Transactive Energy Challenge Phase II Scenario

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ABSTRACT

The Transactive Energy (TE) Challenge Phase II Scenario was developed in a multi-step process in collaboration with industry experts. The Scenario enables comparison of results from different TE simulations and different TE approaches. The Scenario includes a common electric grid definition including attached loads and generators, weather, and reporting metrics. This document and the files that it references serve as a repository for future use.

Key words

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1. Introduction

The TE Challenge Phase II focused on a TE co-simulation exercise based on a collaboratively developed common scenario, including metrics, that advanced the goals of the Challenge [1, 2, 3]. The first goal of Phase II was to perform TE simulations using a collaboratively developed TE scenario that serves as a baseline for comparisons of simulation results. Using a common electric grid, weather, loads, and reporting metrics enables the direct comparison of results from different TE simulations and different TE approaches. This document and the files that it references serve as a repository for future use.

Common scenarios are important tools for understanding and describing the value of various TE components and strategies. Defining use cases with specific objectives allows the effectiveness of TE solutions to be analytically compared against business-as-usual or baseline scenarios. To facilitate meaningful comparison across strategies, use cases must include common reference grids, environmental conditions, and objectives.

Developing the common scenario began in Phase I of the Challenge [3] with development of a set of transactive energy use cases, and then selection and development of one of those use cases for further modeling work. The process and details of that effort are documented in the Appendix. Prior to the Phase II launch, NIST worked with Pacific Northwest National Laboratories (PNNL), Vanderbilt University, and Carnegie Mellon University to further develop the TE Challenge Phase II strawman scenario components. This strawman scenario and a proposed scenario development process [4] were shared during the April 2017 Phase II Launch. The Challenge scenario was then refined with Phase II teams over a series of web conferences and a face-to-face meeting in the months of May and June 2017. Some additional modifications were made as the Challenge progressed. The final simulation components of the Challenge scenario are hosted online [5].

The Challenge Scenario is a collection of components including: a specific electric feeder with specified loads and generators, an event sequence (weather for one day), a time-of-use price schedule for the baseline (non-TE) case, a series of simulations that range from a non-TE baseline to simulations with TE models chosen by each team, and an agreed upon set of common metrics for reporting results. These components are discussed more below.

2. Common Scenario components

Several factors guided the selection of weather, grid and other components. It was initially agreed to focus on the distribution grid as an appropriate place to investigate transactive energy with grid-edge market interactions. The target use case focused on voltage control due to high-penetration of photovoltaic (PV) systems. A large feeder model was chosen to provide diversity of loads and generation with potential for voltage variation across the feeder due to the concentration of PV generation. To reduce complexity of the co-simulation exercise, teams agreed not to model the transmission grid.

2.1. IEEE 8500 Grid
The Institute of Electrical and Electronics Engineers (IEEE) 8500 reference distribution grid [6], shown in Fig. 1, was selected as the basis for the Challenge scenario. This 8500-node test feeder is a moderately large radial distribution feeder consisting of both low and medium

voltage (MV) levels. The nodes occur at approximately 4,800 1-, 2-, and 3-phase bus locations. The power flow is moderately difficult to solve at the specified load level. The test grid also exhibits approximately 10 % power losses at peak load. The circuit contains 170 km of primary (MV) conductor. The circuit contains one set of regulators controlling the feeder voltage at the substation and three sets of voltage regulators along the line. The circuit also contains four capacitor banks, three that include per-phase capacitor control. The controlled capacitor banks monitor each phase separately, and each capacitor bank operates the respective capacitor on the same phase. The capacitor switches ON when the reactive power flow in the line is 50 % of the capacitor size and switches OFF when the flow is 75 % of the capacitor size in the reverse direction. Each controlled capacitor also includes voltage override where the capacitor turns ON at 0.9875 pu and turns OFF at 1.075 pu.

The test feeder makes two load model cases (secondary loading case models with residential loads connected to a 120V/240V split-phase transformer in balanced and unbalanced configurations) available to users. The teams agreed to use a balanced configuration.

