

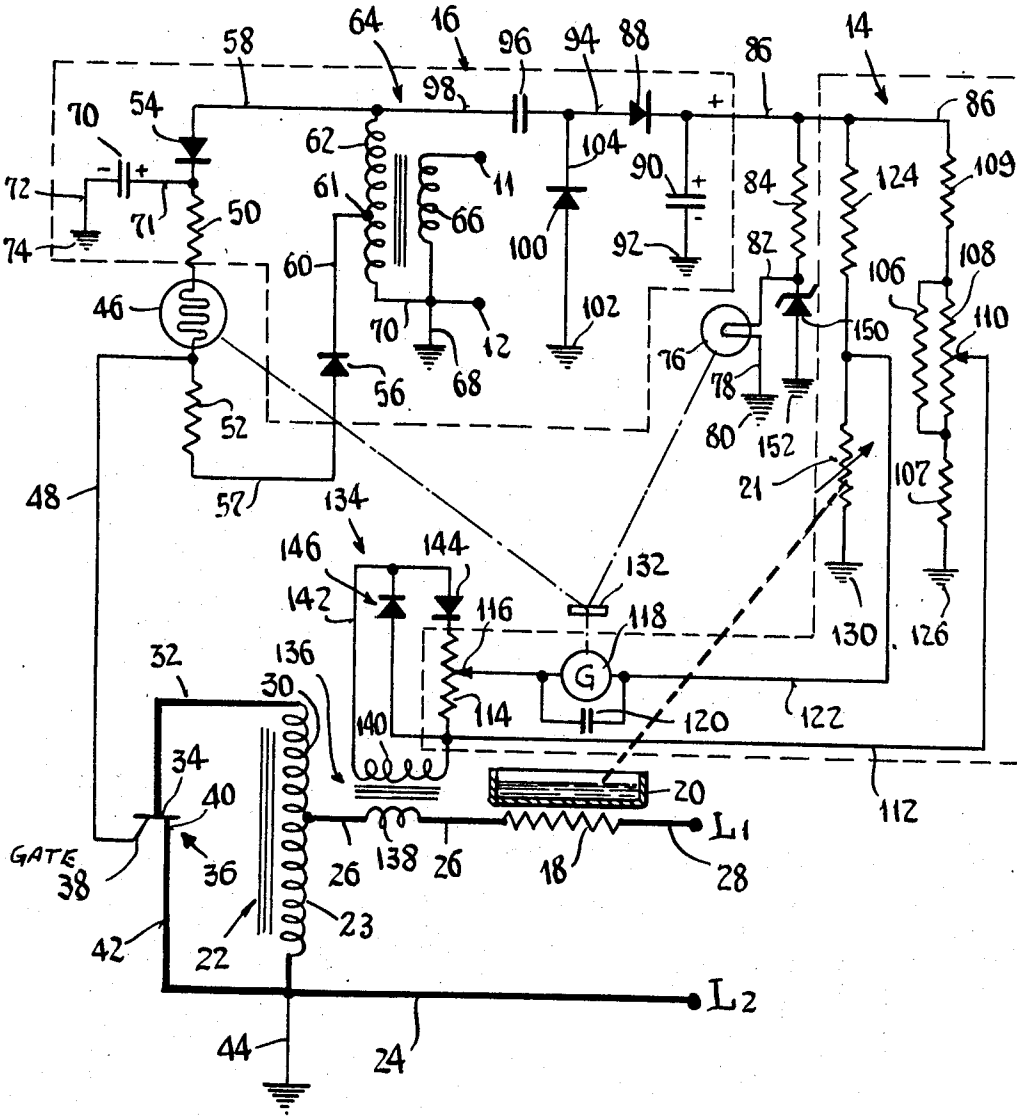
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ALTERNATING CURRENT POWER CONTROL

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ALTERNATING CURRENT POWER CONTROL
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ABSTRACT OF THE DISCLOSURE

An alternating current power control comprising a bridge circuit which responds to the power output of an electrical load. The bridge circuit in turn controls a photo-sensitive device having a variable output voltage which, through a gated SCR and suitable transformer, controls the power to the load. A lamp of the photo-sensitive device is energized from the source that provides the electrical power, and the light output of the lamp is kept steady by a voltage control which utilizes a Zener diode.

