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CIRCUITS FOR ENERGIZING PARALLEL CONNECTED GASEOUS DISCHARGE DEVICES AND MAINTAINING THE DISCHARGE THEREIN

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FIG. 1

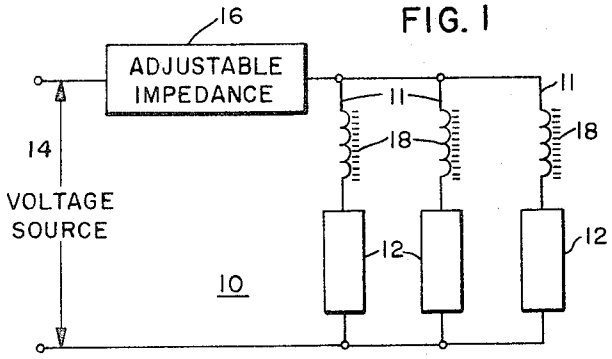
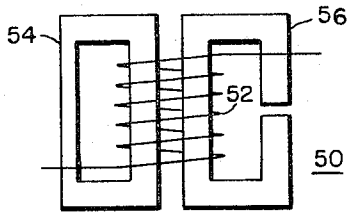


FIG. 4



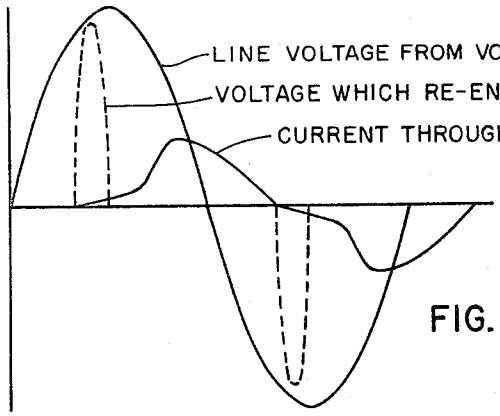


FIG. 2

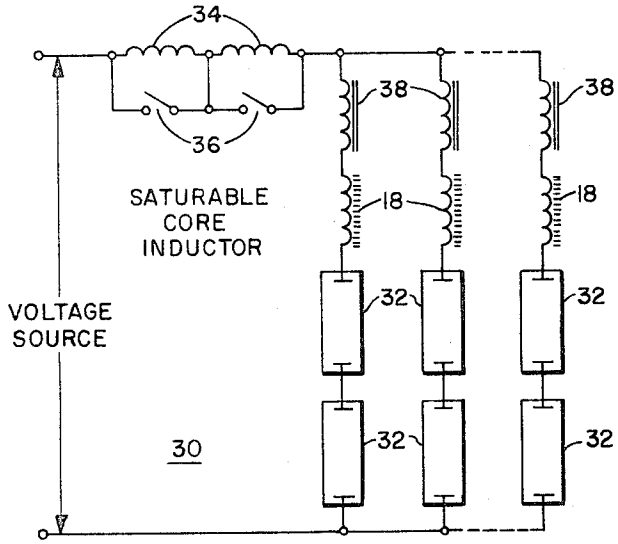


FIG. 3

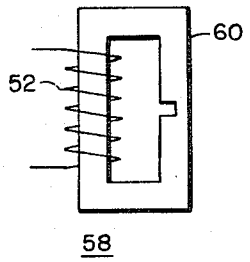


FIG. 5

WITNESSES

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CIRCUITS FOR ENERGIZING PARALLEL CONNECTED GASEOUS DISCHARGE DEVICES AND MAINTAINING THE DISCHARGE THEREIN

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This invention relates generally to circuits for energizing gaseous discharge devices and, more particularly, to such circuits which provide energizing voltages as well as an adjustable operating current which may be reduced to dim the discharge devices.

Generally, gaseous discharge devices such as fluorescent lamps operated on AC voltage, become nonenergized at the end of each half cycle as the current therethrough approaches zero to change direction. The AC operating voltage across the lamps must be high enough to re-energize them each half cycle. To dim the lamps, this operating voltage is reduced. If the lamps are dimmed appreciably, the reduced operating voltage will not re-energize the lamps each half cycle unless some supplemental energization is provided.

Heretofore, such lamps were dimmed by operating at reduced voltages and were re-energized each half cycle by means of additional voltage spikes applied across the lamps immediately after the current went to zero and the lamps extinguished. To accomplish this, two voltage sources were required, one to provide the reduced AC operating voltage and another to provide the additional energizing voltage spikes. Synchronizing circuits were also required to ensure that the application of the energizing voltage spike coincided in time with the zero current, and the lamps were re-energized promptly. These circuits were relatively complicated and expensive.