Specifications for loads, PV generation, and batteries in houses at each meter were developed. As specified, the grid is a purely residential feeder, with a nominal peak load of 10.8 MW and 2.7 MVAr. Of the 1,977 houses on the feeder, all of them were configured with air conditioning (26.15 MW load), and 90 % (1,777) of them with PV systems with total peak solar production of 6,755 kW. In addition, 857 homes have batteries with a total storage capacity of 4,285 kW (although these were not used in the baseline configuration), and 1,013 homes have electric water heaters totaling 4,574 kW. The grid definition and specific details of each house (thermal parameters and equipment), are contained in the inv8500.glm GridLab-D model file, available on a GitHub site managed by PNNL as part of their TE Simulation Platform (TESP) [7]. TE Challenge scenario files are maintained within the /examples/IEEE8500 directory of TESP Release 1.1 [5]. This directory has a readme.md file that explains the various model files, input files, data processing scripts, and results files. This directory serves as a repository of the TE Challenge scenario simulation files.
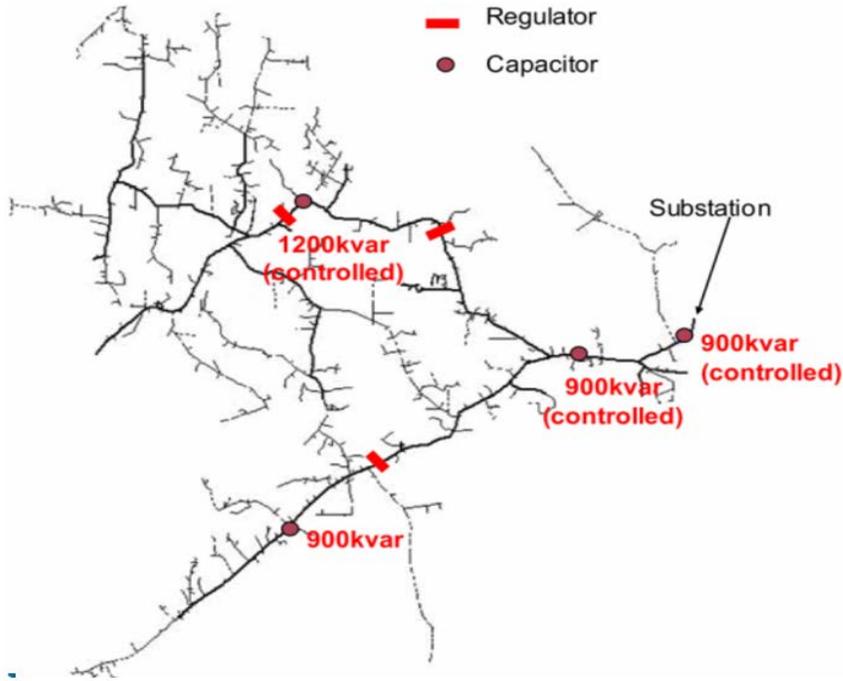
Figure 1 IEEE 8500 grid schematic.

2.2.   Weather scenario

The High-penetration PV and Voltage Control scenario (refer to the Appendix for more detail) was originally written for a distribution system with a high penetration of PV systems and over-voltage conditions under sunny skies. The TE Challenge teams agreed to add a storm passing to induce voltage fluctuations and then to use transactive methods to incentivize controlled changes in load, generation or storage to mitigate the voltage imbalances. The single day scenario begins with clear sky conditions followed by PV generation dropping from full power to 10 % power output in the 2:30 p.m. to 2:40 p.m. time window due to the storm front arrival. The overcast conditions last until a ramp back up to full sun from 4:00 p.m. to 4:30 p.m.

This scenario narrative is realized in simulation using the climate.csv weather input file [5] based on a sunny Tucson weather day with the addition of an artificial storm front per the narrative above. There is no time shift for the storm front passing over the feeder; every PV panel sees the same weather at the same time per above.

