NATIONAL BUREAU OF STANDARDS REPORT

7712

Overcurrent Protector for Monocyclic-Square Type Series-Circuit Regulators

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Overcurrent Protector for Monocyclic-Square Type
Series-Circuit Regulators

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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ABSTRACT

An overcurrent control has been developed for use with series-circuit regulators. This control will indicate the occurrence of an overcurrent condition and will decrease automatically the brightness setting of the regulator from step 5 to step 4 whenever the step 5 current increases to a value which will seriously shorten lamp life.

1. INTRODUCTION

The presence of isolating transformers with open-circuited secondaries in series-lighting circuits supplied by monocyclic-square regulators tends to produce an increase in the output current of the regulator. If the regulator does not have sufficient compensation, the increase in current can seriously shorten lamp life and in some cases it has caused a progressive failure of lamps until all lamps in the circuit have failed.[1/] The specified compensation required for some regulators is not sufficient to prevent a large increase in lamp current. For example, with the C-3 and NC-3 type regulators, an increase in current of 0.75 ampere is permitted when the load is 50 to 75 percent of rated load and 21 to 30 percent of the isolating transformers are open circuited. This increase in current will reduce lamp life to less than 10 percent of rated life. As each lamp fails, the resulting open-circuited secondary of the transformer causes an increase in current which may cause additional lamps to fail and a runaway condition to develop.

To overcome this difficulty an overcurrent control has been developed to indicate overcurrent and to decrease automatically the brightness setting of the regulator from step 5 to step 4 whenever the step 5 current increases to a value which will seriously shorten lamp life.

1/ NBS Report 3260, James E. Davis, Report of a Survey of Visual Landing Aids, May 1954.

2. CIRCUIT DESIGN

2.1 Initial Design

As no alternating-current-operated relay was available with a suitably small difference between the pull-in and drop-out currents, a direct-current meter-movement relay assembly consisting of a current-changing transformer, a rectifier, the d-c meter-movement relay, and an auxiliary relay with power supply was obtained.

Although this assembly had a satisfactorily low difference between the pull-in and the drop-out currents when it was operated in the laboratory from an adjustable-voltage power source, it did not operate satisfactorily when it was connected at the Arcata Field Laboratory* into a runway lighting circuit supplied by a series-circuit regulator. In these tests lamps were removed from the fixtures, two at a time, until all the lamps in the circuit (37) had been removed. Although the current increased to about 9 amperes (rms), the Protector did not function.

Subsequent to these tests a type C-1 (6.6-ampere, 4-kilowatt) Hevi-Duty regulator was installed in the laboratory at Washington and a study was made of the difficulty. The cause of the anomalous behavior was the distortion of the waveform of the regulator output produced by the open-circuited transformers. As the Protector assembly is a rectifier instrument, it responds to the average current. Response to the rms current is required as lamp life and light output are determined by the rms current. The magnitude of the difference between the average and the rms currents is illustrated in table 1. The data given in the table were taken with the type C-1 regulator operating with an initial load of 3600 watts and a current of 6.6 amperes. Lamps were then removed successively from the secondary circuits of isolating transformers with results as indicated.

Table 1. Relation Between RMS and Average Current

Rated Wattage of Open-Circuited Isolating Transformers	Relative RMS Current	Relative Average Current
0	1.00	1.00
200	1.00	.99
500	1.01	.98
700	1.02	.97
1000	1.03	.96
1200	1.04	.96

* Arcata Airport, Arcata, California

Subsequent investigation indicated that the response of the Protector could be corrected by means of a simple filtering circuit of the type shown in figure 1.

