A power supply for starting and operating metal halide short arc lamps comprising a full wave rectifier bridge and voltage doubler circuit having a capacitive ballast connected on the AC side and a pair of voltage tripler circuits connected at the positive and negative DC terminals of the bridge. The arc lamp is connected across one of the triplers, and a starting circuit for the arc lamp is energized by the other tripler. The output of the bridge-doubler is employed to operate a timing circuit which activates an indicator when the arc lamp fails to operate after a predetermined interval of starting circuit operation.
POWER SUPPLY FOR STARTING AND OPERATING ARC LAMPS

BACKGROUND OF THE INVENTION

This invention relates generally to arc lamp power supplies and more particularly to an improved circuit for starting and operating metal halide short arc lamps. Although applicable to a variety of arc discharge lamps, the present invention is particularly useful in connection with the short arc metal halide type in which a pair of electrodes are spaced to provide an arc in the order of one quarter inch within a quartz envelope having a filling including selected metal additives in the form of halogen compounds, generally known as iodides, to achieve desired alterations in lamp discharge characteristics. Such lamps impose severe starting and operating requirements on the associated power supply. For example, a 300 watt metal halide arc lamp may require an open circuit voltage of about 450 volts to cause cathode spots to form on the two electrodes, and a starting voltage of from 7,000 to 10,000 volts may be required to strike an arc. Thereafter, the lamp can be operated with an applied voltage of from 20 to 40 volts.

Early power supplies, or ballast circuits, for metal halide arc lamps employed a transformer ahead of a bridge doubler to boost the open circuit voltage across the arc lamp to the required 450 volts. Such transformers are relatively expensive, heavy, and tend to overheat.

In addition to providing a suitable open circuit voltage, the arc lamp power supply must also provide ballasting and means for repeatedly applying high voltage pulses to the lamp until it starts. U.S. Pat. No 3,467,886 describes a ballast apparatus for operating a DC arc lamp from a 60 Hz AC source. The lamp voltage is provided by a bridge-doubler without transformer boosting, however the open circuit voltage requirement is indicated as being only about 300 volts, and ballasting is provided by an inductive reactor serially connected ahead of the bridge circuit. The starting circuit comprises a pulse transformer or autotransformer in combination with a capacitor discharge circuit and a manually operated switch or mechanical relay.

Yet another object of the invention is to provide an arc lamp power supply which is suitable for operation from a 400 Hz source of alternating current. Briefly, these and other objects, advantages and features are attained, in accordance with the invention, by forming voltage tripler circuits at both DC outputs of a full wave rectifier-voltage doubler circuit, one of the triplers being used for operating the arc lamp, and the other tripler being applied to energize a solid state starting circuit. To provide automatic starting, an autotransformer in the lamp operating loop is periodically pulsed by a starting circuit comprising a discharge capacitor and controlled switching means triggered by a relaxation oscillator. In addition, the supply includes a timing circuit operated off the rectifier-doubler for actuating an indicator when a predetermined voltage remains across the rectifier-doubler output terminals for a predetermined period, thereby denoting failure of the lamp to start and the probable need of a replacement lamp.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention will be more fully described hereinafter in conjunction with the accompanying drawings in which:

FIG. 1 is a block diagram of an arc lamp power supply in accordance with the invention; and

FIG. 2 is a corresponding schematic diagram of a power supply according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the system block diagram of FIG. 1, the power supply includes a line switch 10 for connection to a source of alternating current, followed by an electromagnetic interference filter 12. The output of filter 12 is connected through a reactive ballast circuit 14 to the AC input of a full wave rectifier-voltage doubler circuit 16 having positive (+) and negative (−) DC output terminals 18 and 20, respectively. If $V_p$ is the peak value of the AC input voltage, the output voltage obtainable across the doubler output terminals 18 and 20 may theoretically be indicated as $2V_p$. This voltage is applied across a timing circuit 22, which provides an output signal in the presence of a predetermined voltage (approximately $2V_p$) across terminals 18 and 20 for a predetermined period of time. Connected to the output of timer 22 is an indicating device 24 which is activated by the timer output signal.

A circuit 26 is connected to the positive DC output terminal 18 of the rectifier-doubler to provide a first voltage tripler arrangement having a theoretical output $3V_p$ across the output terminal of tripler 26 and the negative DC output terminal 20 of the rectifier-doubler. The DC lamp operating circuit loop is operated from this first tripler output and includes an arc lamp 28 and pulse transformer 30 connected in that order between terminal 20 and the output terminal of tripler 26.

