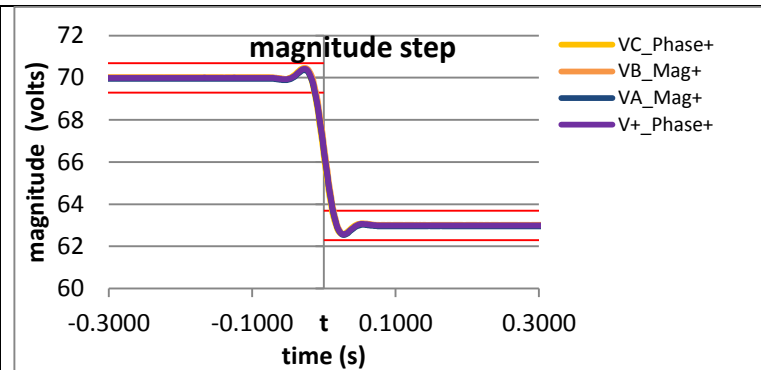


Figure 6120: Fs = 60 FPS, -10% magnitude step

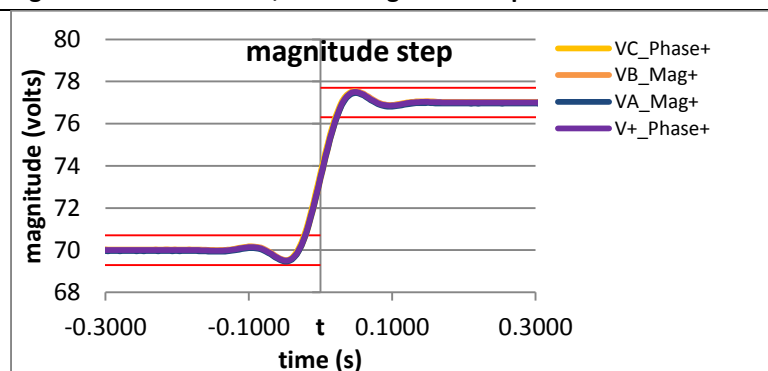


Figure 6121: Fs = 30 FPS, +10% magnitude step

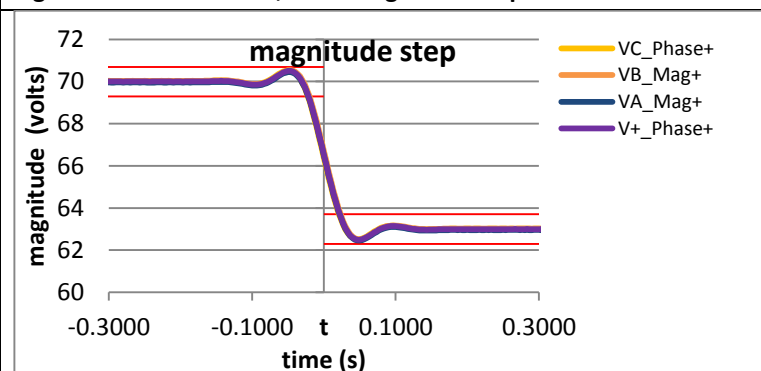


Figure 6122: Fs = 30 FPS, -10% magnitude step

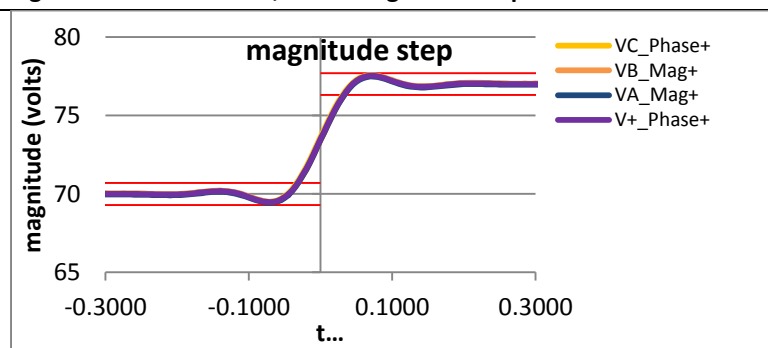


Figure 6123: Fs = 20 FPS, +10% magnitude step

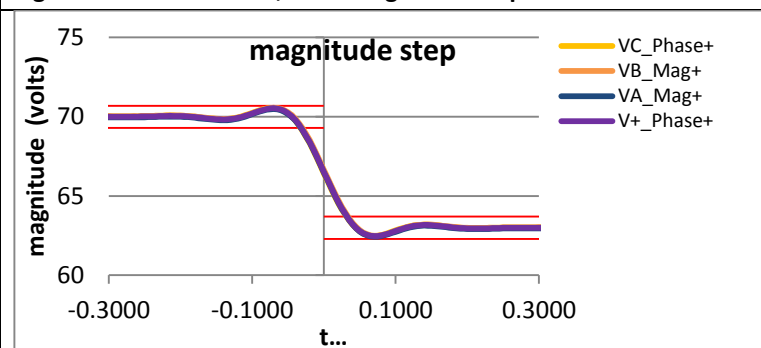


Figure 6124; Fs = 20 FPS, =10% magnitude step

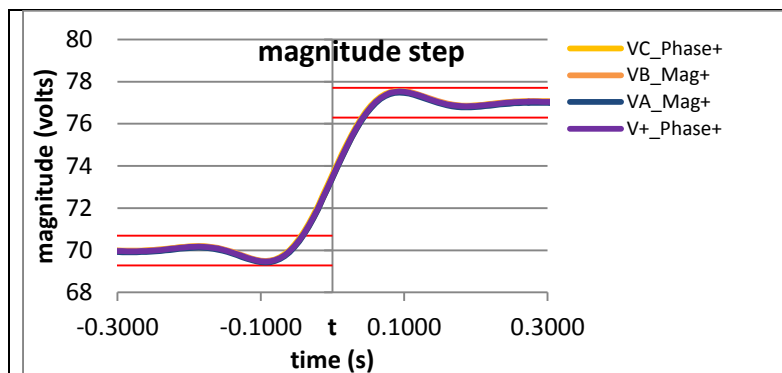


Figure 6125: Fs = 15 FPS, + 10% magnitude step

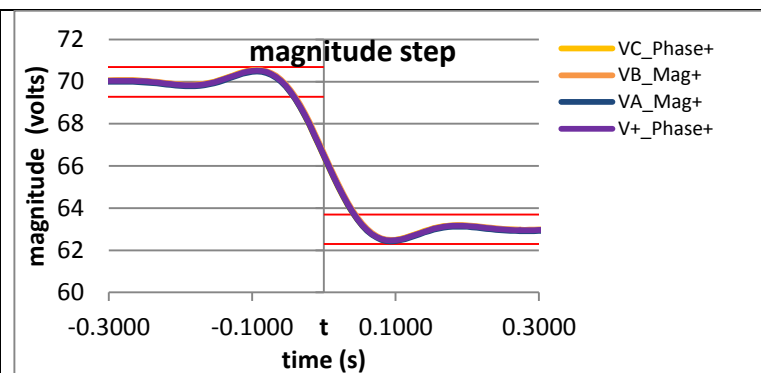


Figure 6126: Fs = 15 FPS, - 10 % magnitude step

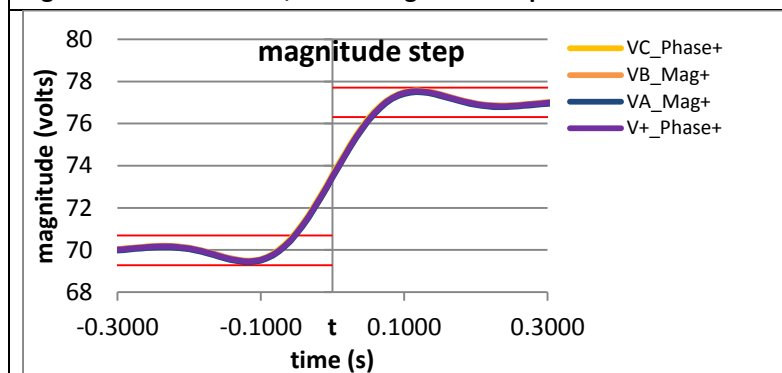


Figure 6127: Fs = 12 FPS, +10% magnitude step

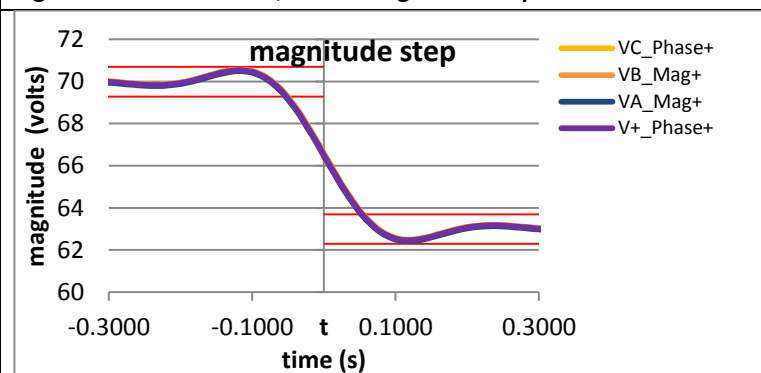


Figure 6128: Fs = 12 FPS, -10% magnitude step

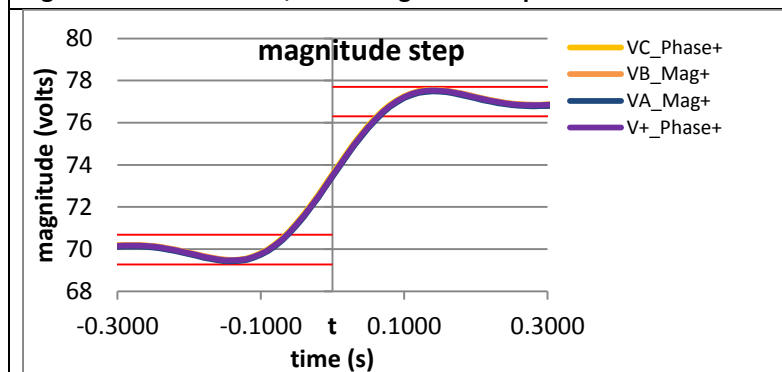


Figure 6129: Fs = 10 FPS, +10% magnitude step

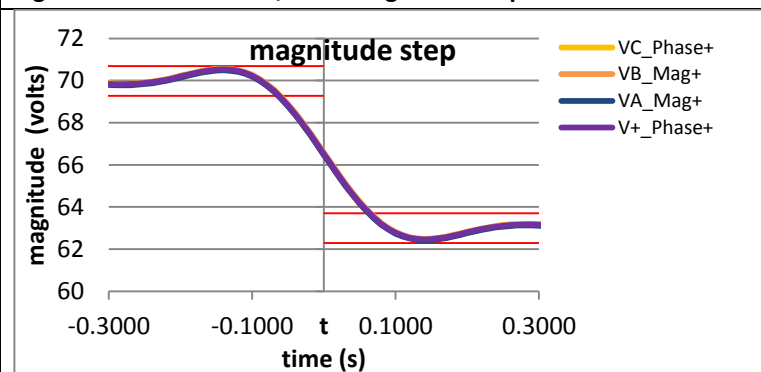


Figure 6130: Fs = 10 FPS, -10% magnitude step

## 10.13 Dynamic step change in magnitude overshoot: $F_0 = 60$ Hz, P class

### 10.13.1 C37.118.1-2011 Annex C dynamic step change in magnitude overshoot: $F_0 = 60$ Hz, P class

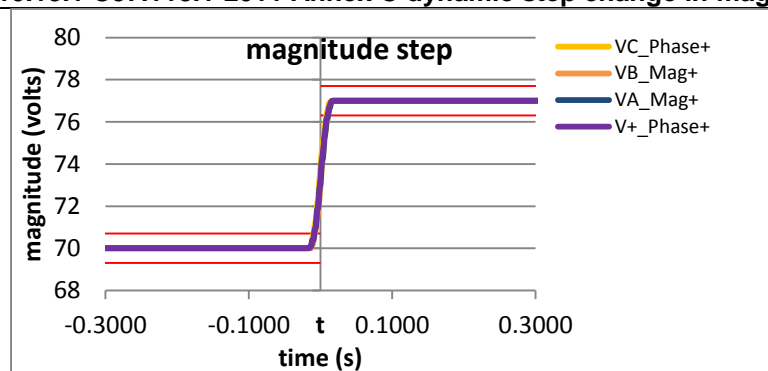


