

Feb. 28, 1967

J. L. HUTSON

3,307,070

POWER CONTROL SYSTEM

Filed Nov. 7, 1963

2 Sheets-Sheet 1

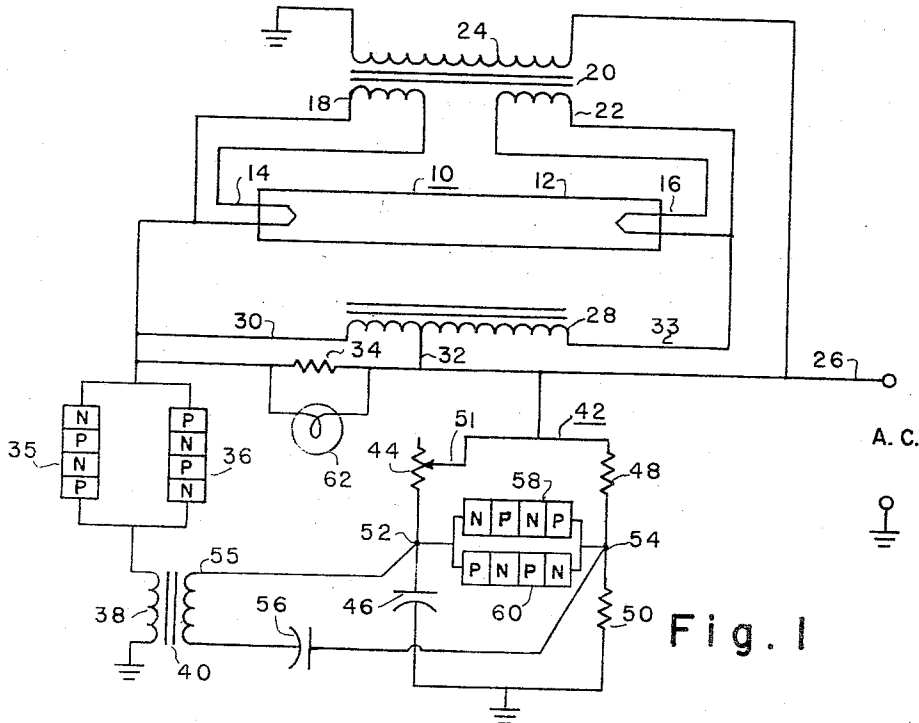


Fig. 1

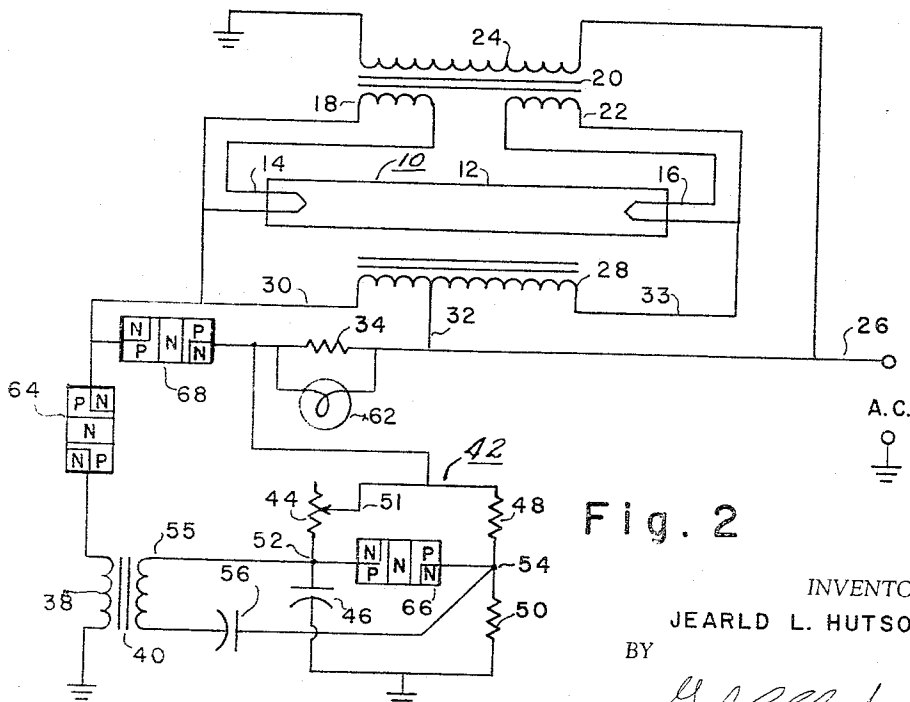


Fig. 2

INVENTOR
JEARLD L. HUTSON
BY

Gibb

1

3,307,070

POWER CONTROL SYSTEM

Jearld L. Hutson, Richardson, Tex., assignor to Hunt Electronics Company, Dallas, Tex., a corporation of Texas

