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STARTING AND OPERATING CIRCUIT FOR DISCHARGE LAMPS

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Fig. 1.

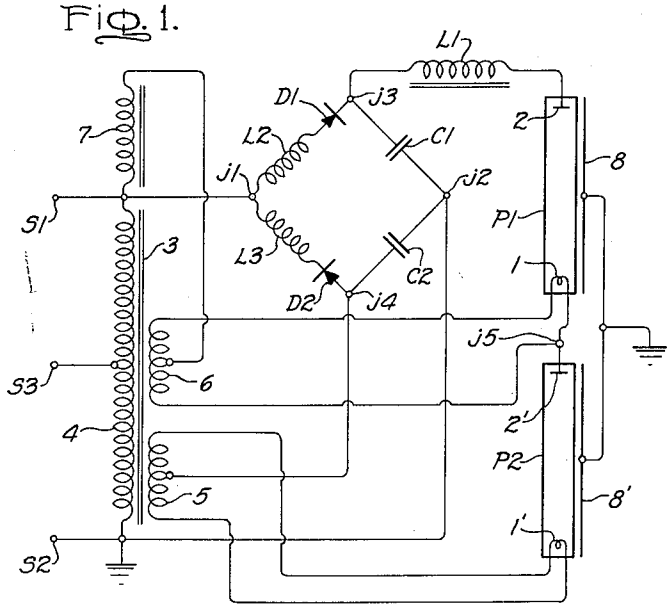
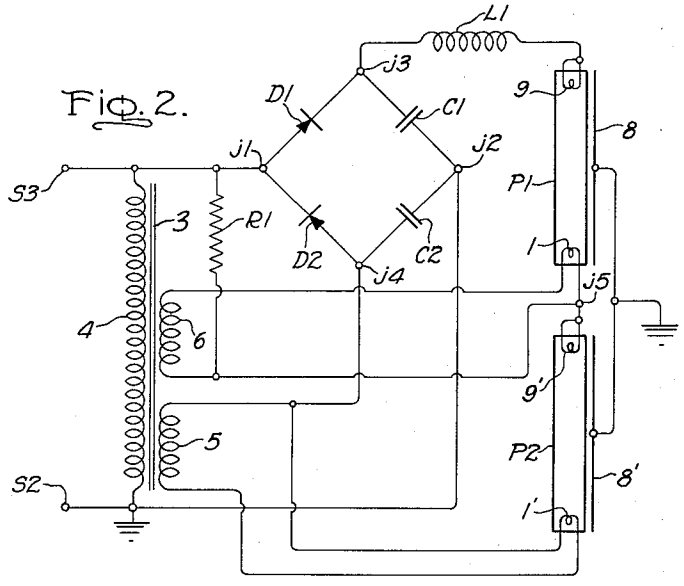


Fig. 2.



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STARTING AND OPERATING CIRCUIT FOR DISCHARGE LAMPS

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This invention relates to an improved starting and current regulating circuit using a rectifier-capacitor bridge for operating discharge lamps on rectified alternating current at high efficiency.

In copending application Serial No. 105,503 of William H. Lake, filed of even date herewith, entitled "Discharge Lamp Ballasting Circuit," and assigned to the same assignee as the present invention, there is disclosed a new type of ballast for electric discharge lamps which is termed a rectifier-capacitor bridge ballast. The rectifier-capacitor bridge is somewhat similar in its wiring configuration to the voltage-doubler circuit heretofore used in electronic equipment as a low-cost transformer-less direct current power supply of low-current capacity. When the rectifier-capacitor bridge is used as a ballasting circuit, the discharge lamp operates on unidirectional rectified current, preferably having a high ripple factor, and current flow through the lamp results not only from the discharging but also from the charging the capacitors of the bridge. The lamp current has a very pronounced alternating component having a fundamental frequency of twice the line frequency superimposed on the unidirectional component, and the polarity of the voltages across the capacitors reverses cyclically at line frequency. In the preferred mode of operation according to the Lake invention, the energy stored in the capacitors of the bridge by the input voltage is transferred with high efficiency to the lamp load, such being made possible because the discharge lamp provides a load operable in two different impedance states with a voltage-sensitive transition point.

