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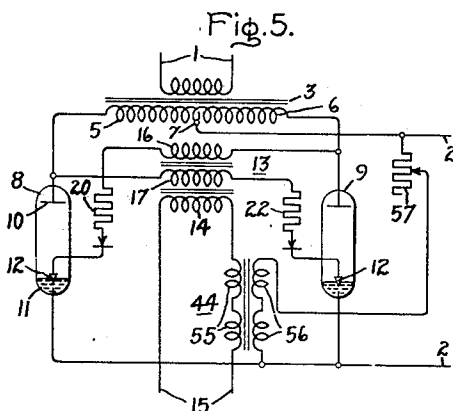
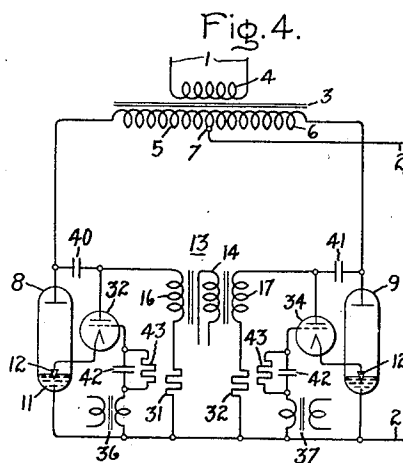
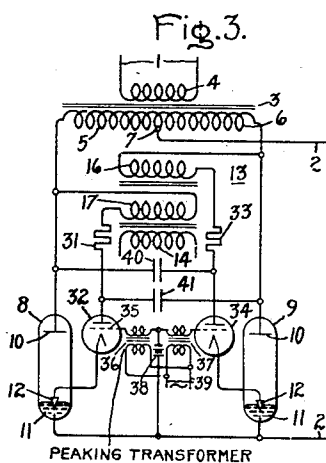
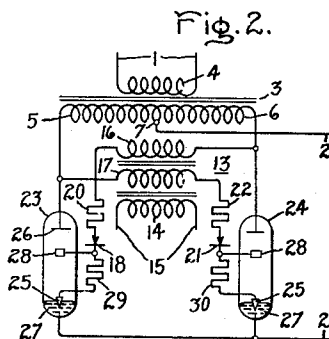
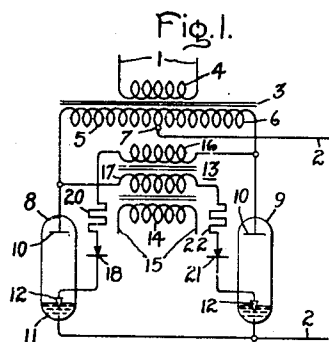
C. H. WILLIS ET AL

2,359,181

ELECTRIC VALVE CIRCUIT

Filed July 22, 1941

2 Sheets-Sheet 1



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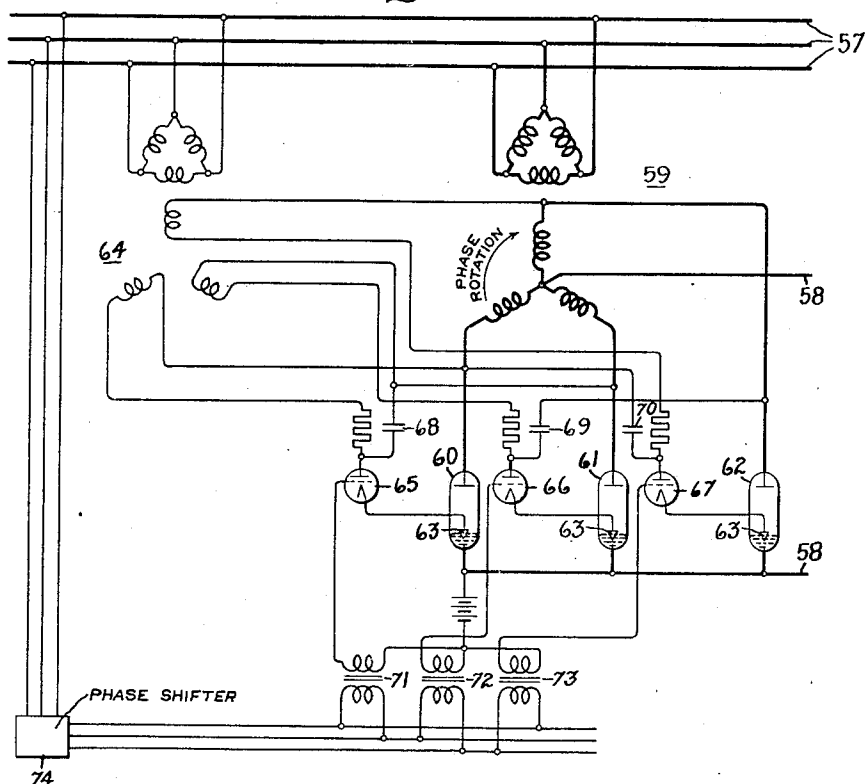
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2 Sheets-Sheet 2