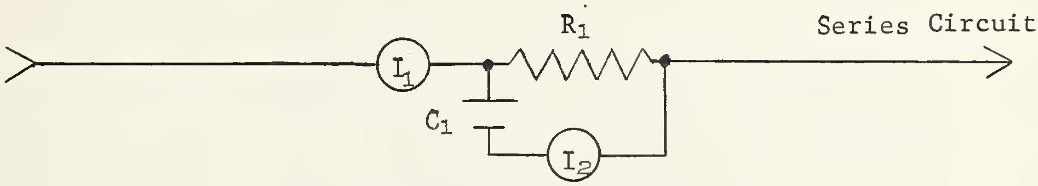
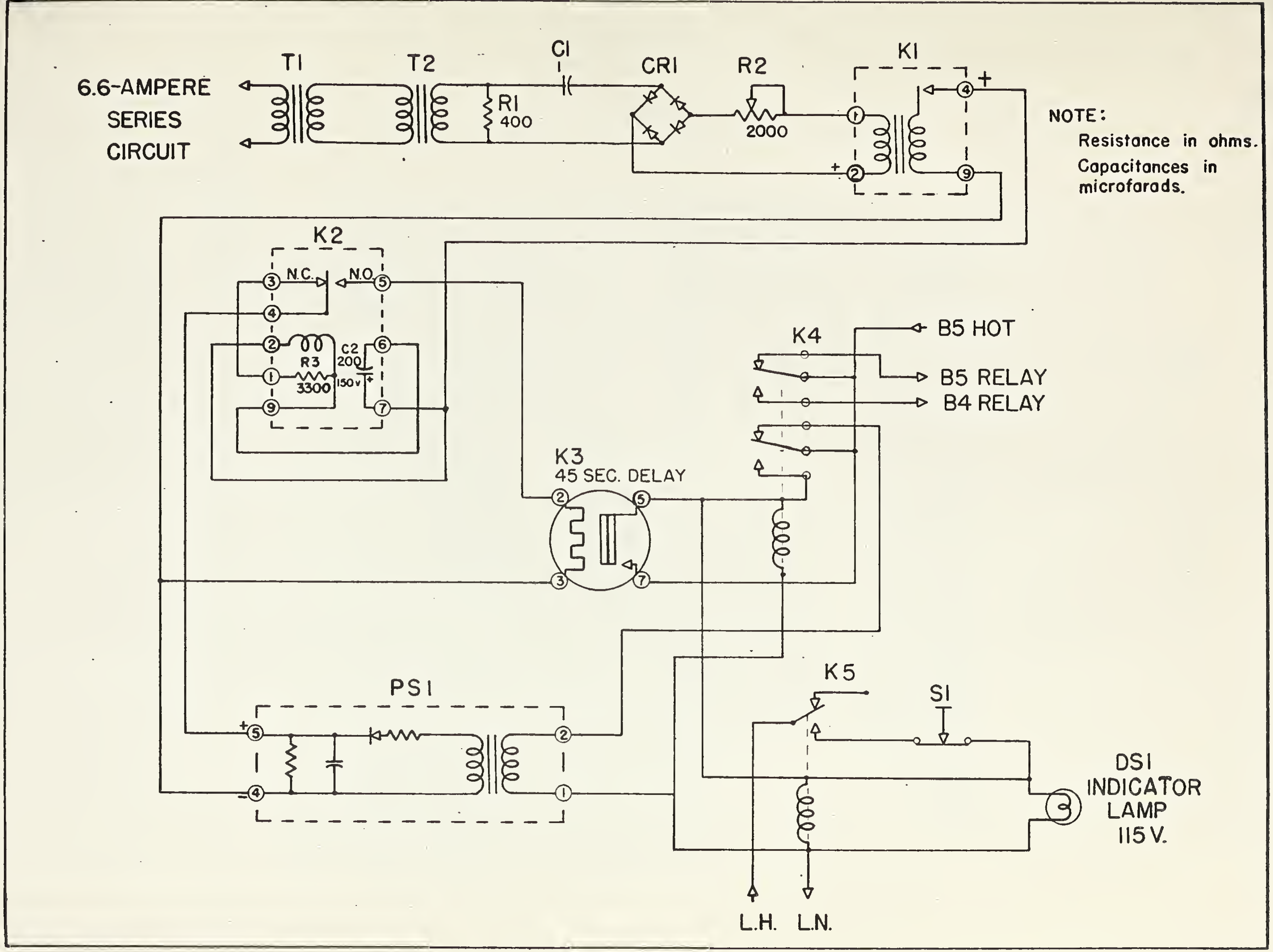


Figure 1

By a suitable choice of C_1 and R_1, it is possible to make I_2, the average current through the sensing element of the Protector, proportional to I_1, the rms circuit current, even though the waveform of I_1 is distorted by the presence of isolating transformers with open-circuited secondaries in the circuit. In fact, the relative increase in I_2 (average) can be made greater than the relative increase in I_1 (rms) if this is desired.