Pulse transformer 30 provides means for coupling an automatic starting circuit 32 to the lamp operating circuit loop for introducing a voltage of sufficient energy to ignite the arc lamp 28. The automatic starting circuit 32 includes a discharge circuit 34, which is connected to the pulse transformer 30, and a trigger circuit 36 for periodically activating the discharge circuit. To provide an adequate energizing potential for the starting cir-
circuit, a circuit 38 is connected to the negative DC output terminal 20 of the rectifier-doubler for forming a second voltage tripler having a theoretical output voltage of 3V<sub>e</sub> across the positive DC output terminal 18 and the output terminal of circuit 38. Both of these terminals are connected to energize the discharge and trigger sections 34 and 36 of the starting circuit.

Referring now to the specific implementation illustrated in FIG. 2, the power supply includes a pair of main input terminals 40 and 42 for connection to a 115 volt 400Hz alternating current source. Power is applied to the apparatus by actuating switch 10 to close a pair of line contacts 44 and 46. The input line from terminal 40 is coupled through a pi filter 12a and a capacitive ballast 14 to a first AC input terminal 48 of the full wave rectifier and doubler circuit 16. The input line from terminal 42 is then coupled through pi filter 12b to a second AC input terminal 50 of the rectifier-doubler circuit 16. In one typical implementation, each of the filters 12a and 12b are rated as 15 amp, 125 volts AC, 400Hz. The capacitive ballast includes a basic ballast capacitor 52 having a pair of trim capacitors 54 and 56 and a resistor 58 connected thereacross. In the aforementioned implementation: capacitor 52 is 20 microfarads, 200 volts AC or DC; capacitors 56 and 54 are 2 microfarads, 200 volts DC; and resistor 58 is 470,000 ohms, one-half watt. When connected to the power source at terminals 40 and 42, the peak input V<sub>p</sub> to the AC terminals of the rectifier-doubler is theoretically about 170 volts.

The full wave rectifier comprises a bridge arrangement of four diodes 61-64 each of which has a protective capacitor connected across its terminals. The capacitors are denoted as 65-68, respectively. AC input terminal 48 is at the junction of diodes 61 and 64, while AC input terminal 50 is at the junction of diodes 62 and 63. The remaining diode junctions, namely, at the interconnection of diodes 61 and 62 and at the interconnection of diodes 63 and 64, respectively comprise the positive and negative DC output terminals 70 and 72. The voltage doubler is formed by a capacitor 74 connected between terminals 50 and 70 and a capacitor 76 connected between terminals 50 and 72. The doubled peak voltage across these two capacitors is denoted as 2V<sub>e</sub> and ranges from about 330 to 340 volts, depending on the load.

In accordance with the present invention, the first voltage tripler 26 is formed at the positive DC output of the bridge by connecting a diode 77 and capacitor 79 in that order across one arm of the bridge between terminals 70 and 48. A protective capacitor 78 is connected across diode 77. Terminal 80 at the junction of diode 77 and capacitor 79 may be considered the output terminal of the first tripler.

A second voltage tripler circuit is formed on the negative side of the bridge by connecting a capacitor 82 and diode 84 across a second arm of the bridge between terminals 48 and 72. A protective capacitor 86 is connected across diode 84. Terminal 88 at the junction of capacitor 82 and diode 84 may be considered the output terminal of the second tripler.

In the aforementioned specific implementation, the bridge, doubler and tripler elements have the following component values:

<table>
<thead>
<tr>
<th>Components</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diodes</td>
<td>61,62,63,64</td>
</tr>
<tr>
<td>Diode</td>
<td>77</td>
</tr>
<tr>
<td>Diode</td>
<td>84</td>
</tr>
<tr>
<td>Capacitors</td>
<td>65,66,67,68,78,86</td>
</tr>
<tr>
<td>Capacitors</td>
<td>74, 76</td>
</tr>
<tr>
<td>Capacitor</td>
<td>79</td>
</tr>
<tr>
<td>Capacitor</td>
<td>82</td>
</tr>
</tbody>
</table>

The first tripler output is applied to the DC lamp operating circuit loop. More specifically the lamp circuit comprises an autotransformer 30 and an arc lamp 28 serially connected in that order between tripler terminal 80 and the negative bridge terminal 72. The voltage across terminals 80 and 72, is denoted as 3V<sub>e</sub>, but actually it ranges from about 430 to 450 volts. When the power supply is connected to the AC source this output from the first tripler provides a sufficient open circuit voltage across the arc lamp electrodes to form the cathode spots required to enable starting of an arc upon application of a high voltage ionizing pulse from the starting circuit via the autotransformer 30.

The discharge portion 34 of the starting circuit includes a capacitor 90 and resistor 92 connected in that order between the positive bridge terminal 70 and the second tripler output terminal 88, and a silicon controlled rectifier 94 having its anode connected to the tap 96 on autotransformer 30 and its cathode connected to the junction of capacitor 90 and resistor 92.