This invention relates to electric control devices, and more particularly to A.C. electric power control equipment.

The invention concerns improvements in the electric power control device which is disclosed and claimed in my Patent No. 3,116,396 dated Dec. 31, 1963 and entitled "Electric Temperature Control."

An object of the present invention is to provide a novel and improved A.C. power control device which is especially sensitive and accurate in maintaining, by means of a photo-sensitive control element and incandescent light source associated therewith, a given condition as for example the temperature of an electrically-heated bath or liquid-containing vessel.

Another object of the invention is to provide an improved power control as above set forth, wherein a simplified and effective anticipator means is provided to narrow or bring closer together the limits of the temperature swing as effected by the control.

A further object of the invention is to provide an improved control handling appreciable power and involving a light-sensitive element and a light source associated therewith in conjunction with a sensing energized bridge, wherein energization of the light source and the bridge is obtained from the power line supplying a heavy load and wherein fluctuations of the light source due to variations of the load and energizing power are largely eliminated or held to an absolute minimum, thereby increasing the accuracy of the control.

An additional object of the invention is to provide a novel and advantageous contactless A.C. power control for an electrical load in the range including several kilowatts, wherein a minimum number of components of simple construction is required, and wherein relatively large currents are switched by small values of voltage and power.

Yet another object of the invention is to provide an improved A.C. power control in accordance with the foregoing, wherein the anticipator means is directly responsive to the heavy load current without the intermediary of intervening circuits which are primarily relied on for other functions.

Features of the invention involve the provision of an improved A.C. electric power control which is relatively small and compact as regards its physical size, especially simple and requiring relatively few parts, which is sturdy and reliable in its operation, and wherein the maximum number of elements and assemblages are rugged and resistant to vibration, rough handling, and the like.

Other features and advantages will hereinafter appear.

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The single figure of the drawing is a schematic circuit diagram of the improved A.C. power control device as provided by the invention.

Referring to the drawing, heavy current power supply terminals are indicated at L1 and L2, from which the system is energized. Additional terminals 11 and 12 are shown, for connection respectively to the terminals L1, L2 to receive energy therefrom simultaneously. A control bridge designated by the numeral 14 is shown within a dotted-outline box.

The terminals 11, 12 provide current for a D.C. power supply designated generally by the numeral 16 and which is also outlined by a broken-line box. The supply 16 provides energy for the bridge 14 as well as for a low-current control means by which the heavy current flowing through the terminals L1 and L2 is controlled, to effect a control of a high power load.

In the illustrated embodiment of the invention, the load indicated at 18 comprises an electric heater or coil which may be rated in kilowatts. The heater 18 is associated with a bath or container of liquid 20, and there is disposed in heat-receiving relation with the heater 18 or the bath 20 a sensing element 21 of the bridge 14. Where a close control of the temperature of the bath 20 is required, the sensing element 21 may be immersed in the bath rather than being associated directly with the heater 18.

The power circuit connected to the terminals L1, L2 includes a current control device for the load 18, which device is responsive to variations of a small control voltage. Such current control device is illustrated herein as an auto transformer 22 having a coil 23 connected by leads 24, 26 respectively to the terminal L2 and the heater 18. The heater in turn is connected by a lead 28 to the terminal L1. The auto transformer 22 has another winding portion 30 connected by a wire 32 to the base 34 of a gate-type silicon-controlled rectifier 36 having a gate 38 and collector 40. The collector 40 is connected by a wire 42 to the power lead 24, which is grounded at 44.

When the SCR is not conducting, the auto transformer 22 represents a high resistance or impedance in the power circuit whereby no substantial load current flows there-through, thereby effecting a de-energization of the heater 18. If the SCR 36 should be rendered conducting, as by the application of a positive or more positive (with respect to ground) voltage to the gate 38, this will result in the circuit having the auto transformer and which is included between the power lines 24, 26 showing a very low impedance, whereby a heavy full wave energizing current passes through the load or heater 18. The SCR 36 will conduct in only one direction, but with the circuit provided full wave current will be supplied to the load, as will be later brought out in detail.

