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W. J. KARASH

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APPARATUS FOR STARTING AND CONTROLLING ELECTRIC DISCHARGE DEVICES

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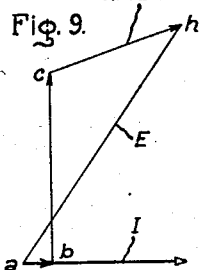
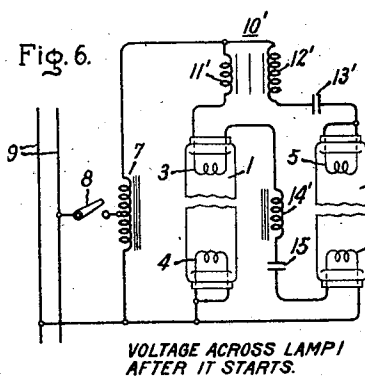
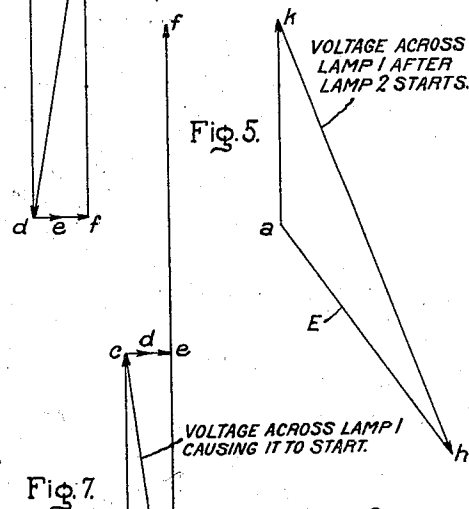
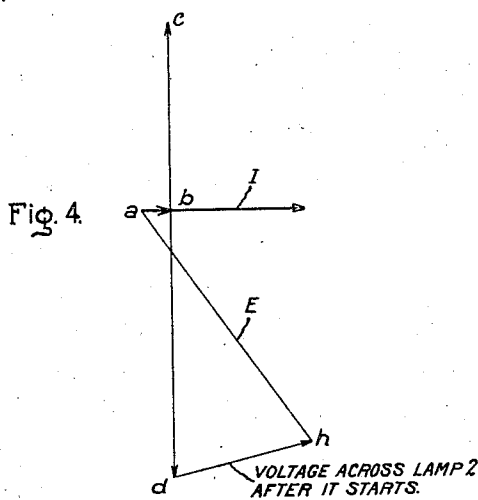
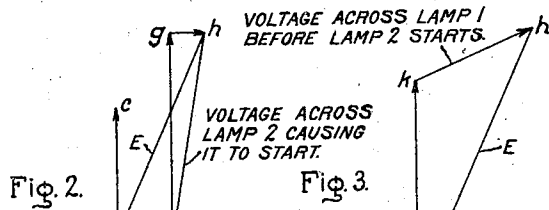
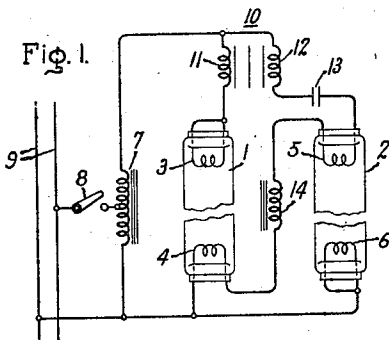
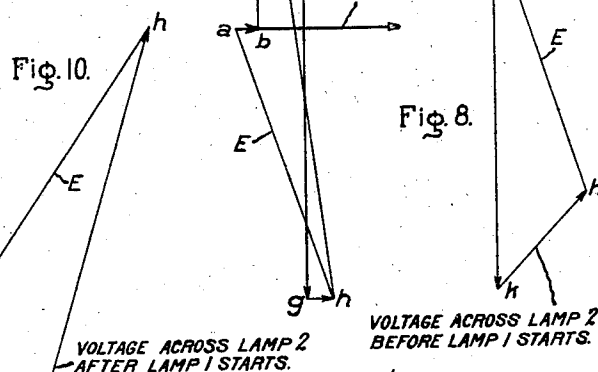


Fig. 10.



