July 8, 1941. E. F. W. ALEXANDERSON ET AL 2,248,600

ELECTRIC VALVE CIRCUITS

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Fig. 1.

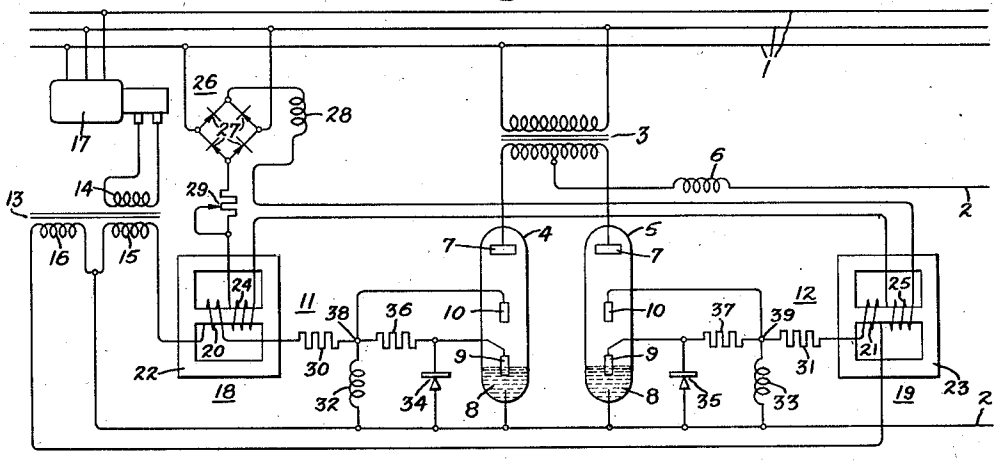


Fig. 2.

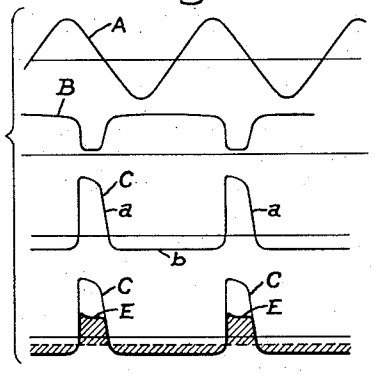


Fig. 3.

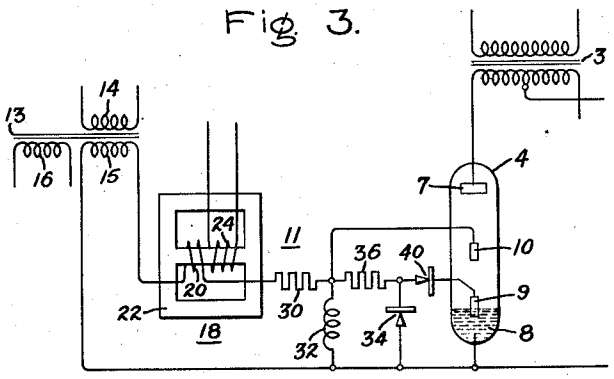


Fig. 4.

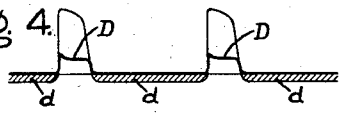


Fig. 1a

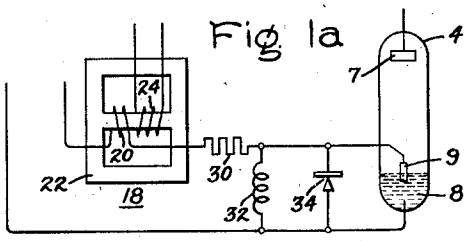
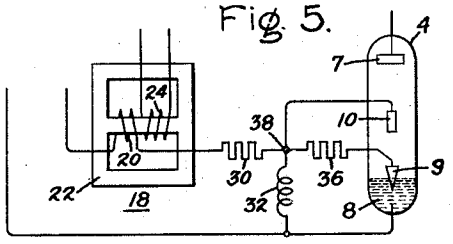


Fig. 5.



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ELECTRIC VALVE CIRCUITS

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Fig. 2a.

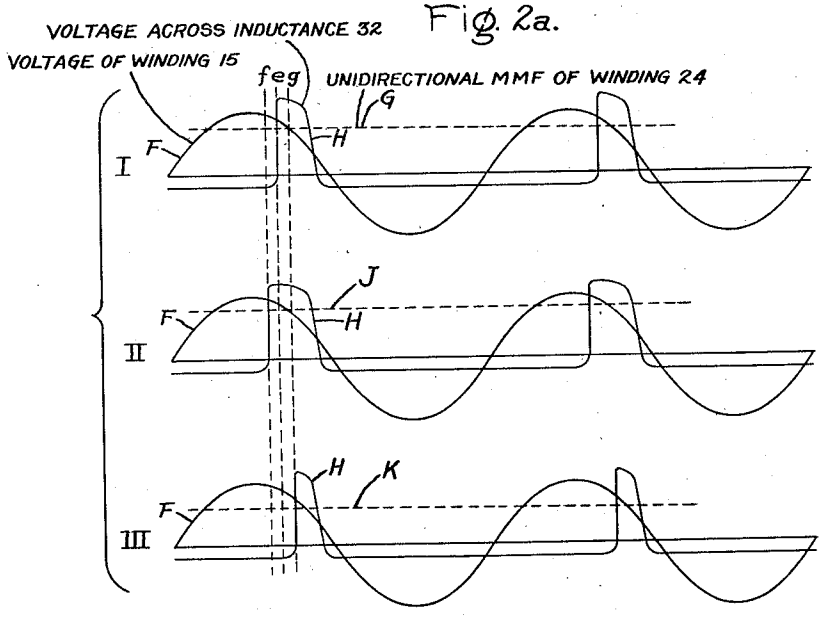
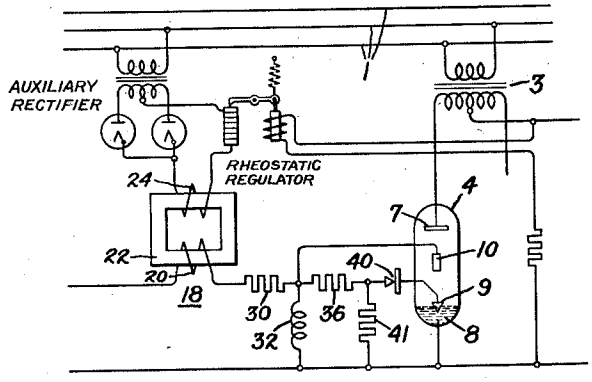


Fig. 6.



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ELECTRIC VALVE CIRCUITS

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Fig. 7.