Fig. 6.



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UNITED STATES PATENT OFFICE

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ELECTRIC VALVE CIRCUITS

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Application July 22, 1941, Serial No. 403,542

9 Claims. (Cl. 175—363)

Our invention relates to electric valve circuits and more particularly to control or excitation circuits for electric valve means of the type employing an ionizable medium, such as a gas or a vapor.

In the control of electric valve apparatus, such as electric valve means including an ionizable medium such as a gas or a vapor capable of supporting an arc discharge, it is frequently desirable to provide control circuits which effect deenergization of the control member after the arc discharge has been established between the anode and cathode of the electric valve means. For example, in electric valve apparatus employing an immersion-ignitor control member constructed of a material such as boron carbide or silicon carbide, it is of advantage in some applications to effect deenergization of the control member after the arc discharge has been established, thereby relieving the duty imposed on the control member and consequently increasing the life of the control member and the electric valve means.

It is an object of our invention to provide new and improved electric valve circuits.

It is another object of our invention to provide new and improved control or excitation circuits for electric valve translating apparatus.

It is a further object of our invention to provide new and improved control or excitation circuits for electric valve means employing immersion-ignitor control members.

Briefly stated, in the illustrated embodiments of our invention, we provide improved control or excitation circuits for transmitting energizing impulses of current to control members of the immersion-ignitor type and in which the flow of current to the control members is interrupted after the establishment of arc discharges within the electric valve means. For example, in translating apparatus including a plurality of electric valve means which are intended to conduct a current in a predetermined order of sequence, we provide new and improved arrangements for effecting deenergization of the control member of an electric valve means in response to the change in conductivity of an electric valve means preceding it in the order of phase rotation.

In several embodiments of the invention we provide means including commutating capacitances connected between the excitation circuits and the electric valves in order to effect the interruption of the current to the control members in response to a change in the conductivity

of the electric valve means other than the one to which the excitation circuit is connected.

For a better understanding of our invention, reference may be had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims. Fig. 1 diagrammatically illustrates an embodiment of our invention as applied to a bi-phase rectifier or inverter, and Fig. 2 is a modification of the arrangement of Fig. 1 as applied to electric valves having transfer or relieving anodes. Fig. 3 diagrammatically illustrates an embodiment of our invention wherein commutating capacitances are connected between the excitation circuits and the electric valves for effecting interruption of the current transmitted to the control members, and Fig. 6 is a three phase arrangement of the system shown in Fig. 3. Fig. 4 diagrammatically illustrates an embodiment of our invention wherein coupling means are employed between the excitation circuits of the various electric valve means and wherein the energization of the control members is effectively interrupted in response to the state of conductivity of the electric valve means. Fig. 5 is a modification of the arrangement shown in Fig. 1 wherein voltage control and phase shifting means are employed for automatically controlling an electrical condition, such as the voltage, of an associated load circuit.

