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[54]	PROTECTIVE CIRCUIT FOR LIGHTING SYSTEM					
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[56]		R	eferences Cited			
UNITED STATES PATENTS						
3,517,	254 6/1	1970	McNamara315/91			

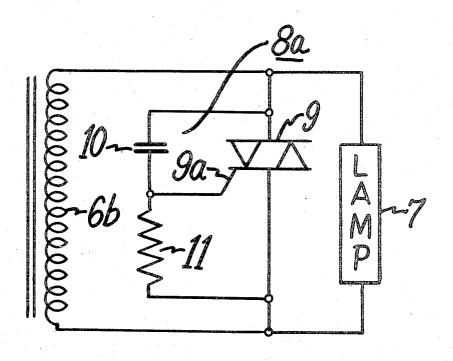
3,611,432	10/1971	Babcock et al	315/92
3,588,605	6/1971	Casson	
3,061,828	10/1962	Hauck	
3,466,500	9/1969	Peek	
3,403,315	9/1968	Maynard	

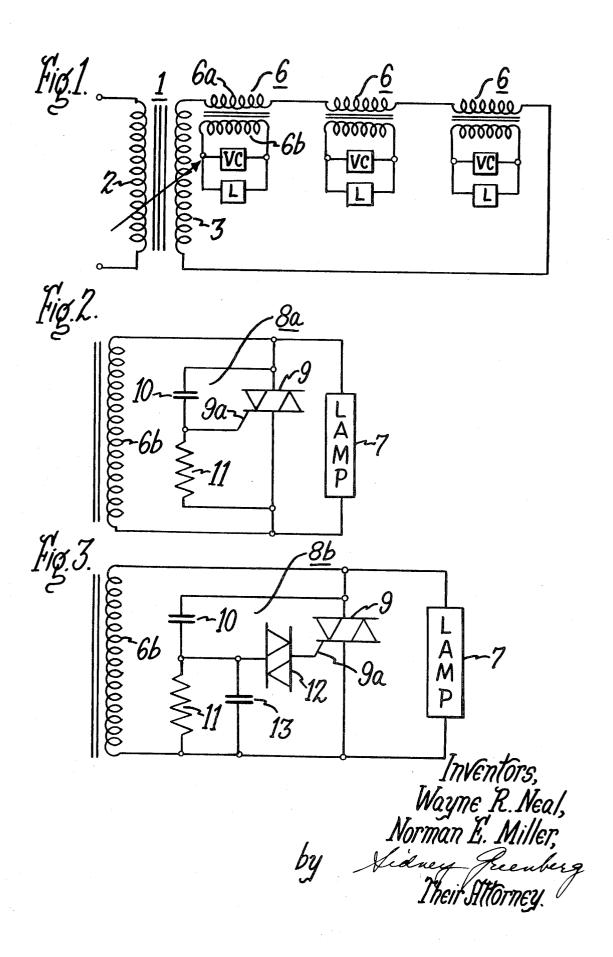
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[57] ABSTRACT

Solid state protective circuit for reducing high open circuit voltage across lamps in secondary circuit of constant current regulator system. The protective circuit includes a triac connected across the lamp load and triggered into conduction by a circuit connected to the triac gate electrode and comprising series-connected capacitor and resistor which triggers the triac upon a rapid rate of rise of the open circuit voltage.

12 Claims, 3 Drawing Figures





PROTECTIVE CIRCUIT FOR LIGHTING SYSTEM

The present invention relates to a protective circuit for constant current circuits and the like, such as constant current regulators employed in lighting systems 5 for supplying selected current levels for desired lamp brightness.

Among lighting circuits of the above type in which the invention may be advantageously employed are those used for lighting airport runways and taxiways.

It is a characteristic of constant current circuits of the above type, in which the output or lighting circuit is usually connected to the secondary of a constant current transformer, that if the output circuit is opened with the input circuit energized, a high open circuit 15 voltage appears which is considerably higher than the normal operating voltage. Thus, if a lamp in the lighting circuit burns out, the replacement of the lamp can be hazardous due to the high voltage, e.g., 2,000 volts, which exists at the lamp terminals.