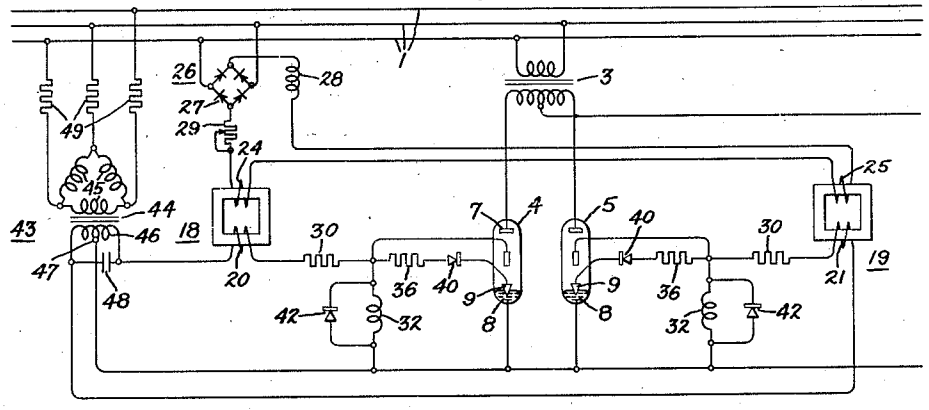
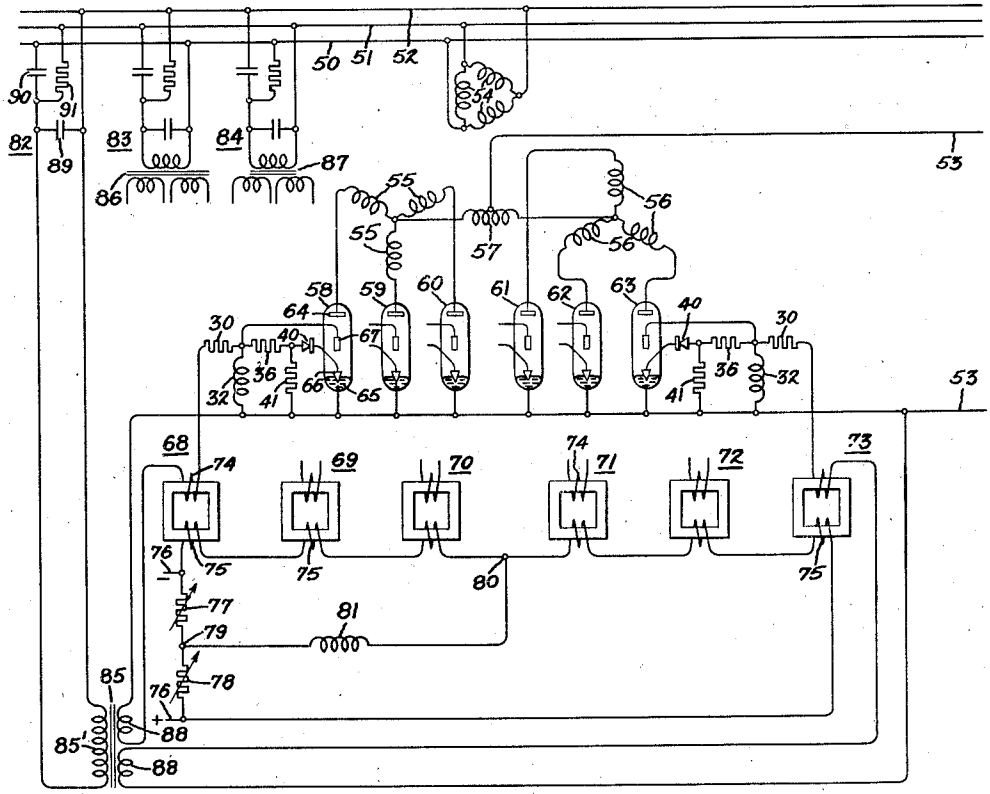


Fig. 8.



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Fig. 9.

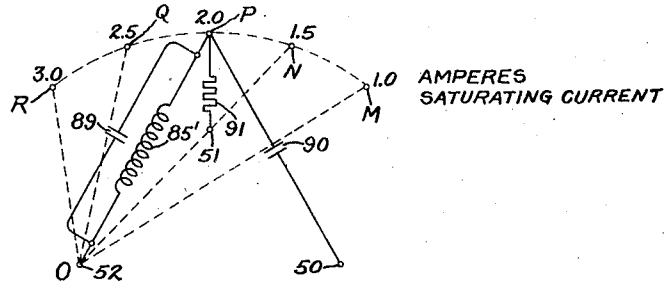
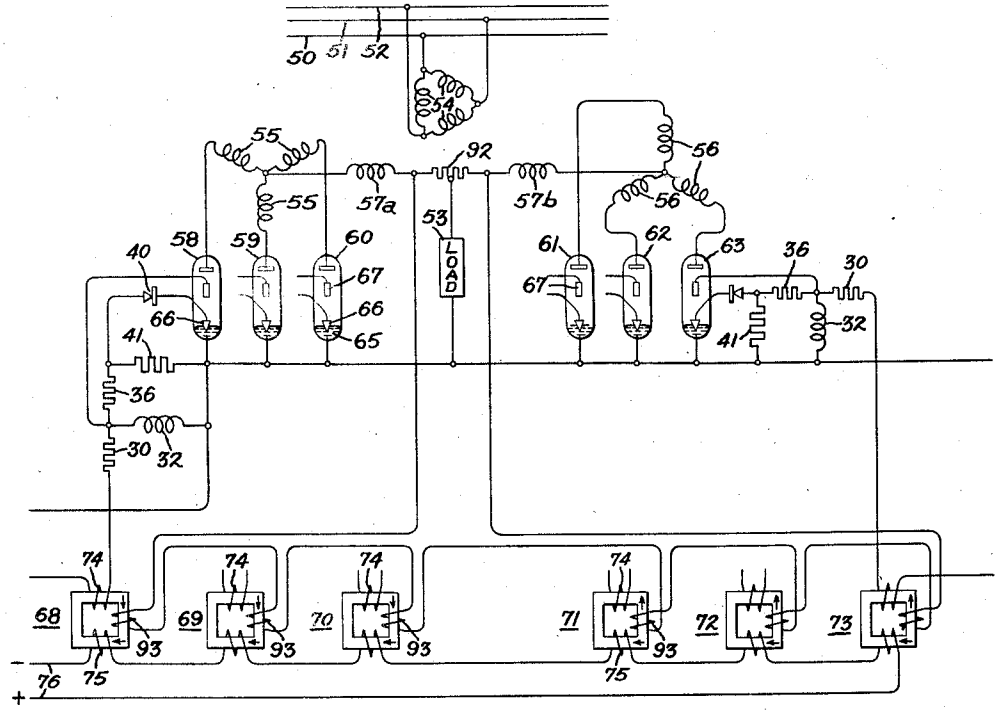


Fig. 10.