A problem present in any discharge lamp operating circuit but found in aggravated form in the rectifier-capacitor bridge ballasting circuit is that of initially starting or striking the discharge lamps. In alternating current circuits, use is frequently made of a capacitive starting means as a conductive strip or coating on the lamp envelope, or a metal member extending the length of the lamp and which may be built into the fixture, to facilitate starting. Due to the use of alternating current, capacitive charging currents then flow from one or the other of the lamp electrodes to the capacitive member and cause the initial ionization in the lamp which gradually increases and builds up into the full discharge. However when direct or unidirectional current is used, the capacitive effect is substantially limited to the first onrush of charging current and this is ordinarily insufficient to start the lamp. This problem is particularly pronounced where it is desired to operate two fluorescent lamps in series from a single rectifier-capacitor bridge ballast circuit and the bridge is operating near the upper limit of its voltage capacity in respect of a given source voltage.

The object of the invention is to provide a convenient and economical starting circuit in conjunction with a rectifier-capacitor bridge ballasting circuit for a pair of series connected discharge lamps.

A feature of the circuit in accordance with the invention is that it allows use of a capacitive starting member extending along the lamps and placed at ground potential whereby it may be an integral part of the fixture.

In accordance with the invention, in a rectifier-capacitor bridge ballasting circuit wherein a pair of discharge lamps are connected in series across the output junctions of the

bridge, an alternating voltage relative to ground is applied to the junction of the two lamps. In one embodiment, a transformer is provided having a high reactance low-current winding which is connected to supply a relatively high A.C. voltage to the junction point of the two lamps. Since the lamps operate on unidirectional current, the junction point will consist of the connection of the cathode of one lamp to the anode of the other. Preferably a grounded capacitive member extends along the lamps in close proximity thereto and where a metal fixture is used, the reflector of the fixture may suffice for this purpose. The application of A.C. voltage to the junction of the two lamps causes capacitive charging curernts to flow through at least one of them in conjunction with the capacitive starting member, whereby that lamp becomes ionized and the voltage drop across it is redcued to the point where the bridge can start both lamps and thereafter operate in normal fashion.

In another embodiment suitable for shorter or lower voltage lamps, the junction point of the two lamps may merely by connected to the high (ungrounded) side of the A.C. supply through a current limiting impedance.

For further objects and advantages of the circuit according to the invention, attention is now directed to the following description of preferred embodiments taken in conjunction with the accompanying drawing. The features of the invention believed to be novel will be more particularly pointed out in the appended claims.

In the drawing, wherein like reference symbols denote corresponding elements in both figures:

FIG. 1 is a schematic diagram of a rectifier-capacitor bridge ballasting circuit for operating two discharge lamps in series and incorporating starting circuit means in accordance with the invention.

FIG. 2 is a schematic diagram of a variant suitable for lower voltage lamps.

Referring to the drawing, the specific circuit illustrated is intended to operate a pair of 8 ft. long fluorescent lamps P1, P2 from a 240 volt, 60 cycle A.C. line voltage applied to input terminals S1, S2. The lamps may be conventional fluorescent lamps with filamentary activated cathodes at both ends for supporting an electric discharge through mercury vapor at a low pressure. However since the lamps operate on unidirectional current, cathodes are in fact needed at one end only as indicated at 1, 1′ and a simple conductor such as a metal disc may be provided for the anodes 2, 2′ at the other end. Where commercially available fluorescent lamps having filamentary electrodes at both ends are used, the electrodes serving as anodes are not provided with heating circuits. Also, by using suitably high voltages to start the lamps as in instant start type operation, electrode preheat may be dispensed with altogether.

The rectifier-capacitor bridge proper is formed of two branches each comprising a rectifier and a capacitor connected in series between input junction points, the rectifiers being poled for conduction in opposite directions. The rectifiers are preferably high efficiency semi-conductive diodes such as silicon diodes, and the capacitors are of a type capable of withstanding A.C. As illustrated, the line terminals S1, S2 are connected respectively to input junction *j*1, *j*2 of the bridge; one branch of the bridge comprises diode D1 and capacitor C1 wherein D1 is poled to permit current flow from junction *j*1; the other branch comprises diode D2 and capacitor C2 wherein diode D2 is poled to permit current flow towards junction *j*1. In addition the first branch includes an inductor L2 connected in series between junction *j*1 and diode D1, and the second branch includes an inductor L3 connected in series between junction *j*1 and diode D2. The purpose of inductors L2, L3 is to cause additional voltage to be stored in capacitors C1, C2

whereby to increase the dynamic transformation ratio and the effective output voltage of the bridge circuit. The increase in output voltage which the bridge applies across the lamps by reason of the presence of inductors L2, L3 is in some respects similar to an increase in the input line voltage and makes possible the operation of longer lamps, or lamps having a higher operating voltage, from the same line voltage supply or A.C. source. With a higher supply voltage or with shorter lamps on the same supply voltage, inductors L2, L3 could be eliminated.