2.3.   Team Simulations

Teams followed an implementation plan with four simulations in a progression to allow building up common understanding, validation by comparison of results, and refinement of the scenario components themselves. The progressive simulations were:

1. Baseline sunny day. The event day is run with no storm front. Electricity price is constant with no TE market interactions.

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2. Adding the storm front. Simulation is repeated with the storm front weather file, with all else the same.
3. Adding dynamic price, without TE market. Teams may enable resources to be price responsive, but there are no TE exchanges.
4. Each team implements a TE model of their choice and applies it to the same feeder and weather event.

2.4. Price data

Teams agreed to use existing Tucson Electric retail tariffs and representative Tucson locational marginal pricing (LMP) data for a summer day. The Residential Basic Service flat rate tariff [9] was used for simulation Steps 1 and 2, with components given in Table 1. The resulting "fixed rate" value used in the one-day TE Challenge simulation, 0.102 $/kWh, is the sum of the 0 to 500 kWh Energy Service Charge plus the Power Supply Charge.

Table 1 Tucson Electric Residential Basic Service Tariff

Tariff Component	Charge	Range
Basic Service Fee	$13.00	
Energy Service	$0.066152/kWh	(0 to 500) kWh
	$0.081152/kWh	(501 to 1000) kWh
	$0.086652/kWh	Over 1000 kWh
Power Supply	$0.035861/kWh	Summer value

The Residential Time-of-Use (TOU) rate [10] was used for Step 3. The TOU rate components are given in Table 2. For TE Challenge simulations, the on-peak or off-peak Power Supply Charge is added to the Energy Service Charge component.

Table 2 Tucson Electric Residential Service Time-of-Use Tariff

Tariff Component	Charge	Range
Basic Service Fee	$10.00	
Energy Service	$0.072152/kWh	(0 to 500) kWh
	$0.081152/kWh	(501 to 1000) kWh
	$0.086652/kWh	Over 1000 kWh
Power Supply	$0.066567/kWh	On-peak*
	$0.026332/kWh	Off-peak

* Summer On-Peak period is 3:00 p.m. to 7:00 p.m., Monday through Friday.

For PNNL TESP Gridlab-D users, the flat price and TOU tariffs are embedded in the GLM file. One can switch between basic and TOU by commenting/uncommenting near the top of the file, and all the meters reference those tariff schedules. LMP five-minute clearing price data [11] are based on the California Independent Service Operator real-time market prices for Tucson[1] for July 6, 2017, which has base prices around $20/MWh and peaks around

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[1] Taken from oasis.caiso.com Prices/Interval Locational Marginal Price at load node SG_LNODE13A.

$50/MWh in the afternoon. Day-ahead market hourly LMPs are also available for July 6-7[2]. Use of the LMP real-time or day-ahead data is not required.

2.5. Common Metrics

To promote the ability to compare the results from simulations using different TE market and control approaches, the participating teams agreed to a set of common performance metrics. The metrics were derived from features of the PNNL TESP, American National Standards Institute (ANSI) C84.1 [12], and IEEE 1366 [13]. Teams were permitted to ignore metrics not applicable to their simulations and to use additional metrics relevant to their results.

General guidelines:

- Save results in a text format, JavaScript Object Notation (JSON) (preferred) or common-separated values (CSV)
- Adjustable metrics interval, defaulting one minute
- If the simulation time step is shorter than the metrics interval, include minimum, maximum and average values within each interval. Integrated metrics (e.g., energy) are an exception
- Optionally, save all power flow data to CSV files by manually inserting recorder statements in the GridLab-D input file
- Separate PV output, battery, and load metrics at the same meter
- No time aggregation, as the use case covers a single day of operation
- Each metric should be associated with specific model components through metadata
- All measurements are time stamped

Specific requirements for base metrics to include in the output:
1. Economic
   a. Wholesale price (defaults to the input LMP player file)
   b. Cleared price(s) on the feeder
   c. Price, quantity, and status (accepted, not accepted) for each bid
   d. Revenue at each meter, separable by load and resource (see 4.f-k,m below)
2. Substation
   a. Real and reactive power
   b. Real and reactive energy
   c. Real and reactive losses
3. At each feeder capacitor bank and voltage regulator
   a. Count of control actuations
4. At each meter (i.e., house)
   a. Voltage magnitude, line-to-neutral, averaged over all phases
   b. Voltage magnitude, line-to-line, averaged over all phases[3]

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[2] Taken from oasis.caiso.com Prices/Locational Marginal Prices with DAM option and SG_LNODE13A selected.

