ARRANGEMENT FOR IGNITING AND OPERATING GASEOUS DISCHARGE LAMPS

19 Claims, 7 Drawing Figs.

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ABSTRACT: An arrangement for applying a train of pulses to a gaseous discharge lamp, so that each pulse has imparted to it the characteristics required for igniting the lamp and maintaining the latter in operation after ignition. A switching transistor operated by a pulse train derived from a pulse generator, applies its output pulses to a transformer with its secondary winding applied across the base-emitter path of the transistor. An inductor connected to the primary winding of the transformer and to the lamp to be operated, applies breakdown voltage to the lamp when the transistor is turned off. The inductor stores energy for transfer to the lamp once the latter has been ignited through the striking of an arc. Dimming of the lamp is accomplished by varying the energy imparted to the individual pulses or by varying the repetition rate of the pulses without incurring energy losses in the process.
ARRANGEMENT FOR IGNITING AND OPERATING GASOUS DISCHARGE LAMPS

BACKGROUND OF THE INVENTION

In the operation of gaseous discharge lamps for lighting purposes, a conventional ballast has, heretofore, been used to raise the voltage and emit the current during operation. The operational system was also based entirely upon an AC type of system. In the event that the original power supply was of the direct current type, conversion circuitry was used to convert from DC to AC power. Accordingly, it is the object of the present invention to provide an arrangement for operating gaseous discharge lamps from a low-voltage source through the application of simple and low-cost circuitry.

It is also an object of the present invention to provide a portable light which, at maximum illumination, will give several times as much light as can be obtained from the same size battery using an incandescent lamp for the same length of time. In accordance with the present invention, the same light can be operated without reduction in efficiency at a wide range of illumination levels, thus greatly prolonging battery life when maximum illumination is not needed.

The arrangement of the present invention is also applicable to an emergency light system which operates directly from power mains and will continue to burn or operate after the current is interrupted. The length of time of the continued operation is dependent on the size of the battery which floats on the line when the power is on, and the light level desired under emergency conditions.

A further feature of the present invention resides in its application to a gaseous discharge lamp street lighting arrangement which stays on when power is interrupted. In accordance with the present invention, furthermore, the gaseous discharge light is readily dimmable with little additional cost, and the discharge lamp provides more light per watt of power input, than may be derived from the same lamp using a standard or conventional type of ballast. Moreover, the presence of an ignition pulse (a voltage spike) with each current pulse eliminates the need to heat the filament of the discharge lamp, thereby further increasing the overall efficiency of the system.

In the operation of gaseous lamps, it is necessary to first strike an arc within the lamp for the purpose of starting it. After the arc has been struck, a second phase of operation is necessary to sustain the light of the lamp by controlling the amount of power transferred to the lamp. Such controlling action is accomplished in the present invention by imparting controlled amounts of energy to the individual pulses of a pulse train. Additional control of the power transfer to the lamp may be realized through a variation in the pulse repetition frequency. It is also possible to control the power transfer to the lamp through varying both the energy per pulse and the frequency of the pulses. Control over the power transferred to the lamp is attractive—attractive because high efficiency is maintained with these methods of dimming a gaseous discharge lamp, in contrast to the low efficiency which results when an incandescent lamp is dimmed by any method. The high efficiency occurs because the dimming procedure does not result in the waste of power. In view of this feature, the present invention is particularly adapted to operation from a DC source such as a battery, since the battery power may be conserved under the circumstances. Thus, by applying the dimming feature, the length of time that light can be maintained from a given battery may be prolonged in emergency situations.

SUMMARY OF THE INVENTION

An arrangement for the operation of gaseous discharge lamps from a DC power supply. Pulses emitted by a pulse generator are applied simultaneously to the base of a switching transistor, which controls current flow in an inductor and a timing transformer. After saturation of the latter, a voltage buildup occurs across the lamp to be operated through the application of an inductor. Energy stored in the inductor is transferred to the lamp upon its ignition. The relationship between the lamp and transistor operation is such that these two elements operate out of phase with each other. Dimming is accomplished either by varying the energy content of the individual pulses or by varying the pulse rate, or by both means together. A control winding mounted on the core of the timing transformer serves as a controlling means for controlling the pulse width of the pulse signals. When the transistor is turned off through its interaction with the timing transformer, the voltage across the lamp builds up until breakdown occurs. Upon such ignition of the lamp, the pulse energy is transferred to the lamp for lighting the latter in a controlled manner. The transistor and timing transformer may be replaced with switching circuitry providing identical results.