Dimmable fluorescent lamps have particular application for automobile tunnel lighting where the lamps are required to be brightly lit during the day and dimly lit during the night, so that the eye will not be subjected to drastic changes in the level of illumination upon entering and leaving the tunnel.

It is therefore, an object of this invention to provide an improved and simple electric circuit for maintaining the discharge in gaseous discharge devices even when operated in a dimmed condition.

It is a further object of this invention to provide a simple electric circuit for re-energizing and maintaining the discharge in dimmable discharge devices.

It is another object of this invention to provide an electric circuit for energizing and maintaining the discharge in dimmable discharge devices, which circuit has improved stability, ruggedness and maintenance, and is relatively inexpensive.

The foregoing objects of the invention, and other objects which will become apparent as the description proceeds, are achieved by providing a circuit comprising a plurality of parallel-connected circuit branches adapted to be connected to a source of alternating current. An adjustable current-limiting means is serially connected between the source of alternating current and the parallel-connected circuit branches for controlling the current through the discharge devices to vary the brightness of same. Each of the parallel-connected circuit branches has at least one of the discharge devices connected therein, and an additional current-limiting means is serially connected with each discharge device in the parallel-connected circuit branches. These additional current-limiting means display at maximum impedance for low values of current therethrough and a minimum impedance for higher values

of current therethrough. In order to shift from a condition of high impedance to low impedance, the additional current-limiting means each require a predetermined time. In addition, the total impedance in the circuit causes a substantial phase displacement between the input voltage and the current through the discharge means.

In the operation of this circuit, once each half cycle the current through the discharge devices is zero. The impedance of the discharge devices is very high at this time, since the devices are essentially non-energized, and because of this, a substantial portion of the energizing voltage is applied across each of the devices. This causes the discharge to be re-established through the devices once each half cycle.

It should be understood that all of the discharge devices will not be re-energized at the same time, and if the adjustable current-limiting means is set for a "dimmed" operating condition, some of the lamps might remain extinguished at the end of a current half cycle, since the resulting voltage drop across the adjustable current-limiting means would drop the voltage across any non-energized lamps. To prevent this happening, the additional current-limiting means in each circuit branch limits the current which can be drawn by any one of the discharge devices during the initial energization thereof. By the time any of the additional current-limiting means have shifted to a condition of minimum impedance, due to increasing current therethrough, all of the lamps are operating on the next half-cycle of energizing current.

For a better understanding of the invention reference should be had to the accompanying detailed description and drawing in which:

FIGURE 1 is a schematic diagram of the present energizing and discharge-maintaining circuit;

FIG. 2 is a waveform diagram showing the current through the lamps and voltage at the circuit input as encountered in the circuit of FIG. 1;

FIG. 3 is a schematic diagram of a modified energizing and discharge-maintaining circuit;

FIG. 4 is a schematic view of a unitary saturable core and ballast inductance as can be used in the circuit of FIG. 3; and

FIG. 5 is an elevational view of another modification of the saturable core and ballast inductance as can be used in the circuit of FIG. 3.

Referring now to FIG. 1, there is shown a circuit **10** comprising a plurality of parallel branch circuits **11** with gaseous discharge means **12** serially connected in each parallel circuit. The fluorescent discharge means or devices **12** display a high impedance when non-energized and a low impedance when energized and a relatively high energizing voltage is required to initiate the discharge each half cycle.

In the circuit **10**, a voltage supply **14** provides the relatively high energizing voltage required for re-energizing the devices **12** each half cycle. An adjustable current-limiting impedance **16** is serially connected between the voltage supply **14** and the devices **12** for dimming the devices as desired.

An additional current-limiting impedance, such as saturable core inductance **18**, is serially connected in each of the circuit branches **11** and in series with each discharge device **12**. Immediately after the initial zero current portion of each half cycle, the current through each of the devices **12** and the associated inductances **18** is low, causing the inductances **18** to display an unsaturated condition. While so unsaturated, the inductance **18** displays a high impedance to the increasing current therethrough. As a result, when the current through the devices **12** is at a minimum each half cycle, the voltage developed across each of the devices **12** approaches

the energizing voltage instantaneously available from voltage source 14, since the circuit 10 is inductive in nature. When the current through each inductance 18 increases to a predetermined value the inductance 18 becomes saturated and displays a low impedance to the current therethrough. By this time, all lamps are operating.

Referring to FIG. 2, there are shown the waveforms of the energizing voltage at the voltage source 14, and the current through the discharge devices 12. Because of the predominantly inductive nature of the circuit 10, the current lags the voltage as shown. Preferably, the phase angle of the circuit is 60° or greater so that when the current through the devices is zero, the voltage from source 14 applied thereacross is almost at its peak value. The distortion at the beginning of each half cycle of the discharge device current waveform is caused by the saturable inductance 18, which prevents devices 12 from conducting normally for a short time while the inductances 18 are in the high impedance state. The voltage shown in dotted lines in FIG. 2 appears across the devices 12 and re-energizes them each half cycle.

