June 27, 1967 J. A. NUCKOLLS 3,328,673

CONTROL CIRCUIT WITH HIGH VOLTAGE STARTING MEANS

Filed Jan. 4, 1966 3 Sheets-Sheet 1

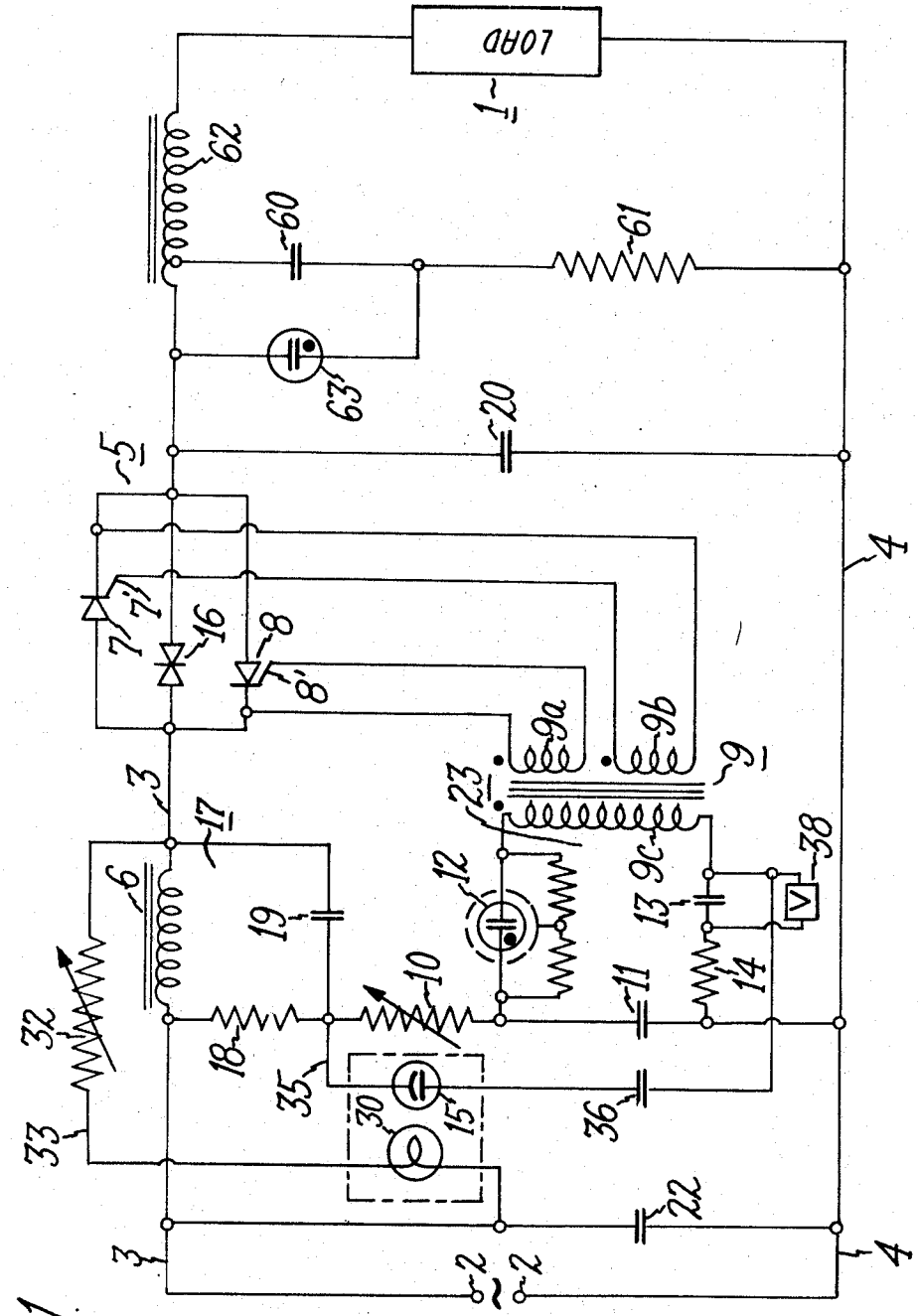

Fig. 1

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Fig. 2.