The novel features which are considered as characteristics for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an electrical schematic diagram of the circuitry used for igniting and operating gaseous discharge lamps in accordance with the present invention;

FIG. 2 is an electrical schematic diagram and shows an embodiment of FIG. 1, in which a control winding is used for the purpose of controlling the operation of the lamp under dimming conditions;

FIG. 3 is an electrical schematic diagram and shows an alternate embodiment of the arrangement of FIG. 2;

FIG. 4 is an electrical schematic diagram and shows the arrangement for reliable ignition and operations of high-voltage lamps;

FIG. 5 is a waveform diagram and shows the variations of current and voltage prevailing in the circuitry of FIG. 1;

FIG. 6 is a graphical diagram and shows the characteristics of the voltage appearing across the primary winding of the inductor in FIG. 1;

FIG. 7 is a graphical representation of the magnetic characteristics of the core in the inductor in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing, an oscillator 100, which serves as a firing circuit for a gaseous discharge lamp, is connected across a DC voltage supply 102, by way of the switch 104. The DC voltage supply 102 may be in the form of a DC battery. A timing transformer 106 has its secondary winding 108 connected across the output of the oscillator or pulse generator 100. The charging winding, 116 of inductor 114, and the primary winding 110 of the transformer 106 are connected in series with the emitter-collector path of a transistor 112. The series combination of the charging winding 116, the primary winding 110 and the emitter-collector path of the switching transistor 112, is connected across the DC voltage supply 102.

The inductor 114 has the winding 116 connected between the DC power supply 102 and one terminal of the primary winding of the transformer 106. Electromagnetically coupled with the winding 116, is a winding 118 of the inductor 114. The winding 118 is connected in series with the gaseous discharge lamp 120, to be lighted, by way of a blocking diode 122.

When the switch 104, in FIG. 1, is closed, the pulse generator 100 emits pulses at periodic intervals and applies them to the base of the transistor 112, as well as the winding 108 of the transformer 106. The pulse generator or oscillator 100 may be of the unijunction type from which a typical pulse is obtained with an amplitude of 2 volts and a pulse duration of 10 microseconds. With the application of such a pulse to the base of the switching transistor 112, the latter is turned on and becomes conductive. As a result of this state of the transistor 112, current flows through the emitter-collector path of the
transistor, the winding 110 and the charging winding 116 connected in series therewith. In view of the current flow through the primary windings 106, current flow is induced in the secondary winding 108 of this transformer. There is positive feedback from the primary 110 to the secondary 108. The current induced in the winding 108 is of such a polarity that the current through the winding 108 makes the transistor 112 still more conductive. The secondary 108 drives the base-emitter circuit of transistor 112. In its fully conductive or turned-on state, the switching transistor 112 becomes saturated, and the current from the voltage source 102 increases linearly as a result of the winding 116 of the inductor 114. Inductor 114 starts accumulating energy in accordance with $LdI/dt$. During the transient period, current flow through the winding 116 increases until the transistor 106 becomes saturated.

Once the timing transformer 106 is in the saturated state, no further current is induced within the winding 108 of the transformer, for maintaining the transistor 112 in the turned-on state. As a result of this condition in which no further current prevails through the winding 108, the transistor 112 begins to turn off, or reverts to the nonconductive state. During the period in which the transistor 112 is in the process of turning off, the voltage across the winding 116 of the inductor 114 decreases. This decrease in the voltage results from the condition that the varying magnetic flux in the transformer is reversed in polarity.

In view of the condition that the magnetic flux change associated with the transformer 106 has reversed in polarity, the induced current through the winding 108, linked by this magnetic flux, is correspondingly reversed in polarity. This reversal in the direction of flow of the primary current through the winding 108, because of the feedback from the primary 110, further turns off the switching transistor 112. Thus, this reversal in the current through the winding 108 serves to hasten the turnoff time of the transistor 112.

With the circuit path through the transistor 112 open, when the latter is turned off, the energy that was accumulated in the circuit during the conduction of 112 forces current flow to take place through the winding 118 of the circuit. As the result, voltage across the lamp 120 increases until the lamp ignites. When once ignited, in this manner, current flows through the lamp in a decaying manner of function, and thereby releases to the lamp the previously stored energy of the inductor 100 for the purpose of commencing a new cycle.