[3] Because of the use of the balanced-secondary version of the IEEE 8500-node feeder, there is no secondary voltage unbalance at single-phase loads. The normalized line-to-neutral and line-to-line voltage magnitudes are equal. For such single-phase loads, V_{avg} should be defined on a 120 V basis.

    c. For three-phase loads only, line-to-line voltage imbalance as defined in ANSI Standard C84.1: $100 \max_{p=1..3}(|V_p - V_{avg}|)/V_{avg}$ [%], where V_p = phase voltage, and V_{avg} is the average of the three phases.

    d. Severity index (SI) for the fluctuation in V_{avg} on per-unit basis at uniform time step. Similar to an L2 norm; $SI = \sum_{k=1}^{n}\sqrt{(V_k - V_{k-1})^2 + 1}$. This metric has also been used to quantify fluctuations in solar irradiance. IEEE 1453 is less applicable because cloud-induced fluctuations are generally too slow.

    e. Violations of ANSI C84.1 voltage limits at the meter. The duration of time in each range should be accumulated. An event count occurs when the voltage transitions from normal to A Range, or from A Range to B Range.

        i. Total duration and event counts below 110 V (B Range)

        ii. Total duration and event counts below 114 V (A Range)

        iii. Total duration and event counts above 126 V (A Range)

        iv. Total duration and event counts above 127 V (B Range)

        v. Total duration and event counts below 10 V (Outage; none expected)

    f. Total house load (real power)

    g. Total heating ventilation air conditioning (HVAC) load (real power)

    h. Total water heater load (real power)

    i. Solar inverter real and reactive power

    j. Battery inverter real and reactive power

    k. House air temperature, and its deviation from scheduled set point evaluated by:

        i. Root mean squared deviation

        ii. Maximum deviation

        iii. Duration, average magnitude, and direction of the longest excursion

    l. Water heater temperature and its deviation from scheduled set point

    m. Total bill synchronized to the cleared market price[4]

5. Local utilization of green power, defined as the percentage of locally-generated green energy in the total energy consumed by all the customers connected to a feeder or in a microgrid. The sources of green energy considered are roof-top solar PV, but not batteries.

3. Conclusion

The TE Challenge Phase II common scenario is a collection of components including grid and weather definition, common metrics and progressive simulation plan. The scenario was developed collaboratively by the TE Challenge teams, with significant input from PNNL for definition of homes and metrics, and providing the grid definition in GridLab-D format. This paper and the PNNL GitHub repository of technical files serves to document this reference scenario so that others can duplicate and use the scenario for comparative TE simulations.

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[4] The 8500-node model as implemented here assumes net metering, with distributed energy resource (DER) disaggregation based on real power. An alternative would be to meter each DER separately from the house, so each could have its own tariff and bill.

References

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[10] Tucson Electric Residential Time-of-Use (2018) https://www.tep.com/wp-content/uploads/2017/02/102-TRREST.pdf.

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[12] ANSI C84.1-1982. American National Standard for Electric Power Systems and Equipment-Voltage Ratings (60Hz).

[13] IEEE 1366-2012 - IEEE Guide for Electric Power Distribution Reliability Indices.

[14] Burns, M., Song, E., Holmberg, D., The Transactive Energy Challenge Abstract Component Model, *NIST Special Pub 1900-602*, available from: https://doi.org/10.6028/NIST.SP.1900-602, 2018.

