ABSTRACT

A discharge lamp lighting device comprises a first silicon symmetrical switch adapted to be turned “on” when a voltage to be applied across both ends of a discharge lamp reaches a predetermined value, a transistor connected to the first silicon symmetrical switch so that a preheating current for the discharge lamp may flow when the first silicon symmetrical switch turns “on.” A second silicon symmetrical switch is connected to the transistor, so as to be turned “on” when the current flowing through the transistor reaches a predetermined value, and when the second silicon symmetrical switch is turned “on” the transistor is turned “off” to generate a high voltage pulse in a coil connected between the discharge lamp and an AC power supply.

26 Claims, 11 Drawing Figures
FIG. 5

Current Voltage Between a and b

Time

FIG. 6

Power Voltage Between a, b, and c

Time

FIG. 7

FIG. 8
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STARTING DEVICE FOR DISCHARGE LAMP

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a lighting device for discharge lamps and, more particularly, to a lighting device employing a solid state switch.

2. Description of the Prior Art

As a lighting device for discharge lamps, mainly for fluorescent lamps, there has heretofore been adopted a circuit shown in FIG. 1. Referring to the figure, numerals 1 and 2 designate AC power input terminals, 3 a choke coil, 4 a fluorescent lamp, 41 and 42 filament of the fluorescent lamp 4, 5 a glow starter, and 51 a bimetal of the glow starter 5. The operation of such a prior art device prior to lighting will be described below.

When an AC supply voltage is applied across the terminals 1 and 2, the applied supply voltage is impressed across terminals a and b since the contact of the bimetal 51 of the glow starter 5 is open. When the voltage across the terminals a and b rises and reaches the generating voltage of the glow starter 5, a glow is generated to cause a glow current to flow across a and b.

The bimetal 51 is heated by the current, so that the contact of the glow starter 5 is closed. The period of time as taken for the contact to be closed is approximately 1 second. It is of a value of several seconds when the glow starter has become deteriorated. As the result of the closure of the contact of the glow starter, current flows from the terminal 1, through the choke coil 3, the filament 41, the glow lamp 5, the filament 42 and to the terminal 2. This current heats the filaments, and is called the preheating current. Owing to the heating of the filaments 41 and 42 of the fluorescent lamp 4, an oxide coated on the filaments is heated to emit electrons, and the state is established under which the fluorescent lamp 4 is easily started. In this case, the magnitude of the preheating current is principally determined by the impedance of the choke coil 3. Under the state in which the preheating current flows, the bimetal 51 of the glow starter has its contact closed, and hence, no glow is generated. For this reason, the bimetal 51 is not heated, and is gradually cooled. After the lapse of a fixed time, the bimetal 51 intends to return to the original state, and the contact becomes open. Letting be the variation of the current induced in the choke coil 3 at this time, the voltage $V$ generated across the choke coil is as follows:

$$V = L \frac{di}{dt} \quad (L: \text{inductance of choke coil 3})$$

Thus, if the current change per unit time and the inductance $L$ are large, a high voltage will be produced. The wave forms of the current and voltage across the terminals a and b after the closure of the contact of the glow starter 5 are illustrated in FIG. 4. The time at which the contact of the glow starter 5 becomes open is independent of the current flowing therethrough, so that the voltage generated at that time differs. As a general tendency of the glow starter, however, the time at which the contact becomes open is prone to be coincident with the time at which the current flowing therethrough is close to zero. Since, at this time, the generated voltage is low, the fluorescent lamp cannot be lit. Consequently, after effecting the opening and closure of the contact several times, the glow starter lights the fluorescent lamp by a high voltage generated at a good timing.

As is apparent from the above explanation, the prior art discharge lamp device employing the glow starter has various disadvantages as mentioned below.

1. The period of time prior to lighting is long. That is, there is, necessarily:
   a. a time until the initiation of the flowing of the preheating current, and
   b. a time for the repetition of the generation of the starting voltage, which repetition is attributed to the fact that the opening of the contact is independent of the current flowing therethrough.

2. The life of the glow starter is short.

3. Since the life is short, maintenance comes into question.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a discharge lamp solid state lighting device.