It is an object of the invention to provide an open circuit protective device for constant current circuits of the above type which avoids the above-described hazards.

It is a particular object of the invention to provide a 25 solid state voltage clamping device in a constant current circuit of the above type to reduce the high open circuit voltage in the output circuit thereof, and particularly at the open lamp terminals.

Still another object of the invention is to provide a 30 voltage clamping device of the above type which is inoperative during normal operation of the lighting circuit and automatically operates to reduce the high
open circuit voltage across a burned-out lamp in the
lighting circuit.

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Other objects and advantages will become apparent from the following description and the appended claims.

With the above objects in view, the present invention relates to a constant current regulator system having a load circuit characterized by a high open circuit voltage with a steep wavefront, wherein a load is series connected in the load circuit, and a protective circuit for reducing the high open circuit voltage across the load upon failure or removal thereof, the protective circuit comprising a controlled bilateral semiconductor switch, such as a triac, connected across the load, the triac having a control electrode adapted when energized to trigger the triac into conduction, a capacitor and a resistor connected in series across the triac with the control electrode connected to the junction of the capacitor and the resistor, the capacitor operating in response to the relatively steep wavefront of the high open circuit voltage to energize the control electrode for triggering the triac into conduction, whereby the voltage across the inoperative load is reduced to a safe level.

The invention will be better understood from the following description taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a circuit diagram of a constant current regulator system having a lighting circuit which may embody the protective device of the present invention;

FIG. 2 is a circuit diagram of an individual lamp circuit of the FIG. 1 system showing an embodiment of a voltage clamping arrangement in accordance with the invention; and

FIG. 3 is a circuit diagram similar to that of FIG. 2 showing a different embodiment of the voltage clamping arrangement.

Referring now to the drawing, and particularly to FIG. 1, there is shown a series lighting circuit in a constant current regulator of a type often employed for airport lighting purposes. The illustrated system comprises a constant current transformer 1 of the moving coil type having a primary winding 2 connected to a suitable source of alternating current, of typically 2,400 volts, and a secondary winding 3 in series with a plurality of isolating transformers 6 each having a load circuit connected to the secondary winding 6b thereof to which a lamp 7 is connected in series. The lamps 7 may be of incandescent or gaseous discharge type such as mercury vapor lamps, or other types of lamps. Other forms of constant current transformers or regulators may be used instead of the moving coil transformer illustrated for maintaining a selected level of constant current to the lamps for regulating their brightness.

A characteristic of such constant current devices is that if the output or load circuit thereof is open, as for example by the burning out or removal of lamp load 7, a high open circuit voltage, which may typically have a peak of up to 2,500 volts, appears across the inoperative load, as compared to the normal operating voltage of the lighting load circuit which typically has a peak of about 45 to 65 volts, depending on the lamp wattage. Under such conditions, there is a substantial safety hazard to service personnel attempting to replace burned-out lamps while the constant current transformer is still energized.

In accordance with the invention, a voltage clamping (VC) device 8 is connected across lamp load 7, the VC device being such as to be inoperative during normal operation of the lighting circuit and automatically coming into operation when the lamp load 7 fails or is removed for immediately reducing the high open circuit voltage appearing across the terminals of the inoperative lamp load.

In the embodiment shown in FIG. 2, the voltage clamping device 8a comprises a triac 9 connected across lamp 7 and a triggering circuit comprising capacitor 10 and resistor 11 connected in series across triac 9, with the control (gate) electrode 9a of the triac connected to the junction of capacitor 10 and resistor 11. As understood in the art, a triac is an alternating current semiconductor controlled switch having a single control (gate) electrode, which when gated by a signal impulse, causes the switch to conduct current as indicated by the forward bias condition of the semiconductor. A triac may also be described as a bilateral or bidirectional triode for gate control of alternating current power.