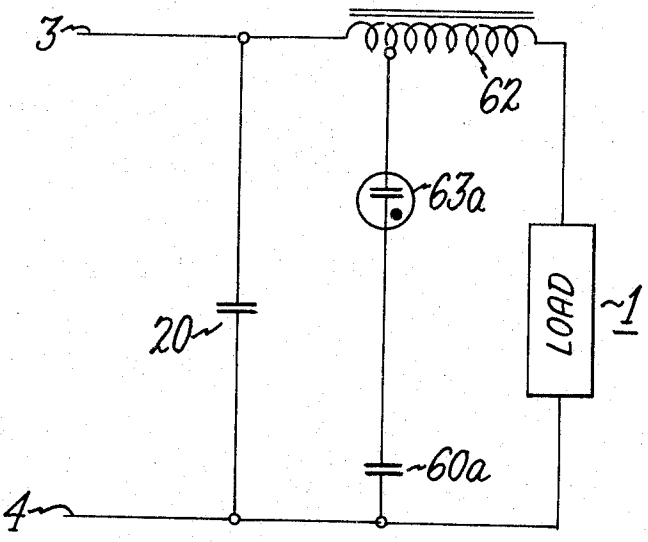
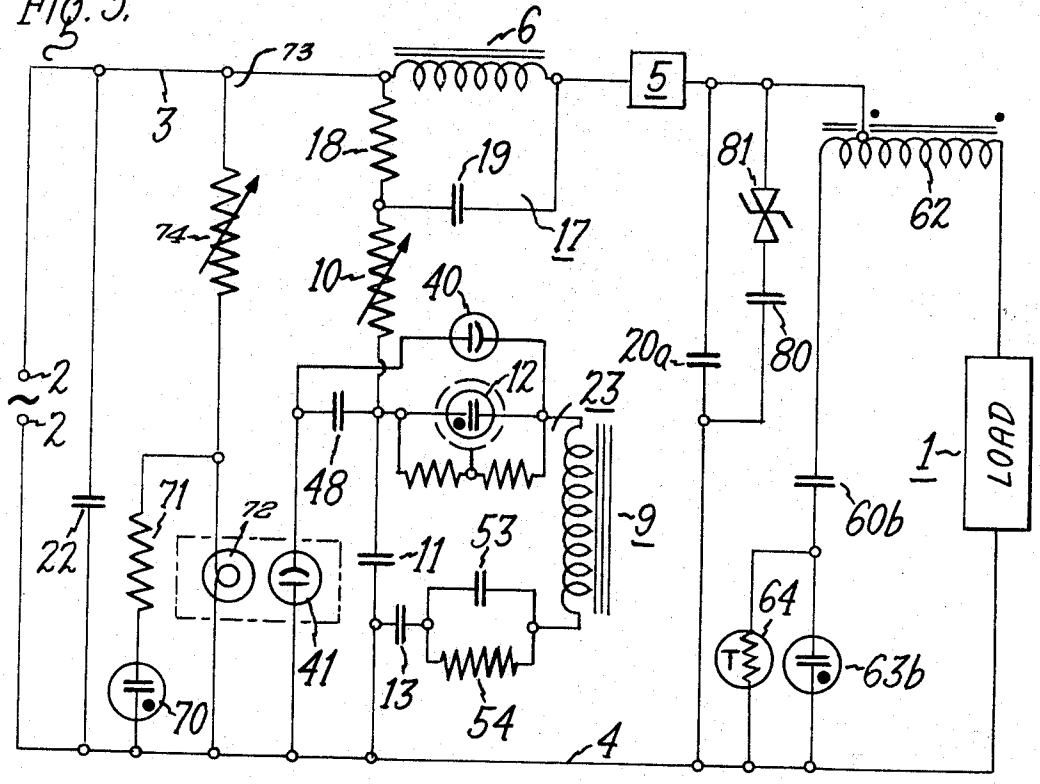


Fig. 3.