Filed Nov. 7, 1963, Ser. No. 322,571
10 Claims. (Cl. 315-101)

The present invention relates to power control systems and more particularly to a power control system that is especially adapted for controlling the intensity of fluorescent lights.

This application is a continuation-in-part of my co-pending application, Serial No. 211,685, filed July 23, 1962, now abandoned, entitled, "Power Control System," which is assigned to the assignee of the present application.

The older type fluorescent systems utilized an automatic starting switch to initiate the arc. To light the tube, the starting switch was maintained in the depressed position for a short period of time to allow the filaments of the tube to become heated. After a few seconds delay, and at the time the switch was released, sufficient voltage was impressed between the filaments to create an arc and cause the tube to flow due to the action of the electrical discharge on the phosphors which coat the surface of the tube. At the present time, fluorescent systems such as that described above are used primarily in small table lamps and similar applications.

The two fluorescent systems that are in most widespread use at the present are usually referred to as the "rapid start" fluorescent system and the "instant start" fluorescent system.

The instant start fluorescent system utilizes a tube which has a filament positioned at each end. It differs from the other system in that the tube is not heated prior to the time that the arc begins. The potential that is initially applied to the tube is sufficiently high to cause the tube to break down without the filaments being heated. When the tube breaks down, current will begin to flow and the flow of current is effective to heat the filaments to the necessary temperature. The instant start fluorescent systems can be dimmed successfully. However, if the instant start fluorescent tube is utilized in applications which require dimming, the lamp life may be shortened appreciably as the filament temperatures will decrease considerably as the current density within the tube is decreased in the course of the dimming operation, causing deterioration of the filaments in many instances.

The rapid start fluorescent system is a system which is most adaptable for those lighting applications in which dimming is desirable and is, therefore, the system which is most frequently used. In the rapid start fluorescent system, the filament located at each end of the tube is continuously heated by a filament transformer which is connected directly to the source of alternating current supply voltage. A starting winding is provided for applying a sufficiently high potential between the two filaments to cause an arc to be formed. The rapid start fluorescent system can be successfully dimmed by controlling the conduction time of the current flowing through the tube. As the filaments are continuously heated, the dimming operation produces no adverse effects on the tube.

From the above, it may be noted that in both the rapid start fluorescent system and the instant start fluorescent system the arc is created by applying a high potential between the two filaments of the tube by a high voltage

2

winding without the necessity for a time delay between the time the starting operation begins and the time that the high voltage is applied between the cathodes of the tube.

As both types of tubes are essentially constant voltage loads, the winding which applies a potential between the filaments must be of the constant current type to prevent the flow of excessive current. Thus, as power is applied to the transformer, the potential across the fluorescent tube will initially increase until a sufficiently high voltage is obtained to produce the desired arc between the cathodes. After the arc is started, the voltage across the tube will decrease to a relatively low constant value and the amount of current flowing through the tube will increase rather rapidly. The transformer is constructed such that as the current flowing through the transformer attains a desired level, the transformer will saturate and the output voltage of the transformer will decrease to maintain the desired level of current flowing through the tube at the constant voltage.

Many systems have been proposed for dimming fluorescent systems. These systems use various types of circuitry that utilizes as principal control elements saturable reactors, gas thyratrons, ignitrons and thyatron type solid state devices that are capable of being switched from a normally high impedance state to a low impedance state. However, each of the known prior art systems are subject to one or more disadvantages.

Thus, systems which utilize gas thyratrons or ignitrons as the control element in a phase control system have not proved practical for dimming fluorescent lights in homes and offices due to the fact that the voltage drop across such elements is in the order of 5 to 15 volts. A considerable amount of power is, therefore, dissipated within the tube and a rather large tube is required to control a substantial amount of current. Another important disadvantage of using gas thyratrons or ignitrons is that their life is rather limited and the tube must be replaced after a thousand hours or so of operation. The gas thyatron or ignitron tubes are expensive making the cost of a system using such elements very high.