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UNITED STATES PATENT OFFICE

2,248,600

ELECTRIC VALVE CIRCUITS

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Application May 3, 1940, Serial No. 333,187

38 Claims. (Cl. 175—363)

Our invention relates to electric valve circuits and more particularly to control or excitation circuits for electric valves of the type having a control member for controlling the conductivity thereof.

This application is a continuation-in-part of our application Serial No. 285,110, filed July 18, 1939, entitled "Electric valve circuits" and which is assigned to the assignee of this application.

Frequently, in the control of electric valve means having control members, it is desirable to impress on the control members voltages of predetermined wave form, such as voltages of peaked wave form. In many applications it is important, in order to obtain the desired precision of operation of the electric valve means to provide periodic control voltages, the positive portions of which are of substantially greater magnitude and of shorter duration than the negative portions. It is also preferable in some applications to provide periodic voltages which are of peaked wave form and which may be utilized to impress on the control member of an associated electric valve only positive voltages of peaked wave form.

Where electric valve means employ control members of the immersion-ignitor or make-alive type, we have found it expedient to impress on the control members voltages of peaked wave form and to reduce the value of inverse current which the control members are required to transmit. We have found that by reducing the magnitude of the inverse voltage applied to the make-alive electrodes, the life of the electric valve means is appreciably increased.

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

It is another object of our invention to provide new and improved control or excitation circuits for electric valve means of the controlled type.

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

Briefly stated, in the illustrated embodiments of our invention, we provide new and improved control circuits for supplying to control members of electric valve means periodic or alternating voltages of peaked wave form. The excitation circuits are energized from an associated source of alternating current. In several embodiments of our invention, alternating voltages are impressed on the control members, the positive portions of the voltage being of substantially greater magnitude and of shorter duration than the negative portions. In another embodiment of our invention, the periodic voltage impressed on the control member is of peaked wave form and the negative portions of the voltage are substantially eliminated so that only unidirectional current is supplied to the control members.

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. Figs. 1, 1*a*, 3 and 5 diagrammatically illustrate embodiments of our invention as applied to electric valve means employing control members of the immersion-ignitor or make-alive type, and Figs. 2, 2*a* and 4 represent certain operating characteristics. Figs. 6 and 7 diagrammatically illustrate other embodiments of our invention as applied to electric valve converting systems. Figs. 8 and 10 represent still further embodiments of our invention as applied to load balancing systems for polyphase rectifying systems, and Fig. 9 represents certain operating characteristics thereof.

Referring now to Fig. 1 of the accompanying drawings, our invention is there diagrammatically illustrated as applied to an electric translating system for transmitting power between an alternating current supply circuit 1 and a direct current load circuit 2 through apparatus including a transformer 3 and electric valve means 4 and 5. A smoothing inductance 6 may be connected in series relation with the load circuit 2. The electric valve means 4 and 5 are preferably of the type employing an ionizable medium, such as a gas or a vapor, and each comprises an anode 7, a cathode 8 and a control member 9. The electric valve means 4 and 5 may be of the type disclosed and claimed in U. S. Patent No. 2,069,283—Slepian et al.—granted February 2, 1937. That is, the cathodes 8 may be of the mercury pool self-reconstructing type and the control members 9 may be of the make-alive or immersion-ignitor type composed of a material such as boron-carbide, silicon-carbide, or a material such as that disclosed and claimed in U. S. Patent 1,822,742 granted September 8, 1931, on an application of Karl B. McEachron and which is assigned to the assignee of the present application. If desired, the electric valve means 4 and 5 may each be provided with an auxiliary electrode or a holding anode 10.

In order to energize the control members 9 of electric valve means 4 and 5, we provide control or excitation circuits 11 and 12, respectively. Excitation circuits 11 and 12 are energized from a suitable source of alternating current, such as the

alternating current circuit 1. The excitation circuits may be energized from circuit 1 through a transformer 13 having a primary winding 14 and secondary windings 15 and 16. As a means for adjusting the phase of the output voltages of secondary windings 15 and 16, we employ any suitable phase shifting device such as a rotary phase shifter 17. Excitation circuits 11 and 12 include means for producing voltages of peaked wave form such as saturable inductive devices 18 and 19 which comprise windings 20 and 21, respectively. The inductive devices 18 and 19 include saturable core structures or members 22 and 23 and associated unidirectional magnetizing members such as unidirectionally energized windings 24 and 25, respectively. The unidirectionally energized windings 24 and 25 magnetically bias the core members 22 and 23 so that the core members are unidirectionally saturated. The core members 22 and 23 are preferably constructed of a magnetic material which becomes abruptly saturated. These core members may be constructed of ordinary transformer iron or may be constructed of special magnetic materials such as that disclosed and claimed in U. S. Letters Patents Nos. 1,862,357 and 1,862,365 granted June 7, 1932, upon applications of W. E. Ruder and which are assigned to the assignee of the present application. As a means for supplying unidirectional current to the windings 24 and 25, we may employ a rectifier 26 including a plurality of unidirectional conducting devices 27, a smoothing inductance 28.

As a means for controlling or varying the unidirectional magnetization of the devices 18 and 19 and thereby to control the phase of the impulses of current transmitted to control members 9 with respect to the respective anode-cathode voltages of electric valve means 4 and 5, or with respect to the voltage of circuit 1, we provide a suitable current controlling means, such as an adjustable impedance or resistance 29, which may be connected in series relation with the output circuit of the rectifier 26. Of course, it will be understood that the current controlling means may be automatically controlled in response to a predetermined electrical condition of the translating apparatus or in response to a predetermined electrical condition, such as the voltage, of the alternating current circuit 1 or the direct current load circuit 2.

To impress on the control members 9 periodic or alternating voltages of peaked wave form, the positive portions of which are of substantially greater magnitude and of shorter duration than the negative portions, we provide, in series relation with the windings 20 and 21 respectively, suitable impedance elements such as resistances 30 and 31. The winding 20 and resistance 30 are, of course, energized from the secondary winding 15 of transformer 13, and the winding 21 and associated resistance 31 are energized in series relation from the secondary winding 16 of transformer 13. We provide inductances 32 and 33 which are connected in circuit in series relation with windings 20 and 21 and resistances 30 and 31, respectively, to provide a short-circuit path for the direct current components of voltage which would appear across the immersion-ignitors 9. Accordingly, the inductances 32 and 33 serve to reduce the value of the negative voltages impressed on the immersion-ignitor control members 9. We may, if desired, also use suitable unidirectional conducting devices 34 and 35 connected between the cathodes 8 and control members 9 of electric valve means 4 and 5, respectively, to serve as discharge paths for inductances 32 and 33 and thereby to limit the magnitude of the negative portions of the control voltages impressed on control members 9. The unidirectional conducting devices 34 and 35 are preferably of the type disclosed and claimed in U. S. Patent 1,640,335 granted August 23, 1927, upon an application of Lars O. Grondahl. These unidirectional conducting devices are poled in opposition to the normal or intended direction of current flow between the control members 9 and the associated cathodes 8.