2.2 Final Design

This method of correction was incorporated into the Protector. The final circuit design is shown in figure 2. Table 2 is a components list. Photographs of the Protector are shown on Figure 3.



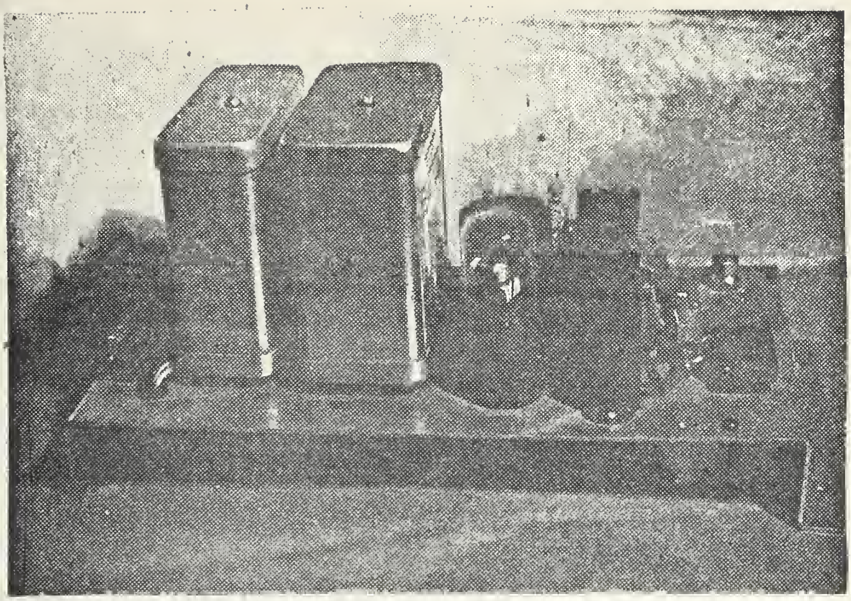
WIRING DIAGRAM OF OVER-CURRENT PROTECTIVE DEVICE FOR SERIES REGULATORS.

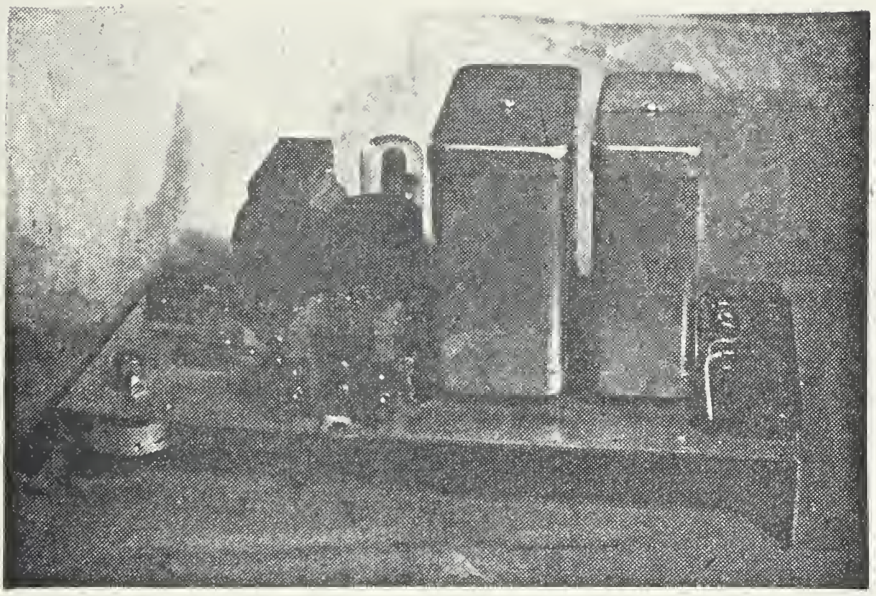
FIGURE 2

Table 2. Components List

C_1	1 µfd, 400-volt capacitor
C_2	200 µfd, 150-volt capacitor
CR_1	Instrument rectifier, full wave, 100 ma.
DS_1	Indicator lamp, 115-volt
K_1	Assembly Products Incorporated (API) VHS meter-movement relay Model 266, closes contact at 20 ma. d.c.
K_2	API R-C Interrupter/Load relay, Cat. No. 1817-2A
K_3	Amperite 115N045
K_4	DPDT relay, 115-volt coil, 5-ampere contacts
K_5	SPDT relay, 115-volt coil, 5-ampere contacts
PS_1	API power supply, Cat. No. 1677-10, input 115-230 vac, output 50 ma. 90 vdc.
R_1	400-ohm, 10-watt, wirewound resistor
R_2	2000-ohm, 4-watt potentiometer
*R_3	3300-ohm resistor
S_1	Push button switch, normally-closed
T_1	30/45-watt, 6.6/6.6-ampere airfield lighting transformer
T_2	117/2.5-volt, 7.5-ampere filament transformer (connected backwards)