Inventor:
Walter J. Karash,
by *Harry E. Durham*
His Attorney.

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APPARATUS FOR STARTING AND CONTROLLING ELECTRIC DISCHARGE DEVICES

Walter J. Karash, Annapolis, Md., assignor to
General Electric Company, a corporation of
New York

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8 Claims. (Cl. 176—124)

My invention relates to apparatus for starting and controlling electric discharge devices such as discharge lamps of the fluorescent type which are now coming into common use. As at present constructed a lamp of that type comprises a long transparent tubular envelope containing mercury vapor at a low pressure and having its side walls coated with a suitable phosphor which under the influence of an electric discharge through the mercury vapor produces fluorescence. The lamp electrodes which are mounted in the ends of the envelope are filamentary in form and are coated with a suitable electron emissive material. Such a lamp requires for its starting the application of a voltage or electric impulse considerably higher than the voltage necessary to keep the lamp in operation after it has been started, the starting voltage required being materially less if one or both of the lamp electrodes are heated to an electron emitting temperature prior to the application thereof. A preheating of the electrodes of such lamps as they have been constructed heretofore, moreover, has been essential in order to avoid excessive damage to the electrodes by the starting voltage and the attendant blackening of the lamp walls in the vicinity of the electrodes by the material knocked off them. By reason of recent developments made in such lamps, particularly in the construction of their electrodes, prior heating of the electrodes is not as essential to the prevention of injury to the lamp as heretofore. Because of the desire to avoid the time delay occasioned by electrode preheating, notwithstanding the fact that lamps as heretofore constructed were known to be seriously injured by being continually started without electrode preheating, apparatus has been used which would produce a voltage peak or impulse sufficiently high to make the lamp break down immediately upon its application thereto. Such apparatus had the disadvantage that it was electrically inefficient and was cumbersome, since it had poor material utilization, and accordingly was expensive to manufacture.

It is an object of my invention to provide improved apparatus for starting and controlling discharge devices with which the above-mentioned disadvantage may be avoided. Another object of my invention is the provision of such starting and controlling apparatus with which the energy losses are reduced to a low value.

My invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

Referring to the drawing, Figs. 1 and 6 are circuit diagrams illustrating two embodiments of my invention, and Figs. 2 to 5 inclusive and Figs. 7 to 10 inclusive are vector diagrams relating thereto.

In Fig. 1 two long tubular similar discharge devices, which for example may be 40 watt fluorescent lamps, are shown diagrammatically at 1 and 2, the one having filamentary electrodes 3 and 4 and the other having filamentary electrodes 5 and 6 of which the electrodes 3 and 6 may or may not be short circuited. The envelopes of the lamps contain mercury vapor at low pressure and the side walls thereof have a phosphor thereon which when excited by a discharge through the mercury vapor produces fluorescence. The two lamps have their circuits connected to be operated in parallel from the secondary of the step-up auto transformer 7 the voltage of which secondary may for example be 220 volts. The primary of the transformer 7 is connected through the switch 8 to be supplied from the source 9 of alternating current which for example may be a 115 volt, 60 cycle lighting circuit.

In the connection between the lamps and the transformer 7 is the transformer 10 whose windings 11 and 12 are wound in the same direction on the core and are loosely coupled with each other. The turn ratio of the winding 11 to the winding 12 preferably is about 1.07 and their reactive impedances may for example be 400 and 350 ohms respectively. During the operation of the lamps the winding 11 functions as the ballast for the lamp 1; hence the current in that lamp is lagging and the winding 12, together with the capacitor 13, whose reactive impedance may be 830 ohms, in series therewith functions as the ballast for the lamp 2. The reactive impedance of the capacitor predominates over the reactive impedance of the winding 12; hence the current in the lamp 2 is leading. As a result of this arrangement, whereby the two lamp circuits are supplied in parallel from the same source, the one lamp circuit drawing a lagging current and the other drawing a leading current, the net power factor of the two circuits combined is nearer to unity than that of either circuit alone. Also, when illumination is obtained from both lamps, there is a reduction in the stroboscopic effect obtained with illumination from either lamp alone.