Referring now to Fig. 1 of the accompanying drawings, our invention is there illustrated as applied to an electric valve translating system for interconnecting an alternating current supply circuit 1 and a direct current load circuit 2. The translating apparatus includes an inductive means such as a transformer 3 having a primary winding 4 and a plurality of secondary windings or electrically displaced winding sections 5 and 6. One conductor of the direct current load circuit 2 may be connected to an intermediate or neutral connection of transformer 3. The translating apparatus also includes a plurality of arc discharge paths such as that provided by a pair of electric valve means or electric discharge devices 8 and 9 each including an anode 10, a cathode 11 and a control member 12 which may be of the immersion-ignitor type constructed of a material such as boron carbide or silicon carbide having an extremity thereof extending into the mercury of the cathode and requiring the transmission of a critical minimum value of current therethrough in order to establish an arc discharge.

We provide a plurality of excitation means or

circuits for transmitting energizing impulses of current to the control members 12 and for effecting the interruption of the current transmitted to control members 12 in response to a change in the state of conductivity of the electric discharge preceding it in the order of phase rotation. For example, when the translating means is of the type such as that shown in Fig. 1 it will be appreciated that electric discharge devices 8 and 9 conduct current alternately, and that the deenergizing control may be derived from circuits associated with the other electric discharge device. When our invention is applied to a poly-phase electric valve converting system, it will be understood by those skilled in the art that the control is obtained from that electric valve preceding it in the order of phase rotation. More specifically, our invention comprises inductive means, such as a transformer 13 having a winding 14 which is energized from a suitable source of alternating current 15 and which serves to energize the control members 12 of electric discharge devices 8 and 9 through secondary windings 16 and 17, respectively. The excitation means is also arranged for transmitting deenergizing impulses of current to the control members in accordance with the voltage of a winding section electrically displaced from the winding section applying voltage to the associated arc discharge path. Winding 16 is connected from the anode 10 of electric discharge device 8 to the control member 12 of electric valve means 8 through a suitable unidirectional conducting device 18 and a resistance 20, and the winding 17 is connected between the anode 10 of electric discharge device 8 and the control member 12 of electric discharge device 9 through a unidirectional conducting device 21 and a resistance 22. By virtue of this arrangement of the windings, it will be apparent that energizing current from the transformer 13 is transmitted to a control member 12 only as long as the anode of the other electric valve is positive with respect to the cathode bus or essentially as long as the arc discharge path of the other electric valve means is maintained in a conducting condition. However, as soon as the electric discharge device 8 becomes non-conducting following the transmission of an energizing impulse of current to control member 12 of electric discharge device 8 by transformer secondary winding 16, the current for energizing this control member is interrupted. The primary winding 14 of transformer 13 may be energized by a voltage which is in phase with respect to the voltage of the supply circuit 1 or having a predetermined angle of displacement with respect thereto.

The operation of the embodiment of our invention shown in Fig. 1 will be explained by considering the system when it is operated as a bi-phase rectifier for transmitting unidirectional current to the load circuit 2. It will be understood by those skilled in the art that electric discharge devices 8 and 9 conduct current alternately, and that upon rendering one of the electric discharge devices conducting the then conducting discharge device will be rendered non-conducting by the phenomenon now generally known as "phase commutation." This expression has been quite generally adopted to describe the function of effecting transfer of current between various electric discharge paths due to the relative magnitude of the respective phases, the current being conducted to that discharge path whose anode is more positive in potential. Of

course, it is to be understood that commutation of current between the various discharge devices will not become effective unless the control member is energized to ionize the medium. The transformer 13 serves to impress an alternating component of voltage to control members 12 of electric discharge devices 8 and 9 through the circuits including secondary windings 16 and 17.