*These components are an integral part of relay K_2.





Overcurrent Protector

Feasibility Model

Transformer T_1, a 30/45-watt, 6.6/6.6-ampere series isolating transformer, serves to isolate the Protector from the high-voltage series circuit. Transformer T_2 is used as a current-changing transformer to reduce the current to be monitored from 6.6 amperes to approximately 0.16 ampere so that a low-current rectifier can be used. Resistor R_1 loads transformers T_1 and T_2 with a load of about 4 watts (a load is necessary in a series circuit) and serves as a shunt for the sensing element of the Protector. Capacitor C_1 serves as the correcting filter. Signal current is rectified by full-wave rectifier CR_1 and flows through meter-movement relay K_1. Adjustable resistor R_2 is used to make fine adjustment of the current at which the contacts of relay K_1 close.

The current flowing through the signal coil of relay K_1 turns the moving element toward the point of contact. When the contacts of the meter relay K_1 close, a circuit through the coil of load relay K_2 and the meter locking coil is completed. The locking coil gives additional torque and the contact of K_1 is locked until this circuit is broken. At this time the current through the signal coil positions the moving element to a position relative to the current in it. Relay K_2 serves as an automatic interrupter. When this relay is energized, the circuit through the locking coil of relay K_1 is opened and the contacts of this relay are free to open. The meter cycles with the load relay until the signal drops below the value at which the contacts make. The cycling frequency is determined by the values of R_3 and C_2.

Time delay relay K_3 is actuated by the cyclic operation of relay K_2. The time delay of this relay is provided so that transient increases in the output current of the regulator will not actuate the Protector.

Closing of the contacts of relay K_3 actuates relay K_4 which locks in and transfers power from relay B5 in the regulator to relay B4, thereby reducing the regulator output to step 4. At the same time, power supply PS_1 is de-energized, thus removing power from relays K_1, K_2, and the heater of K_3.

Note that power is supplied to the Protector only when brightness step 5 is selected; that once activated, the Protector selects brightness step 4 instead of step 5 until the B5 control line is de-energized momentarily; de-energization of this line resets the Protector to its normal position.

4. SERVICE TESTS

The modified Protector as shown in figure 2 was installed April 1958 in the runway lighting circuit at the Arcata Airport. Immediate checks were made with a clamp-on ammeter and it was found that the device functioned as designed. An indicating pilot light circuit (K_5, S_1, and the indicator lamp, DS_1) with a manual reset button was added to the Protector at the time of installation. The indicator pilot light was installed remotely in the Field Laboratory office for monitoring purposes. If the Protector should function due to overcurrent, the pilot light would come on and stay on until the manual reset button was pushed, even though control line B5 was subsequently deenergized. The Protector was connected operationally into a runway lighting circuit and remained connected for 18 months. During this period there were never enough burned out lamps in the circuit at any one time to cause the device to function.

After the 18-month period, tests were made by removing lamps from the circuit until the device functioned to reduce the intensity from step 5 to step 4. This functioning occurred at a regulator current of 6.7 amperes (rms). Tests were also made by changing the regulator input tap selector switch position to simulate a high input-voltage condition. Again the device functioned at a regulator current of 6.7 amperes.

5. SUMMARY

The Protector functions as designed under actual field conditions. It will operate to protect the circuit from high output current caused by high input voltage to the regulator and from the increase in output current resulting from the failure of a number of lamps in the circuit.

The equipment can be installed in the field during routine maintenance periods with tools and equipment normally available to field maintenance personnel.

The Protector is simple and easy to assemble and requires very little maintenance.

The indicating pilot light with the manual reset feature should be included as a part of this device.

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U. S. DEPARTMENT OF COMMERCE
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