Lamps such as represented at 1 and 2 require, if started without any preheating of their electrodes, a voltage which, if in the form of a sine

wave, has an R. M. S. value of approximately 350 volts. Since, as mentioned previously, the secondary voltage of the transformer 7 is only 220 volts, neither lamp will start merely with the voltage applied to it by that transformer, nor would either start even if their electrodes were preheated.

The apparatus by which a starting voltage is obtained will now be described. Connecting the electrodes 4 and 5 is the reactor 14 whose reactive impedance may, for example, be 1000 ohms. Current supplied by the transformer 7 will flow through a circuit including the winding 12, the capacitor 13, the electrode 5, the reactor 14, and the electrode 4, the net reactance of which circuit is inductive; hence the current therein is lagging. With the lagging current in the winding 12 the voltage induced in the winding 11 by transformer action opposes the voltage applied thereto by the transformer 7 whereby the net voltage applied to the lamp 1 will be about 90 volts, which is insufficient to start the lamp. Because of the combination of inductive and capacitive reactance in the above-mentioned circuit a voltage will appear across the winding 12 of about 150 volts and across the reactor 14 of about 425 volts, which is sufficient to cause the lamp 2 to start, particularly since the current in the electrode 5 immediately begins to heat that electrode. The lamp 2, having started, comprises a relatively low resistance shunt across the reactor 14. The supply circuit of that lamp includes the winding 12 and the capacitor 13, and, as the reactive effect of the latter in that circuit predominates, the lamp current is leading. Now, with a leading current in the winding 12, the voltage induced in the winding 11 by transformer action will add to the voltage applied thereto by the transformer 7, producing a net voltage applied to the lamp 1 of approximately 370 volts which, since the electrode 4 has been heated by current flow therethrough, will cause that lamp to start. Both lamps thereafter continue to operate, the lamp 1 with a lagging current and the lamp 2 with a leading current.

The above-mentioned phase relations of the currents and voltages and the effects thereof on the voltage applied to the lamp 1 are represented approximately by the vector diagrams comprising Figs. 2 to 5. These diagrams, however, are only approximate since all of the voltage waves which they represent are assumed for convenience to be sine waves although actually some because of distortion depart somewhat from true sine waves. Since the resistances of the lamp filaments and the transformer and reactor windings are relatively small, the voltage drops therein due to resistance have been exaggerated for convenience in making the diagrams.

In Fig. 2 the vector I represents in direction the current in the circuit comprising the elements 12, 13, 5, 14, and 4 immediately upon closing the switch 8 and the vector E drawn to a scale of one inch per 100 volts represents in length and position the voltage supplied by the transformer 7, the value of the current being approximately .425 ampere and lagging. The voltages across the various elements of the circuit added vectorally must equal the supply voltage. The voltage across the winding 12 is the sum of the voltages due to its resistance and its reactance, or $a-b$ plus $b-c$; the voltage across the capacitor 13 is $c-d$; that across the electrode 5 is $d-e$; that across the reactor 14 is the sum of the voltages due to its resistance and its react-

ance, or $e-f$ plus $f-g$; and the voltage across the electrode 4 is $g-h$. The sum of the voltages across the elements 5, 14, and 4 shown by the line $d-h$ is that which causes the lamp 2 to start, namely 425 volts. Referring now to Fig. 3 the voltage at the same time across the winding 11 due to the winding 12 is 1.07 times as great as the voltage across that winding, is in phase with it, and is represented by the line $a-k$. This, combined with the voltage E of the transformer 7, gives the voltage $k-h$ across the lamp 1 before the lamp 2 starts as 90 volts.