Appendix: Development of the TE Challenge Phase II Scenario

The TE Challenge Phase II Scenario development proceeded over the course of more than a year. The initial work began with the definition of six transactive energy use case scenarios [8] which grew out of the TE Challenge Phase I work. Near the end of Phase I, a focused effort was initiated to develop a common TE abstract model [14]. The development of the TE abstract model began with a meeting on June 23, 2016 with experts from National Institute of Standards and Technology (NIST), Department of Energy (DOE), Pacific Northwest National Laboratory (PNNL), Vanderbilt University, and Carnegie Mellon University (CMU). Experts at this meeting noted that a detailed test scenario would be needed to demonstrate and validate this TE abstract model. To that end, the experts analyzed the six TE use case scenarios according to a set of criteria to identify a single use case which became the basis for the TE Challenge Phase II scenario. Beyond this, they considered a phased approach for increasing the complexity of the use case from a simplistic grid model with baseline conditions to a more realistic grid and environmental conditions.

This appendix begins with a short review of the six use cases, followed by the assessment and prioritization of the use cases against a set of criteria, leading to the selection of the High-penetration PV and Voltage Control scenario for use in simulations. The initial thoughts on the phased use case development are also documented.

Phase I Use Cases
During Phase I of the TE Challenge, one of the teams focused on developing a reference grid design and interoperability requirements to allow testing of different TE approaches for a set of scenarios. That team contributed to a white paper [8] which identified six core use cases (UCs) for TE assessment:

- UC1: Peak Heat Day and Energy Supply;
- UC2: Wind Energy Balancing Reserves;
- UC3: High-Penetration PV and Voltage Control;
- UC4: EVs on the Neighborhood Transformer;
- UC5: Islanded Microgrid Energy Balancing; and
- UC6: System Constraint Resulting in Mandatory Curtailment.

The six use cases represent a diverse set of modeling, environmental, economic, and operational considerations. While each of the use cases represents an interesting scenario and value proposition for TE approaches, there is some overlap of the objectives across use cases. Additionally, given the state of model capability, it is not currently possible to transparently evaluate all the use cases.

Use Case Assessment and Prioritization
At the June 23 meeting of TE modeling experts, the six use cases were qualitatively assessed for prioritization. Because the value of TE assets are maximized in scenarios that require regular and ongoing optimization, use cases with objectives characterized by infrequent or emergency implementation of TE services (UC1 and UC6) were deemed to be of limited

value in assessing early deployment scenarios for developing TE strategies. Furthermore, because emergency grid conditions are typically characterized by supply constraints and an associated need for load curtailment—as is the case in both UC1 and UC6—the team agreed that scenarios characterized by infrequent or emergency use cases do not provide materially different insight into TE operations than would other demand response scenarios.

To assess the remaining scenarios, the team developed a set of five qualitative criteria. These criteria were simplicity, impact, advancement, modeling challenges, and utility relevance:

> **Simplicity –** The ease with which scenario boundaries can be described, and impacts can be quantified. use cases focused on localized effects tended to score higher in this assessment, while use cases that required integration and overlap of bulk and distribution markets and/or operations tended to score lower due to the associated operational, regulatory, and economic uncertainty.

> **Impact –** The extent to which successful mitigation of the concern identified in the UC would fundamentally alter grid operational or infrastructure investment paradigms. use cases that would facilitate greater system flexibility and higher utilization rates for a broad set of existing grid assets tended to score higher in this assessment.

> **Advance TE Frontier –** The likelihood that data and knowledge produced by analyzing the UC would provide new and meaningful insight into TE business models, technologies, or operations. use cases focused on single asset functionality tended to score lower in this assessment.

> **Exercise the Model Environment –** The extent to which multiple tools would be required to work in parallel to assess solutions. use cases that focused on multiple spatial and temporal scales tended to score higher in this assessment.