In general, the systems which utilize saturable reactors as the control element are also quite expensive and bulky. In addition, the quality of dimming provided by most systems that utilize saturable reactors is very poor in that although the dimming is excellent at the higher light intensities, at low light intensities the arc formed within the fluorescent tube is extremely unstable and striations or steps of alternate dark and light areas are frequently present within the tube. Due to the fluctuation of the arc, the light produced at low levels is very undesirable.

Most prior art fluorescent control systems which utilize solid state devices as the control element are also subject to be a disadvantage of poor quality light control at low levels. Although certain solid state control systems have been proposed which provide excellent dimming qualities at both high and low light intensities, such systems are in most instances too bulky for convenient incorporation into home or office lighting installations.

According to the present invention, an improved power control system that is especially adapted for dimming fluorescent lights is provided. The power control system provided by the present invention is extremely reliable, and the quality of control achieved compares favorably with that attained using gas thyratrons or ignitrons in that there is no deterioration in the quality of the light produced at low intensities. The control cir-

cuitry of the present invention is extremely compact and can conveniently be placed in a conventional light switch box.

In practicing the present invention, a diode switching means that is capable of being switched from a normally high impedance state to a low impedance state is connected in series with the load to be controlled, the primary of the starting winding that creates the arc between the two filaments. Phase shift means are provided for switching the diode switching means to the low impedance state at a desired time in the half cycle of the applied line voltage. Shunt means are connected in parallel with the winding to provide a source of holding current to the diode switching means.

The inductance of the starting winding is normally very high, limiting the amount of current which initially flows through the winding and the diode switching means to a level which is usually insufficient to maintain the diode switching means in the low impedance state. The shunt means are, therefore, necessary to provide a source of holding current for the diode switching means and thereby insure that the diode switching means will remain in the low impedance state until such time as the current flowing through the starting winding itself attains a sufficient level to hold the diode switching means in the low impedance state. Optimum firing conditions of the fluorescent tube are attained in that the only current flowing through the starting winding prior to the time that the switching action occurs is the reverse leakage current of the diode switching means and, therefore, extremely low.

Many objects and advantages of the present invention will become apparent to those skilled in the art as the following detailed description of the same unfolds when taken in conjunction with the appended drawings wherein like reference numerals denote like parts and in which:

FIGURE 1 is a schematic diagram illustrating one preferred embodiment of the invention;

FIGURE 2 is a schematic diagram illustrating a second embodiment of the invention; and

FIGURE 3 is a schematic diagram illustrating a third embodiment of the invention.

Turning now to FIGURE 1 of the drawings, the fluorescent tube to be controlled is denoted generally by the reference numeral 10. The fluorescent tube 10 includes a sealed glass case 12 which may be filled with a small amount of mercury and an auxiliary gas to assist in starting. The glass case 12 is coated with a phosphor that will produce the desired color of light.

Positioned at opposite ends of the tube 12 are cathodes 14 and 16. The cathode 14 is connected to the secondary winding 18 of a filament transformer 20 and the cathode 16 is connected to the secondary winding 22 of the filament transformer 20. One end of the primary winding 24 of the transformer 20 is connected directly to line 26, which connects to a source of alternating current supply voltage. The other side of the primary winding 24 is connected to ground.

A starting winding 28 is also provided. The starting winding 28 may be an auto transformer, as shown, in which that portion of the winding between lines 30 and 33 serves as the secondary.

Line 30 may be connected to the cathode 14 and line 33 may be connected to the cathode 16. The line 32 is connected to line 26, that connects to the source of alternating current supply voltage as shown. The line 30 is connected through a pair of parallel connected, oppositely poled four layer semiconductor devices 35 and 36 that are capable of being excited from a normally high impedance state to a low impedance state. The forward breakdown voltage of each of the devices 35 and 36 is in excess of the maximum instantaneous voltage of the applied line voltage. The under terminals of the devices 35 and 36 are connected through the secondary winding 38 of the transformer 40 to ground. The over terminals of the devices 35 and 36 are connected through resistor

34 and line 26 to the source of alternating current supply voltage.