After the lamp 2 starts, the current in that lamp becomes leading and the voltages are as shown in Fig. 4. The voltage in winding 12 is made up of the resistance component $a-b$ and the inductive component $b-c$; the voltage across the capacitor 13 is shown by $c-d$; and the voltage across the lamp 2 is shown by $d-h$. It will be noted that the vector $d-h$ is not parallel with the vector I, as would be expected, inasmuch as the impedance of a discharge device is resistive in character. This departure from parallelism, however, is known to be due to the distortion of the lamp voltage by the lamp, the distortion causing the lamp impedance to appear to have a certain small inductive component.

In Fig. 5, as in Fig. 3, $a-k$ is the voltage across the winding 11 after the lamp 2 starts, which, combined with the voltage E of the transformer 7, gives as the voltage across the lamp 1 after the lamp 2 has started $k-h$ or 370 volts.

Referring now to the form of my invention illustrated by circuit diagram shown by Fig. 6, the transformer 7, the supply circuit 9, and the lamps are similar to the correspondingly numbered parts in Fig. 1. The loosely coupled transformer 10' in this case has its winding 12' wound oppositely to the winding 11' on the same core and has a turn ratio with respect to the winding 11' of 1.414. The reactive impedances of the windings 11' and 12' may, for example, be 400 and 800 ohms respectively. During the operation of the lamps the lamp 1 has a lagging current and the lamp 2 has a leading current. The capacitor 13' may have a reactive impedance of 1260 ohms.

Connected in a circuit shunting the lamp 1 and including the electrodes 3 and 6 are the reactor 14' whose reactive impedance may for example be 500 ohms and the capacitor 15 whose reactive impedance may for example be 1330 ohms.

When the apparatus is energized by closing the switch 8, neither lamp will start by reason of the voltage applied to it by the transformer 7. Current of approximately .51 ampere flows, however, in the circuit comprising the winding 11', the electrode 3, the reactor 14', the capacitor 15, and the electrode 6, producing a voltage across the lamp 1 of about 425 volts, which is sufficient to start it. At the same time a voltage of about 205 volts is produced in the winding 11'. Because the winding 12' is wound oppositely to the winding 11' and has a turn ratio of 1.414 with respect thereto and because the current in the winding 11' is leading, the resultant voltage impressed upon the lamp 2 is approximately 100 volts. After the lamp 1 starts, it shunts the reactor 14' and the capacitor 15. As the only reactance then in the circuit of that lamp is the winding 11', the lamp operates on a lagging current. Under lagging current conditions in the winding 11' the voltage produced in the winding 12' by transformer action is additive to the voltage of the source whereby approximately 440

volts are applied to the lamp 2 which causes it to start. Because of the capacitor 13 the lamp 2 having started operates on a leading current.

Referring now to the vector diagrams comprising Figs. 7 to 10, which are similar to the diagrams shown in Figs. 2 to 5 but relate to the circuit shown by Fig. 6, the vector I represents in direction the current in the circuit comprising the elements 11', 3, 14', 15, and 6 immediately upon closing the switch 8, and the vector E represents in length and position the voltage supplied by the transformer 7, the value of the current being approximately .510 ampere and leading. The voltage across the winding 11' is the sum of the voltages due to its resistance and its reactance, or $a-b$ plus $b-c$; the voltage across the electrode 3 is $c-d$; the voltage across the reactor 14' is $d-e$ plus $e-f$; the voltage across the capacitor 15 is $f-g$; and the voltage across the electrode 6 is $g-h$. The sum of the voltages across the elements 3, 14', 15, and 6 shown by the line $c-h$ is that which causes the lamp 1 to start, namely, 425 volts. Referring to Fig. 8, the voltage at the same time across the winding 12' due to the winding 11' is 1.414 times as great as the voltage across that winding, is in phase opposition with it, and is represented by the line $a-k$. This, combined with the voltage E, shows by the line $k-h$ that the value of the voltage across the lamp 2 before the lamp 1 starts is approximately 100 volts.

After the lamp 1 starts, the voltage values are as shown in Fig. 9 where the voltage across the winding 11' is $a-b$ plus $b-c$ and the voltage across the lamp 1 is $c-h$. The voltage then across the winding 12' due to the winding 11' is shown by the line $a-k$ as shown in Fig. 10 which, combined with the voltage E, gives the voltage $k-h$ or 440 volts applied to the lamp 2, which starts it.