Thus, the auto transformer 22 and the SCR 36 in the arrangement shown constitutes in effect a switching or relay device which is controlled by small positive potentials applied to the gate 38. It will be understood that an alternating current supply is connected to the terminals L1, L2, and any one of alternate half waves of such alternating current has the effect of switching off the SCR 36 for such waves. Whenever the positive potential is removed from the gate 38, the said switching off remains in effect for all alternations. With an A.C. supply and positive polarization of the gate 38, the control will be conducting for both half cycles of the alternating current, providing energization of the heater 18. As long as a positive potential is being applied to the gate 38, conduction will occur through the heater.

The action in the control 22, 36 is as follows: If the gate 38 is not polarized to render the SCR 36 conducting,

the effect of the SCR between the wires 32 and 42 will be that of an open circuit. The transformer 22 will have its flux reversing with the current alternations, presenting a high impedance in the circuit with little current and substantially no heater energization.

When the gate 38 is polarized to render the SCR conducting, conduction will occur during alternate half cycles, and the remaining half cycles will switch off the SCR despite the gate polarization. Such conduction during the first-stated half cycles will pass half cycles of the load current, energizing the heater 18; also, the heavy load current in the coil 30 of the transformer during such half cycles will cause saturation of the core in one direction despite an opposing tendency of smaller current in the coil 23. For the remaining half cycles, during which the SCR 36 is not conducting, heavy load current will flow through the transformer coil 23, again energizing the heater 18 (whereby the latter is energized with full wave current). The reason for this heavy load current during the remaining half cycles is that the transformer core as previously saturated, is maintained in saturated condition by the reversal current (of the cycle) now flowing in the coil 23. This core saturation has the effect of enabling the coil 23 to present a low impedance during said remaining half cycles. The core saturation flux does not change direction at all during operation of the SCR because the alternate flows of current occur in different coils of the transformer. For example, the dominating flow in coil 30 could be downward for alternate half cycles, and also downward in coil 23 for the remaining half cycles.

The control voltage (which is made to be automatically responsive to changes in the temperature of the bath 20) is obtained, in accordance with the invention, from a sensitive and accurate light-responsive means comprising a conductive-type photoelectric cell 46 which has the characteristic of changing from a relatively high resistance to a very low resistance when excited by light. The conductive cell 46 has one terminal connected to a wire 48 which is connected to the gate 38 of the SCR 36. The cell is also connected with drop resistors 50 and 52 energized from the D.C. power supply 16.

The resistors 50, 52 are connected respectively to rectifiers 54, 56 which are in turn connected by wires 58, 60 to one end and a tap 61 of the secondary coil 62 of a power transformer 64 having a primary 66 connected to the supply terminals 11, 12. The terminal 12 is also connected to a ground 68 or common negative lead 68, and such ground is connected by a wire 70 to the remaining end terminal of the secondary coil 62.

A filter or smoothing capacitor 70 has its positive terminal connected to the juncture of the resistor 50 and the rectifier 54, and has its negative terminal connected by a wire 72 to a ground 74 or common negative path.

By such organization, a D.C. voltage exists between the wire 71 (which is positive) and a wire 57 which connects the resistor 52 with the rectifier 56. When the photocell 46 is not illuminated it has a very high resistance, resulting in the wire 48 having a small negative potential which depends for one thing on the voltage of the power supply. Such small negative potential may, for example be -5 volts, and the corresponding positive potential on the wire 71 may be +10 volts, representing a potential difference of 15 volts as obtained from the power supply 16. This assumes negligible voltage drop through the resistor 52.

When strong light impinges on the photocell 46 it will render the latter conducting. Assuming a bright illumination, the resulting conductive conditions of the cell 46 may place a positive potential of 3 volts on the wire 48, which then is impressed on the gate 38 of the SCR 36. Such positive potential will result in the current control device 22 presenting a low impedance in the power circuit, whereby the load 18 is substantially energized, causing heating of the bath 20.