To control the excitation circuits 11 and 12 to reduce the voltage applied to the control members 9 when the ionizable medium of the electric valve means 4 and 5 is in an ionized state, we provide suitable controlling means such as resistances 36 and 37 connected between the common junctures 38 and 39 of resistance 30 and inductance 32, and resistance 31 and inductance 33, respectively, and the holding anodes 10. These circuits serve to control the potentials of the common junctures 38 and 39 in accordance with the state of ionization of the medium to reduce the voltages applied to the control members when the medium is ionized.

It is to be understood that the auxiliary electrodes or holding anodes 10 are connected to the respective associated circuits in a manner to be responsive to the voltage appearing across the inductances 32 and 33. The resistances 30 and 31 may be connected ahead of the coils 20 and 21 if desired. That is, the resistances 30 and 31 may be connected between windings 15 and 16 of transformer 13 and windings 20 and 21 respectively.

Certain features of the control circuit including an auxiliary electrode or holding anode to effect transfer of current from the immersion-ignitor control members as soon as an arc discharge is established within the electric valve means are disclosed and broadly claimed in a copending patent application of Carl C. Herskind, Serial No. 326,924, filed March 30, 1940, and which is assigned to the assignee of this application.

The operation of the embodiment of our invention shown in Fig. 1 will be explained by considering the system when it is operating as a biphase rectifier to transmit unidirectional current to the load circuit 2 from the alternating current circuit 1 through transformer 3 and electric valve means 4 and 5. Periodic voltages are supplied to the control members 9 to render the electric valve means 4 and 5 conductive, and these electric valve means are rendered conductive alternately to transmit both half cycles of current to the load circuit 2. The average value of current transmitted to the load circuit 2 may be controlled by controlling the time during the positive half cycles of anode-cathode voltage at which the electric valve means are rendered conductive. As the times of initiation of arc-discharges are advanced towards the zero point of the positive half cycles of applied voltage, the average output voltage is increased and, conversely, as these instants are retarded in phase, the average output voltage is decreased. Adjustment of the rotary phase shifter 17 permits adjustment and control of the times during the positive half cycles of applied anode-cathode voltage at which the electric valve means 4 and 5 are rendered conductive. Hence, in this manner by the adjustment of phase shifter 17, the magnitude of the voltage

impressed on the direct current circuit 2 may be controlled.

Due to the fact that the core members 22 and 23 are unidirectionally biased magnetically by the action of the windings 24 and 25, the windings 20 and 21 offer an unsymmetrical impedance to the flow of current therethrough; that is, these windings offer a relatively small impedance to the flow of current through the winding when it is in a direction tending to set up a flux which assists that established by the windings 24 and 25, and offer a much greater impedance to that polarity of current flowing through windings 20 and 21 when the current tends to establish a flux in opposition to the flux established by windings 24 and 25. Accordingly, the current which is transmitted through the resistances 30 and 31 will be of unsymmetrical wave form and accordingly the voltage appearing across the terminals of resistances 30 and 31 will be of unsymmetrical wave form. This voltage is a periodic voltage having positive portions of substantially greater magnitude and shorter duration than the negative portions.

The operation of the excitation circuits 11 and 12 may be more fully appreciated by referring to the operating characteristics shown in Fig. 2. Curve A represents the voltage applied to one of the excitation circuits, as for example excitation circuit 11, by secondary winding 15 of transformer 13. Curve B represents the unsymmetrical impedance of the winding 20, and curve C represents the current transmitted through resistance 30 in the excitation circuit 11. Curve C may also represent the voltages impressed across cathodes 8 and the terminals of resistances 30 and 31 by windings 15 and 16 and the saturable inductive devices 18 and 19, respectively. It will be noted that the positive portions *a* are of substantially greater magnitude and shorter duration than the negative portions *b*. We have found that very satisfactory operation occurs when the duration of the positive portions is in the neighborhood of seventy electrical degrees.

Curve E represents the voltages appearing across the inductances 32 and 33 and hence represents the voltage applied to the control members 9 when arc discharges are initiated near the beginning of the positive peaks of the voltage. As soon as the medium becomes ionized, the voltage drop through resistances 36 and 37 reduces the potentials of the associated control members 9 and causes the greater portion of the excitation circuit current to be transferred to the holding anodes 10: The inductances 32 and 33 serve as paths for the direct current components of current which flow through the holding anode circuits. The zero axis of the alternating voltages of the excitation circuits is thereby lowered and the magnitudes of the negative portions of the voltages are correspondingly decreased. In this manner, the magnitude of the negative portions of the voltages applied to the control members is reduced, thereby relieving to a great extent the duty imposed on the control members.

The resistances 36 and 37 serve as a means for reducing the magnitude of the positive voltages applied to the control members 9 as soon as the ionizable medium of the electric valves becomes ionized. That is, the resistances serve to reduce the voltages applied to the control members 9, thereby effecting transfer of the largest part of the current to the holding anodes 10 as soon as the arc discharges are initiated within the electric valve means. It will be readily appreciated that as soon as an arc discharge is established within the electric valve means, most of the current will be conducted between the holding anodes 10 and the associated cathodes 8, thereby greatly relieving the duty imposed on the control members 9. That is, these circuits control the potentials of the junctures 38 and 39 to permit application of large positive voltages to the control members 9 only when the ionizable medium is nonionized.

The manner in which the adjustment of the resistance 29 controls or shifts the phase of the periodic voltages of peaked wave form supplied to the control members 9 may be more fully appreciated by referring to the operating characteristics shown in Fig. 2*a*. The sinusoidal voltage F represents the voltage supplied to windings 20 or 21 of the inductive devices 18 and 19. For the purpose of simplification, the operation of the circuit will be explained by considering the curve F as representing the voltage supplied to the inductive device 18 by winding 15 of transformer 13. Curve G represents the unidirectional magnetomotive force established in inductive device 18 by winding 24, and the curve H represents the voltage across inductance 32 which is, of course, impressed on the control member 9 of electric valve means 4. The wave front of the voltage of peaked wave form for the arrangement shown in Diagram I occurs at time *e* due to the unidirectional magnetomotive force there shown. The exact point or time during the half cycles of voltage of winding 15 at which the voltage appearing across the inductance 32 increases abruptly is determined by the relation between the magnetomotive force produced by winding 24 and the magnetomotive force due to the exciting current flowing in winding 20. The abrupt increase of current through inductance 32 occurs at the knee of the saturation curve of the core member 22. In Diagram II, the unidirectional magnetomotive force has been increased to a value J, effecting an advance in the effective phase position of the periodic voltage to time *f*. In Diagram III, the unidirectional magnetomotive force has been decreased to a value corresponding to the value of curve K and consequently the wave front of the voltage of peaked wave form is retarded to time *g*. It will be appreciated that a considerable variation in the effective phase position of the wave front of periodic voltage of peaked wave form may be controlled or adjusted by controlling the unidirectional current transmitted to winding 24. We have found that the effective phase position of the voltage of peaked wave form may be shifted throughout a region of the order of magnitude of fifteen electrical degrees.