As seen in the drawing and as well understood in the art, the triac has a first terminal (electrode) adjacent the gate electrode 9a and a second terminal (electrode) remote from the gate electrode. In accordance with the invention, capacitor 10 is connected from the second terminal to the gate electrode, and resistor 11 is connected from the first terminal to the junction of the control electrode 9a and capacitor 10, as shown in FIGS. 2 and 3.

During normal operation of lamp 7 in the illustrated circuit, the voltage in the load circuit is characterized by a normal 60 cycle sine wave having a gradual

wavefront, i.e., a relatively slow rate of rise (dv/dt). Under these conditions, the reactance of capacitor 10 is relatively high and full charging of the capacitor occurs; consequently no current is applied to the gate electrode 9a of the triac and the latter remains nonconductive. In the event lamp 7 burns out, the dv/dt of the open circuit voltage rises sharply, and under these conditions the reactance of capacitor 10 to the resulting steep wavefront is much lower, causing a substantial current to flow in the RC branch and actuating gate electrode 9a for triggering triac 9 into conduction. As a result, the voltage across the inoperative load is short-circuited through the triac and the voltage across the open load terminals drops to a low value, e.g., about 4 volts.

Resistor 11 in series with capacitor 10 in the RC triggering circuit may under certain circumstances be omitted, since the impedance of the gate circuit of the triac and suitable selection of capacitor 10 may provide for effective triggering of the triac as described. However, resistor 11 is preferably used to provide for improved stabilization of the triac operation throughout a wide range of temperature and to avoid possible self-triggering of the triac under certain conditions, such as 25 elevated temperature, even when the lamp circuit is operating normally. Resistor 11 also provides a fixed impedance to ensure proper operation of capacitor 10.

In a typical arrangement such as employed in a constant current system which provides a range of current 30 of 2.8 to 20 amperes in the load circuit, capacitor 10 may have a value of 0.047 microfarad and resistor 11 would be 560 ohms. In general, the described RC branch constitutes a differentiation type network in which the components are so selected that at normal operating lamp voltage, e.g., 45 volts RMS, the branch will not produce a voltage drop across resistor 11 which is sufficient to trigger the triac, while being responsive to the high dv/dt of the open circuit voltage to provide a 40 sufficient voltage drop across resistor 11 to trigger the triac for clamping the voltage as described. Preferably, the components should be selected to provide for triggering the triac when the dv/dt of the open circuit voltage is at least twice the dv/dt of the normal operating 45 voltage over a triac operating temperature range of -40° to 125°C.

While lamps 7 are shown in FIG. 1 as connected to the secondary circuit of a constant current transformer via series-connected isolating transformers 6, it will be 50 understood that the lamps may be directly connected in series with the constant current transformer secondary, without the use of transformers 6.

In the embodiment of FIG. 3, an arrangement is provided for ensuring a very rapid turn-on of triac 9 where this is desirable or necessary, as for example when a very high di/dt of the triac load current is encountered. For this purpose, a voltage sensitive bilateral semiconductor switch 12 is arranged in series with the triac gate electrode 9a as shown, and an auxiliary charging capacitor 13 is connected in parallel with resistor 11 at the junction of bilateral switch 12 and the RC triggering circuit. In the operation of this embodiment, when an open circuit voltage appears in the load circuit, capacitor 10 passes current to resistor 11 and capacitor 13. When the charge on the latter reaches the breakdown level of voltage sensitive switch 12, e.g., about 8

volts, the charge on capacitor 13 is applied through switch 12 to triac gate electrode 9a and turns triac 9 on. The provision of switch 12 and associated capacitor 13 as described ensures complete turn-on of the triac with minimum self-heating or power dissipation in the triac.

In an illustrative circuit such as the described FIG. 3 embodiment, capacitor 10 would be 0.10 microfarad, capacitor 13 would be 0.027 microfarad, and resistor 11 would be 560 ohms.