Let it be assumed that electric discharge device 9 is conducting current, having previously been rendered conducting by the proper energization of its control member 12. At a definite time during the positive half cycle of anode-cathode voltage applied to the electric discharge device 8 by winding section 5 and determined by the phase relationship of the voltage of source 15, an energizing impulse of current will be transmitted to control member 12 of electric discharge device 8 through a circuit including winding 16, resistance 20, unidirectional conducting device 18, control member 12, cathode 11, load circuit 2 and secondary winding section 6 back to winding 16. The transmission of current to control member 12 of electric discharge device 8 establishes a cathode spot on cathode 11 and consequently initiates an arc discharge between anode 10 and cathode 11, thereby not only rendering the electric discharge device 8 conducting but also assists in effecting the commutation of current from the electric discharge device 9. The energizing current for control member 12 continues to flow until the discharge path of electric discharge device 9 becomes nonconducting as a result of the anode thereof becoming negative with respect to the cathode bus. As soon as arc discharge device 9 becomes non-conducting, the circuit for energizing the control member 12 has introduced therein the inverse voltage of winding section 6 and the load circuit voltage which overcomes the positive energizing voltage from winding 16 and thereby terminates the flow of current through control member 12. In like manner, the control member 12 of electric discharge device 9 will be energized through secondary winding 17, resistance 22, unidirectional conducting device 21, load circuit 2, and the secondary winding section 5, and will be deenergized upon the transfer of current from electric discharge device 8 to discharge device 9.

In this manner, it will be appreciated that we have provided a simple and highly satisfactory circuit for effecting the interruption of current transmitted to an immersion-ignitor control member after the arc discharge path of an electric valve means has been rendered conducting and after the previously conducting electric valve means has been rendered nonconducting.

Fig. 2 represents a modification of the arrangement shown in Fig. 1 and is shown as applied to electric valves means 23 and 24 of the type employing an ionizable medium, such as a gas or a vapor, and which includes immersion-ignitor control members 25, anodes 26, cathodes 27 and transfer or relieving anodes 28. The transfer or relieving anodes are employed to effect the transfer of current from control members 25 as soon as an arc discharge is established within the electric discharge devices. Transfer resistances 29 and 30 are connected between the control members 25 and the relieving anodes 28 to raise the potential of the relieving anodes 28 as soon as cathode spots are established and consequently effect the transfer of the excitation current to the relieving anodes 28.

In operation, the arrangement of Fig. 2 per-

forms substantially the same as that explained above in connection with Fig. 1. The excitation circuits for exciting the control members 25 are effectively interrupted as soon as the previously conducting electric discharge device becomes nonconducting. In addition, the arrangement of Fig. 2 operates to effect transfer of the excitation current from the control members 25 to the relieving anodes 28 as soon as cathode spots are established on the surface of cathodes 27. Considering the operation of the system at the time of initiation of the transmission of current to control member 25 of electric discharge device 23, the alternating component of voltage supplied by secondary winding 16 is transmitted to control member 25 and a unidirectional impulse of current is transmitted through the control member. The establishment of a cathode spot on the cathode 27 effectively reduces the total impedance of the excitation circuit and accordingly causes the transmission of an increased amount of current which greatly raises the potential of the upper terminal of resistor 29 and consequently raises the potential of the relieving anodes 28. By virtue of this increase of potential, the excitation current is transmitted between the cathode 27 and relieving anode 28, thereby reducing the current which the control member 25 is required to conduct and accordingly relieving the duty imposed thereon.

Another modification of our invention is shown in Fig. 3 and which includes apparatus corresponding to certain elements of the arrangement of Fig. 1 and corresponding elements have been assigned like reference numerals. In the arrangement of Fig. 3 we provide a plurality of excitation means including windings 16 and 17 of transformer 13 which are connected to be responsive to the anode voltages of the electric discharge devices 8 and 9, respectively. That is, the excitation circuits of these electric discharge devices are responsive to the voltages applied to these discharge devices and there is also supplied an alternating component of voltage by means of primary windings 14 which is energized from a suitable source of alternating current. Considering the excitation circuit for electric discharge device 8, a current limiting resistance 31 and a control electric valve means 32 are connected in series relation with control member 12 to transmit thereto unidirectional impulses of current. Referring to the excitation circuit for electric discharge device 9, the current limiting resistance 33 and control electric valve means 34 are connected in series relation to energize control member 12. The control electric valves 32 and 34 are preferably of the type employing an ionizable medium and each includes a control member 35. The conductivities of the control electric valves 32 and 34 are preferably controlled by an excitation circuit including a pair of peaking transformers 36 and 37 and a source of negative unidirectional biasing potential such as a battery 38. The phase of the alternating voltages of peaked wave form supplied by transformers 36 and 37 may be derived from and controlled by a source of alternating current 39 which may be arranged to be of adjustable phase relationship with respect to the voltage of circuit 1.