Dimming control over the lamp 120 may be exercised through variation in the pulse repetition frequency associated with the oscillator or pulse-emitting circuit 100. The pulse repetition rate is high enough so that the observer's eyes, due to the natural persistence of human vision do not see the flashing of the lamp. Thus, as the rate is slowed down, he will see a reduction in the intensity of illumination. The more rapid the pulse rate, the brighter the illumination appears.

Another method of realizing dimming control, resides in maintaining the pulse repetition frequency constant and varying the energy content of the individual pulse. One arrangement by which the latter type of dimming control is realized is shown in Fig. 2.

In this arrangement for providing dimming of the lamp through variation of the pulse energy, a control winding 126 is included in the timing transformer 106. The control winding 126 is connected in series with a variable resistor 128. The series combination of the control winding and this variable resistor is, in turn, applied across the DC voltage supply 102. The fixed frequency pulse generator 124 takes the place, in this arrangement, of the oscillator or pulse generator 100 in Fig. 1. The remainder of the circuitry of Fig. 2 corresponds to that of Fig. 1.

By varying the setting of the variable resistor 128, the current through the control winding 126 is correspondingly varied. As a result of this variation in the current through the control winding 126, the initial flux level within the core of the transformer 106 is also varied, and accordingly the energy within the individual pulse becomes varied. This is derived from the condition that the energy content of an individual pulse is dependent upon the flux variation within the core of the transformer 106. Since the lighting intensity of the lamp 120 is a function of the energy imparted to the lamp, dimming action of the lamp may be realized by diminishing the energy content of the individual pulse through variation of the current within the control winding 126.

Another arrangement for realizing dimming of the lamp 120 by variation of the pulse width of the pulse train for lighting the lamp is shown in Fig. 3. Such variation in the width or duration of the pulse may be accomplished by providing a variable resistor 130 in series with the winding 108, as shown in Fig. 3. In this arrangement, the pulse repetition frequency remains constant, whereas the pulse width becomes varied through the setting of the variable resistor 130. A clamping diode 132 is provided in conjunction with the arrangement of Fig. 3 to assure that no refrining pulse is emitted from the pulse generator 124, until the transformer 106 has passed through a complete cycle. At the same time, the clamping diode 132 prevents excessive voltages from being applied to the pulse generator or oscillator 124. The latter is shown in greater detail in Fig. 3 than in Fig. 2.

Resistor 130 may be nonlinear, as in a tungsten filament. Such a characteristic is applied to limit the inrush current of some discharge lamps. In this case, immediately after the arc is struck the battery voltage is high enough to maintain a DC current through 114 while the lamp is still cold. The lamp current does not drop off at the conclusion of the discharge period. Thus, at the onset of the next trigger pulse, current is flowing in 114. This may cause current to build up in transistor 112 to unsafe levels.

Now, the current in 130 is directly proportional to the collector current of 112. Resistor R130 may be a tungsten filament lamp, operating below its normal voltage, at the "knee" of the volt-ampere characteristic of the filament. Thus, the filament becomes heated, the voltage across it rises sharply causing the timing transformer, 106, to saturate earlier. Thus, the energy accumulation in 114 is reduced. As the lamp warms up, the DC current tends to fall. Resistor 130 cools; its resistance falls; the voltage impressed on winding 108 falls sharply thus causing the pulse to widen again. This action limits the inrush current to be slightly higher than the normal current and thus protects the switching element 112.

Improved features in the operation of the lamp may be realized through the arrangement of Fig. 4. In this circuit arrangement, an additional winding 138 is provided on the inductor 114. This winding 138 has a relatively large number of turns and increases, thereby, the starting voltage applied across the lamp. The winding 138 is connected in series with a capacitor 142 which limits the current flow after ignition of the lamp 120. The resistor 144 in series with the capacitor 142 serves to reduce power dissipation in winding 138. The entire series combination of the winding 138, capacitor 142 and resistor 144 is applied directly across the lamp 120.