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CONTROL CIRCUIT WITH HIGH VOLTAGE STARTING MEANS

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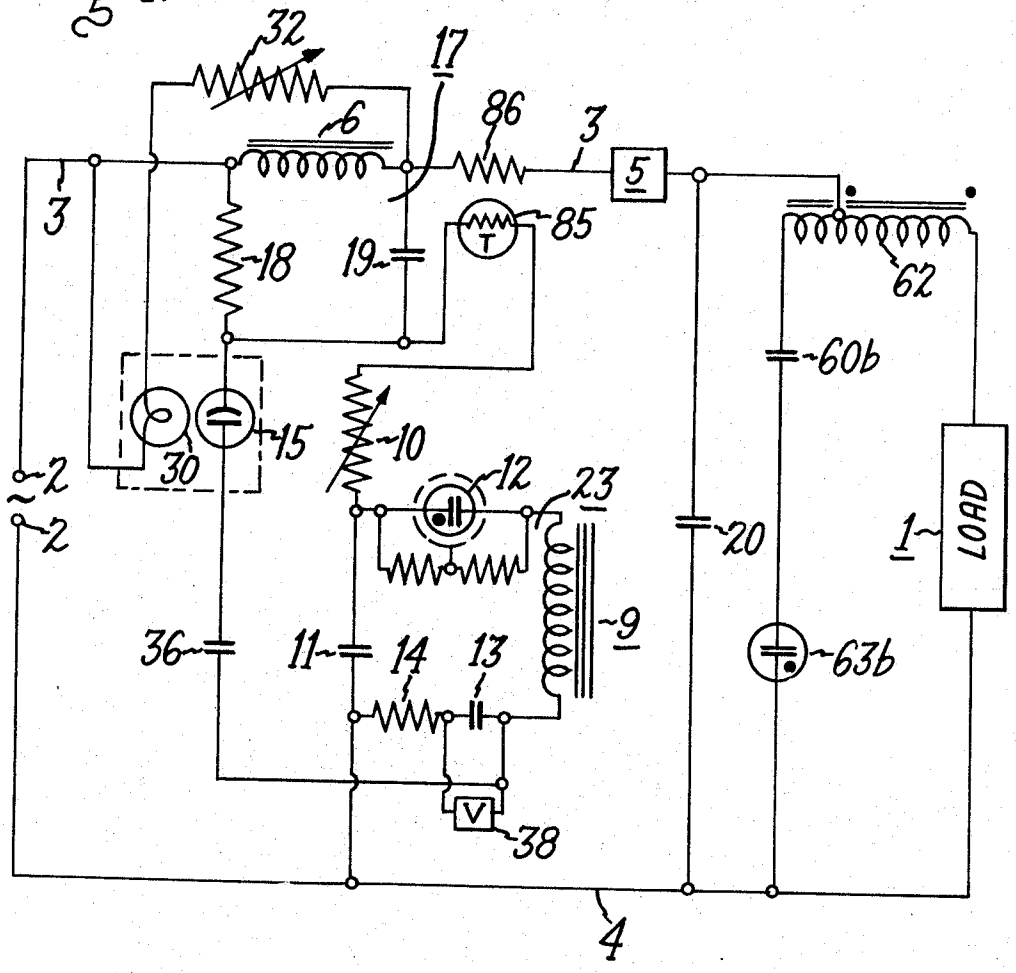
Fig. 4.



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United States Patent Office 3,328,673 Patented June 27, 1967

3,328,673
CONTROL CIRCUIT WITH HIGH VOLTAGE STARTING MEANS

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Filed Jan. 4, 1966, Ser. No. 518,618
16 Claims. (Cl. 323—21)

The present invention is a continuation-in-part of co-pending applications Ser. No. 223,480 filed Sept. 13, 1962, now U.S. Patent 3,249,807 dated May 3, 1966, Ser. No. 451,508 filed Apr. 28, 1965, and Ser. No. 458,353 filed May 24, 1965, all assigned to the same assignee as the present invention.

The present invention relates to control circuits for operating load devices, and more particularly concerns alternating current, phase-controlled circuits which employ controlled rectifier switching devices as disclosed in the aforementioned co-pending applications and which incorporate circuit means for automatically starting, operating and regulating the operation of load devices, such as gas discharge lamps.

It is an object of the invention to provide an improved control circuit of the above type which incorporates high voltage starting means for starting gas discharge lamps, such as sodium vapor lamps, or other lamp or load devices requiring a high voltage for starting.

It is a particular object of the invention to provide a control circuit of the above type which super-imposes a high voltage ignition pulse in the kilovolt range on the normal open circuit wave form of the circuit to ignite high starting voltage gas discharge lamps.

It is another object of the invention to provide a control circuit of the described type which may be employed for starting and operating load devices requiring either high or low voltage for starting.

Another object of the invention is to provide high voltage starting control circuits of the above type wherein the high voltage generation is de-energized automatically upon ignition of the load device.

It is still another object of the invention to provide a control circuit of the described type which provides a number of controlled starting and operating parameters for the lamp, such as optimum placement of the high voltage pulse relative to the half-cycle voltage wave form, lamp current limiting upon ignition, automatic forced lamp wattage buildup to the desired level, and controlled low current starting for certain lamps which have lower starting current than operating current.

Still another object of the invention is the provision of a control circuit of the above type incorporating feedback means to effect lamp current regulation when stabilized, and other forms of feedback.

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

With the above objects in view, the present invention relates to a circuit for controlling the power applied to load means such as gas discharge lamps comprising, in combination, a source of alternating current, load means energized by the alternating current source, controlled rectifier means connected between the alternating current source and the load means, the controlled rectifier means being normally non-conductive to block current flow to the load means and having electrode control means to render it conductive, actuating means connected to the alternating current source and to the electrode control means for applying a control signal to the electrode control means at a predetermined time in each alternating current cycle, the actuating means including a resistance and a capacitance connected together in series and voltage sensitive symmetrical switch means connected across the

capacitance, and means connected between the controlled rectifier means and the load means for providing a high voltage starting pulse on the load means.