On the other hand, the -5 volts resulting from the darkened condition of the photocell 46 will enable the

SCR 36 to cut off, thereby shutting off the power to the load 18.

The contactless control as provided by the invention and set forth above is thus seen to be advantageous in handling loads in the range including several kilowatts, since it has relatively few components of simple construction, rugged character and great reliability, and since heavy currents may be switched readily, utilizing small values of voltage and power.

In accordance with the invention, an accurately controlled beam of light of constant intensity is utilized to excite the photocell 46, such beam being substantially independent of nominal fluctuations in voltage of the energy source which supplies the terminals L1, L2, in spite of the fact that the D.C. power supply 16 receives its energy from the same source.

The electric light source comprises an incandescent lamp 76 which, together with the bridge 14, is energized from the D.C. power supply 16. The lamp 76 has one terminal connected by a wire 78 to a ground 80 and its other terminal connected by a wire 82 to a dropping resistor 84 which is in turn connected to the positive supply line 86 from the supply 16. The line 86 leads from a rectifier 88 and a filter or smoothing capacitor 90, the latter being connected to a ground 92. The rectifier 88 is connected by a wire 94 to a capacitor 96 of high value, which is in turn connected by a wire 98 to the transformer secondary 62 at the same terminal which is joined to the wire 58. A rectifier 100 is connected with a ground 102 and by a wire 104 to the wire 94, thereby completing the circuit of the power supply 16.

The bridge 14 comprises, besides the sensing element 21, parallel resistors 106, 108 having end connections to resistors 107 and 109, these latter two resistors constituting two bridge legs. The resistor 109 connects also with the wire 86, and the resistor 107 is grounded at 126. The resistor 108 has a slider 110 connected by a wire 112 to an anticipator resistor 114. The resistor 114 has a slider 116 connected with a light-control means in the form of a galvanometer or D'Arsonval movement 118 bridged by a capacitor 120 and connected by a wire 122 to the juncture of the sensing element 21 and a resistor 124, these two constituting other legs of the bridge. The resistor 124 is joined to the wire 86. The sensing element 21 is connected to a ground 130.

The galvanometer 118 on its movable system may have a mirror 132 which reflects light from the lamp 76 and directs the light against the photocell 46, or an opaque vane may be used as in my patent above identified. With the above arrangement an automatic control is had of the energization of the load 18, inasmuch as the sensing element 21 of the bridge is responsive to changes in temperature of the bath 20 heated by the load 18. Such response of the sensing element will cause deflection of the galvanometer 118 and will either direct light against the photocell 46 or else direct the light away from such cell, thereby to effect an automatic control of the energizing current for the load 18 and in the manner of well known controls of this type (as explained also in my above identified patent).

In accordance with the present invention, in conjunction with such automatic control I provide a novel and improved, simplified yet effective and reliable anticipator device which is designated generally by the numeral 134 and which includes the anticipator resistor 114 mentioned above. The anticipator device comprises also a current transformer 136 having a heavy current primary 138 in the line 26 and having a light current secondary 140, the latter being connected to the resistor 114 and also by a wire 142 to a rectifier 144 which is in turn connected to the remaining terminal of the resistor 114. Also, an additional rectifier 146 is connected across the transformer secondary 140 to prevent rectifier 144 from breaking down on the negative alternations. The conductive directions of the rectifiers are as indicated.

With such arrangement, for alternate half cycles of the alternating current wave, the rectifier 146 acts as a short-

circuiting device, preventing any appreciable voltage from existing across the resistor 114 and rectifier 144. Thus, for such half cycles of the wave, no effect is produced on the galvanometer 118. The short-circuiting of the winding 140 by the rectifier 146 is not such as to cause excessive heat in or damage to the winding, since low voltages are involved and since the impedance and resistance of the heater winding 18 limits the short-circuiting current to a substantially inappreciable value as regards damaging heat.