At the end of each half cycle, the current through discharge devices 12 goes to zero and the devices 12 become non-energized. The devices 12 are re-energized at the beginning of the next half cycle as follows:

(1) The current through each device 12 is zero and therefore no voltage develops across any of the saturable inductors 18 or the adjustable impedance 16;

(2) substantially the entire instantaneous energizing voltage of the voltage supply 14 appears across each of the devices 12, and because of the lagging current, this voltage is almost at its peak value;

(3) the energizing voltage causes the devices 12 to be energized, but not simultaneously (some of the devices 12 are energized before the others, because each of the devices 12 is slightly different and requires a slightly different energizing voltage);

(4) as each device 12 is energized, the current therethrough increases;

(5) during initial conduction, the saturable inductances 18 are unsaturated and have a high impedance, which limits the current through each energized device 12 serially connected therewith.

(6) at this time, each energized device thus has a high impedance inductance in series therewith and each non-energized device is in the high impedance state, causing the current through the adjustable impedance 16 momentarily to be small, allowing a substantial portion of the energizing voltage of the voltage supply 14 to remain applied across the non-energized devices;

(7) eventually all of the devices 12 become energized and the current through each energized device 12 increases and saturates the inductances 18, thus causing each of the inductances 18 to display a low impedance; and

(8) the current through the devices 12 increases because of the elimination of the high impedance state of the saturable inductances 18 and a voltage develops across the adjustable impedance 16, which establishes the limited discharge-maintaining current through the devices 12.

Referring now to FIG. 3, there is shown a circuit 30 which is a modification of the circuit 10 of FIG. 1. A pair of serially connected fluorescent lamps 32 replaces each of the discharge devices 12 of FIG. 1. A single lamp 32 may be used, or more than two, depending on the peak energizing voltage available from the voltage supply 14.

A plurality of series-connected inductors 34 are provided in place of the adjustable impedance 16 of FIG. 1. Each fixed inductor 34 has a shorting switch 36 connected in parallel therewith for altering the total impedance of the arrangement. Any number of inductors and shorting switches 36 may be employed. The two switches as shown in FIG. 3 provide three steps of brightness for operation of the lamps 32. Of course, continuous or smooth adjustment may be achieved by providing a continuously variable inductor.

The circuit of FIG. 3 is also provided with a fixed ballast inductance 38 in each parallel-connected leg for ballasting the lamps 32 when they are energized. Such ballast inductors are well known and generally are of the linear type, having an air gap in the core member thereof. In the circuit of FIG. 1, the ballasting is provided by the adjustable impedance 16. However, individual ballast inductances 38 are preferred because they provide increased stability for maintaining the discharge in the parallel connected lamp pairs.

As a specific example, the impedance and voltages of the embodiment shown in FIG. 3 are listed hereinafter: voltage supply 14 is 1200 volts AC at a frequency of 60 c.p.s.; fixed inductance 34 is 0.115 henry (0.0585 henry per portion); ballast inductance 38 is 1.58 henries; saturable core inductance 18 is 10.6 henries unsaturated, and saturates at approximately 560 volts AC, the saturation current is approximately 0.2 ampere, the time between the initial zero current portion of each half cycle and saturation of the core is about 50° or about 0.00231 second; fluorescent lamps 32 are 65 watts each (130 watts per pair), the lamps 32 display maximum brightness at 0.6 ampere and minimum brightness at 0.3 ampere. The values of the above-listed components may vary from the foregoing example depending on the particular application and design of the circuit.

Referring to FIG. 4, there is shown an inductor 50 having the properties of both the saturable core inductance 18 and the ballast inductance 38. The inductor 50 is formed by a single winding 52 having plural turns about a saturable core member 54 and an air gap core member 56. At low currents through the winding 52, the saturable member 54 is unsaturated, causing the inductor 50 to have a high impedance. At a predetermined current level, the saturable member 54 becomes saturated. At higher current levels the inductance provided by the air gap member 56 ballasts the lamps 32.

FIG. 5 shows both the saturable core member and the air gap member combined into a unitary device 58, which includes a bridged air gap core member 60. The device 58 has the properties of both the saturable core inductance 18 and the ballast inductance 38.

In the circuits as described hereinbefore, the total circuit impedance is inductive in nature which causes a substantial phase displacement between the input voltage and the current through the discharge device. It should be understood that if high-frequency were to be used to energise the devices, a capacitive impedance could be used as a practical system, because of the decreased size of the capacitors required.