In a preferred embodiment, the circuit includes a charging capacitor for providing an intermediate voltage higher than the source voltage and a high voltage pulse generating circuit in parallel with the charging capacitor and including another capacitor, a pulse transformer and a voltage sensitive switch device, the pulse generating circuit forming a high voltage, high frequency discharge loop for applying high voltage pulses in the kilovolt range to the load means for starting the latter.

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

FIGURE 1 is a circuit diagram of an embodiment of a control circuit having a high voltage lamp starting means in accordance with the invention;

FIGURE 2 is a circuit diagram showing a portion of the control circuit having a different embodiment of the high voltage starting means;

FIGURE 3 is a circuit diagram showing another embodiment of the control circuit of the invention having a modified high voltage lamp starting circuit; and

FIGURE 4 is a circuit diagram of another embodiment of the control circuit of the invention including feedback means for controlling the starting current of the load.

Referring now to the drawing, and particularly to FIGURE 1, there is shown a phase controlled switching circuit for controlling the current and voltage applied to a load **1**, such as a sodium vapor lamp or other variable impedance loads, connected to terminals **2** of a source of alternating current, typically 220 volts, by conductors **3** and **4**. Ballast inductive reactance **6** is connected in series with lamp **1** to provide a current limiting impedance, as is conventional in discharge lamp circuits. Arranged in series with lamp **1** is a controlled rectifier circuit **5** which includes a paralleled pair of oppositely poled controlled rectifiers **7** and **8**, which are typically silicon controlled rectifiers (SCR), having control (gate) electrodes **7'** and **8'** by means of which the SCR's are rendered conductive for unidirectional flow of current when a signal impulse is applied to the respective control electrodes.

Control electrodes **7'** and **8'** are connected to secondary windings **9***a*, **9***b* of coupling transformer **9**. Transformer **9**, which serves to isolate the controlled rectifier circuit **5** from the trigger pulse generating circuit, described below, is a pulse transformer which responds only to high frequency pulses, and therefore only high frequency trigger pulses are applied to the controlled rectifier circuit **5**. This protects the control electrodes from over dissipation caused by follow-through current from the alternating current supply **2** appearing in the signal generating circuit which could otherwise tend to cause overheating and early failure of the controlled rectifier circuit.

The signal generating or actuating circuit **23** comprises a variable resistance **10** in series with a charging capacitor **11** connected across terminals **2**, thereby synchronizing the signal generating function with the source voltage. A discharge loop in actuating circuit **23** for discharging capacitor **11** includes transformer primary **9***c* and a voltage sensitive device **12**, typically a neon glow lamp, which is a bilaterally conducting gas tube and is also referred to herein as a voltage sensitive symmetrical switch means, which becomes conductive only upon the application of a predetermined voltage thereto. Glow lamp **12** can be replaced by a semiconductor voltage sensitive switch device having similar breakdown characteristics and pulsing capabilities, such device comprising, for example, a sym-

metrical Shockley device. Glow lamp **12** is connected to the source in parallel with capacitor **11** but is effectively connected in series discharge relation thereto, as shown, and with transformer primary **9***c*.

In the above described circuit arrangement, on each half cycle of the alternating current input, one of the controlled rectifiers **7** and **8** will have a positive anode and the other a positive cathode. Therefore, a control signal applied to control electrodes **7'** and **8'** will place only one of the controlled rectifiers in a conduction mode on each half cycle. A delay in the point in the alternating current input cycle at which the control signal impulse is applied to render the rectifier conductive is known as phase control.

As more fully described in the aforementioned co-pending applications, the disclosures of which are incorporated herein by reference, when glow lamp **12** becomes conductive as a result of voltage buildup on capacitor **11**, capacitor **11** partially discharges and a signal pulse is applied to the transformer primary **9***c* which induces a current pulse of a particular duration and at a particular time in the half cycle. The controlled rectifier **7** or **8** which has an anode positive with respect to its cathode will then be triggered into conduction by the pulse current applied to control electrodes **7'**, **8'** and the voltage which has built up across the rectifier falls substantially to zero. The controlled rectifier **7** or **8** then permits current to flow, consequently applying power to the load, for the remainder of that half cycle. On the next half cycle as the anode voltage becomes negative, the controlled rectifier **7** or **8** which was conductive becomes non-conductive and no power is transferred to the load until the signal generating circuit fires the other controlled rectifier. The time in the half cycle at which the rectifier is gated is adjustable by the level of resistance **10**.

For the purpose of protecting the rectifier circuit **5** from transient voltages, a thyrector **16**, or double zener diode device, may be connected in parallel with the rectifiers, as shown.