Figure 6131:  $F_s = 60$  FPS, +10% magnitude step

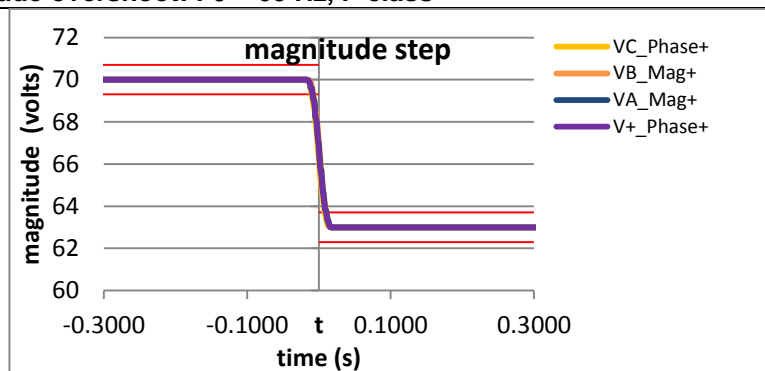


Figure 6132:  $F_s = 60$  FPS, -10% magnitude step

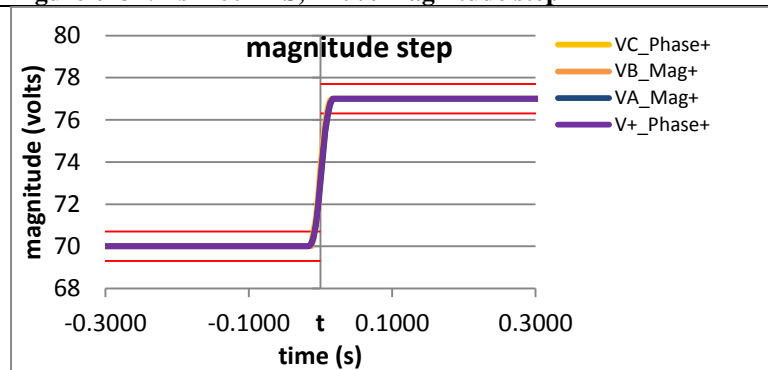


Figure 6133:  $F_s = 30$  FPS, +10% magnitude step

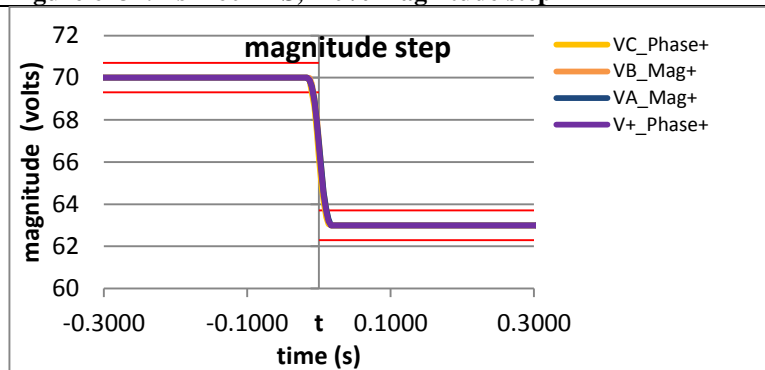


Figure 6134:  $F_s = 30$  FPS, -10% magnitude step

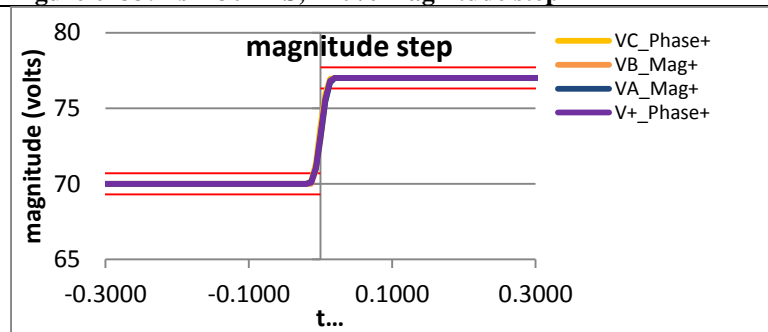


Figure 6135:  $F_s = 20$  FPS, +10% magnitude step

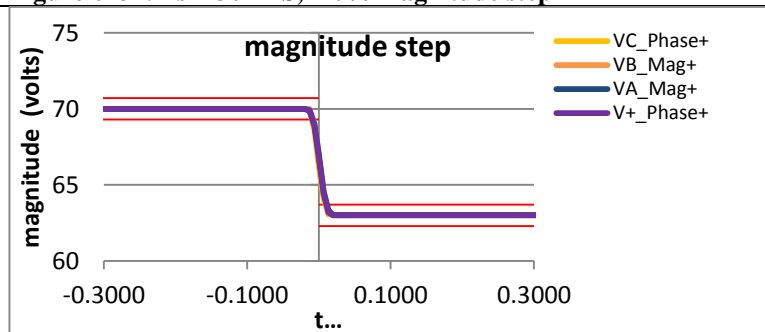


Figure 6136:  $F_s = 20$  FPS, -10% magnitude step

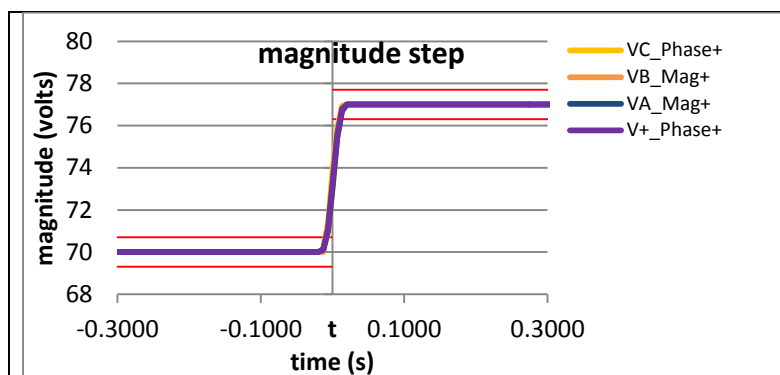


Figure 6137:  $F_s = 15$  FPS, + 10% magnitude step

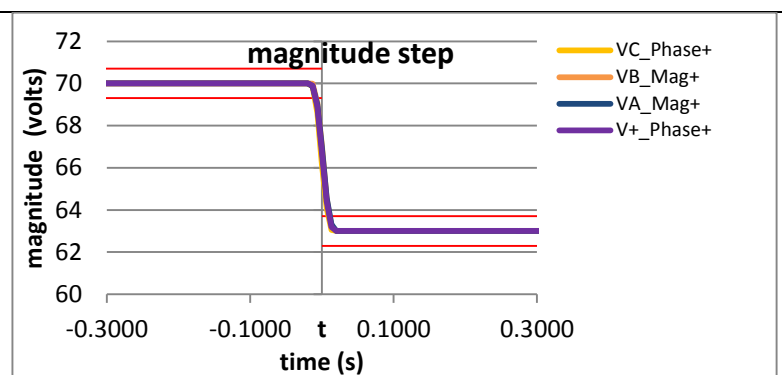


Figure 6138:  $F_s = 15$  FPS, - 10 % magnitude step

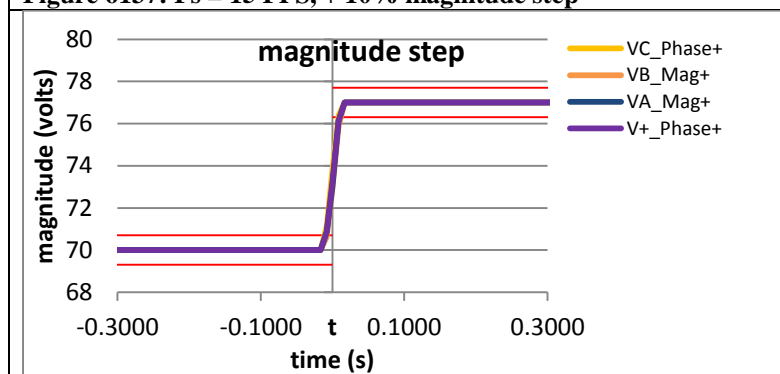


Figure 6139:  $F_s = 12$  FPS, +10% magnitude step

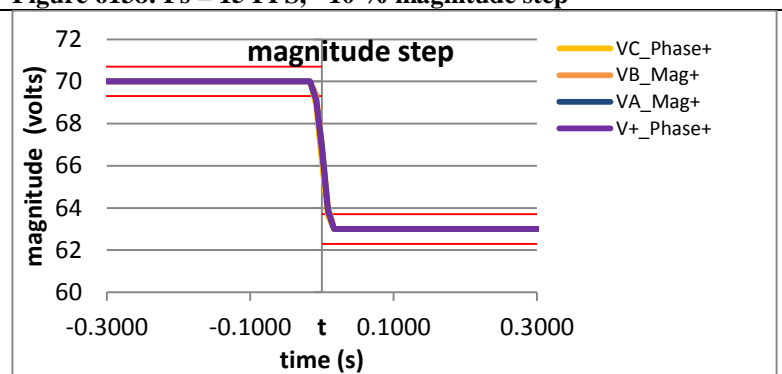


Figure 6140:  $F_s = 12$  FPS, -10% magnitude step

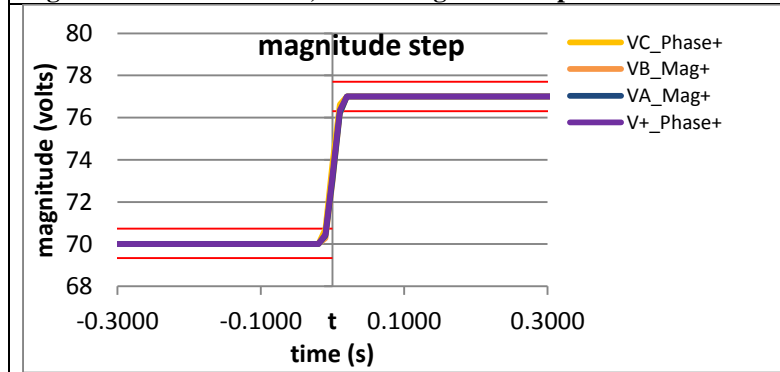


Figure 6141:  $F_s = 10$  FPS, +10% magnitude step

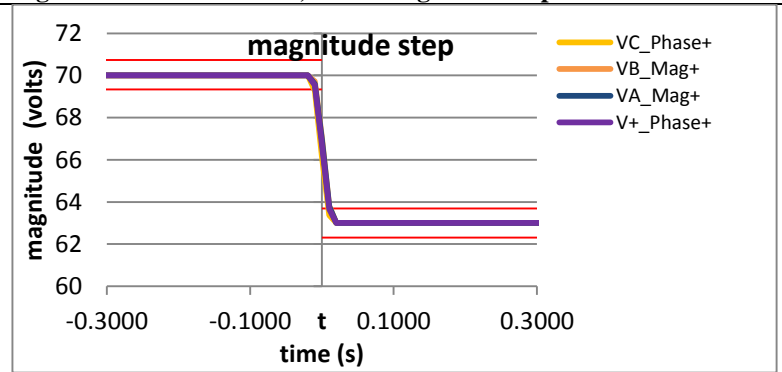


Figure 6142:  $F_s = 10$  FPS, -10% magnitude step