We provide coupling or commutating means, such as a plurality of commutating capacitances 40 and 41, to effect the interruption of the current transmitted to the control members of the electric discharge devices in response to the change in conductivity of another electric dis-

charge device. For example, the commutating capacitance 41 is connected between the anode 10 of discharge device 9 and the excitation circuit for discharge device 8 and serves to impress on the excitation circuit a transient voltage sufficient to render the control electric valve means 32 nonconducting when the discharge device 9 becomes nonconducting. In like manner, the commutating capacitance 40 is connected to de-energize the control member 12 of discharge device 9 as soon as discharge device 8 becomes nonconducting.

The operation of the arrangement of Fig. 3 will be explained by considering the system when it is supplying direct current to load circuit 2. If it be assumed that the electric discharge device 9 is conducting current, an energizing impulse of current will be transmitted to control member 12 of discharge device 8 at a time determined by the magnitude and phase position of the voltage supplied by winding 17 and the control of the conductivity of control electric valve means 32. The phase of the alternating voltage of peaked wave form produced by transformer 36 renders the control electric valve means 32 conducting and consequently an energizing impulse of current will be transmitted to control member 12 through a circuit including winding 17, resistance 31 and control electric valve 32. The control electric valve 32 will continue to conduct current so long as its anode remains sufficiently positive in potential with respect to the cathode. The transmission of energizing current to control member 12 initiates an arc discharge between anode 10 and cathode 11 of discharge device 8, and current is commutated from discharge device 9 to discharge device 8. Discharge device 9 upon becoming nonconducting introduces a transient voltage into the excitation circuit for discharge device 8, effectively lowering the potential of the anode of control electric valve 32 and rendering valve 32 nonconducting. In this manner, the circuit for energizing control member 12 of discharge device 8 is controlled to interrupt the flow of current to the control member as soon as the discharge device 9 becomes nonconducting. Of course, it will be understood that commutating capacitance 40 operates in a similar manner to render the control electric valve 34 nonconducting after current has been commutated from discharge device 8 to discharge device 9 and after discharge device 8 becomes nonconducting. Due to the negative unidirectional biasing potential furnished by battery 38, the control electric valves 32 and 34 are maintained nonconducting due to the fact that the voltage of transformers 36 and 37 are of peaked wave form, and these electric valves are maintained nonconducting until the proper times during the succeeding positive half cycles established by the phase of the peaked voltages.

In the arrangement of Fig. 4, the transformer 13 is inductively coupled to the excitation circuits for the electric discharge devices 8 and 9 and the commutating capacitances 40 and 41 are connected between the anodes of electric discharge devices 8 and 9 and the anodes of the control electric valves 32 and 34, respectively. Instead of using a battery for providing a negative unidirectional biasing potential, we may employ the parallel connected capacitances 42 and resistances 43 for this purpose.

The capacitances 40 and 41 of the arrangement of Fig. 4 introduces into the excitation circuits for discharge devices 8 and 9 a negative transient

voltage to render nonconducting the electric valves 32 and 34 when the discharge devices 3 and 9 become conducting. In this manner, the currents for energizing the control members 12 are interrupted as soon as arc discharges are established within the electric discharge devices.

