

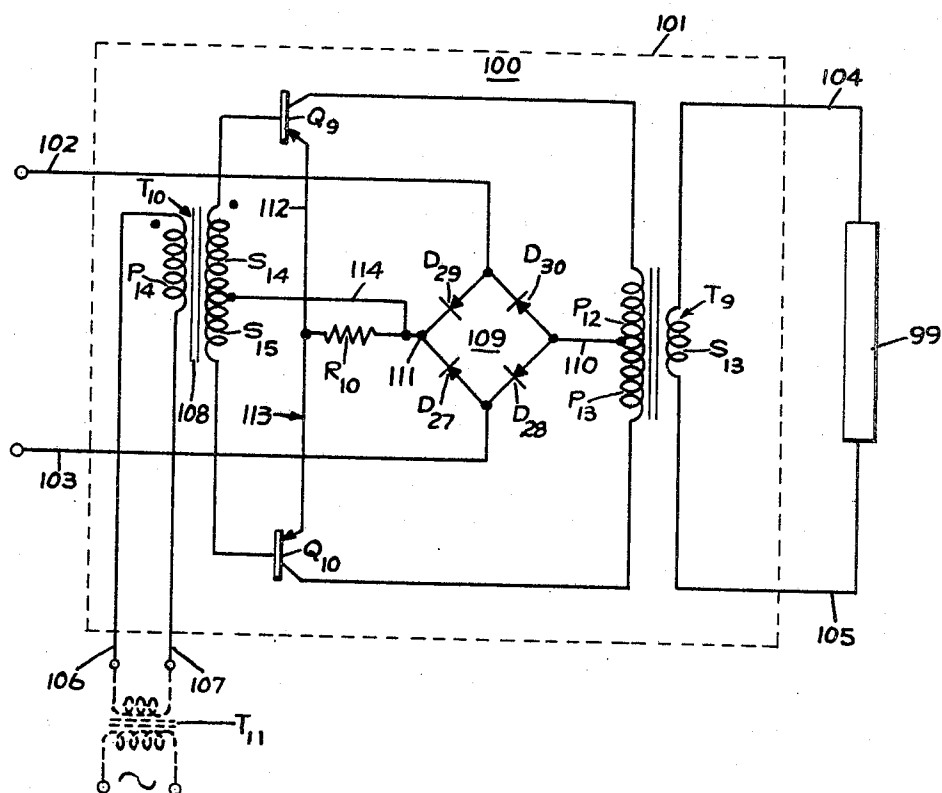
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APPARATUS FOR OPERATING ELECTRIC DISCHARGE DEVICES

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APPARATUS FOR OPERATING ELECTRIC DISCHARGE DEVICES

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5 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus employing a variable impedance network arrangement which provides an instantaneously varying impedance during a portion of each half cycle to control the current supplied to a fluorescent lamp. The network includes at least one transistor connected in circuit with the output terminals of a full-wave bridge rectifier. A transformer is interposed between the rectifier and lamp circuit with the primary winding thereof connected in circuit with the collector electrode of the transistor and the secondary thereof arranged for connection across the lamp. A current measuring resistor is connected between an output terminal and the emitter of the transistor to influence the base drive of the transistor and thereby provide an instantaneously variable impedance in the primary winding circuit of the transformer. The variable impedance in the primary winding circuit is used to regulate the current flow in the secondary winding circuit and thereby effect regulation of the current supplied to the lamp.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional application of my copending application filed June 16, 1965, Ser. No. 464,517 which issued July 18, 1967 as Patent No. 3,331,987, which in turn is a divisional application of the application copending therewith filed July 23, 1962, Ser. No. 211,554 which issued May 3, 1966 as Patent No. 3,249,799.

BACKGROUND OF THE INVENTION

This invention relates generally to apparatus for operating electric discharge devices, such as fluorescent lamps, with alternating current. More particularly, it relates to an improved ballasting and operating arrangement for such apparatus.

The voltage required to initiate current flow in an electric discharge lamp varies with the length and type of electric discharge lamp operated. Usually the voltage required to operate the electric discharge lamp when normal lamp current is flowing through the lamp is less than the starting voltage. If the lamp current increases during operation, the voltage drop across the lamp will decrease as lamp current increases. This tendency of the lamp voltage to vary inversely with the lamp current is generally referred to as its negative resistance characteristic.

It is, therefore, a requirement of an apparatus for operating electrical discharge lamps that it provide some means for limiting the current supplied to the lamp. If the current supplied to the lamp is not limited by some means, the current will continue to build up until the lamp is destroyed. A well-known way of limiting the current supplied to an electric discharge device, such as a fluorescent lamp, is to provide a ballasting resistor in series with the lamp.