### 10.13.2 PMU A dynamic step change in magnitude overshoot: F0 = 60 Hz, P class

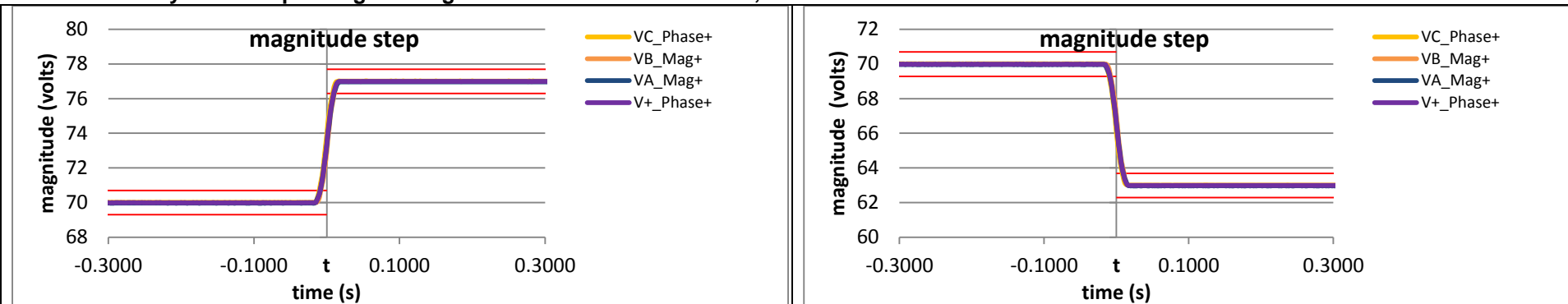


Figure 6143: Fs = 60 FPS, +10% magnitude step

Figure 6144: Fs = 60 FPS, -10% magnitude step

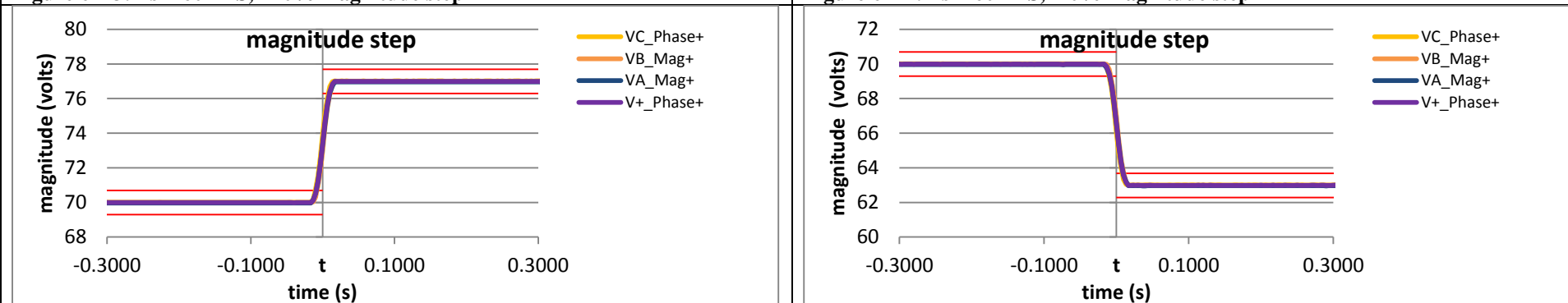


Figure 6145: Fs = 30 FPS, +10% magnitude step

Figure 6146: Fs = 30 FPS, -10% magnitude step

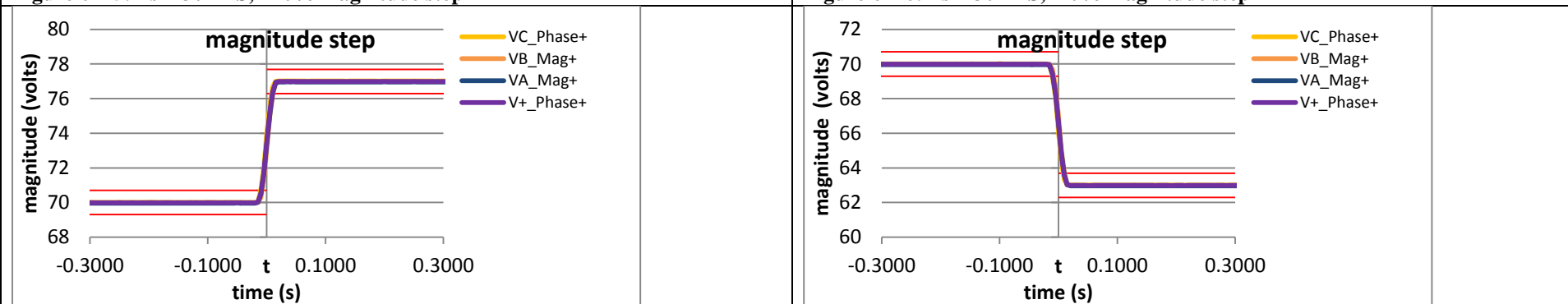


Figure 6147: Fs = 20 FPS, +10% magnitude step

Figure 6148: Fs = 20 FPS, -10% magnitude step



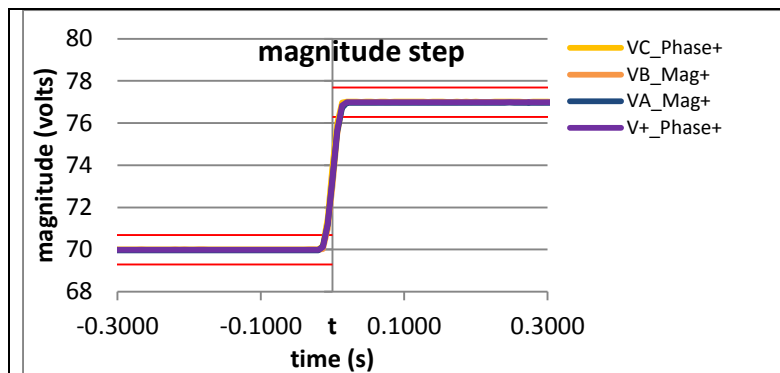


Figure 6149: Fs = 15 FPS, + 10% magnitude step

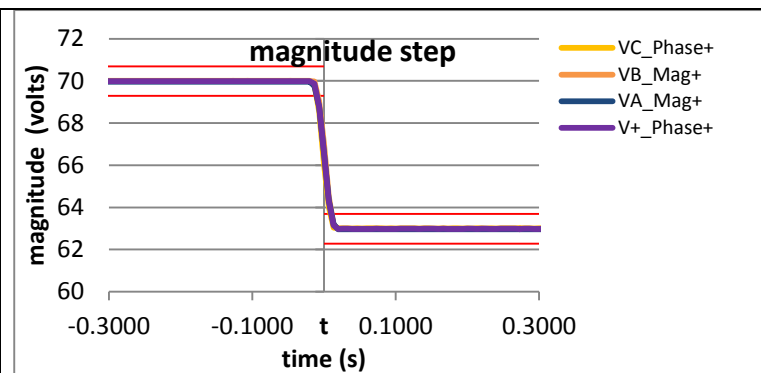


Figure 6150: Fs = 15 FPS, - 10 % magnitude step

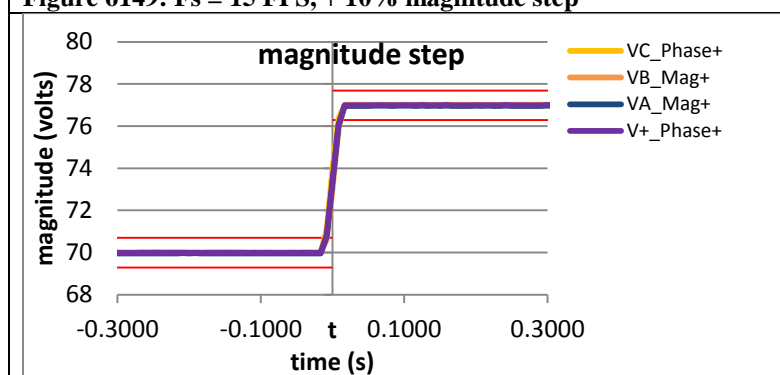


Figure 6151: Fs = 12 FPS, +10% magnitude step

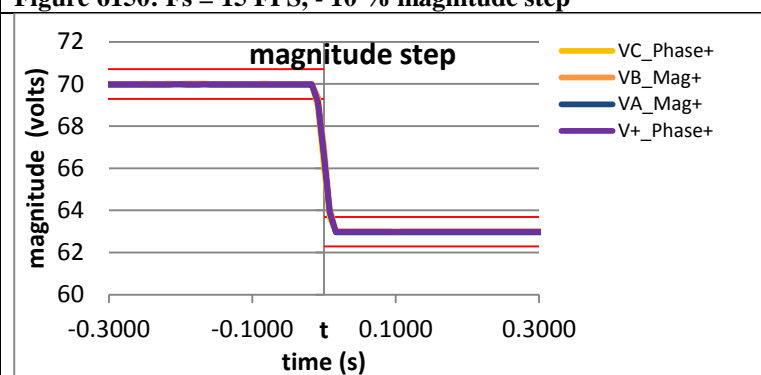


Figure 6152: Fs = 12 FPS, -10% magnitude step

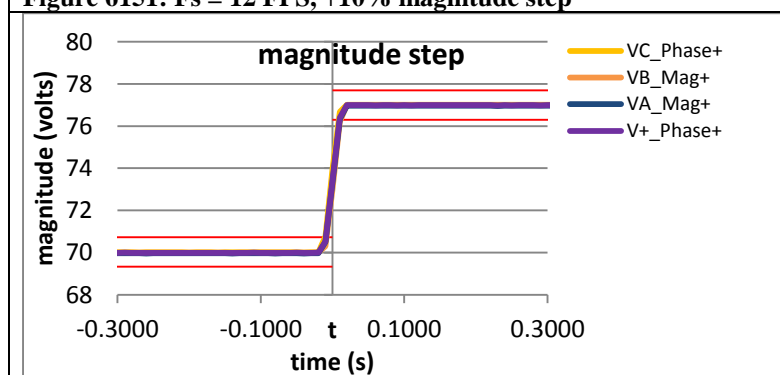


Figure 6153: Fs = 10 FPS, +10% magnitude step

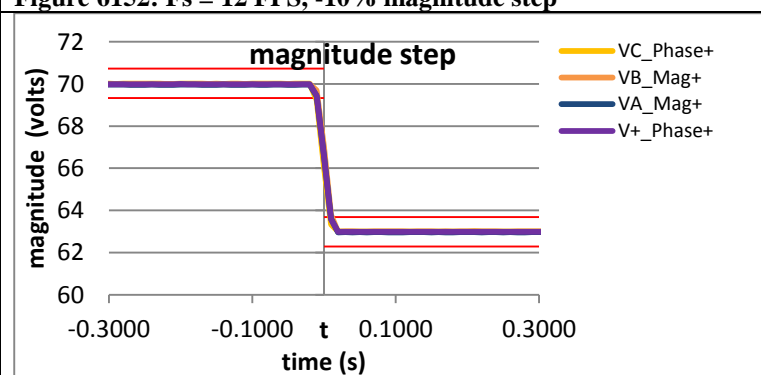


Figure 6154: Fs = 10 FPS, -10% magnitude step

### 10.13.3 PMU B dynamic step change in magnitude overshoot: F0 = 60 Hz, P class

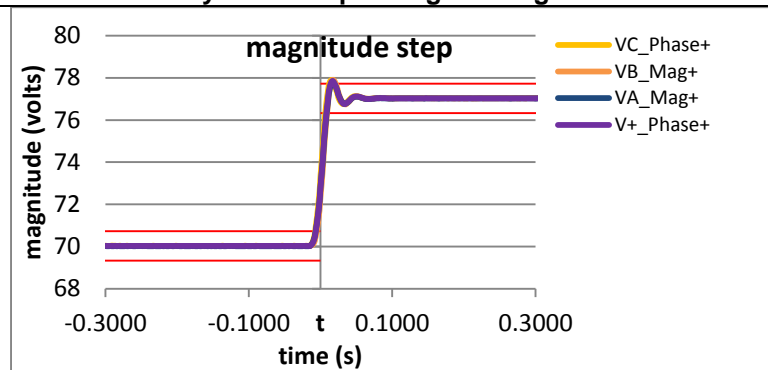


Figure 6155: Fs = 60 FPS, +10% magnitude step

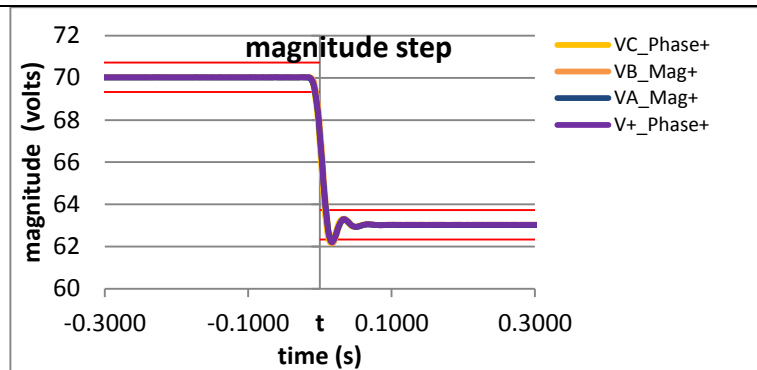