For the remaining half cycles, current will flow from the secondary 140 through the rectifier 144 and the resistor 114, and in consequence the voltage drop of the resistor, as measured to the slider 116, will be included in the circuit of the galvanometer 118, causing a deflection of the latter in a direction which tends sooner to initiate the required control of the power circuit 24, 26. That is, if the load current is cut off and the bath 20 is cooling, the response of the sensing element 21 will change the bridge balance in such a manner that the galvanometer deflection results in light striking the photocell 46. This will place a positive voltage on the wire 48 and render the SCR 36 conducting, and the resultant heavy load current in the line 24, 26 which now energizes the load 18 will also cause a voltage at the resistor 114 which is in a direction tending to increase the light being directed against the photocell 46. Therefore a larger swing of the galvanometer 118 is had than would otherwise occur if no anticipator device were provided.

Conversely, when the sensing element in responding to the increased heat now changes the bridge balance to oppositely deflect the galvanometer so as to shut off the light from the photocell 46, the resultant cessation of the load current in the power line 24, 26 will shut off the voltage across the anticipator resistor 114, thereby tending to increase the said opposite deflection of the galvanometer 118 and directing the light beam further away from the photocell 46.

The anticipator 134 thus provides for a greater response of the galvanometer, and results in a more effective and accurate control. By virtue of the load current being directly utilized through the transformer 136 to provide these desired exaggerated actions of the galvanometer, the control is made especially effective as compared with anticipator devices wherein intermediary equipment is involved in providing the anticipator voltage.

In the present instance, the anticipator voltage is supplied from a device which functions purely as an anticipator and is required to carry out no other function.

Also, in accordance with the invention, the illumination of the lamp 76 is rendered substantially independent of fluctuations of the power source and voltage supplying the power terminals L1 and L2. This is effected by the provision of the dropping resistor 84 and also by the provision of a voltage-responsive and limiting means comprising a Zener diode 150 which is connected across the terminals of the lamp 26 as shown. The Zener diode 150 has one terminal grounded at 152 to effect such shunt circuit, and is so arranged that in conjunction with the nominal voltage (for instance 15 volts) from the supply 16 and the drop through the resistor 84 it maintains a constant applied voltage to the lamp 76. For example, the lamp 76 may have a rating of 5 volts and the Zener diode may have a rating of 4.7 volts and a capacity of 400 milliamperes. The resistor 84 may be 90 ohms, and the line 86 may have a nominal voltage of +15 with respect to ground. The energization of the lamp 76 will thus be held closely to the value of 4.7 volts regardless of nominal fluctuations in the 15 volt output from the power supply 16. Wide variations in the output voltage of -15 from the supply 16 may occur without changing the 4.7 volts applied to the lamp 76. Thus, the intensity of the light is maintained at a constant value regardless of voltage changes of the system, and this results in a more effective and accurate control of the load current being had. Before the brilliance of the lamp 76 drops or decreases, the

voltage of the line 86 would have to drop to a value lower than the rating of the Zener diode 150, that is, below approximately 4.7 volts. This, of course, is a condition which is very unlikely to occur during the normal operation of the control and power unit.

Besides the values given above, the various components shown in the drawing are further characterized as follows: The load 18 may be rated at 2 kilowatts, for 120 volts A.C. Power supplied to L1, L2 may be 115 volts at 18 amperes RMS. The primary coil 138 of the anticipator transformer may comprise a single turn of No. 10 copper wire, and the coil 140 may be constituted of the primary of a Stancor transformer No. P6134. The anticipator resistor 114 may be 6 ohms. The SCR 36 may be rated at 18 amperes, type 2N688. Capacitor 120 may be 250 mfd. Resistors 50 and 52 may be respectively 300 ohms and 2,000 ohms. Capacitors 96 and 90 may be respectively 1,000 mfd. and 500 mfd. Resistors 124 and 109 may be each 1,800 ohms. Resistors 106 and 108 may be respectively 360 ohms and 200 ohms. Sensing element 21 may be approximately 100 ohms at 25° C., and 247 ohms at 300° C. The rectifiers may be type 1N4001. Diode 100 may be a Zener diode for voltage regulation, rated at 15 volts. Resistor 107 may be 110 ohms.