The control circuit also preferably incorporates an integrating network **17** comprising series connected resistor **18** and capacitor **19** connected as shown across reactor **6**, and variable resistor **10** is connected to network **17** at the junction of resistor **18** and capacitor **19**. The characteristics and function of integrating network **17** are more fully disclosed in the aforementioned co-pending application Ser. No. 458,353.

Capacitor **22** connected across source terminals **2** provides power factor improvement in the circuit. Capacitor **20**, connected in parallel with lamp **1**, is a voltage ring-up capacitor and provides a maximum load impedance for the controlled rectifier circuit and serves to raise the voltage of the alternating current source to an intermediate level for purposes of starting the lamp, as explained hereinafter.

In accordance with the present invention, the circuit described incorporates a circuit to provide a high voltage pulse, e.g., in the range of 1–40 kilovolts or higher, for igniting gas discharge lamp **1** which may be a sodium vapor lamp or other vapor lamp requiring such high voltage for starting. The high voltage pulse generator comprises capacitor **60** and resistor **61** connected in series across capacitor **20**, and step-up pulse transformer **62** connected in series between SCR circuit **5** and lamp load **1**. The pulse generating circuit also includes a voltage sensitive symmetrical switch **63** such as a neon glow lamp connected across capacitor **60** and the primary winding of pulse transformer **62** and has a voltage breakdown level of a magnitude less than the peak voltage across capacitor **20**. Typically, glow lamp **63** breaks down and becomes conductive at about 400 volts, whereas the peak voltage across capacitor **20** is about 600 volts. Glow lamp **63**, capacitor **60** and the primary of transformer **62** constitute a resonant high frequency discharge circuit upon conduction through glow lamp **63**, and in a typical case

oscillates at a frequency of 100 kilocycles per second, providing a pulse of 5 kv. having a duration of 5 microseconds.

Step-up pulse transformer **62** typically has a primary-to-secondary turns ratio of 1 to 20, and is preferably but not necessarily an autotransformer as shown. The magnitude of the primary inductance and the turns ratio of transformer **62** and the magnitude of capacitor **60** can be selected to provide various peak ignition voltages, durations, and energy levels as desired. Also the magnitude of resistor **61** can be selected or adjusted relative to the magnitude of capacitor **60** to adjust the placement of the ignition pulse with respect to the half-cycle voltage.

In the operation of the described circuit, upon actuation of SCR circuit **5** as described, an intermediate voltage charge (e.g., 600 volts) is placed on capacitor **20** by virtue of the resonant charging circuit formed by series connected inductance **6** and capacitor **20**. While such resonant charging effect makes possible a very high voltage generating capability across capacitor **20**, the voltage clamping action of thyrector **16** limits the voltage buildup in capacitor **20**.

Capacitor **60** charges up toward the peak voltage appearing across capacitor **20**, e.g., 600 volts, and at the voltage breakdown level of glow lamp **63**, e.g., 400 volts, the latter becomes conductive, placing the voltage of capacitor **60** in a pulse across the primary of transformer **62**. With the step-up ratio of transformer **62** being 1:20, a high frequency pulse of about 8 kilovolts is applied from the secondary of the transformer to lamp **1**. The negative coefficient of resistance of lamp **1** at starting causes the arc drop across the lamp to fall to a low voltage level and the voltage across capacitor **20** no longer builds up as a result of lamp loading. Therefore, the voltage across capacitor **60** can no longer reach the breakdown voltage of switching device **63**, and the operation of the ignition pulse generating circuit is automatically discontinued when lamp **1** starts. When a lamp outage occurs, the starting mechanism is automatically re-applied.

A minimum capacitance in power factor capacitor **22** is often required to provide a stiff instantaneous source of current to ensure the high voltage ring-up across capacitor **20**. Therefore, capacitor **22** should have adequate high-frequency capabilities.

The circuit shown in FIGURE 1 includes a current feedback system as also disclosed in the aforementioned copending application Ser. No. 458,353. The feedback system comprises a feedback circuit **33** connected across reactor **6** and including variable resistor **32** and incandescent lamp **30**. Employed in conjunction with incandescent lamp **30** is a photosensitive circuit **35** including photoconductor **15**, such as a cadmium sulfide cell, arranged seeing lamp **30**, and in series with capacitor **36**. Circuit **35** is connected at one end to integrating network **17** at the junction of capacitor **19** and resistor **18**, and at the other end in series with capacitor **13**. The feedback system provides lamp load wattage regulation compensating for line voltage variations and to a large degree for lamp voltage variations, and essentialy effects constant current. This feedback system is more fully described in the last mentioned co-pending application.