Figure 6156: Fs = 60 FPS, -10% magnitude step

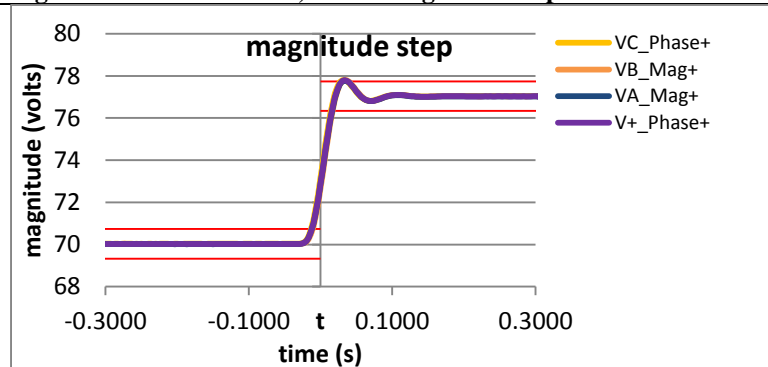


Figure 6157: Fs = 30 FPS, +10% magnitude step

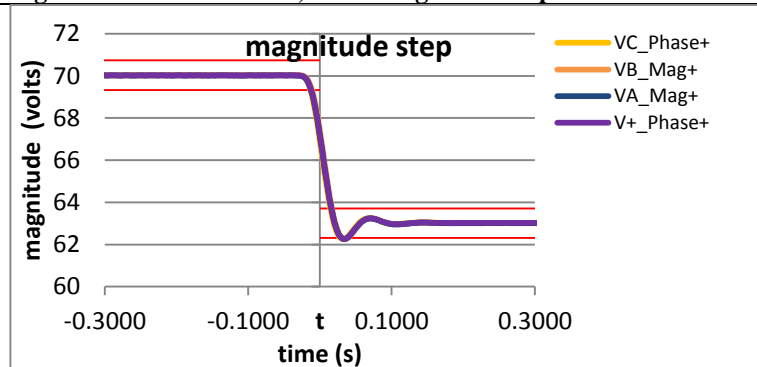


Figure 6158: Fs = 30 FPS, -10% magnitude step

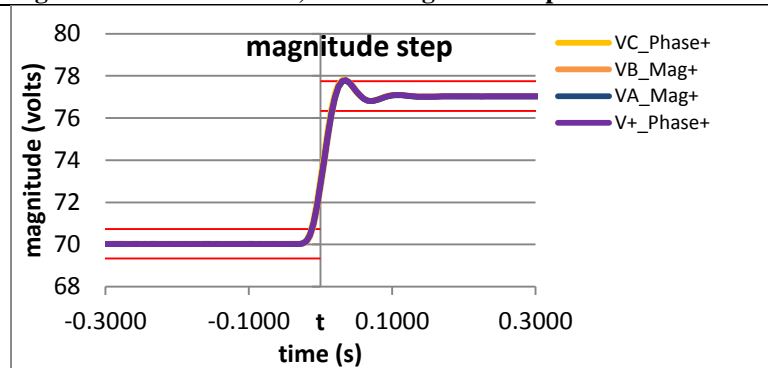


Figure 6159: Fs = 20 FPS, +10% magnitude step

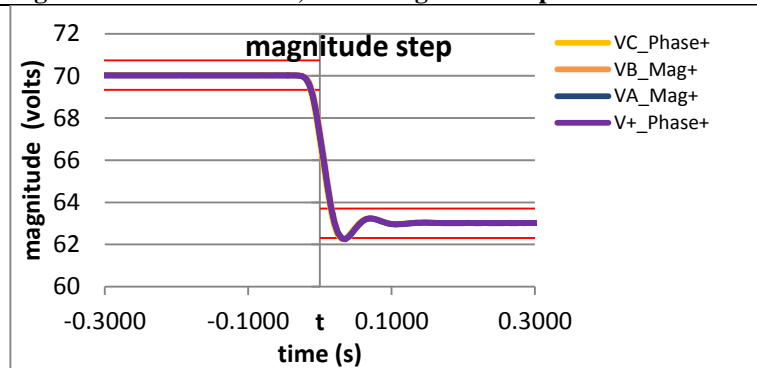


Figure 6160: Fs = 20 FPS, -10% magnitude step

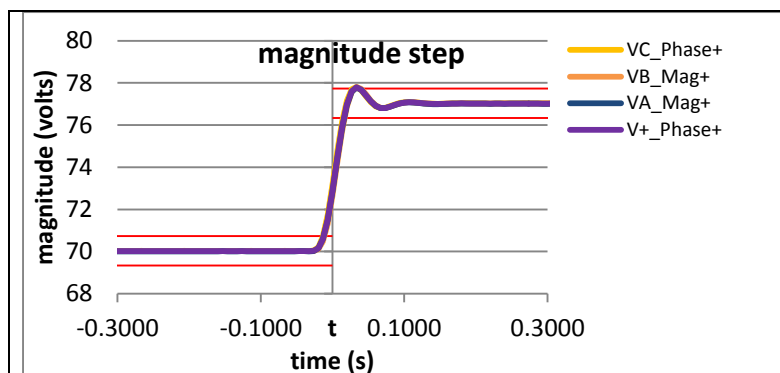


Figure 6161:  $F_s = 15$  FPS, + 10% magnitude step

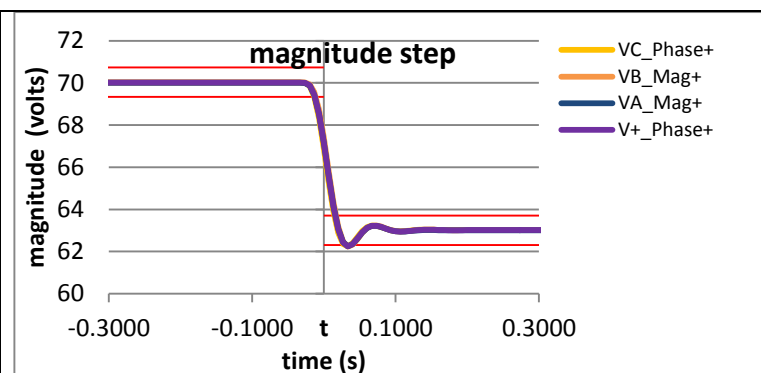


Figure 6162:  $F_s = 15$  FPS, - 10 % magnitude step

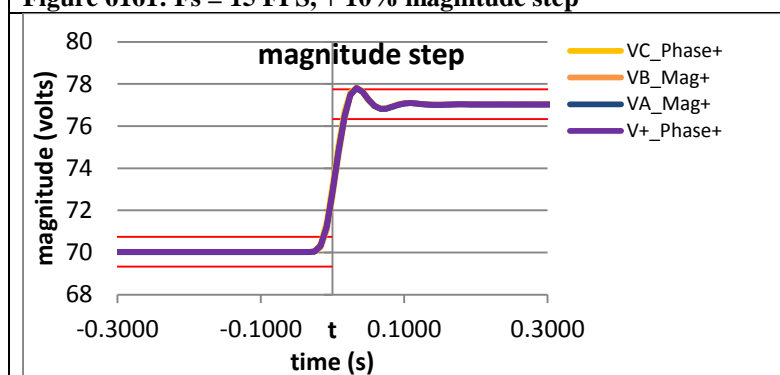


Figure 6163:  $F_s = 12$  FPS, +10% magnitude step

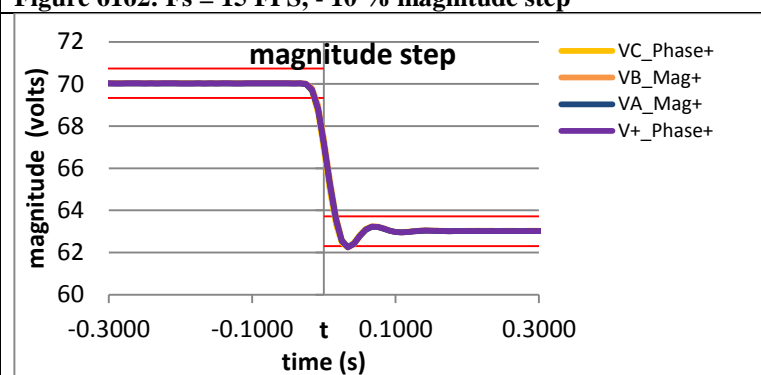


Figure 6164:  $F_s = 12$  FPS, -10% magnitude step

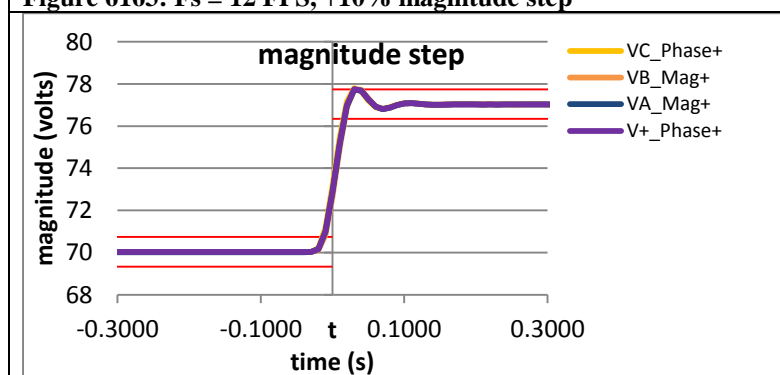


Figure 6165:  $F_s = 10$  FPS, +10% magnitude step

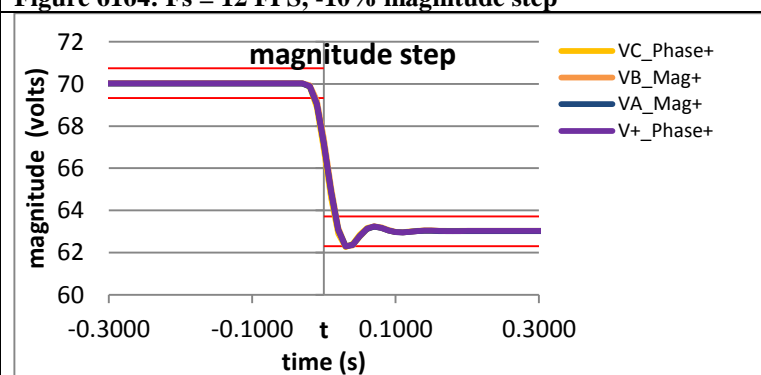


Figure 6166:  $F_s = 10$  FPS, -10% magnitude step

#### 10.13.4 PMU C dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class

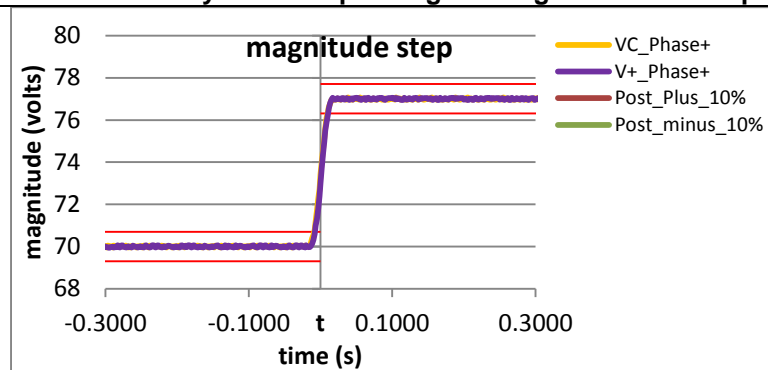


Figure 6167: Fs = 60 FPS, +10% magnitude step