Another object of the present invention is to provide a lighting device adapted to instantly light a discharge lamp.

Still another object of the present invention is to provide a discharge lamp lighting device of long life.

In order to accomplish such objects, the discharge lamp lighting device according to the present invention utilizes the switching operations of semiconductor switches to control the magnitude of a supply voltage to be applied across the filaments of a discharge lamp and to control the magnitude of a current to flow through the filaments, thereby lighting the discharge lamp by a change of the current.

The present invention will now be described with reference to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a diagram showing the construction of the prior art discharge lamp lighting device which employs a glow lamp;

FIGS. 2, 3, 7 and 8 are diagrams each showing the construction of an embodiment of the discharge lamp lighting device according to the present invention;

FIGS. 4, 5 and 6 are diagrams showing the changes-versus-time of currents and voltages in the devices illustrated in FIGS. 1, 2 and 3, respectively.

FIGS. 9 and 10 are diagrams each showing the voltage-current characteristic of a semiconductor switch for use in the discharge lamp lighting device according to the present invention;

FIG. 11 is a diagram showing a section in the case where a semiconductor portion of the device shown in FIG. 7 is put into an integrated circuit;

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 2 is a diagram showing the construction of an embodiment of the discharge lamp lighting device according to the present invention. In the figure, the same symbols as in FIG. 1 indicate the same or equivalent parts.

Reference numerals 6 and 9 designate semiconductor switches represented by silicon symmetrical switches (hereinbelow abbreviated to SSS), P-N-P-N switches or the like. In the illustrated case, the semiconductor switches are SSS type. The SSS 6 has its one
end connected to the terminal of the filament 41 remote from the power supply. Numeral 8 designates a transistor which is a semiconductor switch, the collector of which is connected to the other end of the SSS 6. A resistance element 7 is connected between the juncture between the collector of the transistor 8 and the SSS 6 and the base of the transistor 8. The SSS 9 has its one end connected to the terminal of the filament 42 remote from the power supply, and has its other end connected to the base of the transistor 8. Another resistance element 10 is connected between the emitter of the transistor 8 and the aforesaid terminal of the filament 42.

Here, the SSS and the alternative P-N-P-N switch for use as the semiconductor switches have voltage-current characteristics as shown in FIGS. 9 and 10, respectively.

In the characteristic of the SSS as illustrated in FIG. 9, when a voltage across both the terminals of the SSS exceeds a value \( V_{BO} \) (called the breakover voltage), it is switched to a value as low as the forward voltage of a diode (0.8–1 V). As can be seen from the characteristic curve in FIG. 10, the P-N-P-N switch effects the switching operation on only one side, and exhibits the reverse breakdown characteristic of a diode in the opposite polarity.

Description will be made of the operation of the embodiment shown in FIG. 2. When the power supply voltage is applied across the power supply terminals 1 and 2, the supply voltage per se is applied across the terminals a and b, because the SSS 6 is in the non-conductive state, at first. Assuming now that the polarities of the supply voltage across the terminals a and b are positive on the a-side and negative on the b-side, the base-emitter junction of the transistor 8 is forward-biased. It may therefore be considered that the voltage across a and b is principally impressed on the SSS 6. When the voltage across a and b, namely the supply voltage, exceeds the voltage \( V_{BO} \) of the characteristic shown in FIG. 9, the SSS 6 becomes conductive (it is turned "ON"), and a current (preheating current) flows from the power supply terminal 1, through the coil 3, the filament 41, the SSS 6, the transistor 8, the resistance element 10, the filament 42 and to the power supply terminal 2 in the order mentioned. The relationship between the current and voltage in this case is illustrated in FIG. 5.

In such a manner, when the voltage across a and b exceeds the breakover voltage \( V_{BO} \), current begins to flow. Consequently, the voltage across a and b decreases. That is, the voltage across the fluorescent lamp has its magnitude controlled by the SSS 6. When the supply voltage across the terminals 1 and 2 increases further to increase the current, a voltage increase occurs across the resistance 10, namely the voltage between the emitter of the transistor 8 and the point b. This results in also increasing the voltage across the SSS 9. When the terminal voltage exceeds the breakover voltage \( V_{BO} \) of the SSS 9, the SSS 9 becomes conductive. Then, the base potential of the transistor 8 is abruptly lowered, and the transistor 8 becomes non-conductive.