The junction points of the diode and capacitor in each branch, namely *j*3 and *j*4, form the output points across which the utilization or load circuit is connected. The load circuit comprises the load proper consisting of two lamps P1, P2 connected in series with an inductor L1. In actual practice, the ballast combination is provided with terminals or lamp holders for accommodation of the lamps in the usual way. Inductor L1 serves to limit the rate of change of current through the lamps and is made necessary by the negative impedance characteristic of the lamps in their high conduction state. The value of inductor L1 is a dominant factor in determining the mode of operation and performance of the circuit. Its value is preferably selected, in accordance with the teachings of the aforementioned Lake application, to achieve operation of the discharge lamps with a bimodal impedance variation occurring at twice the frequency of the line supply voltage.

The circuit combination includes a transformer 3 provided with a primary winding 4, a pair of low voltage center-tapped secondary windings 5, 6, and a relatively high voltage high reactance auxiliary secondary winding 7. Primary winding 4 is connected across line terminals S1, S2, terminal S2 being the low or grounded side of the A.C. supply. Secondary windings 5 and 6 are connected to supply preheating current to cathodes 1 and 1′ respectively. The center tap (or either side) of secondary winding 5 is connected to junction point *j*4 of the bridge whereby the operating or high current load circuit is complete across output terminals *j*3, *j*4 and includes the two lamps in series with inductor L1. Auxiliary winding 7 has one end connected to the high or ungrounded side of the line and the other end connected to the center tap (or either side) of secondary winding 6 whereby it is effectively connected to the junction point *j*5 of the two lamps. Thus the line voltage and the voltage of auxiliary winding 7 are effectively added in series relative to ground for application to the lamp junction. The capacitive starting means indicated at 8, 8′ may consist of conductive strips or coatings on the lamp envelopes. More conveniently, in the present instance, it may consist of a metal member extending the length of the lamps in close proximity thereto, that is at a distance not exceeding approximately an inch, and where a metal fixture is used, it may be merely the metal reflector or front conductive plate of the fixture. The capacitive starting members 8, 8 are grounded as indicated, the object of course being to place them at the same potential as the low or grounded side of the line.

In the operation of the circuit, capacitors C1, C2 initially charge in series to twice the peak A.C. line voltage, but this by itself would be insufficient to start the two lamps P1, P2 in series. However an alternating potential is simultaneously applied to cathode 1 of lamp P1 and to anode 2 of lamp P2 which consists of the sum of the line voltage plus the A.C. voltage generated in winding 7. This voltage is sufficiently high, relative to the grounded capactive starting member 8, that the charging currents flowing from cathode 1 in lamp P1 produce ionization in that lamp. After lamp P1 has ionized, the voltage drop across it is reduced and the voltage generated by the bridge is then sufficient to ionize lamp P2 whereupon normal operation ensues with the load current flowing through both lamps in series. During normal operation, winding 7 need not supply any current and therefore it is arranged as a high reactance winding in order to avoid incurring excessive losses. Alternatively or in addition, a high impedance may be connected in series with it.

Where it is desired to operate from a lower voltage supply such as a 120 volt, 60 cycle A.C. supply, an autotransformer may be used to step up the line voltage applied to the bridge. In such case, the windings of transformer 3 may conveniently be combined into the autotransformer so that a single primary winding is used, and the line terminals would be applied to terminal S2 as before, and to terminal S3 tapped into an intermediate point in primary winding 4.