Of course, it will be understood that our invention is not limited to arrangements employing holding anodes and associated circuits for the anodes. For example, our invention may be illustrated as shown in Fig. 1*a* where the unidirectional conducting device 34 is connected directly across the inductance 32, the cathode 8 and the control member 9. The apparatus shown in Fig. 1*a* is merely a fragmentary representation of the portion of the circuit shown in Fig. 1. The embodiment of our invention shown in Fig. 1*a* operates to supply to the control members 9 currents such as that represented by curve C in Fig. 2.

Fig. 3 diagrammatically illustrates another embodiment of our invention but merely shows a

fragmentary portion of the circuit shown in Fig. 1 and corresponding elements have been assigned like reference numerals. Where it is desired to transmit only positive impulses of current to the control members 9, we provide a unidirectional conducting device 40 connected in series relation with the associated control member 9. The current supplied to the control member 9 is represented by the heavy curve D of Fig. 4. The unidirectional conducting device 40 effectively suppresses or prevents the flow of the negative current represented by the shaded portions *d* of Fig. 4. The other elements of the circuit operate in substantially the same way as that explained above in connection with Fig. 1.

Fig. 5 diagrammatically illustrates a still further simplified embodiment of our invention in which the holding anode is connected to the common juncture of resistance 30 and inductance 32. The immersion-ignitor control member is connected to this juncture through resistance 36. Of course, the excitation circuit is energized by alternating current as shown in Fig. 1.

The circuit of Fig. 5 operates to impress on the control member 9 an alternating voltage having positive portions of substantially greater magnitude and shorter duration than the negative portions. As explained above in connection with Fig. 1, as soon as the arc discharge is established, the greater portion of the current present in the excitation circuit is transferred to the holding anode 10, thereby relieving the current carrying duty imposed on the control member 9. The inductance 32 serves as a path for the unidirectional component of current present in the excitation circuit. This unidirectional current may be considered as flowing through holding anode 10, cathode 8 and inductance 32. By so by-passing the unidirectional component of current, the zero axis of the alternating output voltage of the excitation circuit is lowered effecting a reduction in the magnitude of the negative portions thereof.

Fig. 6 diagrammatically illustrates a further embodiment of our invention which is similar in many respects to that shown in Fig. 3. Instead of using a unidirectional conducting device 34 connected between the cathode 8 and the common juncture of resistance 36 and unidirectional conducting device 40, we provide a suitable symmetrically conducting device, such as a resistance 41.

In order to control the phase of the voltage impressed on control member 9 in response to a predetermined controlling influence, we provide apparatus for variably energizing winding 24 of inductive device 18. This controlling influence may be an electrical condition of the translating apparatus or of one of the associated circuits, such as the voltage of the direct current circuit. In the specific embodiment of the invention illustrated, we have chosen to show a rheostatic regulator connected in series relation with the winding 24 and in series relation with the output of an auxiliary rectifier which, in turn, may be energized from the alternating current circuit 1.

The arrangement of Fig. 6 operates to impress on the control member 9 a unidirectional periodic voltage of peaked wave form, having positive portions of short duration. Upon the initiation of an arc discharge within the electric valve means, current is transferred to the auxiliary electrode 10 thereby transferring the current from the control member 9 and reducing the duty imposed thereon.

The rheostatic regulator operates to vary the amount of current transmitted to winding 24 of device 18 to maintain the output voltage impressed across the direct current circuit at a constant value. If the voltage of the direct current circuit tends to rise above a predetermined value, the energization of the actuating coil of the regulator is increased, relieving the pressure on the resistance element of the regulator and effecting a resultant decrease in current through winding 24. As explained above in Fig. 2*a*, the voltage of peaked wave form appearing across inductance 32, that is the voltage supplied to control member 9, is retarded in phase, tending to restore the direct current output voltage to the desired value. Conversely, if the voltage of the direct current circuit tends to decrease, the resultant resistance of the rheostatic regulator is increased effecting an increase in the current transmitted to winding 24 and advancing the phase of the periodic voltage impressed on control member 9. While we have shown a particular type of regulator for controlling the current in winding 24, it is to be understood that any other suitable arrangement for automatically varying the current transmitted to winding 24 may be employed.

A still further embodiment of our invention is diagrammatically illustrated in Fig. 7, and like elements have been assigned reference numerals corresponding to the embodiments of the preceding figures. In the arrangement of Fig. 7, we connect a unidirectional conducting device 42 across the inductance 32, thereby providing an unsymmetrical path for the flow of current through the control circuit and consequently tending to reduce the magnitude of the negative portions of the periodic voltage present in the excitation circuit.

As additional means for shifting the phase of the periodic voltage of peaked wave form produced by the excitation circuit upon variation of the unidirectional current transmitted to winding 24, we provide a phase shifting circuit 43 comprising a transformer 44 having primary winding or windings 45 and a secondary winding 46 provided with a neutral connection 47. A suitable phase compensating or adjusting means, such as a capacitance 48, is connected across the terminals of the secondary winding 46. Suitable impedance elements, such as resistances 49, are connected in series relation with the primary windings 45 to produce variations in phase of the output voltage of secondary winding 46 upon variations in the amount of lagging reactive current transmitted through secondary winding 46, depending upon the unidirectional magnetization of the inductive device 18. In this manner, the phase of the periodic voltage of peaked wave form supplied to control members 9 is shifted by an additional amount determined by the variable angular displacement of the impedance drop appearing across resistances 49.

Transformer 44 may be a three phase transformer, if desired, to energize excitation circuits for a polyphase electric valve converting system. Additional secondary windings (not shown) may be associated with the other two primary windings 45 to energize four additional electric valve means in the event an electric valve converting system employing six electric valve means is used.

The system shown in Fig. 7 permits control of the phase of the periodic voltages impressed on control members 9 of electric valve means 4 and 5 relative to the voltage of circuit 1. The shift in phase of these periodic voltages is the resultant of two effects; one of these effects is a shift in phase of the voltage appearing across inductance 32 with respect to the voltage of secondary winding 46 of transformer 43, and the second effect is that produced by the flow of variable amounts of lagging or reactive current through the resistances 49, which produces a shift in phase between the secondary voltages induced in winding 46 relative to the voltage of circuit 1. Consequently, the resultant shift in phase of the periodic voltages impressed on control members 9 is the sum of these two phase displacements. The phase displacements are additive or accumulative, and are effected by variation or control of the amount of unidirection current transmitted to control windings 24 and 25.