Accordingly, the current through the transistor 8 is cut off, and the current flows only through the resistance 7. Since the current through the resistance 7 is somewhat greater than the base current of the transistor 8, the filament current abruptly decreases to a value of approximately \( \frac{1}{h_{re}} \) where \( h_{re} \) denotes the current gain of the current flowing under the conductive state of the transistor 8.

That is, in response to the switching operation of the SSS 9 for conduction and non-conduction, the current flowing through the filaments 41 and 42 has its magnitude controlled. This current change becomes, in itself, a change in the current flowing through the choke coil 3, so that a high voltage is generated across the choke coil 3 as previously stated. The high voltage is applied across a and b, and has its greater part applied across the base and collector of the transistor 8. As the collector cut-off voltage \( V_{BC} \) of the transistor 8, accordingly, there is desired a voltage of a magnitude sufficient to ignite the discharge lamp 4 (a value of approximately 500–600 volts).

As described above, in accordance with the present invention, the lighting of the discharge lamp is carried out almost instantaneously. In the case of lighting, it is possible, according to the present invention, to further increase the current for heating the filaments (the so-called preheating current). In more detail, in the circuit shown in FIG. 2, the preheating current starts flowing when the supply voltage exceeds the voltage value \( V_{BO} \) of the SSS 6, after the closure of the power supply and, hence, there is a period of cessation in the meantime. Moreover, when the polarity of the supply voltage is inverted, the voltage across a and b does not become less than the value \( V_{BC} \) of the transistor 8 and, hence, the preheating current decreases. In such a case, a diode 11 is connected between the point b and the collector electrode of the transistor 8, as illustrated in FIG. 8 so that, when the positive voltage is applied to the point b, the preheating current may flow by way of the diode 11.

Alternatively, as is also illustrated in FIG. 8, a resistance or diode (in the figure, a resistance element 13) may be connected between the point b and the base electrode of the transistor 8. In order to effect the cut-off of the transistor 8 substantially perfectly and to increase the voltage which is produced from the choke coil, a diode 12 may be connected, as illustrated by dotted lines in FIG. 8.

When the voltage across the SSS 9 exceeds the breakover voltage \( V_{BO} \), a high voltage is generated. Therefore, due to the flow of additional preheating current, the high voltage can be generated at every cycle of the supply voltage in dependence on the magnitude of the voltage generated across the resistance element 10. The present invention, however, is applicable even when the generation of the high voltage causes the choke coil to produce noise or establishes a state under which the discharge lamp produces therein the glow discharge before the lighting thereof and is gradually lit from such a dim condition.

In more detail, the generation of the high voltage is based on the fact that since the resistance element is a linear one, a fixed voltage is produced when a fixed current flows. In order to avoid this inconvenience, therefore, a non-linear resistance element such as positive resistance coefficient thermistor may be used as the resistance element 10. With the positive resistance coefficient thermistor employed as the resistance element, it exhibits a low resistance in a period in which the initial current, after connection of the power supply, flows, and exhibits a high resistance when its temperature is raised by the heating of the current. Thus,
even when a large current flows in the first several cycles to several tens cycles, the voltage across the SSS 9 does not exceed the breakover voltage $V_{th}$, and the high voltage does not appear. Meanwhile, the filaments are sufficiently heated, while the positive resistance coefficient thermistor generates heat, has its own temperature raised and has its resistance increased. After the lapse of a predetermined period of time, the voltage across SSS 9 reaches the value $V_{th}$. Then, the high voltage is generated, and the fluorescent lamp is lit at that time.

Since, in this manner, it is possible to cause a large current to flow at the initial stage, the preheating time is shortened. The required period of time prior to lighting can be easily made 0.5 sec or so.

A further non-linear resistance element is a tungsten filament. The filaments 41 and 42 of the discharge lamp 4 are tungsten filaments, so that they are usable as the non-linear resistance elements.