As shown in Fig. 4, additional transistors may be connected in parallel with the transistor 112, to reduce the current-delivering requirements of this particular transistor. Thus, the bases of the additional transistors 146 are connected to the base of the transistor 112. In a similar manner, the collectors and emitters of the transistors 146 and 112 are joined to each other. As a result of this type of interconnection of the transistors, the latter are connected in parallel and share thereby the current load requirements.
A further feature of the arrangement of FIG. 4 resides in the addition of a coil 140 wound upon the transformer 106. This coil or winding 140 serves the purpose of impedance matching with respect to the pulse generator 124. The winding 140 acts upon the winding 108 and, thereby, serves as an intermediary between the pulse emitter 124 and the winding 108 of the timing transformer. Thus, instead of being connected directly to the winding 108, as in FIGS. 2 and 3, the pulse emitter is connected to an impedance matching winding 140 which, in turn, acts upon the winding 108. The output of the pulse emitter, therefore, is applied directly to the winding 140 which permits close impedance matching to the pulse emitter 124. An additional winding 134 wound upon the inductor 114 is provided in series with the winding or coil 108. This additional or auxiliary winding 134 further aids in providing improved starting characteristics of the lamp 120. Thus, through the inclusion of the winding 134, the pulse characteristics are modified so that the starting characteristics of the pulse are improved to assure more reliable starting of the lamp 120.

A feedback winding 136 wound upon the inductor 114, is connected across the DC voltage supply 102 for the purpose of feeding back the energy to the latter in the event that the lamp fails to ignite. The diode 148 connected in series with the winding 136 assures that the current flow is in the proper direction for feeding back into the direct current power supply. Thus, the diode 148 steers the current back into the DC voltage supply while, at the same time, preventing the shorting of the latter by the winding 136.

The analytical considerations which determine the selection of the components for securing a properly operating circuit, in accordance with the present invention, are given in what follows. The definitions of the symbols and terms are:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_0b</td>
<td>Battery supply voltage</td>
</tr>
<tr>
<td>V_b</td>
<td>Breakdown (ignition) voltage of a cold lamp</td>
</tr>
<tr>
<td>V_s</td>
<td>Sustaining voltage of the lamp</td>
</tr>
<tr>
<td>P_o</td>
<td>Power into lamp at maximum intensity</td>
</tr>
<tr>
<td>a</td>
<td>Step-up ratio = N_118/N_116 of inductor 114</td>
</tr>
<tr>
<td>V_c</td>
<td>Forward voltage drop of the switching transistor</td>
</tr>
<tr>
<td>x</td>
<td>Conduction ratio of the switching transistor</td>
</tr>
<tr>
<td>P_a</td>
<td>Power drawn from battery</td>
</tr>
<tr>
<td>P_o</td>
<td>Output power to lamp</td>
</tr>
<tr>
<td>E</td>
<td>Efficiency</td>
</tr>
<tr>
<td>I_b</td>
<td>Switching transistor current</td>
</tr>
<tr>
<td>I_n</td>
<td>Lamp current</td>
</tr>
<tr>
<td>I_p</td>
<td>Peak value of the input current</td>
</tr>
<tr>
<td>V_a</td>
<td>Base-to-emitter voltage of transistor 112</td>
</tr>
<tr>
<td>L</td>
<td>Inductance of the primary inductor 114</td>
</tr>
<tr>
<td>V_c</td>
<td>Maximum allowable collector-to-emitter voltage of the switching transistor 112</td>
</tr>
<tr>
<td>t</td>
<td>Time to complete one full cycle</td>
</tr>
<tr>
<td>B_a</td>
<td>Change in flux density of inductor 114</td>
</tr>
<tr>
<td>A_c</td>
<td>Cross-section area of the iron core.</td>
</tr>
</tbody>
</table>

The selection of the switching transistor 112 is determined on the basis of the peak input current. The latter may, in turn, be determined from considerations of the design relationships associated with the inductor 114. Assuming that at time t = 0, the transistor 112 receives an "on" pulse from the pulse emitter 100 or 124, the timing transformer 106 serves to feed back in a positive manner for more rapidly turning on the transistor. The action is such that an avalanche condition results for turning the transistor to its "on" state. During the transient state, current I_1 builds up until the timing transformer 106 saturates. The collector current of the transistor is then shunted away by the low value of the primary inductance of the timing transformer 106. As a result, the collector current decreases and thereby further reduces the base drive of the transistor. The switching transistor 112, accordingly, avalanches to its turned-off state through the action of commutation. If the time to saturation is designated by XI, then

\[
I_p = \frac{2P_o}{\eta V_b} \left( x + \frac{1-x}{a} \right) \tag{11}
\]

In determining the step-up ratio "a," the switching transistor 112 has commutated at time t = XT, and I_1 drops to zero. Since the ampere-turns in an inductor cannot change instantaneously, the current switches to I_8 in winding 118 of the inductor 114, and is given by \( I_{peak} / a \). The waveforms of the currents I_1 and I_8, as well as the voltage appearing across the lamp 120 is shown in FIG. 5.