> **Interest by Utilities –** The extent to which the UC could address high-priority operational concerns for utilities.[5]

Experts at the June 23 meeting scored the use cases via two approaches (see Table A-1). Use cases were first graded independently for each of the criteria with numerical scores of 1, 2 or 3 assigned for grades of good, neutral, or bad (respectively), shown as "Absolute Grading" in Table A-1. The intention was to provide some assessment of the absolute value for each use case. There was no restriction on applying the same score for a given criterion to multiple use cases.

Next, the use cases were compared and assigned an ordinal priority for each evaluation criterion ("Relative Ranking" in Table A-1). This was intended to provide some assessment of the relative value and ease of implementation of the use cases.

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[5] No utility representatives participated in the June 23, 2016 meeting, although many meeting participants had extensive experience working for and collaborating with electric utilities.

Table A-1 Ranking use cases.

	Absolute Grading				Relative Ranking			
	UC2	UC3	UC4	UC5	UC2	UC3	UC4	UC5
Simplicity	3	1	1	2	4	2	1	3
Impact	1	2	3	1	1	2	4	3
Advance TE Frontier	2	1	2	2	3	1	4	2
Exercise Model Env.	1	2	3	2	1	3	4	2
Interest by Utilities	1	1	3	2	1	2	4	3
Total	8	7	12	9	10	10	17	13

It turned out that both methods resulted in the same prioritization of the use cases as shown in Table A-2.

Table A-2 Use Case Prioritization

Final Position	Absolute Grading Method	Relative Ranking Method
1	High Penetration PV + VC	High Penetration PV + VC
2	Wind Balancing Reserves	Wind Balancing Reserves
3	Islanded Microgrid Energy Bal.	Islanded Microgrid Energy Bal.
4	EVs on Neighborhood Trans.	EVs on Neighborhood Trans.
Not prioritized	Peak Heat Day Energy Supply	Peak Heat Day Energy Supply
Not prioritized	System Constraint/Curtailment	System Constraint/Curtailment

Both UC3 (High-Penetration PV and Voltage Control) and UC2 (Wind Energy Balancing Reserves) received high marks at the experts meeting, although not without qualification. While the high PV scenario (UC3) was the top scorer, that relative ranking was in part driven by the high modeling complexity of, and therefore poor "simplicity" scores assigned to, the regional wind energy balancing scenario (UC2). As multi-scale models advance, perhaps through implementation of a TE co-simulation platform, and interactions across markets and economic incentives become better defined, the priority use case might switch from localized PV to regional wind integration.

Experts noted that UC3 focuses on PV over-generation, and thus the need for load increase. This runs counter to the majority of early deployments of unconventional distributed energy resources which incorporate some form of infrastructure or energy constraint.[6,7,8] To provide greatest relevance from the analytic exercise, the prioritized TE Challenge analysis scenario

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[6] Olympic Peninsula Project
(http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17167.pdf)
[7] Brooklyn Queens Demand Management (BQDM) Program
(https://assets.documentcloud.org/documents/2782996/BQDM-Update-1-2016.pdf)
[8] Phase 1 of CAISO's Distributed Energy Resources proxy demand resource markets focused "solely on demand reduction, rather than… on both reducing and increasing demand." (Source: https://www.caiso.com/Documents/RevisedStrawProposal_EnergyStorage_DistributedEnergyResourcesPhase2.pdf)

must therefore broaden beyond demand inducement to include increasing measures of system flexibility. This concern was addressed in the TE Challenge Phase II Scenario with the introduction of a storm front.

Use Case Definition
The decision was then made that the TE Challenge-modeled use case(s) would focus on the impacts that high-penetrations of rooftop PV have on the distribution grid. Initial models would explore energy and power flow management over time by including a time-varying but spatially uniform resource curve. And as practical, geospatial resolution would be made finer and the resource modeled as temporally stochastic and spatially heterogeneous. The June 23 meeting envisioned a phased approach to model complexity which would facilitate progressively more complex analysis and understanding of transactive approaches to optimize operations and markets that begin with energy and infrastructure management and grow to include ancillary services and stability issues.

The following use case parameters were discussed. The agreed-on plan was that PNNL experts would fully define details of the model.