The fluorescent lamp may be operated in a series loop arrangement which includes the ballasting resistor, the power source, and the lamp. In order to provide for stable operation and appropriate regulation of the lamp, the voltage drop across the ballasting resistor generally is about equal to the normal operating voltage of the fluorescent lamp. If the difference between the starting voltage and the normal operating voltage of the lamp in such a resistive ballasting arrangement is small, slight changes in the supply voltage would produce appreciable variations in the light output of the lamp. It is, therefore, necessary in applications where a resistor is used as a ballasting element to provide a voltage drop across the ballasting resistor that is about equal to the normal operating voltage of the lamp.

Where the fluorescent lamp is operated in a series loop arrangement with a ballasting resistor, it will be appreciated that the vector sum of the voltage drop across the ballasting resistor and the voltage drop across the lamp is equal to the supply voltage. Since the supply voltage is generally maintained at a substantially constant level, as the lamp current builds up because of the inherent negative resistance characteristic of the lamp, the current through the ballasting resistor increases. This results in a proportional increase in the voltage drop across the ballasting resistor thereby causing the voltage across the lamp to decrease. Conversely, when the lamp current decreases, the voltage across the ballasting resistor decreases thereby causing the lamp voltage to increase. In this manner, the current supplied to the lamp is effectively limited.

Resistive elements have not been generally used in alternating current ballasting systems since they dissipate an appreciable amount of power. Reactive type of ballasting devices have been widely used since they consume less power than a ballasting resistor. Since reactive devices do not impede the flow of direct current, reactive ballasting elements have not been used in direct current systems for ballasting. However, resistors have been used in direct current systems despite the relatively large power losses occurring in the resistor.

A principal disadvantage of conventional resistive ballasting systems is that the power consumed by the ballasting resistor is generally about the same as that required to operate the lamp. Thus, the efficiency of the system is about fifty percent. It is desirable, therefore, to reduce the power losses in a resistive type of ballast while achieving satisfactory regulation and stability. Further, it is desirable to provide an apparatus for operating electric discharge lamps that does not require a large difference between the lamp starting voltage (open circuit voltage) and the lamp operating voltage. It will be appreciated that as the difference between the starting voltage and the operating voltage is reduced, less energy is required to be dissipated or stored in the ballasting elements. Consequently, the components in the system can be smaller in size and weight, and where a ballasting resistor is employed, less power is dissipated in the resistor.

Accordingly, it is a general object of the present invention to provide an improved apparatus for operating electric discharge devices.

A more specific object of the present invention is to provide an improved apparatus for operating electric discharge lamps, such as fluorescent lamps, wherein the lamp can be operated with a relatively smaller difference between the lamp starting voltage and the lamp operating voltage.

It is another object of the present invention to provide an improved apparatus for operating a fluorescent lamp that utilizes a resistive type of ballasting and can be operated at relatively greater efficiency than conventional

ballasting systems employing resistors as ballasting elements.

SUMMARY OF THE INVENTION

In accordance with one form of my invention, I have provided an improved apparatus for operating at least one electric discharge lamp, such as a fluorescent lamp, from an alternating power source that employs a variable impedance network arrangement. The network arrangement provides an instantaneously varying impedance during a portion of each half cycle to control the current supplied to the electric discharge lamp in order to prevent the lamp from destroying itself because of its negative resistance characteristic. In the preferred form of my invention, the variable impedance network includes at least one transistor that is driven to provide an instantaneously variable impedance to control the lamp current, and a relatively low impedance is provided during an early and late portion of each half cycle. The emitter and collector electrodes are connected in circuit with the output terminals of a full-wave bridge rectifier. Base drive for the transistor may be obtained from the full-wave bridge rectifier or may be obtained from a separate source, such as a feedback source, a variable D.C. supply or a fixed D.C. supply. The input terminals of the bridge rectifier may be placed directly in the lamp circuit, or if it is desired to employ transistors having relatively lower voltage ratings, a transformer may be interposed between the bridge rectifier and the lamp circuit.