We have illustrated in Fig. 5 an embodiment of our invention as applied to a system for automatically controlling an electrical condition, such as the voltage of the load circuit 2. The arrangement of Fig. 5 includes many of the elements of Fig. 1 and corresponding elements have been assigned like reference numerals. In order to control the phase of the alternating component of voltage supplied to control members 12 of discharge devices 8 and 9, we provide suitable means responsive to the voltage of load circuit 2 and which may comprise a saturable inductance 44 including windings 45 connected in series relation with primary winding 14 and control windings 56 which are energized by variable amounts of unidirectional current through an adjustable resistance 57. The resistance 57 may be adjusted to establish the time during the positive half cycles of voltage at which the energizing impulses of current are transmitted to the control members 12 and, hence, control the magnitude of the voltage impressed across load circuit 2. As the voltage of circuit 2 varies, the amount of current transmitted to winding 56 also varies to shift the phase of the voltage of windings 16 and 17 in a manner to compensate for the load voltage change. For example, if the voltage of load circuit 2 tends to rise above a predetermined value, the current transmitted to winding 56 increases, thereby causing a retardation in phase of the voltages induced in windings 16 and 17. As a result, the energizing impulses supplied to control members 12 will be retarded in phase and the electric discharge devices 8 and 9 will be rendered conducting at later times during the positive half cycles of voltage, returning the direct current load voltage to the desired value. The system, of course, operates to raise the voltage if it tends to decrease below the desired value.

Fig. 6 diagrammatically illustrates certain aspects of our invention as applied to a polyphase system wherein a polyphase alternating current supply circuit 57 is employed to energize a direct current load circuit 58 through translating apparatus including a transformer 59 and electric discharge devices 60-62 having control members 63 of the immersion-ignitor type. We provide a plurality of excitation circuits for transmitting current to control members 63. The excitation circuits are energized through a transformer 64 and include control electric valves 65, 66 and 67. As in Fig. 3, we may employ between the excitation circuits and the electric valves preceding in the order of phase rotation, suitable commutating means such as commutating capacitances 68, 69 and 70 to effect interruption of the control member current as soon as the electric valves preceding in the order of phase rotation become nonconducting. Peaking transformers 71, 72 and 73 may be energized from the alternating current circuit 57 through a phase shifter 74 to control the time at which the electric valves 65-67 are rendered conducting and, hence, control the load voltage. The arrangement of Fig. 6 operates substantially the same as that explained above in connection with the arrangement of Fig. 3.

While we have shown and described our invention as applied to particular systems of con-

nections and as embodying various devices diagrammatically shown, it will be obvious to those skilled in the art that changes and modifications may be made without departing from our invention, and we, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of our invention.

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

1. In combination, an alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising an inductive means including a plurality of electrically displaced winding sections and a plurality of electric discharge paths each associated with a different one of said winding sections and each including a control member for controlling the conductivity of the associated path, a source of alternating voltage having a predetermined phase relation relative to the voltage of said alternating current circuit for transmitting impulses of current to the respective control members in a predetermined order, and a plurality of excitation circuits arranged one for each of said control members and including in each excitation circuit in series relation said source of alternating voltage and the electrically displaced winding section associated with an electric discharge path immediately preceding in the order of firing of said plurality of discharge paths so that current flow initiated through the control member of one discharge path by said source of alternating voltage is terminated during conduction of its associated discharge path by an opposing voltage derived from said last mentioned winding section upon interruption of current flow in the discharge path associated with said last mentioned winding section.

2. In combination, an alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising inductive means including a plurality of electrically displaced winding sections and a plurality of electric discharge paths each including an anode, a cathode, and a control member requiring the transmission of a predetermined minimum value of current therethrough in order to initiate current conduction between the associated anode and cathode, the various electric discharge paths each being connected to a different one of said winding sections, a unilateral conducting device connected in series relation with each control member for permitting current flow only from said control member to said cathode, means including a source of alternating voltage for supplying energizing impulses of current in the direction of conductivity of said unilateral conducting device to the respective control members in a predetermined order, and a plurality of excitation circuits arranged one for each control member and including in series relation in each excitation circuit means for deriving a component of voltage from said source of alternating voltage and an electrically displaced winding section associated with the electrical discharge path immediately preceding in the order of phase rotation for introducing a component of voltage in said excitation circuit opposite to the component of voltage from said source of alternating voltage upon interruption of current flow in the discharge path associated with said last mentioned winding section and having a value sufficient to cause termination of current flow in said control mem-

ber during conduction of its associated discharge path.