The transition in current is accompanied by a high transient voltage, and since the amplitude of this transient voltage is limited only by the breakdown voltage of the lamp 120, ignition of the latter takes place. This breakdown voltage of the lamp is designated by V_o. This resulting peak voltage or breakdown voltage is reflected back to the transistor 112 which is now in the "blocking" mode, since the windings 116 and 118 are closely coupled on the inductor 114.

On the basis of the maximum collector-emitter voltage, V_c, as determined from the rated value of the selected transistor, the maximum collector voltage is

\[
a = \frac{V_a - V_b}{V_c + V_a - V_b} \tag{12}
\]

Equation (12) indicates that the ratio a is fixed or determined by the characteristics of the lamp, the battery voltage, and the safe operation of the switching transistor 112.

The conduction ratio, X, may be derived by referring to FIG. 6 which shows the waveform of the voltage appearing across the winding 116 of the inductor 114. If the winding resistance and the ignition-pulse area are neglected, the voltage across the inductor must be zero when averaged over a full cycle. Therefore,

\[
X = \frac{a - 1}{E_b - V_b} \tag{13}
\]

Equation (13) is based on the assumption that the lamp 120 conducts continuously throughout the period (1-XT).

To ascertain that the magnetic core of the inductor 114 does not saturate, and to determine the core loss of the inductor, it is essential to evaluate the peak flux density which occurs at the time of commutation of the switching transistor 112. From FIG. 7, and the assumption that the lamp current is small at the end of a full cycle,

\[
\Delta B_{AC} = \frac{X T (E_b - V_b) 10^4}{N_{1AAC}} \tag{14}
\]

The core loss may be determined from the manufacturer's specification and charts.

To determine the copper loss of the inductor 114, it is essential that the r.m.s. values of the currents in the coils of the inductor be computed. Denoting the RMS in the windings 116 and 118 by I_{116} and I_{118}, respectively, then

\[
I_{115} = I_p \sqrt{\frac{x}{3} - \frac{1-x}{3a^2}} \tag{15}
\]

\[
I_{114} = I_p \frac{1-x}{a} \tag{16}
\]

The second term under the radical of equation (15) represents the contribution of the lamp current to the heating of the primary winding 116. However, this second term may
generally be neglected in comparison with the first term under the radial.

The timing transformer is a small saturable current transformer in which the primary is connected in series with the collector of the transistor 112. The secondary winding of this transformer is applied across the base-emitter path of the transistor. The transformation ratio of this transformer is given by

\[ \beta = \frac{N_{206}}{N_{130}} \tag{17} \]

where \( \beta \) is the switching current gain of the transistor, under worst case conditions.

The time interval \( XT \) is determined by the interaction of the magnetic characteristics of the timing transformer 106 with the base-emitter junction voltage \( V_{EE} \) on the winding 108. Thus,

\[ XT = \frac{N_{130}A_{41}DB_{AC}}{V_{EE}} \times 10^{-3} \tag{18} \]

where \( DB_{AC} \) is the change in flux density, \( A_4 \) is the magnetic core, \( N_{130} \) is the number of turns in the winding 108, and \( V_{EE} \) is the base-emitter voltage of the transistor 112.

In providing the control winding 126 on the core of the timing transformer 106, the transformer core may be made in the form of a toroid with a square loop magnetic core. The core is chosen so that

\[ \Delta B_{max} = 22B_1 \tag{19} \]

where \( B_1 \) is the saturation flux density. A toroid core for the timing transformer 106 saturates faster than a laminated core, and this results in reduced power losses in the transistor.

In an alternate design of the timing transformer 106, the core is of "EI" or "F" laminations that have a natural air gap. Since transformer steel has only slight magnetic retentivity, the small air gap is adequate to reset the core so that \( B = 0 \). In one method for controlling the pulse duration, laminations are added or removed. Once the adjustment is made, the timing pulse duration is permanent. The basis of this method may be derived from equation (14) which indicates that XT is proportional to \( A_4 \). The other method of pulse width control resides in the configuration of Fig. 3 in which the variable resistor 130 is connected in series with the base of the transistor 112. In addition to the functions already indicated, the clamping diode 132 prevents frequency shifting of the oscillator or emitter 124, due to the natural flux reset voltage of the timing transformer 106. With an increase in the magnitude of the resistance 130, the voltage across the winding 108 is increased. From equation (18) it may be seen that \( V_{EE} \) is increased with the magnitude in the magnitude of the resistance 130, and thereby XT is reduced.