It will now be seen from the foregoing that I have provided a novel and improved, simplified yet highly effective and accurate automatic alternating current power control employing a light-responsive element, wherein accurate contactless control is effected with few and simple components, wherein the light intensity is maintained at a constant value regardless of voltage fluctuations, and wherein the control galvanometer, by means of a simplified and effective anticipator device, is made to have an increased movement in response to flowing and shut-off of the power current.

Variations and modifications may be made within the scope of the claims, and portions of the improvement may be used without others.

I claim:

1. In an automatic electrical power consuming device, in combination:

- (a) a power circuit having an electrical load and a current control device for said load, responsive to variations of a small control voltage,
- (b) light-responsive means providing a small variable control voltage for said control device,
- (c) an electric light source and means for energizing the same from said power circuit,
- (d) light control means responsive to changes in the load current through said power circuit, for directing more or less light from said source to said light-responsive means, thereby to establish an automatic control of energization of said electrical load, and
- (e) a voltage-responsive, voltage limiting device connected to the light-source energizing means, limiting the maximum voltage applied to the light source to a value close to its rated voltage, said energizing means being arranged to deliver a voltage higher than the rated voltage of the light source, thereby to minimize variations of said source with changes in the loading of the power circuit.

2. A device as in claim 1, wherein:

- (a) the means for energizing the light source provides D.C. power for said source, and
- (b) the voltage-limiting device comprises a Zener diode connected across the light source.

3. A device as in claim 2, wherein:

- (a) a drop resistor is connected in series with the parallel circuit of Zener diode and light source.

4. A device as in claim 1, wherein:

- (a) the light control means includes an energized electric bridge receiving its power from the said means for energizing the light source, said bridge having a supply conductor connected with the said light source.

5. In a control device, in combination:
- (a) an A.C. power circuit having an electrical load and a current control device for said load;
 - (b) a D.C. bridge including a sensing element acted on by said load,
 - (c) said bridge having a circuit which includes an electrically-operated control mechanism energized by direct current of the bridge;
 - (d) means responsive to load current changes in the power circuit and comprising an anticipator device connected with said power circuit, providing a small D.C. voltage which fluctuates with load current in said circuit, and
 - (e) means connecting said anticipator device to the control mechanism of the bridge, to operate the latter in the same sense as the operation thereof in response to action on the sensing element by the said load.
6. A device as in claim 5, wherein:
- (a) said anticipator device comprises a coupling means energized by A.C. from the power circuit and a rectifier circuit connected to said coupling means and control mechanism and converting said A.C. to D.C. for use by the latter.
7. A device as in claim 6, wherein:
- (a) said coupling means comprises a transformer having a primary connected in series with the power circuit and having a secondary bridged by the rectifier circuit,
 - (b) said rectifier circuit comprising parallel branches constituted of a rectifier which is connected across a series-joined rectifier and voltage divider resistor,
 - (c) said rectifiers having one set of unlike terminals connected together.
8. An A.C. electric power control device comprising, in combination:
- (a) a saturable core and two windings on said core connected in series,
 - (b) a gate control type SCR device having collector and base connected to the free ends of the windings,
 - (c) means providing a D.C. control potential applied

- to the gate of the SCR device to render the same either conducting or non-conducting, and
 - (d) an energized load circuit including an electrical load, said circuit having leads connected respectively to the series connection of said windings and to the collector of the SCR device,
 - (e) said core remaining saturated with flux in one direction for a given half wave of power when the SCR is provided with a control potential to effect its conduction and is conducting power pulses in one direction whereby the load circuit has included in it a low impedance to increase the current therein,
 - (f) said core remaining saturated with flux in said one direction for the succeeding half wave of power when the SCR is non-conducting while still provided with a control potential to effect its conduction, and
 - (g) said core having an alternating flux when the SCR is provided with a control potential to establish its non-conduction and is non-conducting whereby the load circuit has included in it a high impedance to greatly reduce the current therein and through the load.
9. A power control device as in claim 8, wherein:
- (a) the means providing a control potential applied to the gate of the SCR comprises a photo-sensitive cell and a light source adapted to activate said cell,
 - (b) said photo-sensitive cell being connected to the gate of the SCR and applying a more positive potential to said gate in response to the cell being activated.

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