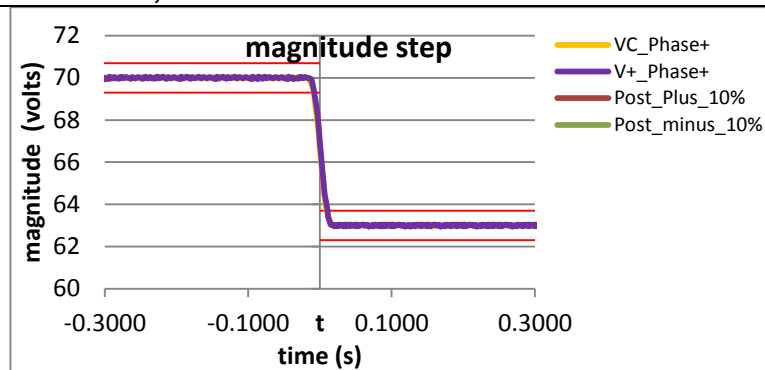


Figure 6168: Fs = 60 FPS, -10% magnitude step

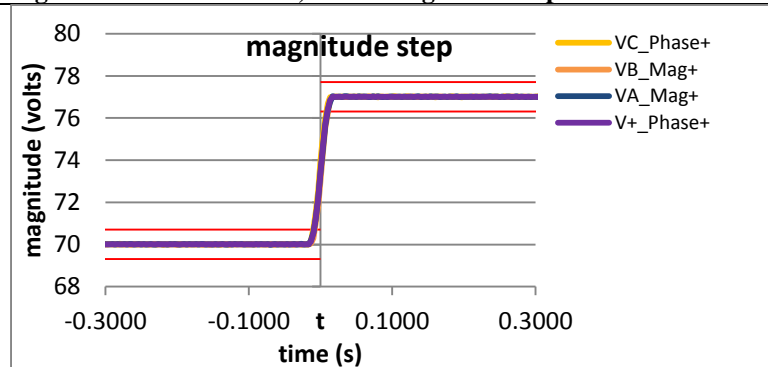


Figure 6169: Fs = 30 FPS, +10% magnitude step

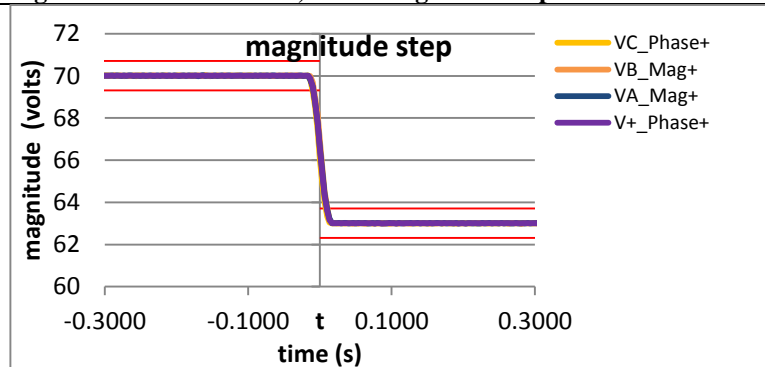


Figure 6170: Fs = 30 FPS, -10% magnitude step

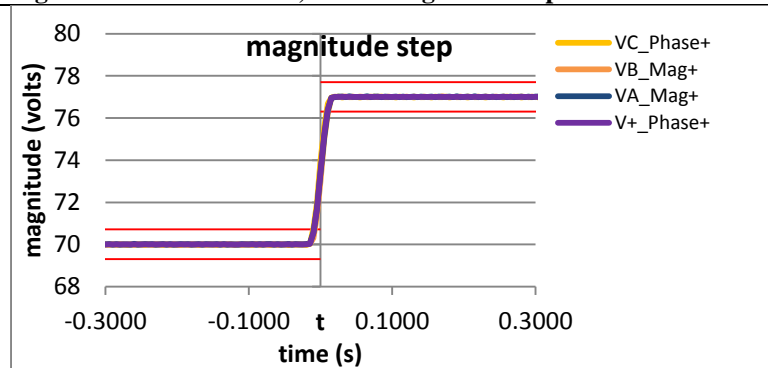


Figure 6171: Fs = 20 FPS, +10% magnitude step

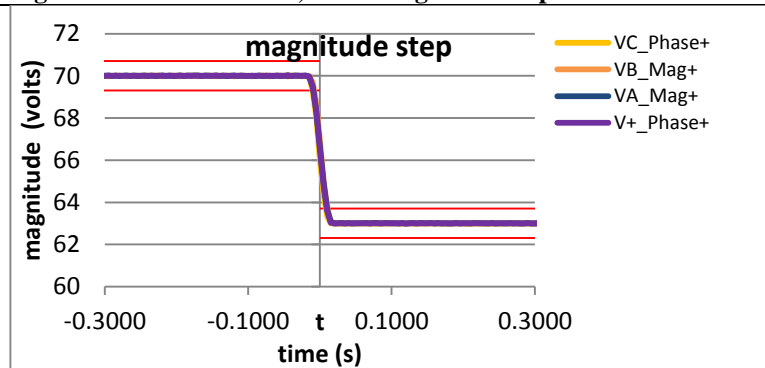


Figure 6172: Fs = 20 FPS, -10% magnitude step

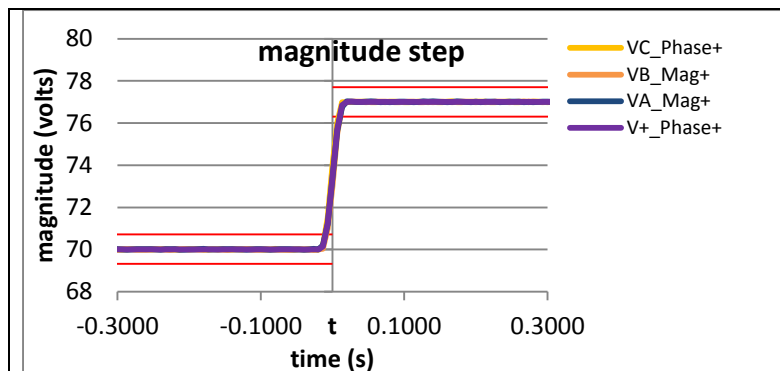


Figure 6173:  $F_s = 15$  FPS, + 10% magnitude step

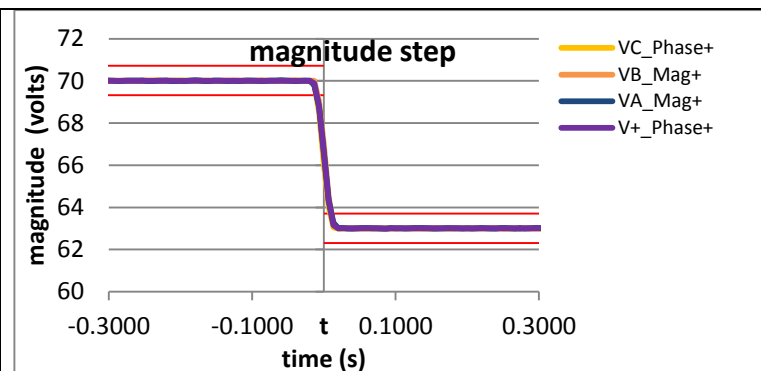


Figure 6174:  $F_s = 15$  FPS, - 10 % magnitude step

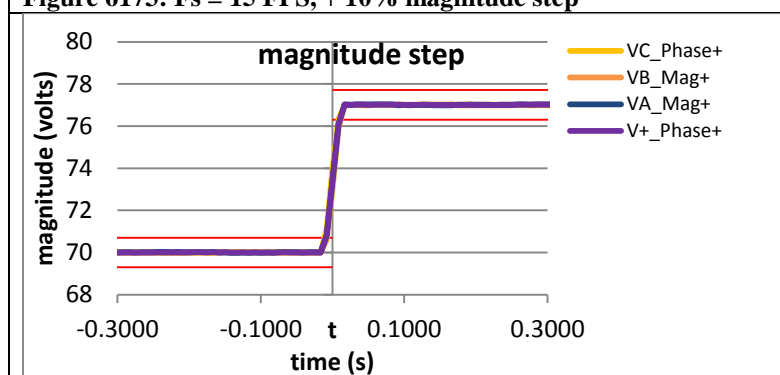


Figure 6175:  $F_s = 12$  FPS, +10% magnitude step

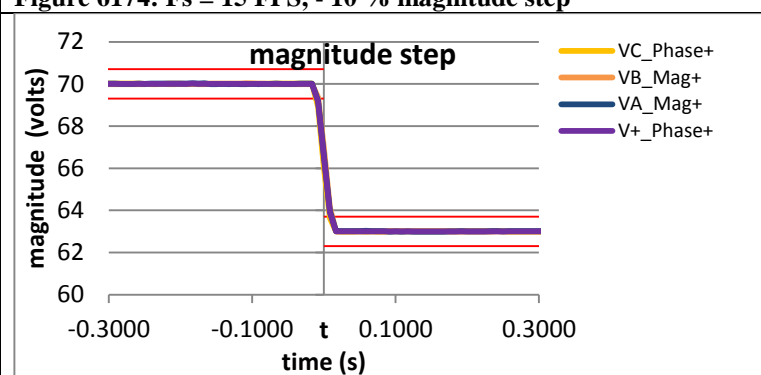


Figure 6176:  $F_s = 12$  FPS, -10% magnitude step

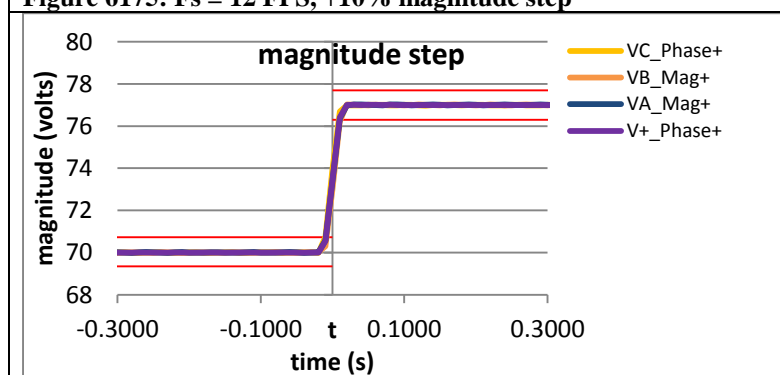


Figure 6177:  $F_s = 10$  FPS, +10% magnitude step

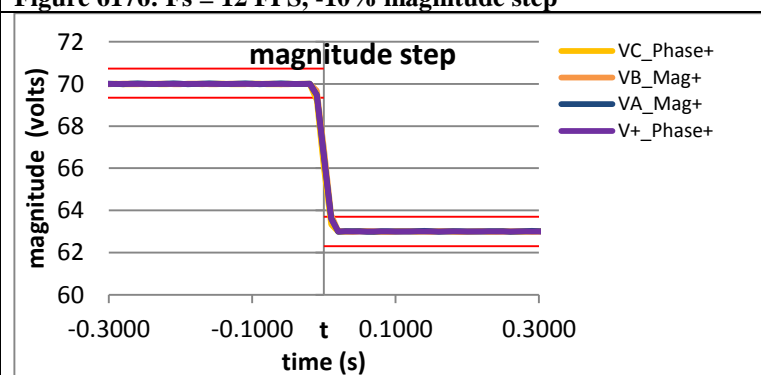


Figure 6178:  $F_s = 10$  FPS, -10% magnitude step

### 10.13.5 PMU D dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class

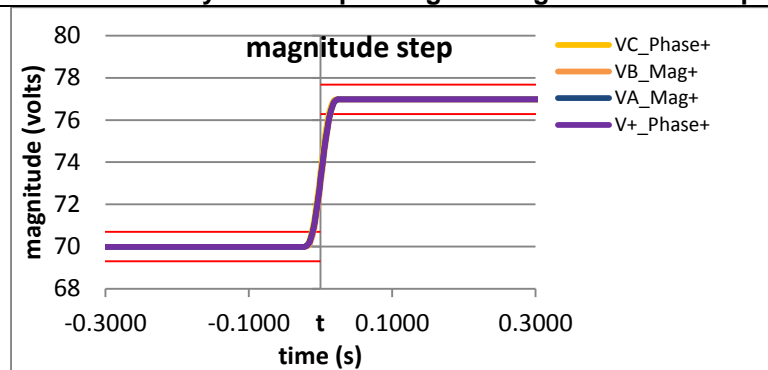


Figure 6179: Fs = 60 FPS, +10% magnitude step