The circuit losses due to the insertion of the resistor 130 in Fig. 3, are small since the output power is approximately proportional to \( (XT)^2 \).

In carrying out the preceding analysis, simple linear current fall characteristics were assumed as shown in Fig. 5. The actual voltage-amperance characteristics of a typical fluorescent lamp, however, is nonlinear and exhibits strong hysteresis characteristics. The error introduced by the calculations, however, affect only the value of the r.m.s. current in the high-voltage winding of the inductor 114. When calculating the total transformer loss of this inductor, the effect of this inaccuracy is negligible.

The equivalent source impedance of the battery varies with the charge state of the battery and its previous cycle history. For nickel-cadmium and lead-acid batteries, however, the source impedance is sufficiently low so that the average terminal voltage may be designated as \( E_{bb} \), with the inductor 114.

Carbon-zinc batteries have a comparatively high source impedance. It is desirable to provide an AC bypass capacitor across the battery terminals to improve the efficiency of the system energy conversion.

In the operation of the circuit of Fig. 4, pulses from the pulse emitter or generator 124 turn the transistor 112 on. As a result, the capacitor 142 charges through the diode 122. Upon completion of the "on" period, transistor 112 commutates. The surge voltage produced in the winding 138 is superimposed upon the voltage accumulated during the "on" cycle, and therefore the peak voltage stress on the winding 138 is minimized. The lamp voltage then rises to the breakdown level of the lamp, at which time the arc is struck and the lamp is thereby turned on. When the arc is once struck, the capacitor 142 limits the current through the winding 138, because it is a high-impedance element. At this point the operation and control of the circuit is identical to the previous description relating to the inductor 114. The winding 136 on the inductor 114 is used for automatic protection in the event that the lamp arc is not ignited when intended, or if the lamp current accidentally ceases. Thus, the energy accumulated in the inductor 114, is transferred back to the DC power source. Without this winding and diode, the voltage across the transistor 112 would increase until breakdown occurs. The winding 136 and the diode 148 act as a safety device in providing a temporary return path of this energy to the power supply. The number of turns on the winding 136 is selected so that no current flows in normal operation. When the winding 136 is called upon to exercise its safety function, the collector-emitter voltage of the transistor 112 is maintained safely below the breakdown level.

It will be understood that each of the elements described above, or two or more together, may also find useful application in other types of gaseous lamp operating arrangements differing from the types described above.

While the invention has been illustrated and described as embodied in a gaseous lamp operating arrangement, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will fully reveal the gist of the present invention that others can by applying current knowledge, readily adapt it for various applications without omitting features that from the standpoint of prior art fairly constitute essential characteristics of the generic or specific aspects of this invention.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. An arrangement for the operation of a gaseous discharge lamp, comprising, in combination, gaseous lamp means adapted to be lighted by striking an arc within said lamp means; a source of DC voltage connected in circuit with said lamp means; a single energy storage means arranged in said circuit; pulse-generating means connected to said source of DC voltage and emitting a train of pulses; and semiconductor switching means having an on state and an off state and controlled by said pulse-generating means for alternately causing storage of energy from said source of DC voltage in said energy storage means, during said on state, and discharge of the stored energy into said lamp means, during said off state, said switching means having a sufficiently rapid rate of change from said on state to said off state so that at each discharge there is produced a voltage spike sufficient in amplitude to fire said lamp means followed by a current pulse as soon as said lamp means is ignited.

2. An arrangement for the operation of a gaseous discharge lamp as defined in claim 1 including means for modifying the repetition rate of said pulses.

3. The arrangement for the operation of a gaseous discharge lamp as defined in claim 1, further including auxiliary switching means, said energy storage means enabling operation of said lamp means by said source of DC voltage and said auxiliary switching means having a voltage rating less than the operating voltage drop of said lamp means.
4. The arrangement for the operation of a gaseous discharge lamp as defined in claim 1, wherein filamentary-type lamp means are operated without filament heating and gaseous discharge lamps are operated that do not have filaments.