3. In combination, an alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising an inductive means including a plurality of electrically displaced winding sections and a plurality of electric discharge paths each associated with a different one of said winding sections and each including an anode, a cathode and a control member for controlling the conductivity of the associated path, and excitation means for energizing the control members by transmitting energizing impulses of current to one of the control members and comprising a transformer having a primary winding energized by alternating current and a secondary winding connected between the control member of one of said electric discharge paths and the anode of another electric discharge path for impressing on the associated control member a voltage to effect deenergization of the control member when said another discharge path is rendered nonconducting.

4. In combination, an alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising an inductive means including a plurality of electrically displaced winding sections and a plurality of electric discharge paths each associated with a different one of said winding sections and each including an anode, a cathode and a control member for controlling the conductivity of the associated path, and excitation means for transmitting an energizing impulse of current to the control member of one of said electric discharge paths comprising a transformer having a primary winding energized by alternating current and having a secondary winding connected in series relation with a unidirectional conducting device, said secondary winding and said device being connected between said control member and the anode of another electric discharge path for impressing on the associated control member a voltage to effect deenergization of the control member when said another discharge path is rendered nonconducting.

5. In combination, an alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising an inductive device having a pair of electrically displaced winding sections and a pair of electric discharge paths each associated with a different one of said winding sections and each including an anode, a cathode and a control member for controlling the conductivity of the associated path, and excitation means for transmitting alternately energizing impulses of current to the control members and comprising a transformer including a primary winding energized by alternating current and a pair of secondary winding sections which are connected between the control members and the winding sections which are electrically displaced relative to the winding sections which supply the associated discharge paths for supplying voltage to effect deenergization of the control members.

6. In combination, an alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuit and comprising an inductive device having a pair of electrically displaced winding sections and a pair of electric discharge paths each associated with a different one of said winding sections and each including an anode, a cathode and a control member

for controlling the conductivity of the associated path, and excitation means for transmitting energizing impulses of current alternately to the control members and comprising a transformer including a primary winding energized by alternating current and a pair of secondary windings, one of said secondary windings being connected in series relation with a rectifier and being connected between the control member of one of said electric discharge paths and the anode of the other discharge path and the other secondary winding being connected in series relation with a rectifier and connected between the control member of said other electric discharge path and the anode of said one discharge path.

7. In combination, an alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising inductive means including a plurality of electrically displaced winding sections and a plurality of electric discharge paths each associated with a different one of said winding sections and each including a control member for controlling the conductivity of the associated path, a plurality of excitation means connected to the control members of different predetermined electric discharge paths for transmitting energizing impulses of current thereto, and commutating means connected between the excitation means for discontinuing the energization of the control members when the electric discharge path preceding in the order of phase rotation become nonconducting.

8. In combination, an alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising inductive means including a plurality of electrically displaced winding sections and a plurality of electric discharge paths each associated with a different one of said winding sections and each including a control member for controlling the conductivity of the associated path, a plurality of excitation means for transmitting energizing impulses of current to the control members to render the electric discharge paths conducting in a predetermined order, and commutating means including a capacitance connected between the excitation means for one of the discharge paths and the electric discharge path preceding in the order of phase rotation for effecting deenergization of said control member when the preceding electric discharge path is rendered nonconducting.

9. In combination, an alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising inductive means including a plurality of electrically displaced winding sections and a plurality of electric discharge paths each associated with a different one of said winding sections and each including a control member for controlling the conductivity of the associated path, a plurality of excitation means for transmitting energizing impulses of current to the control members to render said discharge paths conducting in a predetermined order, and commutating capacitances connected between the excitation circuits and the electric discharge paths preceding in the order of phase rotation to effect deenergization of the control members when the preceding electric discharge path becomes nonconducting.

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