FIG. 3 shows the construction of an embodiment of the discharge lamp lighting device according to the present invention in the case where a tungsten filament is employed. In the figure, the filament 42 is used instead of the resistance element 10, and one terminal of the SSS is connected to a point c which is the terminal of the filament 42 on the power supply side. The changes-versus-time of the voltage and current across the points a and c in this case are as illustrated in FIG. 6.

It is seen in FIG. 6 that no high voltage is generated in the first several cycles. In the half cycle in which the polarity of the supply voltage changes, the current across the points a and c decreases. As in the foregoing, this can be avoided by connecting the diode 11 as shown in FIG. 7.

After the discharge lamp has been lit, the voltage across a and b does not exceed the threshold voltage $V_{th}$ of the SSS 6 and, hence, the lighting circuit does not operate.

As is stated above, in accordance with the present invention, the lighting device is constituted of the stationary switches made of a semiconductor device. Since it therefore has good instant lighting properties and a long life, it can eliminate the disadvantages of the prior art lighting device employing the glow starter. Also, since it is satisfactorily possible to limit the current at the preheating by means of the stationary switch, the choke coil is only needed to generate a high voltage and to serve as a ballast. This is advantageous in that the choke coil in the present invention need not effect even the control of the preheating current, in contrast to the choke coil in the prior art. The value of the inductance of the coil for generating the high voltage may be in the order of $\mu$H, which is sufficiently smaller than a value required for ballast. That is, a choke ballast is only required to function as a ballast, so that the present invention has the advantages of facilitating the design of the ballast choke and allowing the device to be rendered small-sized.

Moreover, in accordance with the present invention, the lighting device is constructed from a semiconductor material and, hence, it can be in the form of an integrated circuit. When the P-N-P-N switch is employed as the stationary switch, an example of an integrated circuit is as shown in FIG. 11.

Referring to FIG. 11, $Q_1$ indicates a P-N-P-N switch, $Q_2$ a transistor, $Q_3$ a P-N-P-N switch, and $Q_4$ a diode which uses the N-type region of the transistor $Q_4$ at the same time. These elements respectively correspond to the SSS 6, the transistor 8, the SSS 9 and the diode 11 shown in FIG. 7. As the resistance 7 in FIG. 7, the embodiment in FIG. 11 employs the resistance of the base region of the transistor $Q_4$. Terminals a, b and c in FIG. 11 correspond to the terminals a, b and c in FIG. 7, respectively. With such an integrated circuit, the lighting device is easily made small in size, and can be manufactured inexpensively.

While we have shown and described several embodiments in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of numerous changes and modifications as known to those skilled in the art, and we therefore do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are encompassed by the scope of the appended claims.

We claim:

1. A device for lighting a discharge lamp, said lamp having first and second filaments to which first and second pairs of filament terminals, at opposite ends thereof for initiating a discharge therein, are respectively connected, comprising:

first and second input terminals for coupling a source of AC voltage to respective ones of the filament terminals of said first and second pairs of filament terminals at the opposite ends of said lamp;

an inductive coil connected between said first input terminal and one of the filament terminals of said first pair;

a first switching circuit which controls the magnitude of the voltage between the other filament terminals of said first and second pairs of filament terminals;

a second switching circuit which controls the magnitude of the current which flows through said filaments and said first switching circuit when the first switching circuit is in the conductive state; and

said first and second switching circuits are directly connected in series between the respective other filament terminals of said first and second pairs of filament terminals, so that a pulse is generated in said inductive coil.

2. A device according to claim 1, wherein said second switching circuit is also connected to the one of the filament terminals of said second pair of filament terminals.

3. A device according to claim 1, wherein each of said first and second switching circuits includes a semiconductor switching element having a PN junction therein.

4. A device according to claim 3, wherein said semiconductor switching element of each of said first and second switching circuits comprises a silicon symmetrical switch.

5. A device according to claim 1, wherein said second switching circuit comprises a transistor switching circuit connected between said first switching circuit and the other filament terminal of said second pair of filament terminals.

6. A device according to claim 5, wherein said transistor switching circuit comprises a transistor having a collector electrode coupled to said first switching circuit, a base electrode connected through a first resistor element to said collector electrode, and an emitter
electrode coupled to the other filament terminal of said second pair of filament terminals.