FIGURE 2 shows a modified high-voltage pulse generating circuit which may alternatively be used in the control circuit shown in FIGURE 1. In the embodiment of FIGURE 2, voltage sensitive symmetrical switch **63***a* such as a spark tube or glow lamp in series with capacitor **60***a* is connected to the primary of autotransformer **62** and in parallel with charging capacitor **20** as shown. In this embodiment resistor **61** is omitted. This circuit serves to place the ignition pulse on the leading edge of the 60-cycle wave form occurring across capacitor **20**, and functions as follows. As the voltage rises across capacitor **20**, it also rises across spark tube **63***a* to the breakdown potential of the latter, which then conducts a current pulse from capacitor **20** to capacitor **60***a*, placing the

instantaneous voltage of capacitor **20** across the primary of transformer **62** and thereby applying the ignition pulse to the leading edge of the voltage buildup occurring across capacitor **20** each half-cycle.

In the FIGURE 1 circuit, the pulse is always applied sometime after the leading edge as determined by the RC time constant of resistor **61** and capacitor **60**. The earlier placement of the ignition pulse by the modification shown in FIGURE 2 provides earlier in-cycle ignition of the lamp load, thereby enabling a greater remaining portion of the wave half-cycle to be applied to the lamp following the high voltage ignition pulse. In the FIGURE 2 embodiment the high frequency discharge circuit comprises capacitor **20**, switch device **63***a*, and capacitor **60***a* connected in series with the primary of transformer **62**. In this connection, symmetrical switch **63***a* upon becoming conductive applies the instantaneous sum voltage of capacitor **20** and the residual voltage of capacitor **60***a* to the primary turns of transformer **62**. As the current pulse flows, an opposing voltage buildup occurs across capacitor **60***a*, thereby limiting the switch follow-through current.

In addition to this current limiting function, and the provision of the dominant capacitance involved in the resonant high frequency, high voltage generation which also characterize corresponding capacitor **60** in the FIGURE 1 circuit, capacitor **60***a* serves in the FIGURE **2** embodiment to hold a residual charge aiding the next half cycle high voltage breakdown of spark tube **63***a* and operating to place the ignition pulse on the leading edge of the wave. The spark tube **63***a* can be replaced by a semiconductor device having similar breakdown characteristics.

FIGURE 3 shows a modification of the high voltage pulse generating circuit which provides an ignition pulse which is positive-going with respect to the voltage buildup of capacitor **20**, in contrast to the negative-going ignition pulse provided by the FIGURE 2 arrangement. This feature may be preferred for use with certain types of lamps and circuitry. In this embodiment, charging capacitor **20***a* is connected to a tap of transformer **62** between its primary and secondary windings, and capacitor **60***b* in series with voltage sensitive symmetrical switch **63***b* is connected to the start of the primary winding of transformer **62** and forms therewith and with capacitor **20***a* a high frequency, high voltage discharge loop. The transformer tap connection is polarized as shown so as to provide a positive-going ignition pulse with respect to the voltage buildup across capacitor **20***a*. With this connection, as the voltage builds up across capacitor **20***a*, the voltage also appears across switch **63***b*. When the latter becomes conductive at its voltage breakdown level (e.g., 400 volts), the high frequency current flows from the positive terminal of capacitor **20***a* through the tap on transformer **62** to the start of its primary winding and through the series connected capacitor **60***b*, placing approximately 400 volts across the primary turns of transformer **62**, the polarity being such that positive voltage appears at the tap and negative voltage at the primary start. Consequently, the high voltage side of pulse transformer **62** provides a positive-going pulse across lamp **1** with respect to the voltage appearing across capacitor **20**. When the opposing voltage buildup across capacitor **60***b* reaches the de-ionization level for neon glow lamp **63***b*, the latter de-ionizes, thus turning off the high voltage pulse.

A variable resistance **64** may be placed in parallel with switch **63***b* to ensure its extinguishing over a large input voltage range. This variable resistance may be constituted by a thermistor as shown, which forces the high voltage pulse turnoff as a result of self-heating after a period of pulsing. This function may be desired for the purpose of turning off the ignition pulse if lamp **1** burns out.

Also shown in the circuit diagram of FIGURE 3 is an auxiliary photosensitive control circuit comprising photoconductor **40** connected across capacitor **48** and neon glow lamp **12** for automatically turning lamp **1** on and off at a desired ambient light level, as more fully disclosed in co-pending application Ser. No. 458,353. In addition, there is shown feedback circuit **73** including variable resistance **74** and incandescent lamp **72** for compensating for line voltage variation, as also disclosed in the last mentioned co-pending application. Variable resistance **74** should have a minimum resistance sufficient to protect the incandescent lamp from excessive voltages.