It will be apparent to those skilled in the art that the objects of this invention have been achieved by providing a circuit which operates discharge lamps in the dimmed condition by re-energizing the lamps each half cycle. Only one power supply is required to provide both the energizing and the discharge-maintaining voltages. The circuit is simple and employs rugged components, which decreases the initial cost and the maintenance thereof.

Since numerous changes may be made in the above-described apparatus, and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative, and not in a limiting sense.

I claim as my invention:

1. A circuit for operating a plurality of gas-discharge devices at a predetermined and adjustable brightnesses, said circuit comprising:

a plurality of parallel-connected circuit branches adapted to be connected to a source of alternating current;

at least one discharge device connected in each of said circuit branches;

an adjustable current-limiting means serially connected between the source of alternating current and said plurality of circuit branches for controlling the current through said discharge devices and adjusting the brightness thereof; and

an additional current-limiting means serially connected with said at least one discharge device in each of said circuit branches, said additional current-limiting means displaying a maximum impedance for low values of current therethrough and displaying a minimum impedance for higher values of current therethrough, said additional current-limiting means requiring a predetermined time to shift from said maximum impedance to current flow to said minimum impedance to current flow, and the total impedance in said circuit causing a substantial phase displacement between the input voltage and the current through said discharge devices; whereby during operation a high voltage is applied across each said discharge device once during each half-cycle of said alternating current to maintain the discharge in said discharge devices even while said discharge devices are operating in the dimmed condition.

2. The circuit as specified in claim 1, wherein each said additional current-limiting means is a saturable core inductance which displays said maximum impedance to the increasing current therethrough immediately after the initial zero current portion of each half cycle of said alternating current, and said saturable core inductance displays said minimum impedance at a later portion of each half cycle when the current therethrough is greater than a predetermined saturating value.

3. The circuit as specified in claim 1, wherein said adjustable current-limiting means comprises a plurality of series-connected separate impedance members, and shorting switch means are provided across individual ones of said separate impedance members to short out at least a part of the impedance to vary the brightness of said discharge devices.

4. The combination as specified in claim 1, wherein at least two discharge devices are serially connected in each of said circuit branches.

5. A circuit for operating a plurality of gas-discharge devices at predetermined and adjustable brightnesses, said circuit comprising:

a plurality of parallel-connected circuit branches adapted to be connected to a source of alternating current;

at least one discharge device connected serially in each of said circuit branches;

an adjustable current-limiting means serially connected between the source of alternating current and said plurality of circuit branches for controlling the current through said discharge devices and adjusting the brightness thereof;

at least one discharge device connected serially in each of said circuit branches;

a ballast means serially connected with said at least one discharge device in each of said circuit branches for ballasting said discharge devices; and

an additional current limiting means serially connected with said at least one discharge device in each of said

circuit branches, said additional current limiting means displaying a maximum impedance for low values of current therethrough and displaying a minimum impedance for higher values of current therethrough, said additional current limiting means requiring a predetermined time to shift from said maximum impedance to current flow to said minimum impedance to current flow, and the total impedance in said circuit causing a substantial phase displacement between the input voltage and the current through said discharge devices; whereby an energizing voltage is applied across each said discharge device once during each half-cycle of said alternating current to maintain the discharge in said discharge devices even while said discharge devices are operating in the dimmed condition.

6. The combination as specified in claim 5, wherein said ballast means is a ballast inductance, and each said additional current-limiting means is a saturable core inductance which displays said maximum impedance to the increasing current therethrough immediately after the initial zero current of each half cycle, and said saturable core inductance displays said minimum impedance at a later portion of each half cycle of said alternating current when the current therethrough is greater than a predetermined saturating value.

7. The combination as specified in claim 6, wherein each said saturable inductance and said ballast inductance serially connected with each discharge device are formed as one inductance means having a single winding with plural turns enclosing two core members, one of said core members being saturable for providing a saturable inductance characteristic, and the other of said core members having an air gap for providing a ballast inductance characteristic.

8. The combination as specified in claim 6, wherein said ballast inductance comprises a single core member having a bridged air gap, the bridged portion of said single core member providing a saturable inductance characteristic and the gap portion of said single core member providing a ballast inductance characteristic.

9. The circuit as specified in claim 5, wherein said adjustable current-limiting means comprises a plurality of serially-connected separate impedance members, and shorting switch means are provided across individual ones of said separate members to short out at least a part of the impedance to vary the brightness of said discharge means.

10. The combination as specified in claim 5, wherein at least two gaseous discharge devices are serially connected in each of said circuit branches.

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