7. A device according to claim 6, wherein said second switching circuit further comprises a first diode connected between the collector electrode of said transistor and the other filament terminal of said second pair of filament terminals.

8. A device according to claim 6, wherein said second switching circuit further comprises a semiconductor switching element connected in series between the base electrode of said transistor and the one filament terminal of said second pair of filament terminals.

9. A device according to claim 8, wherein said semiconductor switching element of each of said first and second switching circuits comprises a silicon symmetrical switch.

10. A device according to claim 8, wherein said second switching circuit further comprises a first diode connected between the collector electrode of said transistor and the other filament terminal of said second pair of filament terminals.

11. A device according to claim 10, wherein said first switching circuit comprises a P-N-P-N switch connected between the collector electrode of said transistor and the other filament terminal of said first pair of filament terminals, and wherein the semiconductor switching element of said second switching circuit comprises a P-N-P-N switch connected between the base electrode of said transistor and said one filament terminal of said second pair of filament terminals.

12. A device according to claim 8, wherein the emitter of said transistor is connected directly to the other filament terminal of said second pair of filament terminals.

13. A device according to claim 12, wherein said second filament of said discharge lamp to which said second pair of filament terminals is connected is made of non-linear resistance material.

14. A device according to claim 13, wherein said non-linear resistance material is tungsten.

15. A device according to claim 6, wherein said second switching circuit further comprises a semiconductor switching element connected in series between the base electrode of said transistor and the other filament terminal of said second pair of filament terminals.

16. A device according to claim 15, wherein said semiconductor switching element of each of said first and second switching circuits comprises a silicon symmetrical switch.

17. A device according to claim 15, wherein said second switching circuit further comprises a second resistor element connected in series between the emitter electrode of said transistor and the other filament terminal of said second pair of filament terminals.

18. A device according to claim 17, wherein said second resistor comprises a positive resistance coefficient thermistor.

19. A device according to claim 15, wherein said second switching circuit further comprises a first diode connected between the collector electrode of said transistor and the other filament terminal of said second pair of filament terminals.

20. A device according to claim 19, wherein said second switching circuit further comprises a second resistor connected between the base electrode of said transistor and the other filament terminal of said second pair of filament terminals.

21. A device according to claim 19, wherein said second switching circuit further comprises a second resistor and a diode connected in series between the emitter electrode of said transistor and the other filament terminal of said second pair of filament terminals.

22. A device according to claim 21, wherein said second switching circuit further comprises a third resistor connected between the base electrode of said transistor and the other filament terminal of said second pair of filament terminals.

23. A device for lighting a discharge lamp, said lamp having first and second filaments to which first and second pairs of filament terminals, at opposite ends thereof for initiating a discharge therein, are respectively connected, comprising:

- first and second input terminals for coupling a source of AC voltage to respective ones of the filament terminals of said first and second pairs of filament terminals at the opposite ends of said lamp;
- an inductive coil connected between said first input terminal at one of the filament terminals of said first pair;
- first and second switching circuits connected directly in series between the respective other filament terminals of said first and second pairs of filament terminals, wherein said first switching circuit includes first means, responsive to the magnitude of said A.C. voltage, for controlling the magnitude of the voltage between the other filament terminals of said first and second pairs of filament terminals, and said second switching circuit includes second means, responsive to the control of the magnitude of the voltage by said first means, for controlling the magnitude of the current flowing through said filaments and said first switching circuit when the first switching circuit is in the conductive state.

24. A device according to claim 23, wherein said means of said second switching circuit includes means, responsive to the voltage applied thereto as a result of the control of the magnitude of the voltage applied by said first means, for abruptly changing the magnitude of current flowing through said filaments and, accordingly, said inductive coil, so as to cause the generation of a high voltage pulse sufficient to ignite said discharge lamp.

25. A device according to claim 24, wherein each of said first and second switching circuits includes a respective first and second semiconductor switching element and said second switching circuit includes a transistor circuit connected to said first and second semiconductor switching elements and to one of said other filament terminals.

26. A device according to claim 25, wherein said transistor circuit includes a transistor so connected with said first and second switching elements that, upon the conduction of said second switching element, said transistor is rendered nonconductive.