Arranged adjacent incandescent lamp **72** is photoconductor **41** which in series with capacitor **48** is placed in parallel with actuating circuit **23**. In the operation of this system, if the line voltage increases, the current through incandescent lamp **72** increases, brightening lamp **72** and causing photoconductor **41** to decrease in resistance and thereby shunting more of the available charging circuit from capacitor **11**. This slows the voltage buildup across capacitor **11**, hence delaying the firing of SCR circuit **5** and regulating the power delivered to lamp load **1**.

The photoelectric control for turning the system on and off is achieved by exposing photoconductor **40** to the ambient light. As the ambient light level increases, the photocell resistance increases allowing the current to pass around neon glow lamp **12**, keeping the latter from reaching a breakdown voltage level and becoming conductive, and thus preventing operation of the triggering or signal generating circuit **23**. Photoconductor **41** can be used, if desired, as the ambient light sensing photoconductor in lieu of photoconductor **40** to turn off the actuating circuit. As more fully disclosed in the last mentioned co-pending application, capacitor **48** serves both as a symmetry forcing component during the photoelectric current on and current off functions and provides more stabilized footcandle levels at which such switching occurs, and also linearizes the normal feedback function. Damping resistor **54** is placed in series with capacitor **13** to ensure a surge or damped trigger pulse so as to provide a discharge without oscillatory tendencies or multiple pulsing.

Also shown in FIGURE 3 is a voltage sensitive switch **70** such as a neon glow lamp in series with resistance **71** and connected across incandescent lamp **72** for the purpose of turning off lamp **1** in the event of failure of feedback circuit **73** due to burning out of incandescent lamp **72**, glow lamp **70** being arranged to illuminate photoconductor **41** for disabling the operation of the actuating circuit **23** upon failure of lamp **72**.

Another feature shown in the FIGURE 3 circuit is the provision of a branch circuit comprising capacitor **80** in series with a switch device **81** connected across capacitor **20***a* for the purpose of obtaining higher high-voltage starting energy where this is desired or necessary to effectively pick up or start certain lamp loads by applying the high voltage pulses at much higher energy levels than is afforded by the use of capacitor **20***a* alone. Switch device **81** may be a symmetrical voltage sensitive switching device such as the double Zener device shown, a thyrector, or back-to-back SCR's having a voltage sensing triggering means, or a double Shockley device, or it may be simply a manually operable switch used only for the starting operation. Capacitor **80** typically will have the same voltage rating as capacitor **20***a*, and at the intermediate voltage level to which the latter becomes charged as previously described, capacitor **80** discharges its energy as switch device **81** becomes conductive at that voltage level and adds its start energy to that of capacitor **20***a*. When the lamp ignites, the voltage in the ignition circuit drops and the operation of the double Zener device forces the automatic dropout of capacitor **80**. Such dropout is necessary since too high a capacitance during the normal operation of the lamp would cause excessive peak lamp current which would result in shortened lamp life.

Certain lamps such as sodium vapor lamps require during the initial lamp warm-up period a low lamp current which is less than the normal lamp operating current. FIGURE 4 shows a lamp control circuit which in-

corporates a feedback modification to provide such a function. In this embodiment, thermistor **85** or other suitable variable resistance is connected between integrating network **17** and actuating circuit **23** and placed in proximity to, i.e., in thermal contact with, heating resistor **86** connected in series between reactor **6** and SCR circuit **5**. This feedback which, as shown, may function in conjunction with current feedback circuit **33** (which is more fully disclosed in co-pending application Ser. No. 458,353) operates as follows. At the instant of lamp starting, thermistor **85** and resistor **86** are at ambient temperature. The resistance of thermistor **85** is thus relatively high, providing a retarding of the SCR firing phase angle and thereby limiting the current applied to the lamp load **1**. With lamp current flowing for a period of time, resistor **86** becomes heated thereby, in turn heating thermistor **85**. The times of heating involved can be adjusted by selection of the total thermal mass to be heated (e.g., of resistor **86** or associated mass), the resistance of resistor **86**, or the type of thermistor employed. The increase in thermistor temperature causes a decrease in resistance therein to saturation level, which in turn advances the SCR firing angle, causing the lamp current to increase to some controlled level.

In the case where the type of lamp load used requires a higher starting current than operating current, the thermistor **85** could be of a type which increases in resistance with increase in temperature.

It will be understood that the circuit arrangements of the invention may find application for various types of loads other than gas discharge lamps, such as electric and electronic welding equipment, electric ignition systems, and other apparatus requiring high starting voltages.