A variant of the invention suitable for starting and operating shorter fluorescent lamps having lower starting and operating voltages is illustrated in FIG. 2. Lamps P1, P2 are here shown as conventional fluorescent lamps having filamentary electrodes at both ends. But only electrodes 1, 1′ serving as cathodes are preheated; electrodes 9, 9′ serving as anodes are not preheated and their respective lead wires may be short-circuited. The operating voltage requirements make inductances L2, L3 unnecessary and they are eliminated from the circuit. The starting voltage requirements are met by applying to the common lamp junction *j*5 merely the line voltage so that an A.C. potential difference equal thereto is developed between cathode 1 of lamp P1 (or anode 9′ of lamp P2) and the starting members 8, 8′. This is accomplished by connecting the high (ungrounded) side of the line at terminal S3 to one side of heater winding 6 through a current limiting resistance, suitably a resistor R1 as shown, or alternatively a small capacitor. The resistor does not carry appreciable current after the lamps have started and may be of low wattage rating, for instance 1 watt. With this arrangement transformer 3 requires only the cathode heating windings 5, 6. Where lamps that do not require electrode preheating are used, transformer 3 may be eliminated altogether, and resistor R1 would then simply be connected from the high line terminal to the common lamp junction.

By way of illustrative example of the invention, a circuit constructed in accordance with FIG. 1 of the drawing has operated under test a pair of 8′ long, 200 watt configurated fluorescent lamps, commonly designated 96PG17 (Power Groove) on a line supply voltage of 240 volts, 60 cycles A.C. The following values of circuit elements were used: for L1, 0.07 henry; for L2 and L3, 0.04 henry each; for C1 and C2, 15 microfarads each (330 volt peak A.C.). Secondary winding 7 of transformer 3 provided 320 volts R.M.S. to the junction of the two lamps measured from ground. The secondary windings 5, 6 each provided 3.5 volts to the lamp cathodes. The circuit started the lamps readily and operated them at rating without noticeable flicker. The voltage, current and power per lamp were respectively 158 volts, 1.6 amperes, and 208 watts; light output per lamp was approximately 14,000 lumens. The total power consumed from the line was 446 watts and the ballast loss was 26 watts, the ballast efficiency being 94%. The over-all efficiency of the system was 63 lumens per watt input from the line terminals, an efficiency better than that obtainable with the usual inductive ballast.

While a specific embodiment of the invention has been illustrated and described in detail, it is intended as illustrative and not in order to limit the invention thereto. Modifications will readily occur to those skilled in the art and it is intended by the appended claims to cover any such as fall within the true spirit and scope of the invention.

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

1. An operating and starting circuit for a pair of electric discharge devices comprising input terminals for alternating current energization, a rectifier-capacitor bridge having a pair of branches connected across said input terminals, each branch including a rectifier and a capacitor connected in series, the junction points of the rectifier and capacitor in each branch forming output junctions, a

utilization circuit comprising a pair of electric discharge devices connected in series across said output junctions, and high impedance means supplying an alternating voltage to the common junction of the electrodes in said devices in order to ignite them.

2. An operating and starting circuit for a pair of electric discharge devices comprising input terminals for alternating current energization, a rectifier-capacitor bridge having a pair of branches connected across said input terminals, each branch including a rectifier and a capacitor connected in series, the junction points of the rectifier and capacitor in each branch forming output junctions, a utilization circuit comprising a pair of electric discharge devices connected in series across said output junctions, high impedance means supplying an alternating voltage to the common junction of the electrodes in said devices in order to ignite them, and grounded capacitive means extending along said devices in close proximity thereto.

3. An operating and starting circuit for a pair of electric discharge devices comprising input terminals for alternating current energization, a rectifier-capacitor bridge having a pair of branches connected across said input terminals, each branch including a rectifier and a capacitor connected in series, the junction points of the rectifier and capacitor in each branch forming output junctions, a utilization circuit comprising a pair of electric discharge devices connected in series across said output junctions, and transforming means having a primary winding connected across said input terminals and a low current capacity secondary winding connected to the common junction of the electrodes in said devices to supply an alternating voltage thereto whereby to ignite said devices.

4. An operating and starting circuit for a pair of electric discharge devices comprising a pair of input terminals for alternating current energization, a rectifier-capacitor bridge having a pair of branches connected across said input terminals, each branch including a rectifier and a capacitor connected in series, the junction points of the rectifier and capacitor in each branch forming output junctions, a utilization circuit comprising a pair of electric discharge devices connected in series across said output junctions, a transformer having a primary winding connected across said input terminals, a pair of secondary low voltage windings in said transformer each connected to the electrode of one of said devices operating as cathode and supplying preheating current thereto, an auxiliary relatively high voltage low current capacity secondary winding in said transformer, and a connection from said auxiliary winding to the junction of the electrodes in said devices to supply an alternating voltage thereto whereby to ignite said devices.