A phase shift network, designated generally by the reference numeral 42 is also provided. The phase shift network 42 produces a firing signal which is suitably operated upon to induce a high voltage in the secondary winding 38 of the transformer 40 to cause one of the diode switching elements 35 and 36 to switch from their normally high impedance state to a low impedance state.

The phase shift network 42 is seen to comprise a variable resistor 44 which is connected through a capacitor 46 to ground. The phase shift network 42 also includes a resistor 48 which is connected through resistor 50 to ground. The over terminal of the resistor 48 and the tap 51 of the variable resistor 44 are each connected to line 26 as shown. A firing signal is produced between the junction points 52 and 54 whose phase angle relationship with the applied alternating current supply voltage may be varied by varying the resistance of the variable resistor 44.

The junction point 52 of the phase shift network 42 is connected through the primary winding 55 of the transformer 40 and the capacitor 56 to the junction point 54. A pair of oppositely poled, parallel connected diode elements 58 and 60 are connected between the junction points 52 and 54.

In operation of the circuit shown in FIGURE 1, a source of alternating current supply voltage is applied to the line 26. Power is applied through the filament transformer 20 to the cathodes 14 and 16 of the fluorescent tube 10 causing the cathodes 14 and 16 to be heated to the desired operating temperature.

Power is also applied through line 26 and line 32 to one side of the primary portion of the starting winding 28. However, as both of the devices 34 and 36 are in their normally high impedance state, no current will flow through the starting winding 28 or the resistor 34.

The phase shift network 42 also receives line voltage through the line 26. The voltage applied to the phase shift network 42 by the line 26 produces a firing signal between the junction points 52 and 54 that will charge the capacitor 56. Thus, during positive half cycles, that is those half cycles in which line 26 is positive with respect to ground, the capacitor 56 is charged through a charge path consisting of the primary winding 55 of transformer 40 and resistor 50 until such time as the amplitude of the firing signal developed between the junction points 52 and 54 exceeds the breakover voltage of the device 60.

When the firing signal produced by the phase shift network 42 exceeds the forward breakover voltage of the device 60, the device 60 will switch from its normally high impedance state to the low impedance state providing a low resistance discharge path for the capacitor 56. When the device 60 breaks down, the capacitor 56 will discharge through the device 60 and the primary winding 55 of the transformer 40. Because of the very low resistance of the discharge path, the discharge will occur very quickly, producing a high current pulse which is effective to induce a high voltage in the secondary winding 38 of the transformer 40.

The high voltage pulse produced across the secondary winding 38 is effective to energize the device 36 from its normally high impedance state to the low impedance state. The shunt circuit comprising the resistor 34 provides a source of holding current to the device 36 to maintain it in its low impedance state. It is to be noted that the impedance of the starting winding 28 is initially very high and that sufficient current will not flow through the starting winding 28 initially to maintain the device 36 in its low impedance state. If the shunt circuit were not provided, the device 36 would switch to its high impedance state prior to the time that the current flowing through the winding 28 attained a level sufficiently high to maintain the device 36 in its low impedance state.

5

As the device 36 switches to its low impedance state, the change in current flowing through the starting winding 28 is sufficiently large to produce a voltage between the cathode 14 and the cathode 16 sufficiently high to create a strong stable arc within the tube 10. In this connection, it is to be noted that if a substantial current flows through the winding 28 prior to the time that the switching action occurs, the change in flux in the winding 28 will be lessened considerably and the potential produced between the cathodes 14 and 16 may not be sufficient to produce the desirably strong arc, but rather create a flickering effect in which the striations or steps of alternating light and dark and light are formed in the tube.

During negative half cycles the operation of the circuit is similar to that described with regard to the positive half cycles of the applied line voltage. Thus, the capacitor 56 will be charged through the primary winding 55 and the resistor 50 until such time as the device 58 switches to its low impedance state allowing the capacitor 56 to discharge and produce the desired high current pulse. The polarity of the current pulse is such that the voltage induced in the secondary winding 38 will cause the device 35 to switch to its low impedance state and allow conduction through the fluorescent tube 10 during negative half cycles. It is apparent that only the devices 36 and 60 could be utilized in which case only half wave power would be applied to the fluorescent tube 10.