In another form of my invention, I have provided a variable impedance bridge network for controlling the current supplied to a fluorescent lamp which is comprised of a full-wave rectifier, a pair of transistors, and a transformer. One of the windings of the transformer is connected in circuit with at least one output lead of the apparatus to place the variable impedance bridge network in series circuit with the lamp during operation. The other of the transformer windings is connected in circuit with the collector electrodes of the transistors and has a tap connected in circuit with at least one output terminal of the full-wave rectifier. Further, a resistor may be connected in circuit with the other of the output terminals and in circuit with the emitter electrodes of the transistors to function as a current measuring element. A bias supply means is connected in circuit with the base electrodes of the transistors. The transistors are driven by the bias supply means to provide an instantaneously variable impedance in the primary circuit of the transformer whereby the current supplied to the lamp is regulated.

According to another aspect of the invention, the bias supply means is comprised of a transformer having a primary and a center tapped secondary winding. The primary winding is connected to a suitable signal source. For example, the transformer may be connected across the output leads of the apparatus where it is desired to sense the voltage or in series with the lamp where it is desired to sense the lamp current or to a separate source having a predetermined wave shape where it is desired to provide a lamp current with a corresponding wave shape. Further, the center tap of the secondary winding is connected to one of the output leads of the full-wave bridge rectifier, and the ends of the secondary winding are connected to the base electrodes of the pair of transistors to supply base drive current thereto.

The subject matter which I regard as my invention is set forth in the appended claims. The invention itself, however, together with other objects and advantages may be better understood by referring to the following description taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The figure of the drawing is a schematic circuit diagram of an apparatus embodying a form of my invention where-

in the variable impedance bridge network supplies the voltage to the primary winding of a transformer for operating a fluorescent lamp.

In the figure of the drawing, I have shown one form of my invention embodying a variable impedance network for controlling and supplying the current required for operation of an electric discharge lamp 99. The apparatus for operating the electric discharge lamp 99 is generally identified by reference numeral 100 and is shown enclosed in a dashed rectangle 101. The apparatus 100 is energized by connecting a pair of input leads 102 and 103 across a suitable alternating current source. The output of the apparatus 100 is supplied to the electric discharge lamp 99 by output leads 104 and 105.

As will hereinafter be more fully explained, the variable impedance bridge network arrangement in the exemplification of the invention shown will reproduce across output leads 104, 105 a current corresponding in waveshape to the waveshape of a feedback signal applied across a pair of feedback leads 106, 107 or, in other words, across the primary winding P_{14} of the bias signal transformer T_{10} . The bias signal transformer T_{10} has a pair of secondary windings S_{14} and S_{15} inductively coupled with the primary winding P_{14} on a magnetic core 108.

It will be noted that the input leads 102 and 103 are connected with the input terminals of a full wave bridge rectifier 109 which includes diodes D_{27} , D_{28} , D_{29} and D_{30} . One of the output terminals of the bridge rectifier 109 is connected by lead 110 to the tap to which primary windings P_{12} and P_{13} of transformer T_9 are joined. The other output terminal of bridge rectifier 109 is connected in circuit with the emitter electrodes of transistors Q_9 and Q_{10} through a resistor R_{10} and leads 111, 112 and 113 and is also connected with secondary windings S_{14} , S_{15} by lead 114.

Continuing with the description of apparatus 100, the operation will now be more fully described. In order to start the operation of the apparatus 100, the input terminal leads 102 and 103 were connected to an A.C. power source and the feedback leads 106 and 107 were also connected with an A.C. power supply through a small filament transformer T_{11} to apply a sinusoidal signal across the feedback leads 106 and 107.

Let us arbitrarily assume that the voltage across the primary winding P_{14} at a given instant is such that the upper end of the winding P_{14} is negative with respect to the lower end. As a result, the voltage induced across the secondary windings S_{14} and S_{15} is such that the upper end is negative with respect to the lower end. A negative voltage is now applied at the base electrode of the transistor Q_9 to switch transistor Q_9 into conduction. At this instant, substantially the entire output voltage of the bridge rectifier 109 is applied across primary P_{12} , and a voltage is induced across the secondary winding S_{13} of the transformer T_9 . Assuming that this instantaneous voltage is sufficient to ionize lamp 99, lamp 99 will begin to conduct. Consequently, current begins to flow in the loop which includes lamp 99, output lead 104, secondary winding S_{13} and output lead 105.

A current flow through the secondary winding S_{13} , in effect, lowers the resistance reflected to the primary winding P_{12} . Consequently, more current is supplied by the power source through the bridge rectifier 109. However, the increased current flow produces a voltage drop across the current sensing resistor R_{10} . This current is allowed to build up until the voltage drop across the current sensing resistor R_{10} approximately equals the potential applied at the base of transistor Q_9 , at which time the base drive on the transistor Q_9 will be insufficient to support additional current flow. When this occurs, the voltage across the current sensing resistor R_{10} will in effect track the voltage applied at the base electrode of transistor Q_9 . Also, transistor Q_9 has a voltage drop that is substantially equal to the difference between the supply voltage and voltage developed across the transformer T_9 .