5. An operating and starting circuit for a pair of electric discharge devices comprising low and high input terminals for alternating current energization, a rectifier-capacitor bridge having a pair of branches connected across said input terminals, each branch including a rectifier and a capacitor connected in series, the junction points of the rectifier and capacitor in each branch forming output junctions, a utilization circuit comprising an inductance and a pair of electric discharge devices connected in series across said output junctions, a transformer having a primary winding connected across said input terminals, a pair of secondary low voltage windings in said transformer each connected to the electrode of one of said devices operating as cathode and supplying preheating current thereto, and an auxiliary high reactance secondary winding in said transformer connected between said high input terminal and the common junction of the electrodes in said devices to supply an alterating voltage thereto whereby to ignite said devices, and grounded capacitive means extending the length of said devices in close proximity thereto.

6. An operating and starting circuit for a pair of electric discharge lamps comprising low and high input terminals for alternating current energization, a rectifier-capacitor bridge having a pair of branches connected across said input terminals, each branch including a rectifier and a capacitor connected in series, the junction points of the rectifier and capacitor in each branch forming output junctions, a utilization circuit comprising an inductance and terminals for accommodating a pair of electric discharge lamps serially connected across said output junctions, a transformer having a primary winding connected across said input terminals, a pair of secondary low voltage windings in said transformer each having terminals for connection to the electrode of one of said lamps operating as cathode and supplying preheating current thereto, and an auxiliary high reactance secondary winding in said transformer connected between said high input terminal and the common junction of the terminals for said serially connected lamps to supply an alternating voltage thereto whereby to ignite said lamps in the presence of grounded capacitive means extending along said lamps in close proximity thereto.

7. An operating and starting circuit for a pair of electric discharge devices comprising low and high input terminals for alternating current energization, a rectifier-capacitor bridge having a pair of branches connected across said input terminals, each branch including an inductor, a rectifier and a capacitor connected in series, the rectifiers being poled for conduction in opposite directions in the two branches, the junction points of the rectifier and capacitor in each branch forming output junctions, a utilization circuit comprising an inductance and a pair of electric discharge devices connected in series across said output junctions, a transformer having a primary winding connected across said input terminals, a pair of secondary low voltage windings in said transformer each connected to the electrode of one of said devices operating as cathode and supplying preheating current thereto, and an auxiliary relatively high voltage high reactance secondary winding in said transformer connected between said high input terminal and the common junction of the electrodes in said devices to supply an alternating voltage thereto whereby to ignite said devices, and grounded capacitive means extending the length of said devices in close proximity thereto.

8. An operating and ballasting circuit for a pair of electric discharge devices each having a pair of electrodes, comprising a pair of input terminals for alternating current energization, a rectifier-capacitor bridge having a pair of branches connected across said input terminals, each branch including a rectifier and a capacitor connected in series, the rectifiers being connected to one input terminal and poled for conduction in opposite directions, the capacitors being substantially equal in value and connected to the other input terminal, the junction points of the rectifier and capacitor in each branch forming output junctions, a utilization circuit comprising an inductance and a pair of electric discharge devices connected in series across said output junctions, said utilization circuit having an impedance proportioned to achieve substantial transfer of energy to said discharge devices during the charging periods of said capacitors as well as during the discharging periods, transforming means having a primary winding connected across said input terminals, a pair of low voltage secondary windings in said transformer each connected to the electrode of one of said devices operating as a cathode and supplying preheating current thereto, an auxiliary high reactance and relatively low current capacity secondary winding in said transformer, and a connection from said auxiliary winding to the junction between the cathode of one lamp and the anode of the other lamp, thereby providing to said junction an A.C. voltage with respect to ground in order to ignite said devices.

9. An operating and starting circuit for a pair of electric discharge devices comprising low and high input terminals for alternating current energization, a rectifier-

capacitor bridge having a pair of branches connected across said input terminals, each branch including a rectifier and a capacitor connected in series, the junction points of the rectifier and capacitor in each branch forming output junctions, a utilization circuit comprising an inductance and a pair of electric discharge devices connected in series across said output junctions, a transformer having a primary winding connected across said input terminals, a pair of secondary low voltage windings in said transformer each connected to the electrode of one of said devices operating as cathode and supplying pre-

heating current thereto, and a high impedance connected between said high input terminal and the common junction of the electrodes in said devices to supply an alternating voltage thereto whereby to ignite said devices, and grounded capacitive means extending the length of said devices in close proximity thereto.

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