The resistance of resistor 34 is preferably of a value which will only allow sufficient current to flow to sustain the devices 35 or 36 in the low impedance state. It is to be noted that the resistance of the resistor 34 is not critical, but that any current flowing through it must also flow through the devices 35 or 36 and if the current flowing through resistor 34 is of an appreciable magnitude it will make it necessary to increase the current rating of the devices 35 and 36.

In this connection, it is also to be noted that most frequently the filament transformer 20 and the starting winding 28 are wound on a common core. If the resistance of the resistor 34 is not large, the coupling between the winding 24 of the filament transformer 20 and the starting winding 28 may cause sufficient current to flow in the winding 28 to adversely affect the potential produced between the cathodes 14 and 16.

It is also to be noted that the phase shift network 42 is primarily a voltage using circuit, it only being necessary that sufficient current flow within the phase shift network to charge the capacitor 56. Thus, the phase shift network 42 may be formed of very high impedance elements minimizing the power dissipated within the phase shift network and allowing the entire control circuit to be very small.

The dimming action is obtained by varying the resistance of resistor 44 to vary the phase angle relationship between the firing signal and the line voltage. When resistor 44 is adjusted for a sufficiently high resistance, the firing signal will be substantially 180° out of phase with the applied line voltage and the devices 34 or 36 will not conduct during any part of a half cycle. If the resistor 44 is adjusted to be a low resistance, the firing signal will be substantially in phase with the applied line voltage, and virtually full power will be applied to the load. By varying the resistance of resistor 44 between those extremes, a desired level of light intensity can be obtained. Reference may be had to United States No. 3,188,490 which issued June 8, 1965, assigned to the assignee of the present invention, for a more detailed explanation of the operation of the phase shift network and the pulse producing circuit, if such be necessary.

In practicing the present invention, it is possible to achieve simultaneous dimming of a fluorescent lamp and an incandescent lamp using the same control circuitry. Thus, an incandescent lamp 62 may be connected in parallel with the resistor 34 as shown and the power

6

applied to the lamp 62 will be controlled by the devices 35 and 36. It is, of course, possible, to dispense with the resistor 34 if the incandescent lamp 62 is provided. However, it is preferable that the resistor 34 be retained to provide a source of holding current to the devices 35 and 36 in the event that the incandescent lamp 62 should burn out thereby allowing control of the fluorescent lamp to continue although the incandescent lamp is no longer operable.

The circuitry shown in FIGURE 1 provides excellent dimming of both the fluorescent lamp 10 and the incandescent lamp 62, either individually or in combination. However, certain undesirable effects are present in that the potential developed across the resistor 34 is sufficient to produce a firing signal between the junction points 52 and 54 that will continue to cause the capacitor 56 to be charged to a voltage in excess of the breakover voltage of the device 58 or 60 during a particular half cycle and cause voltage pulses to be produced in the line containing the starting winding 28. At certain particular settings of the resistor 44, generation of these pulses can cause undesirable effects.

Turning now to FIGURE 2 of the drawings, an embodiment of the invention in which provision is made for disabling the pulse producing network after breakdown of the device 35 or 36 is illustrated. FIGURE 2 also illustrates the manner in which a single symmetrical semiconductor diode may be utilized rather than use two oppositely poled parallel connected asymmetrical devices.

As shown in FIGURE 2, a single five layer semiconductor device 64 which exhibits symmetrical switching action is connected between the line 30 and the secondary winding 38 of the transformer 40. In similar fashion, a single five layer symmetrical device 66 is connected between the junction points 52 and 54 and a third symmetrical diode 68 is connected between line 30 and the resistor 34. By symmetrical it is meant that the device is capable of being excited to a low impedance state to allow conduction in one direction during one half cycle and conduction in the opposite direction during opposite half cycles. Such a device is disclosed in my co-pending United States patent application, Serial No. 197,308, filed May 24, 1962, now abandoned, and assigned to the assignee of the present invention.

The tap 51 of the variable resistor 44 and the over terminal of resistor 48 are connected to the juncture between the device 68 and the resistor 34 rather than connecting them to the line 26 as described with reference to FIGURE 1. All other portions of the circuitry are suitably as described previously with reference to FIGURE 1.