If lamp 99 tries to draw more current than the value corresponding to the limited voltage developed across the current sensing resistor R_{10} , the transistor impedance increases and the voltage drop across the collector and emitter electrodes of transistor Q_9 will increase thereby causing the voltage applied to the primary winding P_{12} to decrease. Similarly, when the lamp current decreases, this voltage drop will decrease and cause the voltage across the secondary winding S_{13} to increase. In this manner, the current to lamp 99 is dynamically controlled by the varying impedance introduced by the transistor Q_9 . If the secondary winding S_{13} is short circuited, the current in the circuit is still effectively limited by the voltage drop across the resistor R_{10} and by the voltage available at the base electrode of transistor Q_9 . In this case, the voltage developed across transformer T_9 is zero. On the other hand, when output leads 104, 105 are open circuited, the full rectified output of the power source is made available across the primary winding P_{12} to provide the maximum voltage across the secondary winding S_{13} .

When the voltage across the primary winding P_{14} reverses, it will be understood that the lower end of the secondary winding S_{15} is now negative with respect to the upper end and a negative voltage now appears at the base electrode of transistor Q_{10} . During this alternation of the power source, primary winding P_{13} provides the driving voltage for transformer T_9 , and the loop which includes transistor Q_{10} , current sensing resistor R_{10} and the primary winding P_{13} come into play. In the same manner as during the previous alternation of the power supply, a decreasing current flow through the secondary winding S_{13} has the effect of lowering the resistance reflected into the primary winding P_{13} and thereby causing more current to be supplied thereto from the power source through bridge rectifier 109. As this current flow in the loop increases, the voltage drop across the current sensing resistor R_{10} increases. The current is allowed to build up until the voltage drop across the current sensing resistor R_{10} is nearly equal to the potential at the base electrode of transistor Q_{10} . At this point, the base drive on transistor Q_{10} will be insufficient to support additional current flow through the transistor Q_{10} . If the lamp circuit now attempts to draw more current, the voltage drop across the collector and emitter electrode of transistor Q_{10} will increase. Thus, the voltage across the primary winding P_{13} will decrease, and lamp operating voltage across the secondary winding S_{13} decreases. In this way, the lamp current is limited by the varying impedance of the transistor Q_{10} .

Although, in the above described exemplification of the invention, the feedback signal was an alternating signal having a substantially sinusoidal waveshape, and in phase with the power source, it will be appreciated that other signals of different waveshapes may be provided to drive the variable impedance bridge circuit of the apparatus 100. For example, if the voltage across the transformer secondary winding S_{13} is fed back to the feedback leads 106 and 107, the signal will have the waveshape of the lamp voltage, and the lamp current waveshape will be controlled to correspond with the lamp voltage waveshape. With such an arrangement, it will be apparent that unity lamp power factor can be achieved. Further, it will be appreciated that with the variable impedance bridge network arrangement shown, any desired waveshape of the lamp current can be obtained since the apparatus 100 will essentially provide a current in the secondary winding S_{13} having a waveshape corresponding to the waveshape of the voltage signal applied across the primary winding P_{14} .

From the foregoing description of the invention, it will be apparent that the ballasting action for one or more fluorescent lamps is provided by a variable impedance network. This network introduces an instantaneously variable impedance which may regulate lamp current indirectly. An important advantage of the invention is that the

variable impedance network makes it possible to minimize losses in the circuit that would otherwise result if a linear resistor were used as the ballasting element. Also, the variable impedance network arrangement makes it possible to design an apparatus for operating electric discharge lamps with a smaller difference between the supply voltage and the operating voltage of the lamp than would be the case if conventional ballasting elements were employed in the circuit to provide the current limiting action for the electric discharge lamps. Further, the variable impedance network of the invention is readily adaptable to control by a signal responsive to the lamp operating condition. A signal sensing an operating condition or a signal from an independent source may be employed to control the waveshape of the lamp current.

Although a variable impedance network utilizing a bridge has been employed in the exemplification of my invention, it will be apparent to those skilled in the art that variable impedance networks employing bilateral semiconductor devices or unidirectional devices in an inverse arrangement may be used in the practice of the invention. It will be understood that the specific exemplifications of the invention which I have described herein are intended for illustrative purposes only and that many modifications may be made. It is, therefore, intended by the appended claims to cover all such modifications that fall within the true spirit and scope of my invention.