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

1. In combination, a plurality of electric discharge devices arranged to be connected with a source of alternating current supply, the voltage of which is less than the starting voltage of said devices, a first reactive means connected to be responsive to the voltage across one of said devices, a second reactive means whose reactive voltage is opposite to that of said first reactive means connected in series with said one device, and means responsive to the current passing said one device after it starts for increasing the voltage applied to the other of said devices from said source.

2. In combination, a plurality of electric discharge devices, connecting means for supplying each device from a source of alternating current, the connecting means for one of said devices including a first inductive member and the connecting means for the other of said devices including a first reactive member and a second inductive member in series therewith and inductively related to said first inductive member, and a second reactive member, the reactive voltage of which is opposite to that of said first reactive member, connected to be responsive to the voltage across said other device, the current in said second inductive member being operative after said other device starts to induce a voltage in said first inductive member which is additive to the voltage applied to said one device from said source.

3. In combination, a plurality of electric discharge devices, connecting means for supplying

each device from a source of alternating current, the connecting means for one of said devices, including a first inductive member and the connecting means for the other of said devices including a capacitive member and a second inductive member in series therewith and inductively related to said first inductive member, and a third inductive member connected to be responsive to the voltage across said other device, the current in said second inductive member, after said other device starts, being leading and being operative to induce a voltage in said first inductive member which is additive to the voltage applied to said one device from said source.

4. In combination, a plurality of electric discharge devices having filamentary electrodes, means for connecting said devices with a source of alternating current to be supplied in parallel therefrom, the connecting means for one of said devices including a first inductive member and the connecting means for the other of said devices including a capacitive member and a second inductive member in series therewith and inductively related to said first inductive member, and a third inductive member connected in a circuit shunting said other device and including one electrode of each of said devices, the current flowing through said second inductive member before said other device starts serving to heat said one electrode of each device and after said other device starts being operative to induce a voltage in said first inductive member which is additive to the voltage applied to said one device from said source.

5. In combination, a plurality of electric discharge devices having filamentary electrodes, means for connecting said devices with a source of alternating current to be supplied in parallel therefrom, a transformer having one winding included in the connecting means of one of said devices and having another winding included in the connecting means of the other of said devices, said latter connecting means including a capacitor between said other winding and said other device, and a reactor connected to be responsive to the voltage across said other device, the current traversing said other winding of the transformer being lagging before said other device starts and being leading after it starts and the windings of said transformer being arranged to cause the voltage induced in said one winding to add to the supply voltage when the current in said other winding is leading.

6. In combination, a plurality of electric discharge devices, connecting means for supplying each device from a source of alternating current, the connecting means for one of said devices including reactive means, means connected in a circuit shunting said one device and operative in cooperation with said reactive means to raise the voltage applied to said one device from said source to effect the starting of that device, and means responsive to the current in the connecting means for said one device after that device has started for raising the voltage applied to the other device from said source to effect the starting thereof.

7. In combination, a plurality of electric discharge devices, connecting means for supplying each device from a source of alternating current, the connecting means for one of said devices including a first inductive member and the connecting means for the other of said devices including a first reactive member and a second inductive member in series therewith and inductively related to said first inductive member, and a capacitive circuit connected to be responsive to

the voltage across said one device, the current in said first inductive member being operative after said one device starts to induce a voltage in said second inductive member which is additive to the voltage applied to said other device from said source.

8. In combination, a plurality of electric discharge devices, connecting means for supplying each device from a source of alternating current, the connecting means for one of said devices including a first inductive member and the connecting means for the other of said devices including

a first reactive member and a second inductive member in series therewith and inductively related to said first inductive member, and a circuit connected to be responsive to the voltage across said one device including a third inductive member and a capacitor in series therewith, the current in said first inductive member after said one device starts being lagging and being operative to induce a voltage in said second inductive member which is additive to the voltage applied to said other device from said source.

WALTER J. KARASH.