In operation of the circuitry shown in FIGURE 2, each of the devices 64, 66 and 68 are initially in their high impedance state and the only current which flows in the circuit will be that flowing in the phase shift network 42. At such time as the capacitor 56 charges to a voltage equal to or in excess of the breakover voltage of the device 66, the device 66 will break down allowing the capacitor 56 to discharge and produce a desired high voltage pulse in the secondary winding 38 of the transformer 40. The high voltage pulse produced in the secondary winding 38 will cause the device 64 to switch to its low impedance state. Virtually simultaneously, the device 68 will also be switched to its low impedance state. Switching of the device 68 may be caused either by the strength of the pulse produced in the secondary winding 38, by the rate of rise of the potential at the line 30, or other suitable means. As both of the devices 64 and 68 are energized to their low impedance states virtually simultaneously, the device 68 in conjunction with the resistive element 34 and, if provided, the lamp 62 provide a source of holding current to the devices 64 and 68 to insure that they re-

main in their low impedance state until near the end of the half cycle.

It is noteworthy that in those instances in which only fluorescent tube 10 is to be controlled, the current carrying capacity of the device 68 may be very small, in the order of the few miliamps necessary to provide holding current to the device 64. On the other hand, if simultaneous control of both the fluorescent lamp and the incandescent lamp are desired, the current carrying capacity of the device 68 must be sufficient to carry the load of the lamp and the current carrying capacity of the device 64 must be capable of supplying current to both the lamp 62 and the tube 10.

It is to be observed that the devices 64 and 68 in their low impedance states have a very low resistance and that the juncture between the device 68 and resistor 34 will be very nearly at ground potential preventing the capacitor 56 being charged to a level that will cause the device 66 to break down during any particular half cycle after the devices 64 and 68 are energized to their low impedance state. It is also noteworthy that when the devices 64 and 68 are in their normally high impedance state, the primary portion of the starting winding 28 is virtually open circuited restricting the current which may flow in the winding 28 due to coupling with the filament transformer 20 to a minimum value thereby insuring that the voltage produced between the cathodes 14 and 16, due to the flow of current through the starting winding 28, will be the maximum attainable insuring that the arc formed in the tube 10 will be strong and continuous rather than fluctuating.

Turning now to FIGURE 3 of the drawings, still a third embodiment of the invention especially adapted for use with a rapid start fluorescent ballast and which utilizes a somewhat different phase shift and pulse forming circuit 69 is shown. Thus, a source of alternating current supply voltage, suitably 110 volts, is connected through a switch 70 to a line 72. The line 72 is connected through the primary winding 74 of the ballast transformer 75 to ground. Filament windings 18 and 22 supply power to the filaments 14 and 16 of the fluorescent tube 10 in the manner described previously. An inductor 76 and a capacitor 78 are suitably provided for power factor correction, the inductor 76 and capacitor 78 each also being connected from line 72 to ground. A series circuit comprising a secondary winding 38 of transformer 40, symmetrical device 64, a symmetrical device 68 and the resistor 34 is connected between line 72 and ground. The juncture 71 between the device 64 and the device 68 is connected to one end of the starting winding 80, the other end of the starting winding 80 being connected to the filament winding 22.

The pulse forming circuit 69 is seen to comprise diodes 86 and 88 which are connected in series between the lines 72 and 84 with their anodes commonly connected to line 89. In similar fashion, diodes 90 and 92 are connected in series between lines 72 and 84 with their cathodes commonly connected to line 93. Resistors 94 and 96 are connected between lines 89 and 93. The juncture 95 between the resistors 94 and 96 is connected to one base of a unijunction transistor 98, the other base of the unijunction transistor 98 being connected to the control electrode of a silicon control rectifier 102 and through resistor 100 to line 89. The cathode of the silicon control rectifier 102 is connected to line 89 and the anode of the silicon control rectifier is connected to line 93.

Resistor 106 is connected in parallel with the potentiometer 104, the tap 108 of the potentiometer 104 being connected to line 93. As shown, one end of the parallel circuit comprising the resistor 106 and potentiometer 104 is connected through resistor 110 to the

control electrode of the unijunction transistor 98. The control of the unijunction transistor 98 is also connected through a capacitor 112 to line 89. Primary winding 55 of the transformer 40 and capacitor 81 are connected in series between the line 72 and the line 84. The line 84 is connected through resistor 82 and resistor 34 to ground.