Voltage sensitive switch 12 is preferably a semiconductor switch such as a diac or a silicon bilateral switch (SBS), or a neon glow lamp, or other equivalent voltage sensitive bi-laterally conducting (symmetrical) switch device.

The invention thus provides for a simple, economical and reliable solid state protective system for avoiding the hazards of the high open circuit voltage encountered in constant current systems of the type described without the need for de-energizing the system. A further advantage of its use in series lamp systems for protecting the individual lamp is that failure of several of the lamps would not cause undue overloading of the constant current transformer, such as may occur in systems where the lamps are not similarly protected. Moreover, upon restoring the circuit to normal operating condition, as by replacing the lamp, the protective circuit automatically ceases operation and is ready for further automatic protective action upon a re-occurrence of an open circuit condition.

While the present invention has been described with reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the scope of the invention. Therefore, the appended claims are intended to cover all such equivalent variations as come within the true spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. In a constant current regulator system having a load circuit characterized by a high open circuit voltage with a steep wavefront, a load series connected in the load circuit, and a protective circuit for reducing the high open circuit voltage across the load upon failure or removal thereof, said protective circuit comprising a controlled bilateral semiconductor switch connected across said load, said switch having a control electrode adapted when energized to trigger said switch into conduction, said switch having a first terminal adjacent said control electrode and a second terminal remote from said control electrode, and a capacitor connected from said second terminal to said control electrode, said capacitor having a reactance to the relatively steep wavefront of the high open circuit voltage which is considerably lower than its reactance to the relatively gradual wavefront of the normal operating voltage of the load circuit, said capacitor operating upon occurrence of an open circuit at said load to energize said control electrode for triggering said switch into conduction, whereby the voltage across the inoperative load is reduced.

2. A device as defined in claim 1, including a resistor connected from said first terminal to the junction of said control electrode and said capacitor.

3. A device as defined in claim 2, said capacitor operating to energize said control electrode when the rate of rise of said open circuit voltage is at least twice the rate of rise of said normal operating voltage.

4. A device as defined in claim 3, said constant current regulator system having an output circuit including an isolating transformer series connected in said output circuit and having a secondary winding connected to said load circuit in series with said load.

5. A device as defined in claim 4, wherein said output 10 circuit comprises a plurality of series connected isolating transformers, each having a load connected thereto with a protective circuit as defined connected across the load.

6. A device as defined in claim 1, said load compris- 15 ing lamp means.

7. A device as defined in claim 2, a voltage sensitive bilateral switch having a predetermined breakdown voltage connected in series with said control electrode, and an auxiliary capacitor connected to said voltage 20 sensitive bilateral switch in parallel with said resistor, said auxiliary capacitor being charged by said first mentioned capacitor upon the appearance of the high open circuit voltage and operating upon reaching said breakdown voltage to discharge through said voltage sensitive bilateral switch for energizing said control electrode.

8. A device as defined in claim 7, said voltage sensitive bilateral switch comprising a semiconductor switch.

9. A device as defined in claim 8, said semiconductor switch comprising a silicon bilateral switch.

10. A protective circuit arrangement comprising, in combination, controlled bilateral switch means adapted to be connected across a load subject upon failure to a high open circuit voltage characterized by a steep wavefront, said switch means having a control electrode adapted when energized to trigger said switch means into conduction, said switch means having a first terminal adjacent said control electrode and a second terminal remote from said control electrode and a capacitor connected from said second terminal to said control electrode, said capacitor having a reactance to the relatively steep wavefront of the high open circuit voltage which is considerably lower than its reactance to the relatively gradual wavefront of the normal operating voltage of the load, said capacitor operating upon occurrence of an open circuit at the load to energize said control electrode for triggering said switch means into conduction, whereby the voltage across the inoperative load is reduced.

11. A device as defined in Claim 10, including a resistor connected from said first terminal to the junction of said control electrode and said capacitor.

12. A device as defined in claim 11, said capacitor operating to energize said control electrode when the rate of rise of the open circuit voltage is at least twice the rate of rise of the normal load operating voltage.

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