- **Grid conditions:**
    - Single radial feeder to emphasize local effects. Beta version of feeder will be a four-node feeder, including:
        - 1 node for substation
        - 3 nodes for service transformers, each connected to 10 houses
    - Aggregate distributed rooftop PV capacity exceeds instantaneous demand by 20 % at peak insolation. Distribution and capacity of PV to be determined by PNNL.
    - System shall remain in compliance with feeder capacity constraint, as defined by the reference grid; feeder capacity constraints to be modeled from IEEE 8500 Node Test Feeder [6] to facilitate future scenario expansion.

- **Environmental conditions:**
    - Resource: uniform sunshine, no clouds (clouds to be inserted in future iterations)
    - Suggested location and season: Spring in Southern California, determined to maximize the compound net load ramp as sun sets and demand peaks, while providing greatest flexibility to advance the scenario complexity as issues like regional balancing and integration are introduced.

- **Performance objectives:**
    - Requirement 1: Minimize reverse power flows at feeder substation at peak PV generation
    - Requirement 2: Meet a scheduled load program throughout the day
        - Initially, load program to be set for single model node (e.g., the feeder substation). As the scenario progresses beyond the beta example, load programs can be implemented at substation, regulators, or service transformers.

- **Customers, loads, and PV distribution:**
  - 30 customers (beta model). Each customer load will be aggregated at the building level and consist of a number of representative systems and load profiles, including:
    - HVAC;
    - Lighting;
    - Water heating;
    - Miscellaneous electric loads;
    - PV array (if appropriate, see below); and
    - Battery storage system (if appropriate).
  - PV deployments distributed so that total peak output is 120 % of peak demand.
  - Aggregate net customer loads to be reported at the building level

- **TE market model:**
  - Depends on modeler

- **Analytics:**
  - Not decided

- **Simplified behavior models:**
  - Common customer load profile schedule default for each load category
  - PV conversion efficiency
  - Weather model provides insolation vs. time
  - Common customer price responsiveness for each load category

Planned Use Case development approach

The sample 30-house feeder described above was envisioned as a beta formulation meant to demonstrate the functionality of a TE modeling platform. Following demonstration of co-simulation analysis on this simple feeder, the model would be progressively modified to properly reflect real-world grid complexities. Building from the 4-node, 30-customer feeder described above, progressive expansion of the sample feeder would include:

- Node/customer expansion:
  - Intermediate model: 50 nodes, 400 residential customers.
  - Complex model: Full 8500 node circuit, including residential and commercial customer load profiles.
- Topology expansion:
  - Intermediate model: include feeder secondaries, maintain balanced secondary loads.
  - Complex model: Full 8500 node circuit, including regulators, capacitors, and imbalanced split-phase secondary loads.
- Load variability:

- o Intermediate model: Common customer load profiles, statistical distribution of customer price responsiveness.
        - o Complex model: Statistical distribution of both load profile and customer price responsiveness.
- Resource variability:
        - o Intermediate model: Variability inserted at the feeder secondary level, in accordance with statistics for documented PV variability from a moderate-low variable resource.[9]
        - o Complex model: Variability inserted at the service transformer level.
- Performance objectives:
        - o Intermediate model: Same as beta analysis
        - o Complex model: Net load profile requirements to be introduced at major feeder assets, including regulators and capacity banks (e.g., at 7 points along the IEEE 8500 Node Test Feeder)

In the actual realization of co-simulation using the TE Challenge Scenario, TE Challenge Phase II teams decided to take a large step along this use case development approach path, moving toward the "Complex model" described in each element above. The teams desired to have team efforts applied to a realistic scenario. The agreed on TE Challenge Scenario using the IEEE 8500 grid would serve to demonstrate the value of different TE approaches on a real-world distribution grid.

The final TE Challenge Scenario thus was based on the efforts initiated in TE Challenge Phase I and framework established largely in the June 23, 2016 meeting of experts.

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[9] https://pvpmc.sandia.gov/applications/pv-variability-datasets/