The tap 108 on potentiometer 104 and the switch 70 are suitably commonly connected to a control knob 114 such that when the control 114 is positioned for minimum power to the fluorescent tube, the switch 70 will be open and the tap 108 of potentiometer 104 will be in a position to provide maximum resistance between the line 93 and the control electrode of the unijunction transistor 98. When the control 114 is first turned, the switch 70 is closed and current will flow through the primary winding 74 of the ballast transformer 75, applying power to the heater of the filaments 114 and 116. The capacitor 81 will be charged through a charge circuit comprising the primary winding 55, resistor 82 and resistor 34 and positive anode voltage is applied to the SCR by the full wave rectifier bridge comprising the diodes 86, 88, 90 and 92. After a time interval, determined by the time constant of the RC circuit comprising the capacitor 112, resistor 110, resistor 106 and potentiometer 104, the unijunction transistor 98 will trigger, causing the silicon controlled rectifier 102 to switch to a low impedance state from a high impedance state.

When the silicon controlled rectifier 102 switches, a low impedance discharge path is provided for the capacitor 81, providing a current pulse which induces a voltage in the secondary winding 38 of a character to switch the devices 64 and 68 to their low impedance state. The capacitor 116 connected across the series circuit comprising devices 64 and 68 and winding 38 assist in turning the devices on and attenuate high frequency noise generated as the devices 64 and 68 turn on. When the device 64 switches to its low impedance state, the starting winding 80 is effectively connected in series with the primary winding 74. A voltage will thereby be applied by the winding 80 that is sufficient to cause the fluorescent tube 10 to turn on. As described previously with reference to the preceding two embodiments of the invention, the impedance of the winding 80 will be such that sufficient holding current will now flow to maintain the device 64 in its low impedance state. Accordingly, the juncture 71 is connected through device 68 and resistor 34 to ground, thereby providing a path through which holding current for the devices 64 and 68 can flow.

The pulse forming network shown in FIGURE 3 has some advantages over that shown in FIGURES 1 and 2 in that if the line voltage should drop, the pulse would be produced at an earlier time in a half cycle without variation of the position of the tap 108. Conversely, if line voltage should increase, the voltage which causes the devices 64 and 68 to switch to the low impedance state would occur at a later time in the half cycle. It will, therefore, be apparent that the light intensity will be maintained more nearly constant. Obviously, the intensity of light produced by the tube 10 will vary as a function of the position of the tap 108 as the position of the tap 108 controls the phase relation between the firing signal produced by the trigger circuit comprising the unijunction transistor and each half cycle of the alternating current supply voltage.

Although the invention has been described with reference to certain particular embodiments, many changes and modifications will be obvious to those skilled in the art in view of the foregoing description. Thus, devices and arrangements of devices other than those shown may be utilized to obtain similar results and means other than the specific phase shift pulse forming networks shown may be utilized to energize the primary control elements to the low impedance state. The invention is to be lim-

9

ited, therefore, not to what has been shown herein but only as necessitated by the scope of the appended claims.

What I claim is:

1. A power control circuit that comprises:

- (a) first diode switching means capable of being excited from a normally high impedance state to a low impedance state;
- (b) means connecting said first diode switching means in a series with the load to be controlled and a source of alternating current supply voltage;
- (c) means for exciting said first diode switching means to the low impedance state at a desired time in the cycle of the applied alternating current supply voltage to thereby control the power applied to the load;
- (d) a resistive element;
- (e) a second diode switching means capable of being excited from a normally high impedance state to a low impedance state; and
- (f) means connecting said second diode switching means in series with said resistive element across said load for supplying holding current to said first diode switching means when said first and second diode switching means are switched to the low impedance state.

2. A power control circuit as defined in claim 1 wherein said resistive element is one of a resistor, an incandescent lamp, and a resistor and incandescent lamp connected in parallel.

3. A power control system that comprises:

- (a) a first symmetrical, solid state switching device capable of being excited from a normally high impedance state to a low impedance state;
- (b) means for connecting said first switching device in series with a load to be controlled and a source of alternating current supply voltage;
- (c) means connecting a resistive element and a second symmetrical, solid state switching device capable of being switched from a normally high impedance state to a low impedance state in parallel with the load to be controlled; and
- (d) means effective to switch said first switching device and said second switching device from the normally high impedance state to the low impedance state at a desired time in each half cycle of the applied supply voltage to thereby control the effective power applied to said load.