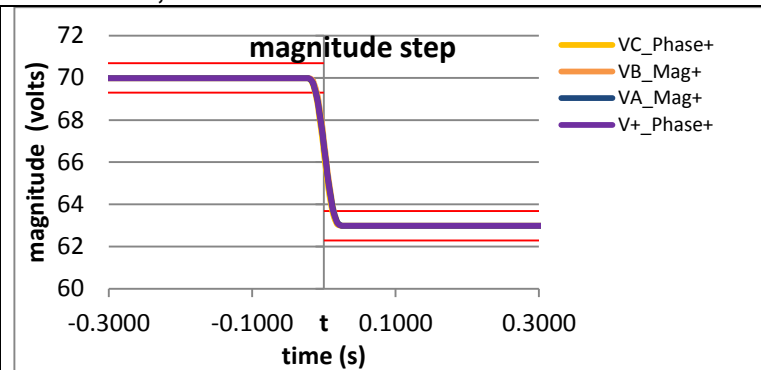


Figure 6180: Fs = 60 FPS, -10% magnitude step

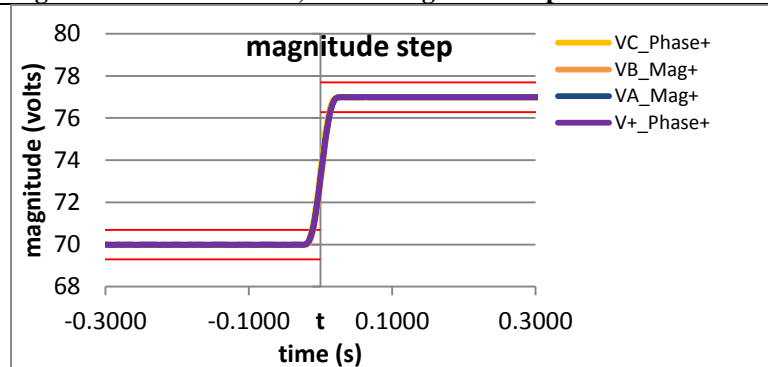


Figure 6181: Fs = 30 FPS, +10% magnitude step

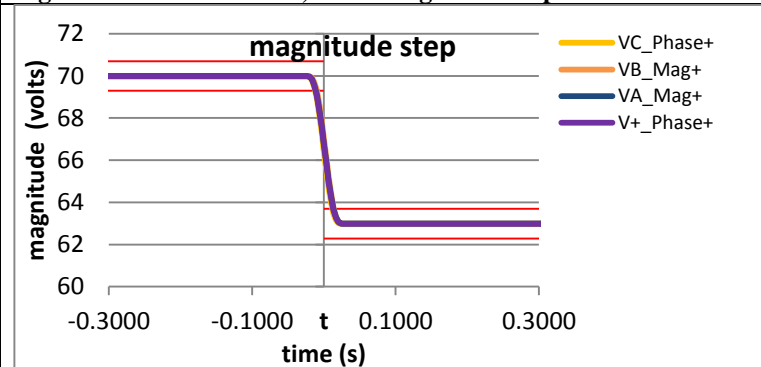


Figure 6182: Fs = 30 FPS, -10% magnitude step

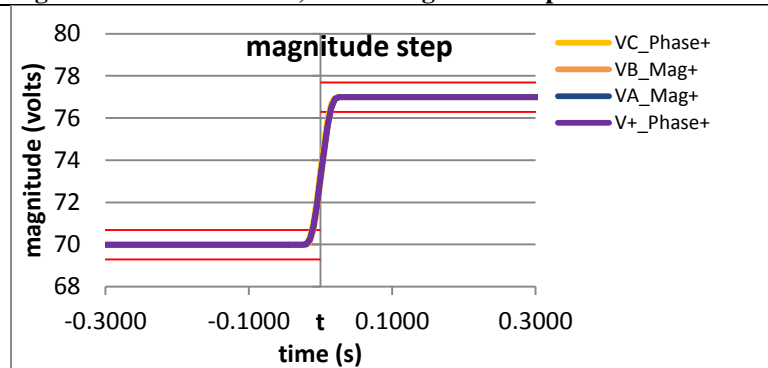


Figure 6183: Fs = 20 FPS, +10% magnitude step

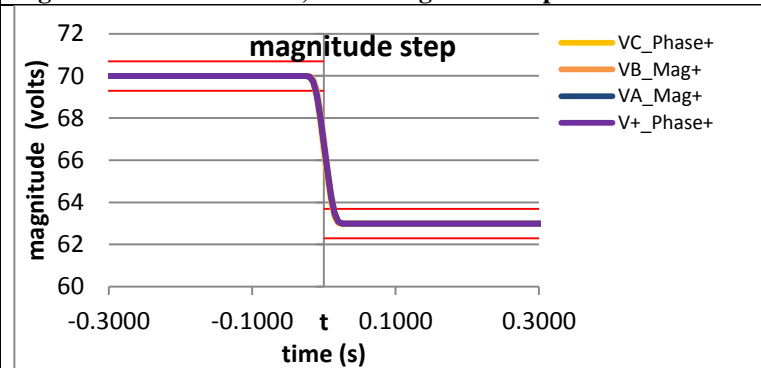


Figure 6184: Fs = 20 FPS, -10% magnitude step

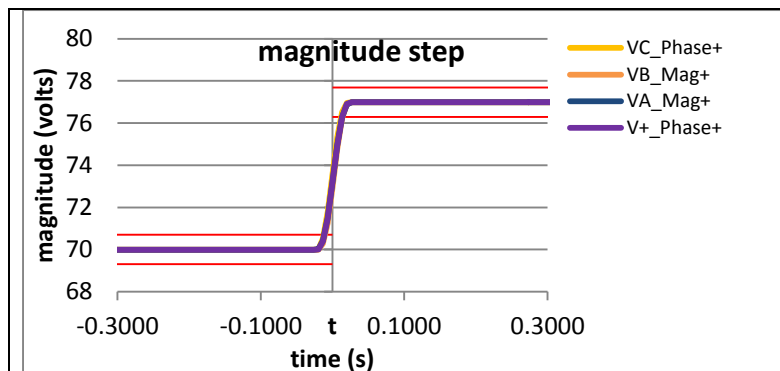


Figure 6185:  $F_s = 15$  FPS, + 10% magnitude step

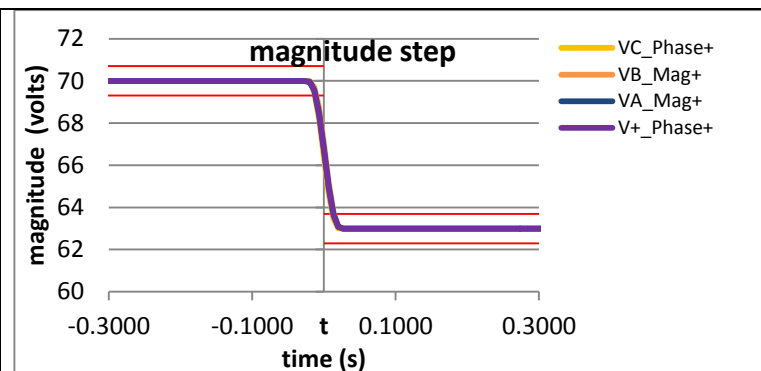


Figure 6186:  $F_s = 15$  FPS, - 10 % magnitude step

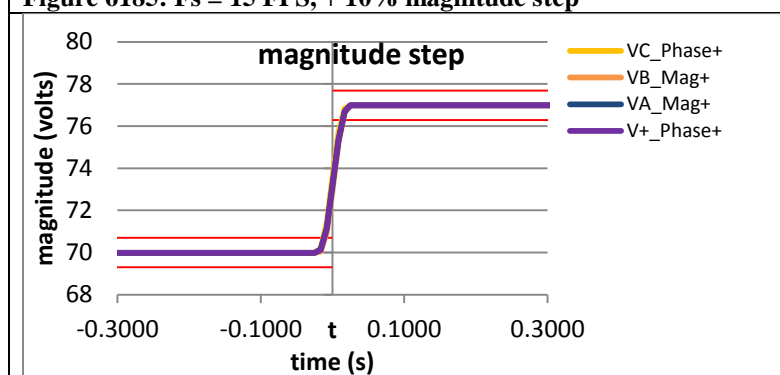


Figure 6187:  $F_s = 12$  FPS, +10% magnitude step

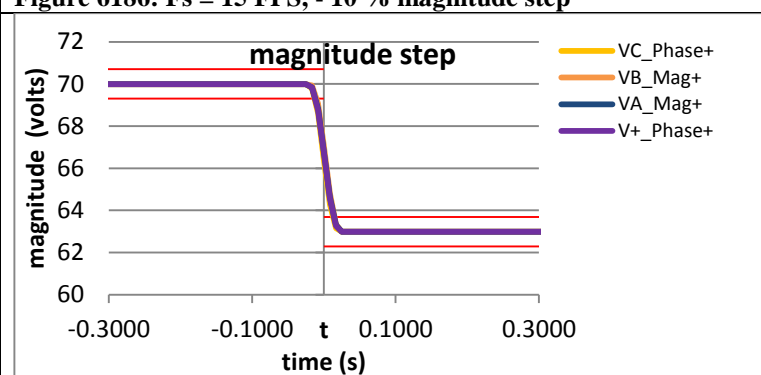


Figure 6188:  $F_s = 12$  FPS, -10% magnitude step

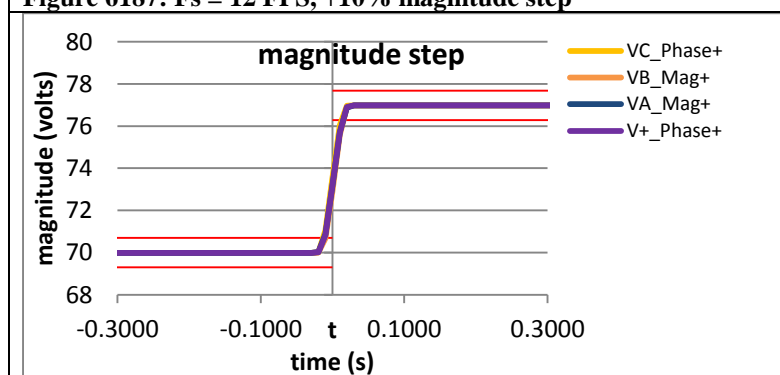


Figure 6189:  $F_s = 10$  FPS, +10% magnitude step

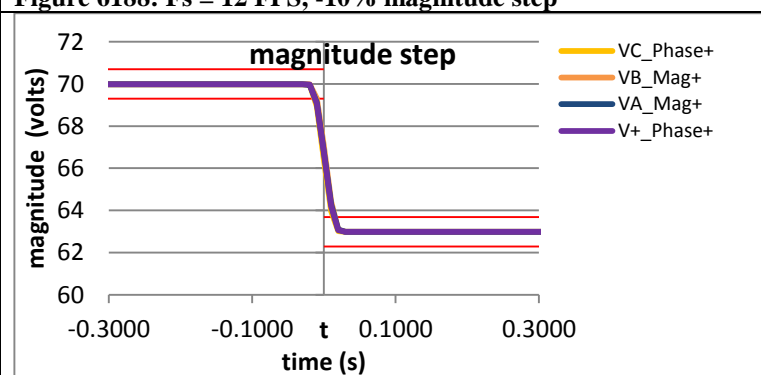
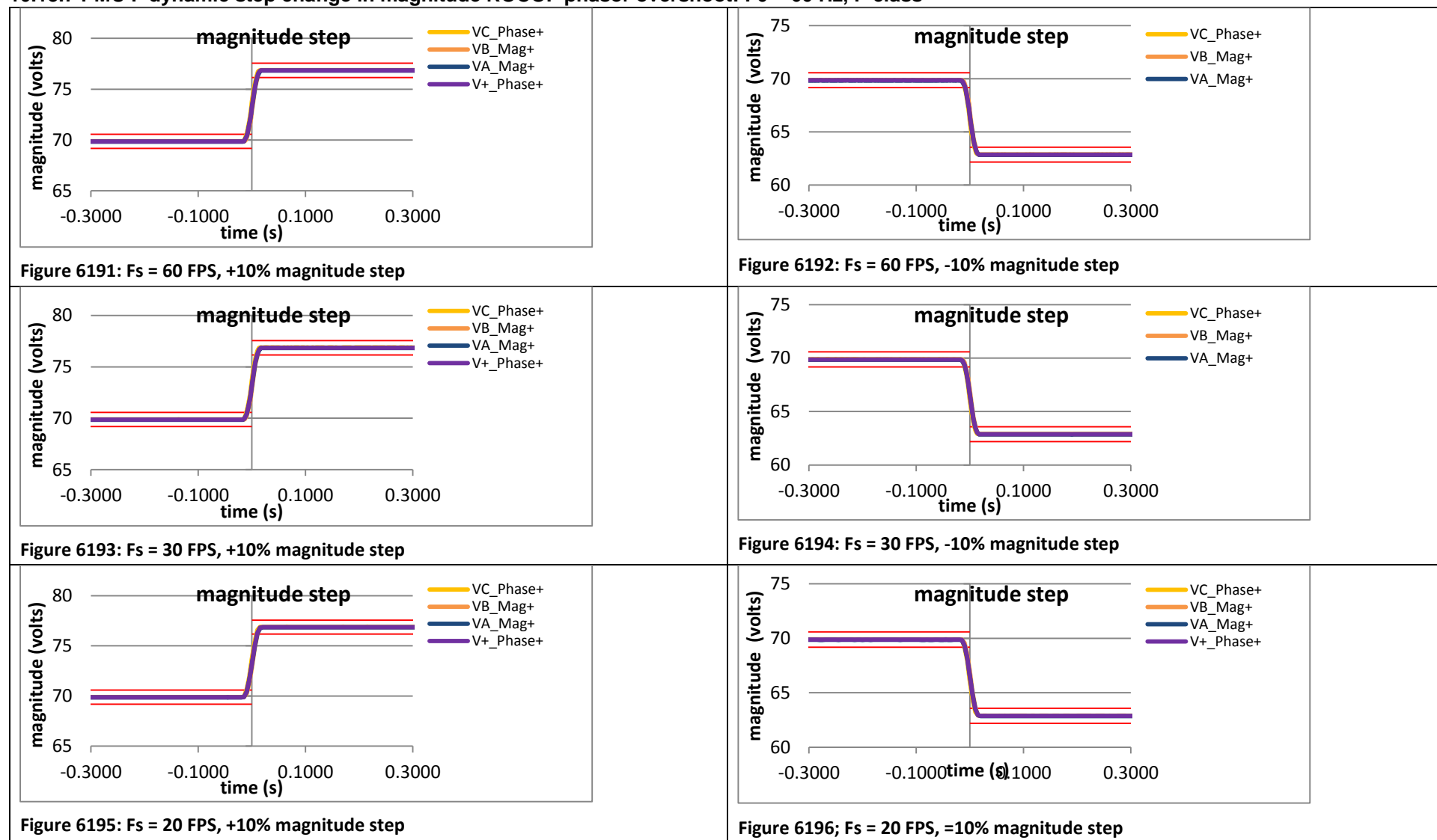


Figure 6190:  $F_s = 10$  FPS, -10% magnitude step

### 10.13.6 PMU E dynamic step change in magnitude ROCOF phasor overshoot: $F_0 = 60$ Hz, P class

PMU E does not support P class.