Fig. 8 diagrammatically illustrates an embodiment of our invention as applied to a polyphase electric valve converting system for transmitting power between a polyphase alternating circuit comprising conductors 50, 51 and 52 and a direct current circuit 53. The translating apparatus interconnecting the alternating current circuit and the direct current circuit may include a transformer comprising primary windings 54 and two groups of secondary windings 55 and 56 interconnected through an interphase transformer 57 so that the system operates as a double three-phase system. Electric valve means 58—63 are connected to the secondary windings 55 and 56 and transmit current in a predetermined order. Due to the interconnection of the groups of secondary windings 55 and 56, each electric valve conducts current for 120 electrical degrees but for only 60 electrical degrees with any one other electric valve of another group. That is, two electric valves, one in each group, are conducting current at any one time. These electric valves are also of the type preferably employing an ionizable medium and having an anode 64, a self-reconstructing cathode such as a mercury pool cathode 65, and an immersion-ignitor control member 66 and an auxiliary electrode 67.

In order to supply periodic voltages of peaked wave form to the control members 66 of electric valves 58—63, we provide a plurality of excitation circuits, several of the elements of which correspond to the elements in the excitation circuit of Fig. 6, and corresponding elements have been assigned like reference numerals. Each of the electric valves 58—63 is provided with an excitation circuit, but only the excitation circuits associated with electric valves 58 and 63 have been illustrated in detail in order to simplify the presentation of this aspect of our invention. The excitation circuits are provided with saturable inductive devices 68—73 associated with electric valve 58—63, respectively. Each inductive device comprises a winding 74 which is connected to the resistance 30 and also includes a direct current saturating winding 75.

As an agency for adjusting or pre-establishing a predetermined division of average load current between the two Y portions of the electric translating system including secondary windings 55 and electric valves 58—60, and secondary windings 56 and electric valves 61—63, we provide means for controlling the relative phase displacements between the periodic voltages of peaked wave form impressed on the control members of the electric valves in these two groups. More specifically, we provide means for adjusting the relative magnitudes of the unidirectional currents transmitted to the direct current windings 75 of the inductive devices 68—80 and 71—73. The direct current saturating winding 75 may be energized from a suitable source of direct current 76, and a suitable current controlling means, such as a pair of variable resistances 77 and 78, may be connected across the source 76, and the common juncture 79 of resistances 77 and 78 may be connected to a point 80 intermediate windings 75 of devices 68—70 and devices 71—73. A suitable smoothing reactance 81 may be connected between points 79 and 80 if desired.

The phase of the voltage supplied to the various excitation circuits for electric valves 58—63 is controlled or adjusted by means of a plurality of phase shifting circuits 82, 83 and 84. For example, the phase shifting circuit 82 associated with electric valves 58 and 63 is shown connecting the respective excitation circuits. A plurality of transformers 85, 86 and 87 are connected between the phase shifting circuits 82—84 and the respective associated excitation circuits. These transformers, as for example transformer 85, are provided with primary winding 85' and a pair of secondary windings 88 which are connected to the excitation circuits for electric valves 58 and 63. While the transformers 86 and 87 are not shown connected to the excitation circuits for electric valves 59—62, it will be appreciated that these transformers are connected in the same manner to electric valves 59—62.

A suitable phase displacing capacitance 89 is connected across the primary winding of transformer 85 and cooperates with a capacitance 90 and a resistance 91 to produce a phase displacement of the voltages impressed across primary winding 85' upon variation in the amount of lagging reactive current transmitted to the excitation circuit, depending upon the amount of unidirectional magnetization of the saturable inductive devices 68 and 73. It will be noted that the upper terminal of capacitance 90 is connected to conductor 50 of the alternating current circuit and the upper terminal of the resistance 91 is connected to conductor 51.

The operation of the system shown in Fig. 8 will be explained by considering the system when it is operating as a polyphase rectifier energizing the direct current circuit 53 from the alternating current circuit. The system operates as a double three-phase rectifier through the action of the interphase transformer 57 so that two electric valves in each group conduct current at any one time. The phase of the periodic voltages of peaked wave form impressed on control members 66 of electric valve means 58—63 may be adjusted throughout a substantial range, that is, of the order of magnitude of 60 or 70 electrical degrees, by the adjustment of the resistances 77 and 78. The shift in phase of these periodic voltages, as explained above, is the result of two effects. One of these is the shift in phase of the periodic voltages of peaked wave form relative to the voltages induced in secondary windings 88, and the other effect is that due to the shift in phase produced by the associated phase shifting circuits 82—84 occasioned by the flow of variable amounts of reactive current through the phase

shifting circuits. The amount of this reactive current transmitted through the phase shifting circuits 82—84 is obtained by control of the amount of unidirectional current transmitted through control windings 75 of the devices 68—73.

The manner in which the shift in phase produced by phase shifting circuits 82—84 is effected may be more fully appreciated by referring to the operating characteristics shown in Fig. 9. The various elements of the phase shifting circuit 82 are there represented as connected to conductors 50, 51 and 52 of the alternating current supply circuit. Variation in the amount of reactive current or the phase of the current consumed from secondary windings 83 shifts the phase of the voltage impressed across primary winding 85'. The vectors OM, ON, OP, OQ and OR represent the phase of the voltage impressed across the primary winding 85' for different magnitudes of saturating current transmitted to windings 75 of devices 68 and 73. As the current through windings 75 is varied throughout a region of from 1 to 3 amperes, the phase of the voltage impressed on the transformer 85 is varied throughout a substantial range.

In addition to the phase shift of voltages illustrated in Fig. 9, it will be understood that there is a shift in phase between the voltages of peaked wave form and the voltages induced in secondary windings 83 as explained above in connection with Fig. 2a.

By operating or adjusting resistances 77 and 78, we may control the division of load or control the average current conducted by the two groups of electric valves 58—60 and 61—63. This arrangement affords a simple and highly satisfactory way of obtaining an equal distribution of load current between the two three-phase or Y rectifying sections of the polyphase system. By varying the values of resistances 77 and 78, the current transmitted through the windings 75 is controlled and the phase of the voltages impressed on control members 66 of valves 58—60 and 61—63 is independently adjustable to obtain the desired equal division of load current therebetween.