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

1. In a ballast apparatus for operating at least one electric discharge lamp from an alternating power source, said apparatus having a pair of input leads for connection with the alternating power source and a pair of output leads for connection to the electric discharge lamp, a variable impedance network comprising a full wave rectifying means having a pair of input terminals and a pair of output terminals, said input terminals being connected in circuit with the input leads for connection to the alternating power source, a pair of transistors, each of said transistors having a collector, an emitter and a base electrode, a transformer having a primary winding and a secondary winding inductively coupled therewith, one of said windings being connected in circuit with at least one of said output leads, the other of said windings having the ends thereof connected in circuit with the collector electrodes of said transistors, said other winding having a tap connected in circuit with one of the output terminals of said full wave rectifying means, circuit means including a resistor connecting the other of said output terminals of said full wave rectifying means in circuit with the emitter electrodes of said transistors, a bias supply means connected in circuit with the base electrodes of said transistors, said transistors being driven by said bias supply means to provide a variable impedance in the primary circuit of said transformer in each half cycle of the alternating power source whereby the current provided at said output leads is regulated.

2. The apparatus as set forth in claim 1 wherein said bias supply means includes a transformer having a primary winding and a secondary winding, the ends of said secondary winding being connected in circuit with the base electrodes of said transistors, said secondary winding having a tap connected in circuit with said other output terminal of said full wave rectifying means, said primary winding having leads for connection in circuit with a feedback signal source whereby the waveform of the current supplied at said output leads corresponds to the waveform of the feedback signal supplied from the feedback signal source.

3. Ballast apparatus comprising a pair of input leads for connection to an alternating current power source, a pair of output leads for connection to an electric discharge lamp, a rectifier having input terminals and output terminals, said input terminals being connected in circuit with said input leads for connection to said power

source, at least one transistor having an input electrode and output electrodes, a transformer having a primary winding and a secondary winding coupled thereto, means coupling said secondary winding in circuit with said output leads for connection to said lamp, means coupling said primary winding to one of said output electrodes of said transistor, means coupling another point on said primary winding to one of said rectifier output terminals, means coupling an impedance between the other of said rectifier output terminals and the other of said output electrodes of said transistor, and means coupled to said input electrode of said transistor for alternately supplying signals thereto to render said transistors alternately conductive and nonconductive.

4. Ballast apparatus comprising a pair of input leads for connection to an alternating current power source, a pair of output leads for connection to an electric discharge lamp, a full wave rectifier having a pair of input terminals and a pair of output terminals, means coupling said rectifier input terminals in circuit with said input leads for connection to said power source, a pair of transistors each having an input electrode and output electrodes, a transformer having a tapped primary winding and a secondary winding coupled thereto, means coupling said secondary winding in circuit with said output leads for connection to said lamp, means coupling said primary winding to corresponding ones of said output electrodes of each of said transistors, means coupling said tap on said primary winding to one of said rectifier output terminals, means coupling an impedance between the other of said rectifier output terminals and corresponding other output electrodes of each of said transistors, and means coupled to said input electrodes of each of said transistors for alternately supplying a signal thereto to alternately render one of said transistors conductive and the other of said transistors nonconductive.

5. A ballast apparatus for operating at least one electric discharge lamp from an alternating power source, said apparatus comprising a pair of input leads for connection with the alternating power source and a pair of output leads for connection to the electric discharge lamp, a variable impedance network for controlling the current

supplied by said output leads, said network comprising a full wave rectifying means having a pair of input terminals and a pair of output terminals, said input terminals being connected in circuit with the input leads for connection to the alternating power source, a pair of transistors, each of said transistors having a collector, an emitter, and a base electrode, a first transformer having a primary winding and a secondary winding inductively coupled therewith, one of said windings being connected in circuit with at least one of said output leads, the other of said windings having the ends thereof connected directly to the collector electrodes of said transistors, said other winding having a tap connected in circuit only with one of the output terminals of said full wave rectifying means, circuit means including a current sensing resistor connecting the other of said output terminals of said full wave rectifying means in circuit with the emitter electrodes of said transistors, a bias supply means for driving said transistors, said bias supply means comprising a bias signal transformer isolated from said first transformer and having a primary winding and a secondary winding with the ends thereof connected to the base electrodes of said transistors, and circuit means connecting the center tap of said secondary winding directly with said other one of the output terminals of said full wave rectifying means, said transistors in response to the voltage drop across said current sensing resistor providing a variable impedance in the primary circuit of said transformer in each half cycle of the alternating power source, whereby the current provided at said output leads is regulated.

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