### 10.13.7 PMU F dynamic step change in magnitude ROCOF phasor overshoot: $F_0 = 60$ Hz, P class





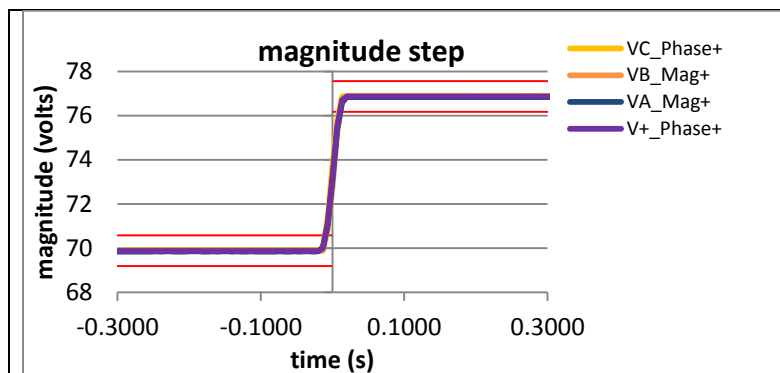


Figure 6197: Fs = 15 FPS, + 10% magnitude step

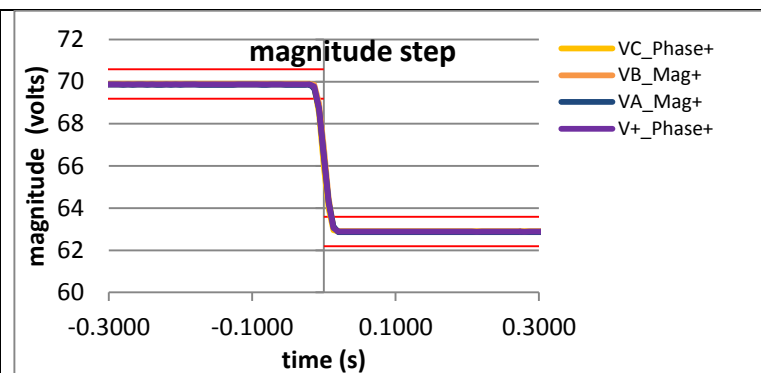


Figure 6198: Fs = 15 FPS, - 10 % magnitude step

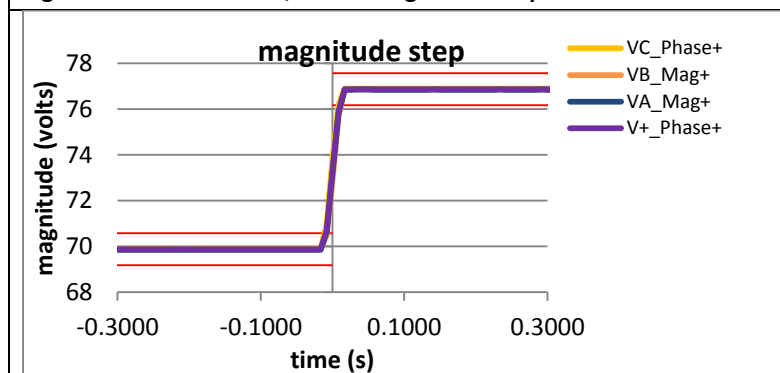


Figure 6199: Fs = 12 FPS, +10% magnitude step

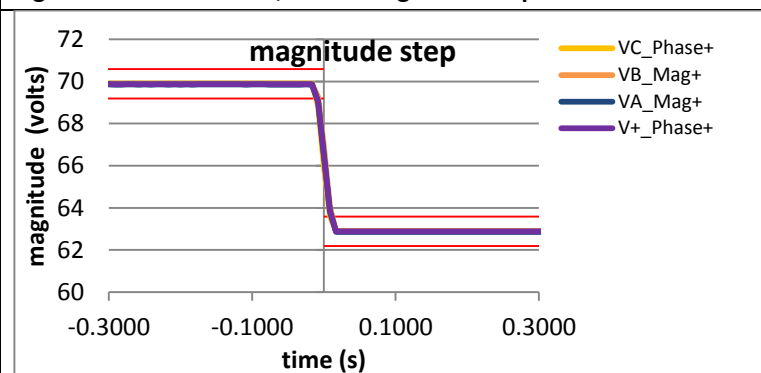


Figure 6200: Fs = 12 FPS, -10% magnitude step

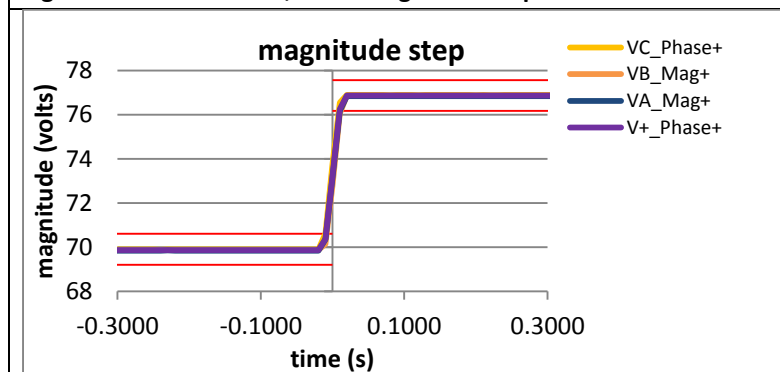


Figure 6201: Fs = 10 FPS, +10% magnitude step

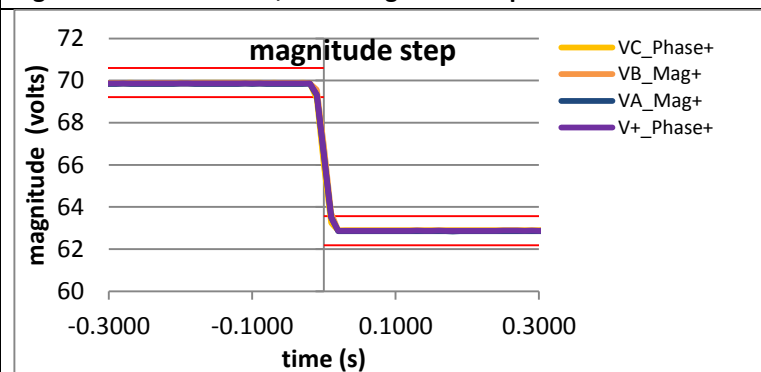
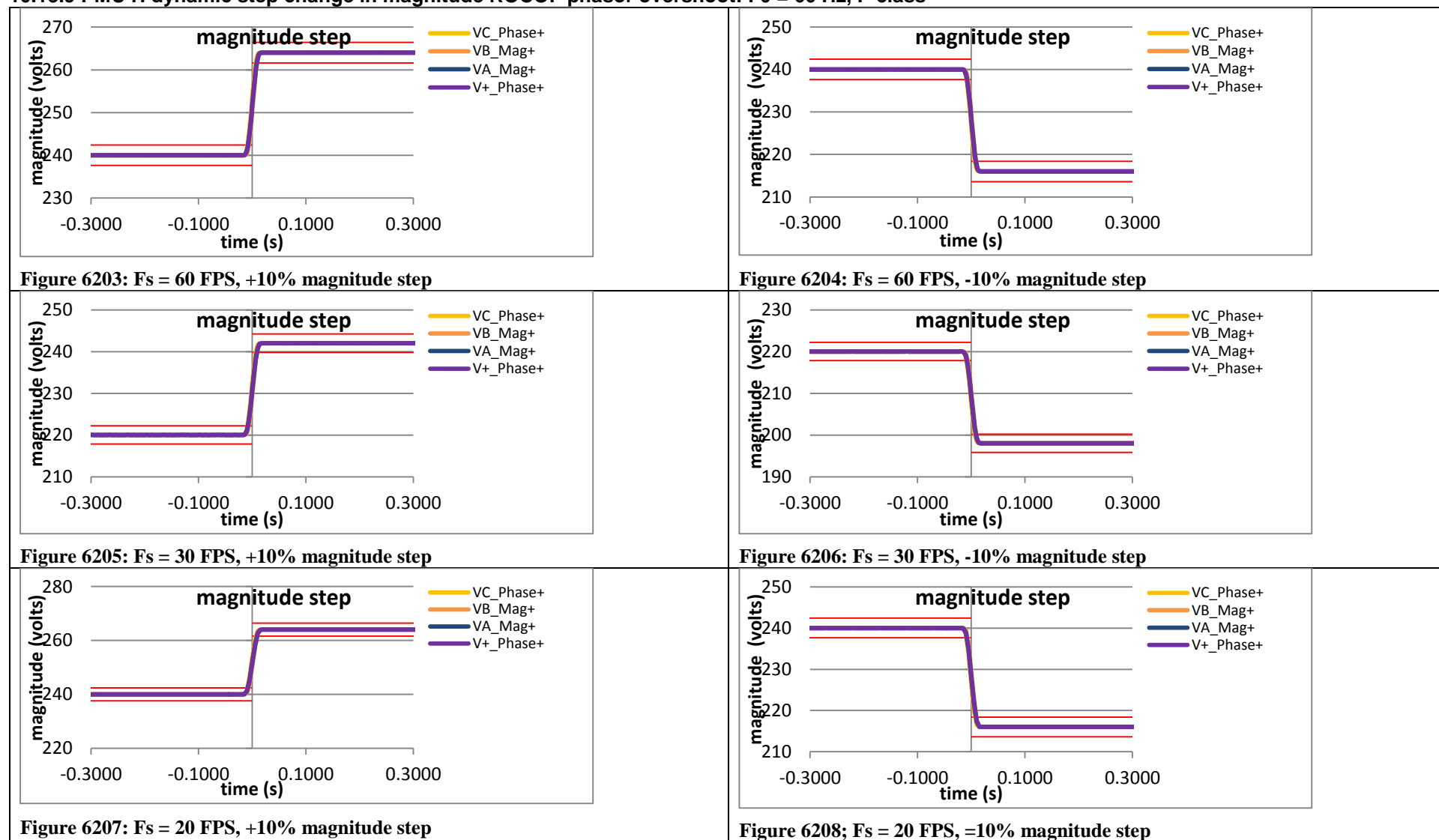


Figure 6202: Fs = 10 FPS, -10% magnitude step

### 10.13.8 PMU G dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class

PMU G does not support P class.

### 10.13.9 PMU H dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class



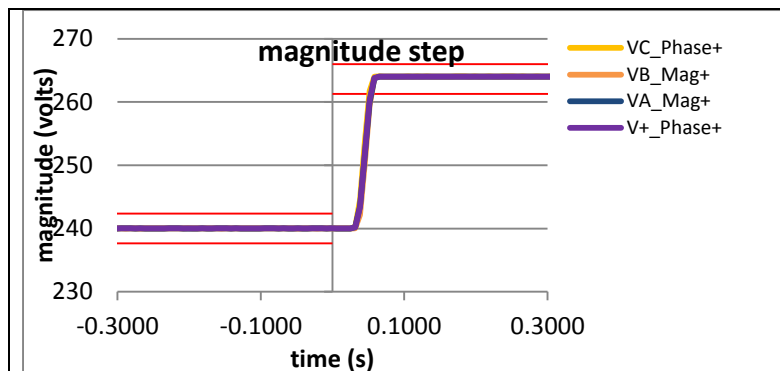


Figure 6209: Fs = 15 FPS, + 10% magnitude step

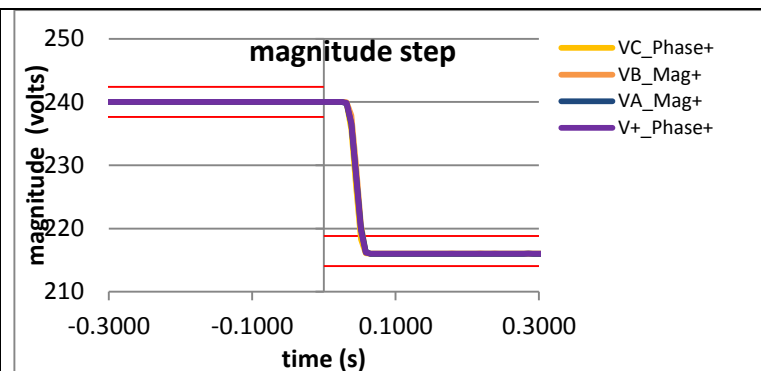


Figure 6210: Fs = 15 FPS, - 10 % magnitude step

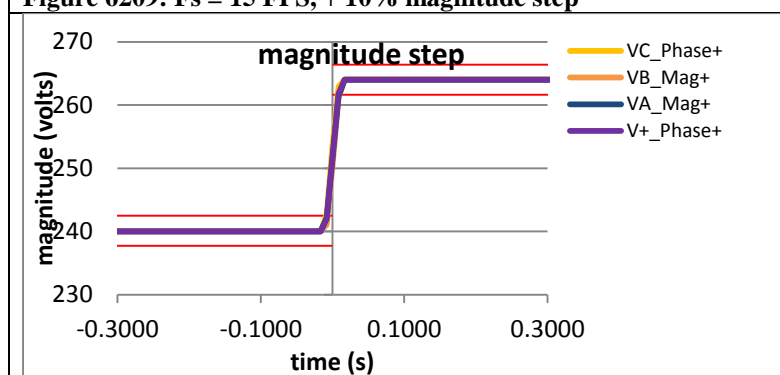


Figure 6211: Fs = 12 FPS, +10% magnitude step

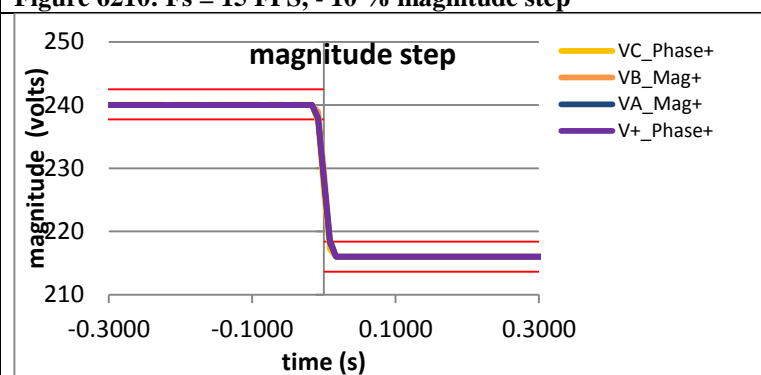


Figure 6212: Fs = 12 FPS, -10% magnitude step

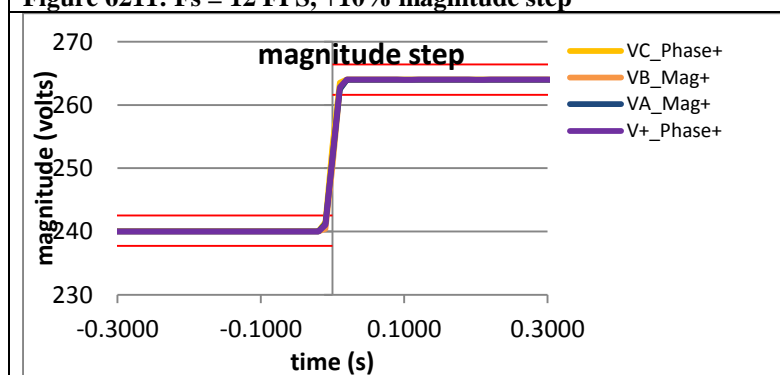


Figure 6213: Fs = 10 FPS, +10% magnitude step

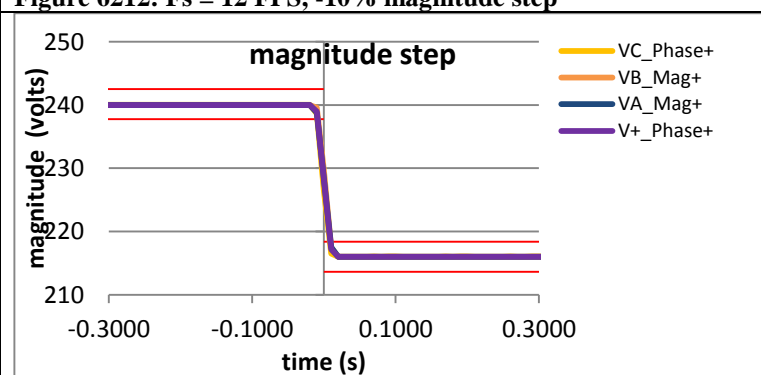
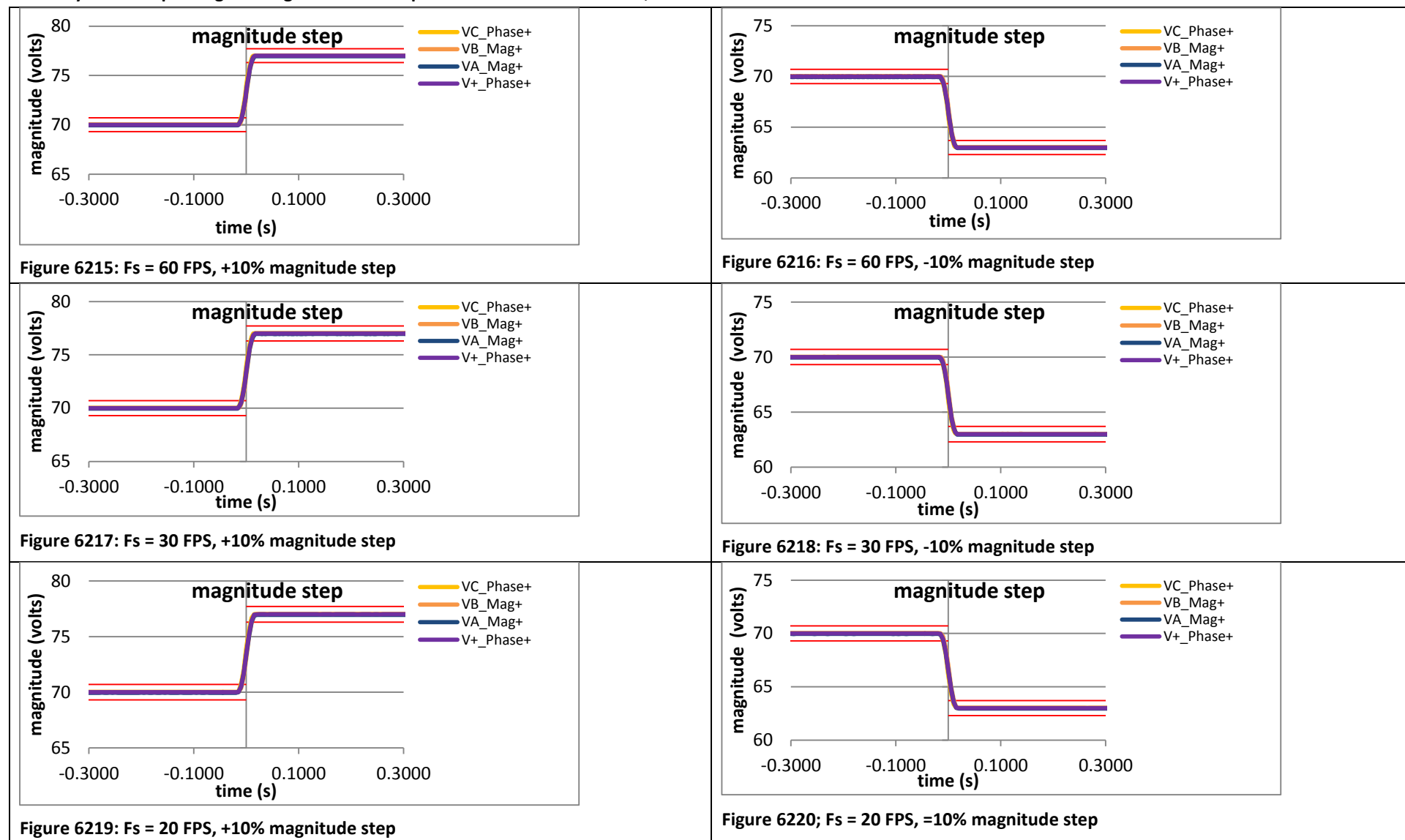