A still further embodiment of our invention is shown in Fig. 10 which is similar in many respects to the arrangement of Fig. 8, and corresponding elements have been assigned like reference numerals. In the arrangement of Fig. 10, the interphase transformer 57 is shown as comprising portions 57a and 57b having connected therebetween a resistance 92. The load circuit 53 may be connected between the common juncture of the cathodes and a terminal or intermediate connection of the resistance 92. Control or saturating windings 93 of the inductive devices 68—73 are connected to the terminals of resistance 92 as a means for automatically controlling the saturation of devices 68—73 to maintain an equal distribution of load current between the groups of valves 58—60 and 61—63. It will be understood that any other means may be employed to control automatically the energization of windings 75 or 93, or both, in response to the relative amounts of current conducted by the groups of valves or in response to any other desired controlling influence. Variation in the relative magnitudes of currents conducted by the two groups of main electric valves automatically shifts the phase of the periodic voltages impressed on control members 66 so that the equal distribution of load is re-established or maintained. The arrows shown on devices 68—73 represent the relative directions of the magnetomotive forces of the respective associated windings 75 and 93 when the load assumed by electric valve means 61—63 exceeds that carried by electric valve means 58—60. Under this condition the phase of the control voltages impressed on members 66 of electric valve means 61—63 are retarded in phase, and the control voltages impressed on control members 66 of electric valve means 58—60 are advanced in phase, thereby re-establishing the desired equal division of load. For a reverse uneven distribution of load current, devices 68—73 also effect a balancing of the load current.

While we have shown and described our invention as applied to particular systems of connections 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 electric valve means having an anode, a cathode and a control member, a source of alternating current, an excitation circuit for impressing on said control member an alternating control voltage having positive portions of substantially greater magniture and shorter duration than the negative portions and comprising in series relation with said source means for producing an alternating voltage of peaked wave form, a resistance and an inductance, and means connected between said excitation circuit and said electric valve means for transmitting a direct current component of current therebetween, the inductance being connected in circuit with said cathode and said control member to provide a path for the direct current component of current flowing in said excitation circuit thereby reducing the magnitude of said negative portions of control voltage.

2. In connection, an electric valve means having an anode, a cathode and a control member, a source of alternating current, an excitation circuit for impressing on said control member an alternating control voltage having positive portions of substantially greater magnitude and shorter duration than the negative portions and comprising means energized from said source and including a serially connected unidirectionally saturable inductive device, a resistance and an inductance, and means connected between said excitation circuit and said electric valve means for transmitting a direct current component of current between said excitation circuit and said electric valve means, the inductance being connected in circuit with said cathode and said control member to provide a path for the direct current component of current flowing in said excitation circuit thereby reducing the magnitude of said negative portions of control voltage.

3. In combination, an electric valve means having an anode, a holding anode, a cathode, a control member of the immersion-ignitor type associated with said cathode and employing an ionizable medium, a source of alternating current, an excitation circuit for impressing on said control member an alternating control voltage having positive portions of substantially greater

magnitude and shorter duration than the negative portions and comprising means energized from said source and including a serially connected unidirectionally saturable inductive device, a resistance and an inductance, means for connecting said control member to be energized in accordance with the voltage appearing across said inductance, and means for connecting said holding anode to said excitation circuit.

4. In combination, an electric valve means having an anode, a holding anode, a cathode of the self-reconstructing type, an immersion ignitor control member associated with said cathode and employing an ionizable medium, a source of alternating current, an excitation circuit for impressing on said control member an alternating control voltage having positive portions of substantially greater magnitude and shorter duration than the negative portions and comprising means energized from said source and including in series relation a unidirectionally saturable inductive device, a resistance and an inductance, means including a resistance for connecting said control member to be energized in accordance with the voltage appearing across said inductance, and means for connecting said holding anode to said excitation circuit.

5. In combination, an electric valve means having an anode, a holding anode, a mercury pool cathode and a control member of the immersion ignitor type associated with said cathode, a source of alternating current, an excitation circuit for producing an alternating control voltage having positive portions of substantially greater magnitude and shorter duration than the negative portions and comprising means energized from said source and including a serially connected unidirectionally saturable inductive device, a resistance and an inductance, means for impressing on said control member a predetermined component of the voltage appearing across said inductance and including a resistance connected between said control member and said excitation circuit, and means for reducing the voltage applied to said control member upon the initiation of an arc discharge within said electric valve means comprising a circuit connected between said common juncture and said holding anode.

6. In combination, an electric valve means having an anode, a cathode and a control member, a source of alternating current, and an excitation circuit for impressing on said control member an alternating voltage having positive portions of substantially greater magnitude and shorter duration than the negative portions and comprising means energized from said source and including a serially connected impedance element and an inductive device having a unidirectional magnetizing element and a unidirectional conducting device connected in said excitation circuit and being poled in opposition to the normal intended direction of current flow between said control member and said cathode to limit the magnitude of the negative portions of said alternating voltage.

7. In combination, an electric valve means having an anode, a cathode and a control member, a source of alternating current, and an excitation circuit for impressing on said control member an alternating voltage having positive portions of substantially greater magnitude and of shorter duration than the negative portions and comprising in series relation a resistance, an inductance and an inductive device having a unidirectional magnetizing element, and a unidirectional conducting device connected between said cathode and said control member and being poled in opposition to the normal intended direction of current flow between said control member and said cathode to limit the magnitude of the negative portions of said alternating voltage.

8. In combination, an electric valve means having an anode, a cathode and a control member and employing an ionizable medium, a source of alternating current, an excitation circuit for impressing on said control member an alternating voltage having positive portions of substantially greater magnitude and shorter duration than the negative portions and comprising means energized from said source and including a serially connected impedance element and a unidirectionally saturable inductive device and a unidirectional conducting device connected between said cathode and said control member and being poled in opposition to the normal intended direction of current flow between said control member and said cathode to limit the magnitude of the negative portions of said alternating voltage, and means responsive to the state of ionization of said medium for reducing the voltage applied to said control member when said medium is in an ionized state.

9. In combination, an electric valve means having an anode, a cathode, a control member and employing an ionizable medium, a source of alternating current, an excitation circuit for impressing on said control member an alternating voltage having positive portions of substantially greater magnitude and shorter duration than the negative portions and comprising means energized from said source and including a serially connected resistance, an inductance and a unidirectionally saturable inductive device having a unidirectional magnetizing element, a second resistance connected between the common juncture of said first mentioned resistance and said inductance and said control member and a unidirectional conducting device connected between said cathode and said control member and being poled in opposition to the normal intended direction of current flow between said control member and said cathode to limit the magnitude of the negative portions of said alternating voltage, and means connected to said common juncture and responsive to the state of ionization of said medium for reducing the magnitude of the positive portions of voltage applied to said control member when said medium is in an ionized state.