In the aforementioned specific implementation: capacitor 90 is 2 microfarads, 600 volts; resistor 92 is 10,000 ohms, 2 watts; and the silicon controlled rectifier 94 is a type S6025H, manufactured by ECC Corporation of Euless, Texas.

Trigger circuit 36 includes a voltage divider comprising resistors 98 and 100 connected between terminal 70 and the junction of capacitor 90 and resistor 92, and a timing circuit including resistor 102 and capacitor 104 connected across resistor 100. Connected between the junction of resistor 102 and capacitor 104 and the trigger electrode of the controlled rectifier 94 is a series circuit combination comprising a silicon bilateral switch 106, a resistor 108 and a diode 110. A resistor 112 is connected between the trigger and cathode electrodes of the controlled rectifier 94. In the preferred implementation, the trigger circuit has the following component values:

<table>
<thead>
<tr>
<th>Components</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistor</td>
<td>98</td>
</tr>
<tr>
<td>Resistor</td>
<td>100</td>
</tr>
<tr>
<td>Resistor</td>
<td>102</td>
</tr>
<tr>
<td>Resistor</td>
<td>108</td>
</tr>
<tr>
<td>Resistor</td>
<td>112</td>
</tr>
<tr>
<td>Capacitor</td>
<td>104</td>
</tr>
<tr>
<td>Switch</td>
<td>106</td>
</tr>
<tr>
<td>Diode</td>
<td>110</td>
</tr>
</tbody>
</table>

With this arrangement trigger circuit 36 comprises a relaxation oscillator, which in the preferred embodiment operates at a frequency of about 5Hz.

The starting circuit operates as follows. With the power supply connected to the AC input but prior to lamp ignition, the output of tripler 38 (approximately 430 volts) charges capacitor 90 through resistor 92, and the voltage across capacitor 90 is fed through the voltage divider 98, 100 and resistor 102 to capacitor 104. When the voltage across capacitor 104 reaches approximately 8 volts, the bilateral switch 106 breaks down and conducts a pulse into the gate, or trigger electrode, of the silicon controlled rectifier 94. In response to this trigger pulse, the controlled rectifier 94 fires, thereby connecting capacitor 90 in a loop circuit through the primary 114 of autotransformer 30 and
The voltage to the divider circuit is divided down 10 to one through divider resistors 122, 124 and 128 so that approximately 32 volts appear at contact 126 (top of resistor 150) when the lamp is not lit and the power supply is on. The timing of the RC circuit consisting of capacitor 154 and resistor 150 is adjusted by padding the resistor 150 with a selected resistor 152. Capacitor 154 builds up a charge under these conditions until at the end of the preselected 30 second period, the voltage on emitter 148 is sufficient to break down the unijunction transistor. When this occurs, capacitor 154 is discharged into relay coil 118. The capacitor discharges at approximately 22 volts and has sufficient stored energy to actuate or pull in both sets of relay contacts. When the upper set of relay contacts is actuated, common terminal 120 is connected to contact 130, and the incoming voltage is transferred directly to the relay coil 118, thereby latching, or sealing, the relay until such time as the incoming voltage is sufficiently reduced. The lower contact set, when actuated, causes common terminal 136 to be connected to contact 132 whereby the red indicator light 116 is energized or activated, by the 28 volt supply 134, 138.

When arc lamp 28 is ignited, the voltage across DC terminals 70 and 72 is reduced to a value between 20 and 40 volts and the voltage at relay contact 126 (top of resistor 150) is reduced to a maximum of 4.3 volts. Due to leakage currents through the unijunction transistor 140 and capacitor 154, the voltage on capacitor 154 never exceeds 0.2 volts under these conditions, and this voltage is insufficient to operate the unijunction transistor. Even if the capacitor voltage did build up to a level where it operated the unijunction transistor (about 2.6 volts), there would be too low a voltage present on capacitor 154 to operate the 28 volt relay.

With this circuit arrangement, timing circuit 22 is adapted to be reset by any one of the following events:

a. If the arc lamp 28 is ignited before the relay is pulled in to activate the red indicating light 116, the resulting reduced voltage on the base electrode 142 causes the unijunction transistor to discharge the voltage on capacitor 154 through the relay coil 118, but the reduced input voltage to the timing circuit will not be sufficient to cause latching of the unijunction transistor.

b. If the arc lamp starts after the relay is actuated to turn on the indicator light, the resulting reduced voltage across terminals 70 and 72 deprives the relay coil 118 of the necessary latching voltage, and thereby permits the relay contacts to open up.

c. If switch 10 is opened to disconnect the power supply from the AC input before the relay activates the indicating light 116, the resulting reduction in the DC output across terminals 70 and 72 causes a reduction in the voltage on the base electrode 142, whereas the unijunction transistor is rendered momentarily conducting to discharge capacitor 154 without permanent latching in the same manner described with respect to event (a).

d. If the power supply is disconnected after the relay is actuated to turn on the indicating light 116, the resulting reduction in the DC voltage across terminals 70 and 72 deprives the relay of its latching voltage and causes it to open up as described with respect to event (b).