4. A system for dimming fluorescent lights that comprises:

- (1) a ballast having a primary winding and a start winding;
- (2) means connecting said primary winding in series with a source of alternating current supply voltage;
- (3) first diode switching means capable of being excited from a normally high impedance state to a low impedance state;
- (4) a load comprising said start winding and a fluorescent tube connected in series;
- (5) means connecting said first diode switching means in series with said load and said source of alternating current supply voltage;
- (6) means connecting a resistive element and a second diode switching means capable of being switched from a high impedance state to a low impedance state in parallel with said load; and
- (7) means for exciting said first diode switching means and said second diode switching means to said low impedance state at a desired time in each half cycle of the applied alternating current supply voltage to thereby control the flow of current through said load.

5. A system as defined in claim 4 further including capacitor means connected across the series circuit comprising the output of the transformer and said first and second diode switching means.

10

6. A system as defined in claim 4 wherein said ballast further includes first and second filaments, a first filament winding for supplying heat current to said first filament, and a second filament winding for supplying heat current to a second filament, a means connecting said first filament to ground potential and connecting said second filament to said start winding.

7. A system as defined in claim 4 wherein said means for exciting said first diode switching means and second diode switching means to the low impedance state comprises:

- (1) transformer means having an output connected in series with said first and second diode switching means;
- (2) a capacitor;
- (3) means providing a charge circuit for said capacitor;
- (4) means including an input of said transformer means and an additional switching means for providing a discharge circuit for said capacitor, said additional switching means being switched from a high impedance state to a low impedance state responsive to the presence of a firing signal;
- (5) means for generating said firing signal;
- (6) and means for varying the phase relation between said firing signal and said each half cycle of alternating current supply voltage;
- (7) a voltage of a character to excite said first and second diode switching means to the low impedance state being produced at the output of said transformer responsive to the discharge of said capacitor through said input of said transformer.

8. A system as defined in claim 7 wherein said additional switching means comprises a silicon controlled rectifier and said means for generating a firing signal comprises a unijunction transistor.

9. A system for dimming fluorescent lights that comprises:

- (a) first diode switching means capable of being excited to a low impedance state from a high impedance state;
- (b) means for connecting said first diode switching means in a series with primary of the ballast winding of the fluorescent light to be dimmed and a source of alternating current power;
- (c) phase shifting means for producing a firing signal having a desired phase angle relationship with the power applied to said load;
- (d) transformer having a primary winding and a secondary winding;
- (e) means connecting said secondary winding in series with said first diode switching means, said source of alternating current power and said primary of the ballast winding;
- (f) a capacitor;
- (g) means connecting said capacitor and said primary winding in parallel with said second diode switching means;
- (h) means connecting said capacitor to be charged by said firing signal, said second diode switching means switching to the low impedance state responsive to said capacitor being charged to the breakover voltage thereof and providing a discharge path for said capacitor through said primary winding to induce a voltage in said second winding to excite said first diode switching means to the low impedance state;
- (i) third diode switching means;
- (j) a resistive element; and
- (k) means connecting said third diode switching means and said resistive element in series with said first diode switching means and in shunt said primary said ballast winding, said third diode switching means being positioned between said resistive element and said first diode switching means.

10. A system as defined in claim 9 wherein said phase shift means is connected across said first and said third diode switching means.

3,188,490 6/1965 Hoff et al. 307—88.5
3,196,330 7/1965 Moyson 317—235

OTHER REFERENCES

References Cited by the Examiner

UNITED STATES PATENTS

2,315,926 4/1943 Bivens 315—199
3,130,347 4/1964 Harpley 315—195
3,159,766 12/1964 Harpley 315—195
3,163,077 12/1964 Shank 315—194

5 E. E. Von Zastro, "Semiconductor Dimmers in Architectural Lighting," reprinted from Lighting for April 1962, pp. 36-39, 62, 63.

JOHN W. HUCKERT, *Primary Examiner*.

10 D. O. KRAFT, *Assistant Examiner*.