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

1. A circuit for controlling the power applied to load means comprising, in combination, a source of alternating current, load means energized by said alternating current source and requiring a high voltage starting pulse, controlled rectifier means connected between said alternating current source and said load means, said controlled rectifier means being normally non-conductive to block current flow to said load means and having electrode control means to render it conductive, actuating means connected to said alternating current source and to said electrode control means for applying a control signal to said electrode control means at a predetermined time in each alternating current cycle, said actuating means including a resistance and a capacitance connected together in series and to the alternating current source and voltage sensitive symmetrical switch means connected across said capacitance, means connected between said alternating current source and said load means for producing an intermediate voltage higher than the voltage of said alternating current source, and means connected between said controlled rectifier means and said load means for providing a high voltage starting pulse on said load means.

2. A circuit as defined in claim **1**, said intermediate voltage producing means including impedance means connected in series with said load means and said controlled rectifier means, a first capacitor connected across said load means and in series with said impedance means and forming therewith a resonant circuit, said high voltage pulse producing means comprising a second capacitor, voltage sensitive switch means and step-up pulse transformer means connected together in circuit across said first capacitor for producing on said load means repetitive pulses of a voltage substantially higher than said intermediate voltage for starting said load means.

3. A circuit as defined in claim **2**, wherein said pulse transformer means has a primary winding and a secondary winding, and said second capacitor is connected in series with said primary winding in series with said voltage sensitive switch means connected across the first capacitor and said secondary winding being connected in series with said load means.

4. A circuit as defined in claim **3**, wherein a resistor is connected in series with said second capacitor across said first capacitor, said voltage sensitive switch means being connected to the junction of said second capacitor and said resistor and forming with said second capacitor and said primary winding a high frequency, high voltage discharge loop.

5. A circuit as defined in claim **3**, wherein said pulse transformer means is an autotransformer having a tap between said primary and secondary windings, and said series connected second capacitor and voltage sensitive switch means are connected to said tap, and said first capacitor is connected to the start of said primary winding.

6. A circuit as defined in claim **3**, wherein said pulse transformer means is an autotransformer having a tap between said primary and secondary windings connected to said controlled rectifier means, and said series connected second capacitor and voltage sensitive switch means are connected to the start of said primary winding, and said first capacitor is connected to said tap.

7. A circuit as defined in claim **3**, wherein said first capacitor, said second capacitor, said voltage sensitive switch means and said primary winding form a high frequency, high voltage discharge loop.

8. A circuit as defined in claim **7**, wherein a variable resistance is connected across said voltage sensitive switch means for disabling the operation of the latter in the event of failure of said load means.

9. A circuit as defined in claim **8**, wherein said variable resistance across said voltage sensitive switch means is a thermistor.

10. A circuit as defined in claim **3**, wherein a third capacitor and second switching means are connected in series across said first capacitor for providing increased energy for starting said load means.

11. A circuit as defined in claim **10**, wherein said switching means is a symmetrical voltage sensitive switching means.

12. A circuit as defined in claim **1**, wherein a pair of line conductors connect said load means and said alternating current source, said circuit further including feedback circuit means comprising light producing means connected between said line conductors for detecting voltage variations across said conductors, photosensitive means responsive to said light producing means and connected to said actuating means for controlling the operation thereof in response to the light output of said light producing means, and a voltage sensitive light producing switch device connected across said first mentioned light producing means and arranged to illuminate said photosensitive means for disabling the operation of said actuating means upon failure of said first mentioned light producing means.

13. A circuit as defined in claim **1**, including feedback means connected to said alternating current source and said actuating means for producing during the load starting interval a load current different from the normal load operating current.

14. A circuit as defined in claim **13**, wherein said feedback means comprises a heating resistance connected between said alternating current source and said load means, and a temperature sensitive variable resistance connected between said alternating current source and said actuating means and arranged in proximity to said heating resistance, and operating in response to varia-

tions in temperature of said heating resistance to control the operation of said actuating means and thereby control the load current.

15. A circuit as defined in claim **14**, wherein said temperature sensitive variable resistance is a thermistor which decreases in resistance with a rise in temperature.

16. A circuit for controlling the power applied to load means comprising, in combination, a source of alternating current, load means energized by said alternating current source and requiring a high voltage starting pulse, controlled rectifier means connected between said alternating current source and said load means, said controlled rectifier means being normally non-conductive to block current flow to said load means and having electrode control means to render it conductive, actuating means connected to said alternating current source and to said electrode control means for applying a control signal to said electrode control means at a predetermined time in each alternating current cycle, said actuating means including a resistance and a capacitance connected together in series and to the alternating current source, and voltage sensitive symmetrical switch means connected across said capacitance, and means connected between said controlled rectifier means and said load means for providing a high voltage starting pulse on said load means, said high voltage pulse producing means comprising a capacitor, voltage sensitive switch means and step-up pulse transformer means connected together in circuit and between said controlled rectifier means and said load means.

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