Although the invention has been described with respect to a specific embodiment, it will be appreciated that modifications and changes may be made by those
skilled in the art without departing from the true spirit and scope of the invention.

What I claim is:

1. A power supply for starting and operating an arc lamp from a source alternating current comprising, in combination:
   power supply input means for connection to said source of alternating current;
   a full wave rectifier-voltage doubler circuit having AC input means and first and second DC output terminals;
   a reactive ballast means coupled between said power supply input means and the AC input means of said rectifier-doubler circuit;
   means connected to the first DC output terminal of said rectifier-doubler circuit for forming a first voltage tripler having an output terminal;
   means for connecting said arc lamp between said first tripler output terminal and the second DC output terminal of said rectifier-doubler circuit to form a DC lamp operating circuit loop;
   a lamp starting circuit coupled to said lamp operating loop for introducing a voltage pulse of sufficient energy to ignite said arc lamp;
   means connected to the second DC output terminal of said rectifier-doubler circuit for forming a second voltage tripler having an output terminal; and
   means connecting the first DC output terminal of said rectifier-doubler circuit and said second tripler output terminal to said starting circuit for energizing said starting circuit.

2. A power supply in accordance with claim 1 further including a timing circuit connected across the first and second DC output terminals of said rectifier-doubler circuit and adapted to provide an output signal in the presence of a predetermined voltage across said rectifier-doubler output terminals for a predetermined period of time, and indicating means adapted to be activated by the output signal from said timing circuit, said predetermined voltage normally being present when said power supply input is connected to said source of alternating current and said arc lamp is not operating.

3. A power supply in accordance with claim 2 wherein said timing circuit is adapted to be reset by any one of the following events: (a) starting of said arc lamp before said indicating means is activated; (b) starting of said arc lamp after said indicating means is activated; (c) disconnection of said power supply input from said source of alternating current before said indicating means is activated; and (d) disconnection of said power supply after said indicating means is activated.

4. A power supply in accordance with claim 1 wherein said reactive ballast means comprises a capacitor serially connected between said power supply input and the AC input means of said rectifier doubler circuit.

5. A power supply in accordance with claim 4 wherein said power supply is adapted to be started and operated from a source of 400 Hz alternating current.

6. A power supply in accordance with claim 1 wherein said rectifier-doubler circuit comprises a bridge rectifier including four diodes and at least one capacitor connected across the bridge rectifier to produce a voltage doubling action at the DC output terminals thereof; said means forming a first tripler comprises a fifth diode and a second capacitor connected in that order across a first arm of said bridge between the first DC output terminal and AC input means of said rectifier-doubler circuit, said first tripler output terminal being the junction of said fifth diode and second capacitor; and said means forming a second tripler comprising a third capacitor and a sixth diode connected in that order across a second arm of said bridge between the AC input means and second DC output terminal of said rectifier-doubler circuit, said second tripler output terminal being the junction of said sixth diode and third capacitor.

7. A power supply in accordance with claim 6 wherein: an autotransformer is connected in said lamp operating circuit loop to couple said starting circuit thereto; and said starting circuit comprises a controlled switching means and fourth capacitor connected in circuit with the primary of said autotransformer, and circuit means for periodically generating trigger pulses for said switching means, said controlled switching means being operative in response to each of said trigger pulses for discharging said fourth capacitor through the primary of said autotransformer.

8. A power supply in accordance with claim 7 wherein said power supply is adapted to be started and operated from a source of 400 Hz alternating current.

9. A power supply in accordance with claim 7 wherein said means for periodically generating trigger pulses is a relaxation oscillator.

10. A power supply in accordance with claim 9 further including a timing circuit connected across the first and second DC output terminals of said rectifier-doubler circuit and adapted to provide an output signal in the presence of a predetermined voltage across said rectifier-doubler output terminals for a predetermined period of time, and indicating means adapted to be activated by the output signal from said timing circuit, said predetermined voltage normally being present when said power supply input is connected to said source of alternating current and said arc lamp is not operating.

11. A power supply in accordance with claim 10 wherein said relaxation oscillator operates at about 5 Hz and the predetermined period of said timing circuit is about 30 seconds.