5. The arrangement for the operation of a gaseous discharge lamp as defined in claim 1, wherein said switching means includes positive feedback means for accelerating said rate of change.

6. The arrangement for the operation of a gaseous discharge lamp as defined in claim 5, wherein said semiconductor switching means includes a transistor, and said positive feedback means includes a transformer with a ferromagnetic core, primary winding means wound about said core and connected in series with said transistor, and secondary winding means wound about said core and connected to said transistor so as to drive the base-emitter circuit thereof, said secondary winding means being magnetically linked with said primary winding means so that there is positive feedback from the former to the latter for causing saturation of said transistor for a period determined by the characteristics of said core and for causing a sufficiently rapid opening of said transistor so as to obtain the required said voltage spike and said current pulse.

7. The arrangement for the operation of a gaseous discharge lamp as defined in claim 6, wherein said transformer further includes control winding means for controlling and varying the duration of said pulses; and variable resistor means connected in series with said control winding means for varying the current through said control winding means, the series combination of said control winding means and said variable resistor means being connected in parallel with said source of DC voltage.

8. The arrangement for the operation of a gaseous discharge lamp as defined in claim 6, including thermally dependent resistor means connected in series with said transformer secondary winding means for stabilizing the energy content of the pulses.

9. An arrangement for the operation of a gaseous discharge lamp as defined in claim 6, wherein said positive feedback means includes means for modifying the width of said pulses after generation by said pulse-generating means so as to change the total energy in each pulse.

10. An arrangement for the operation of a gaseous discharge lamp, comprising, in combination, gaseous lamp means adapted to be lighted by striking an arc within said lamp means; a source of DC voltage connected in circuit with said lamp means; a single energy storage means arranged in said circuit, said energy storage means including inductor means having a ferromagnetic core, said inductor means being connected between said source of DC voltage and said lamp means; pulse-generating means connected to said source of DC voltage and emitting a train of pulses; and switching means controlled by said pulse-generating means and connected to said inductor means for alternatingly causing storage of energy from said source of DC voltage in said inductor means so that at each discharge there is produced a voltage spike sufficient in amplitude to fire said lamp means followed by a high-frequency discontinuous current conducted through said lamp means.

11. The arrangement for the operation of a gaseous discharge lamp as defined in claim 10, including diode means connected between said lamp means and said inductor means to isolate said lamp means while the pulse energy is being stored in said inductor means.

12. The arrangement for the operation of a gaseous discharge lamp as defined in claim 10, wherein said inductor means includes safety winding means connected across said source of DC voltage; and steering diode means connected in series with said secondary winding means for returning energy to said source of DC voltage when said lamp means fails to ignite after the application of a said voltage spike to said lamp means.

13. The arrangement for the operation of a gaseous discharge lamp as defined in claim 10, wherein said switching means includes a transistor, and further including at least one auxiliary transistor connected in parallel with said transistor for reducing the current there-through.

14. An arrangement for the operation of a gaseous discharge lamp as defined in claim 10, wherein said inductor means has a primary winding means and a secondary winding means, said primary winding means being connected between said source of DC voltage and said switching means, said secondary winding means being magnetically linked with said primary winding means through said ferromagnetic core and connected to said lamp means and said primary winding means.

15. The arrangement for the operation of a gaseous discharge lamp as defined in claim 10, wherein said inductor means includes auxiliary starting winding means connected across said lamp means for increasing the starting voltage applied across said lamp means.

16. The arrangement for the operation of a gaseous discharge lamp as defined in claim 15, including capacitor means connected in series with said auxiliary starting winding means for limiting the current there-through.

17. An arrangement for the operation of a gaseous discharge lamp as defined in claim 16, wherein said switching means includes a transistor, and further including a transformer with a ferromagnetic core, primary winding means on said core connected in series with the emitter-collector path of said transistor, secondary winding means on said core connected in parallel with the base-emitter path of said transistor so as to provide positive feedback from said primary winding means to said secondary winding means so as to accelerate the discharge of the stored energy into said lamp means and thereby to obtain the desired said voltage spike followed by said high-frequency discontinuous current.

18. The arrangement for the operation of a gaseous discharge lamp as defined in claim 16, wherein said transformer further includes control winding means for controlling the energy content of each said current pulse.

19. The arrangement for the operation of a gaseous discharge lamp as defined in claim 16, wherein said inductor means includes booster winding means connected in series with said transformer secondary winding means.