Figure 6214: Fs = 10 FPS, -10% magnitude step

### 10.13.10 PMU I dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class

PMU I does not support P class

### PMU J dynamic step change in magnitude ROCOF phasor overshoot: F0 = 60 Hz, P class



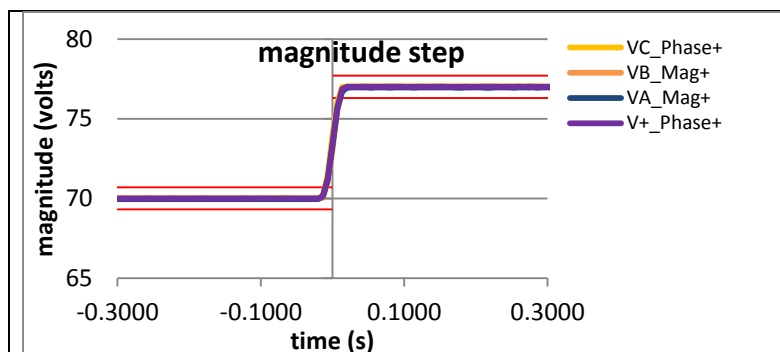


Figure 6221: Fs = 15 FPS, + 10% magnitude step

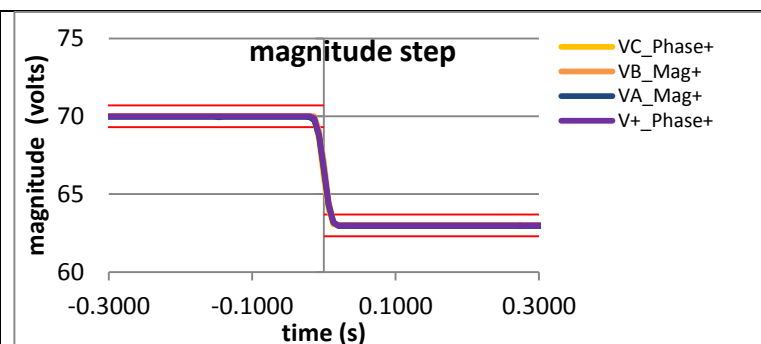


Figure 6222: Fs = 15 FPS, - 10 % magnitude step

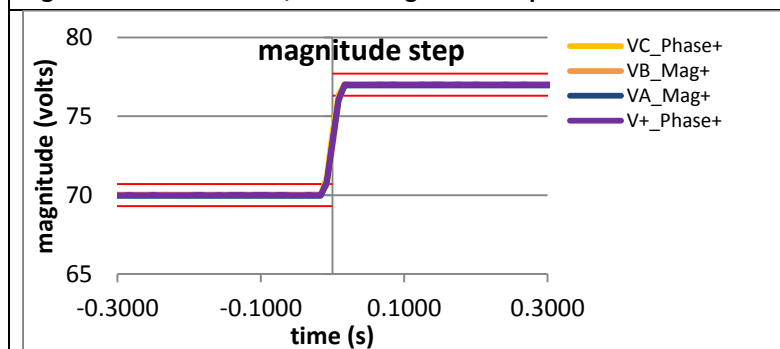


Figure 6223: Fs = 12 FPS, +10% magnitude step

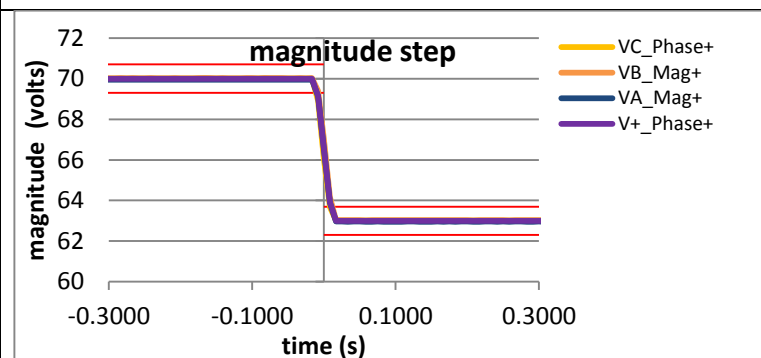


Figure 6224: Fs = 12 FPS, -10% magnitude step

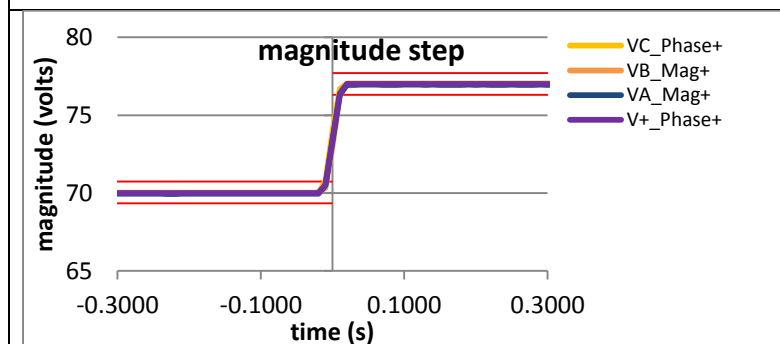


Figure 6225: Fs = 10 FPS, +10% magnitude step

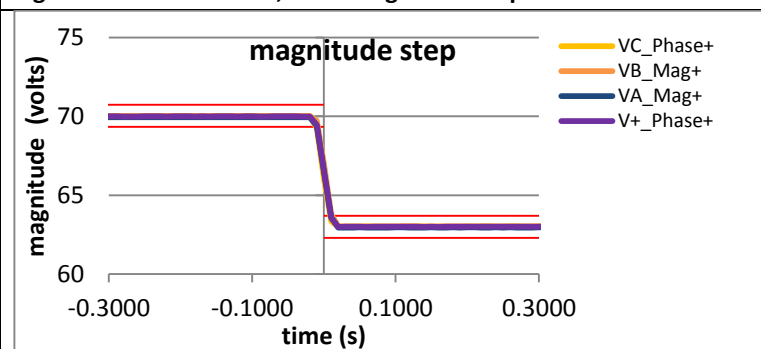


Figure 6226: Fs = 10 FPS, -10% magnitude step

## 11. Conclusion

11. Conclusion .....	1073
11.1 Intent .....	1074
11.2 Amendments to the synchrophasor standard.....	1074
11.2.1 Relaxation of Rate of Change of Frequency (ROCOF) performance limits. ....	1075
11.2.2 Measurement Bandwidth test changes.....	1075
11.2.3 Changes to ramp of system frequency tests .....	1075
11.2.4 Limit of M class PMU reporting latency .....	1075
11.2.5 Revision to the Annex C reference signal processing model .....	1076
11.3 Typical PMU performance issues .....	1076
11.3.1 Offset in the time of the frequency estimate .....	1076
11.3.2 Out of band interfering signal test performance.....	1077
11.3.3 Issues with the performance of frequency tracking and adaptive filter PMU algorithms. ....	1077
11.4 IEEE Synchrophasor Measurement Test Suite Specification (TSS) .....	1077
11.5 Compliance testing .....	1077

## 11.1 Intent

The intent of this assessment of PMU performance is multi-fold:

- Invite all PMU vendors to participate in an independent assessment of the performance of their PMU products
  - Provide the participating vendors with test data
    - Allow for vendors to compare independent test results with their in-house testing
    - Vendors may revise their PMU designs and submit for re-testing
      - This report contains the latest re-test results
- Provide test results (vendor name and PMU model obscured) to the synchrophasor standards setting organizations
  - Test results were used to validate test methods and resulted in:
    - Amendment to IEEE Std. C37.118.1-2011 published as C37.118.1a-2014
    - Drafting and publication of IEEE Synchrophasor Measurement Test Suite Specification
  - Detailed test data to be used in the evaluation of requirements for applications which use PMU data as input
  - Help NIST and other organizations gain an understanding of common performance issues in PMUs as well as some issues only seen in one make and model of PMU
- Produce this report:
  - Intended to be used by
    - Utilities to aid in understanding that PMU performance from model to model varies significantly
    - Designers of applications which use PMU data as their inputs
    - Test labs to provide examples of test results of different models of PMU
    - Students and professors as examples of the performance of PMU models and principles of test reporting
    - Governments and regulatory agencies to provide examples of the range of performance of PMUs currently used in electrical power systems

## 11.2 Amendments to the synchrophasor standard

Several lessons were learned over the course of the NIST PMU assessment that lead directly to the 2014 amendment of IEEE C37.118.1-2011. All the limits shown in this assessment report were based upon the IEEE Std. C37.118.1a-2014 amendment. The following sections describe these changes.

#### **11.2.1 Relaxation of Rate of Change of Frequency (ROCOF) performance limits.**

The NIST PMU assessment provides information indicating that many PMUs installed in power systems were susceptible to internal noise from analog to digital conversion processes and digital algorithms. The performance limits for ROCOF had been determined through the use of digital simulations of the C37.118.1a Annex C Signal Processing Model that did not implement this noise. The standards setting organization determined that the ROCOF limits could become a limiting factor in the design of PMUs and that ROCOF performance did not need to impose such stringent limits so they were relaxed for all tests, and removed for out-of-band interfering signals tests and for M class harmonic distortion testing.

#### **11.2.2 Measurement Bandwidth test changes**

Analysis of the assessment data for the combined amplitude and phase modulation tests showed that little useful information about the root cause of PMU performance issues could be attained from the test results. The combined modulation test was removed from the standard and replaced with an amplitude-modulation-only test to complement the existing phase modulation test.

The performance limits for frequency and ROCOF for the measurement bandwidth phase modulation test were found by NIST to be so high for some reporting rates, that a PMU that reported '0' for all frequency and ROCOF would still pass the tests. Frequency and ROCOF limits for measurement bandwidth tests were revised so that PMUs reporting '0' frequency or ROCOF would not pass the test.

#### **11.2.3 Changes to ramp of system frequency tests**

During NIST's implementation of the ramp of system frequency test, several ambiguities were found in the standard's description of the test. NIST recommended descriptive changes that were adopted in the amendment for clarification. Some PMUs tested by NIST were unable to provide meaningful synchrophasors beyond the standard-specified bandwidth limits, depending on PMU class and reporting rate, and required a long period of time to once again begin providing meaningful information. NIST recommended that the test prohibit operation beyond the specified bandwidth. NIST found that the concept of "transition time" in the standard was ambiguous and difficult to implement. The amendment revised the "transition time" to a "measurement exclusion interval". The test now requires that the frequency ramp begin and end at the specified synchrophasor bandwidth limits and that an interval of reports at the beginning and end of the ramp shall not be included in the measurement. This is intended to remove the response of the PMU to the step in ROCOF which occurs at the beginning and end of the test.

#### **11.2.4 Limit of M class PMU reporting latency**

Through NIST's work with several vendors and after several PMU revisions from one vendor, it was determined that some implementations would not be able to meet the maximum PMU reporting latency specified by the standard. The issue was brought up and discussed by the standards setting organization, and the body decided from what was known to date about the needs of applications using M class PMU data, reporting latency did not need to be a critical factor behind



M class designs. The reporting latency was relaxed from five reports to seven reports. Research into the performance needs of applications which use PMU data is ongoing.

#### **11.2.5 Revision to the Annex C reference signal processing model**

Part of NIST's assessment included assessment of the C37.118.1-2011 Annex C reference signal processing model. Some ambiguities in the model descriptions were found and revisions were proposed. An error in the M class filter parameter table was found and one filter reference frequency and filter order was amended.

### **11.3 Typical PMU performance issues**

Some of the PMUs assessed by NIST exhibited some typical issues. Several of the vendors were able to correct for these issues and submitted revisions for re-testing.

#### **11.3.1 Offset in the time of the frequency estimate**

Some PMUs do not estimate their frequency at the precise time of the timestamp in the report. This offset in the time of the frequency estimate is only exhibited by the results of the ramp of system frequency or measurement bandwidth phase modulation tests. In the ramp of system frequency test, it is exhibited by a constant offset in frequency error which is directly proportional to the difference between the time of PMU report timestamp and the actual time of the frequency estimate. Since the frequency ramp rate of the test is specified to be 1 Hz/s, the frequency error (FE) offset will be 1 Hz for each second of time offset. NIST pointed out that the definition of frequency error in the PMU standard had an inverted sign inside the absolute value marks so that if frequency error were measured as defined by the standard but without the absolute value being taken, the FE offset would be the opposite sign of the time offset. the new draft PMU standard being considered at the time of this writing removes the absolute value marks and negates the difference so a signed frequency error has the correct sign value.

##### **11.3.1.1 Offset in the time of the ROCOF estimate**

Because ROCOF is defined by the PMU standard as the derivative in frequency, those PMUs that have an offset in the time of the frequency estimate will also have an offset in the time of the ROCOF estimate. The magnitude of the offset may be greater for the ROCOF estimate since multiple frequency estimates are used to determine a ROCOF estimate. The offset in the time of the ROCOF estimate can only be seen in the results of the measurement bandwidth phase modulation tests and not in any other test.

### **11.3.2 Out-of-band interfering signal test performance**

Many of the PMUs as they were first submitted to NIST failed to pass the limits for out-of-band interfering signals testing. This test exposes the PMU to interfering signals (a single interharmonic) from 10 Hz up to the nominal frequency minus the Nyquist frequency of the reporting rate, and from the nominal frequency plus the reporting rate Nyquist frequency up to the second harmonic of the nominal frequency. The test verifies the performance of the PMUs anti-aliasing filters since any signal not properly filtered out would be aliased and appear as a signal frequency within the PMU bandwidth as a false frequency component that does not actually exist in the input signal. Many of the PMU vendors revised their PMU performance and submitted for re-testing.

### **11.3.3 Issues with the performance of frequency tracking and adaptive filter PMU algorithms.**

The 2005 PMU standard did not require any testing under dynamic conditions. Some PMU vendors used frequency tracking or adaptive filtering algorithms in order to improve the steady state performance of their products. However some of these PMUs were unable to perform within the limits for the 2011 dynamic tests. There were various root causes such as the time constant of the adaptive algorithms not being fast enough to keep up with dynamic signal changes. Several of the vendors revised their PMUs and submitted for re-test which subsequently passed the tests.

## **11.4 IEEE Synchrophasor Measurement Test Suite Specification (TSS)**

PMU assessment testing at NIST was carried out prior to and during development of the IEEE Synchrophasor Measurement Test Suite Specification. Much of what was learned, during the assessment, about implementing PMU tests in accordance with the synchrophasor standard supported the drafting of the TSS.

## **11.5 Compliance testing**

Assessing PMUs models for conformity to the latest standards can ensure the best performance and interoperability under dynamically-changing grid conditions. Since PMUs have many configuration options and may be included in multi-function devices, end users can additionally have their PMUs tested using the configuration with which they will be installed.