10. In combination, an electric valve means having an anode, a cathode, a control member, a holding anode and employing an ionizable medium, a source of alternating current, an excitation circuit for impressing on said control member an alternating voltage having positive portions of substantially greater magnitude and shorter duration than the negative portions and comprising means energized from said source and including a serially connected resistance, an inductance and a unidirectionally saturable inductive device having a unidirectional magnetizing element, a second resistance connected between the common juncture of said first mentioned resistance and said inductance and said control member and a unidirectional conducting device connected between said cathode and said control member and being poled in opposition to the normal intended direction of current flow

between said control member and said cathode to limit the magnitude of the negative portions of said alternating voltage, and means connected between said common juncture and said holding anode for controlling the potential of said juncture to reduce the magnitude of the positive portions of voltage applied to said control member when said medium is in an ionized state.

11. In combination, an electric valve means having an anode, a cathode and a control member, a source of alternating current, and an excitation circuit for impressing on said control member a periodic voltage of peaked wave form and comprising means energized from said source and including a serially connected impedance element and an inductive device having a unidirectional magnitzing element, a unidirectional conducting device connected between said cathode and said control member and being poled in opposition to the normal intended direction of current flow between said control member and said cathode and a second unidirectional conducting device connected in series relation with said control member to permit the flow of only positive current to said control member.

12. In combination, an electric valve means having an anode, a cathode and a control member, a source of alternating current, and an excitation circuit for impressing on said control member a periodic voltage of peaked wave form and comprising in series relation a resistance, an inductance and an inductive device having a unidirectionally magnetizing element, a unidirectional conducting device connected between the common juncture of said resistance and said inductance and the control member and being poled to permit the flow of only positive current to said control member, and a unidirectional conducting device connected between said cathode and said first mentioned unidirectional conducting device.

13. In combination, an electric valve means having an anode, a cathode, a holding anode and a control member and employing an ionizable medium, a source of alternating current, an excitation circuit for impressing on said control member a periodic voltage of peaked wave form and comprising means energized from said source and including a serially connected resistance, an inductance and a unidirectionally saturable inductive device, a serially connected resistance and a unidirectional conducting device connected between said control member and the common juncture of said first mentioned resistance and said inductance, said unidirectional conducting device being poled to permit the transfer of only positive current to said control member, a second unidirectional conducting device connected between said cathode and the common juncture of said second mentioned resistance and said first mentioned unidirectional conducting device, and means connected between said first mentioned juncture and said holding anode to reduce the voltage applied to said control member when said medium is in an ionized state.

14. In combination, electric valve means having an anode, a cathode and a control member, a source of alternating current, an excitation circuit for impressing on said control member a periodic voltage of peaked wave form and comprising means energized from said source and including a serially connected unidirectionally saturable inductive device having a control winding, a resistance and an inductance, means for connecting said control member to be energized in accordance with the voltage appearing across said inductance, and means for transmitting variable amounts of unidirectional current to said control winding to control the effective phase position of said periodic voltage relative to the voltage applied to said anode and said cathode.

15. In combination, electric valve means having an anode, a cathode and a control member, a source of alternating current, an excitation circuit for impressing on said control member a periodic voltage of peaked wave form and comprising means energized from said source and including a serially connected unidirectionally saturable inductive device having a control winding, a resistance and an inductance, means for connecting said control member to be energized in accordance with the voltage appearing across said inductance, and means responsive to a predetermined controlling influence for variably energizing said control winding to control thereby the effective phase position of said periodic voltage relative to the anode-cathode voltage of said electric valve means.

16. In combination, alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising an electric valve means having an anode, a cathode and a control member, a source of alternating current, an excitation circuit for impressing on said control member a periodic voltage of peaked wave form comprising means energized from said source and including a serially connected saturable inductive device having a control winding, a resistance and an inductance, means for connecting said control member to be energized in accordance with the voltage appearing across said inductance, and means responsive to a predetermined electrical condition of said translating apparatus for controlling the effective phase position of said periodic voltage relative to the voltage of said alternating current circuit.

17. In combination, electric valve means having an anode, a cathode and a control member of the immersion-ignitor type associated with said cathode, a source of alternating current, an excitation circuit for impressing on said control member a periodic voltage of peaked wave form and comprising means energized from said source and including a serially connected unidirectionally saturable inductive device, a resistance and an inductance, means for connecting said control member to be energized in accordance with the voltage appearing across said inductance and including a serially connected second resistance and a unidirectional conducting device connected between said control member and said excitation circuit, and a third resistance connected between said cathode and the juncture of the second mentioned resistance and said unidirectional conducting device.

18. In combination, electric valve means having an anode, a cathode, a control member of the immersion-ignitor type associated with said cathode and having an auxiliary electrode, a source of alternating current, an excitation circuit for impressing on said control member a periodic voltage of peaked wave form comprising means energized from said source and including in series relation a unidirectionally saturable inductive device, a resistance and an inductance, means for connecting said control member to be energized in accordance with the

voltage appearing across said inductance and including a serially connected second resistance and a unidirectional conducting device connected between said control member and the juncture of the first mentioned resistance and said inductance, a third resistance connected between said cathode and the juncture of the second resistance and said unidirectional conducting device, and means for connecting said auxiliary electrode to said common juncture of the first mentioned resistance and said inductance.

19. In combination, electric valve means having an anode, a cathode and a control member of the immersion-ignitor type associated with said cathode, a source of alternating current, an excitation circuit for impressing on said control member a periodic voltage of peaked wave form comprising means energized from said source and including a serially connected unidirectionally saturable inductive device, a resistance and an inductance, means for connecting said control member to be energized in accordance with the voltage appearing across said inductance comprising in series relation a second resistance and a unidirectional conducting device connected between said control member and said excitation circuit, and a second unidirectional conducting device connected across said inductance and being poled to transmit current in the same direction as said first mentioned unidirectional conducting device relative to the transfer of current through said control member.

20. In combination, electric valve means having an anode, a cathode, a control member of the immersion-ignitor type associated with said cathode and having an auxiliary electrode, a source of alternating current, an excitation circuit for impressing on said control member a periodic voltage of peaked wave form comprising means energized from said source and including a serially connected unidirectionally saturable inductive device, a resistance and an inductance, means for connecting said control member to be energized in accordance with the voltage appearing across said inductance comprising in series relation a second resistance and a unidirectional conducting device connected between said control member and said excitation circuit, a second unidirectional conducting device connected across said inductance and being poled to transmit current in the same direction as said first mentioned unidirectional conducting device relative to the transfer of current through said control member, and means for connecting said auxiliary electrode to said excitation circuit.

21. In combination, electric valve means having an anode, a holding anode, a cathode, a control member of the immersion-ignitor type associated with said cathode and employing an ionizable medium, a source of alternating current and an excitation circuit for impressing on said control member a periodic voltage of peaked wave form and comprising means energized from said source and including a serially connected unidirectionally saturable inductive device, a resistance and an inductance, means for connecting said control member to be energized in accordance with the voltage appearing across said inductance, means for connecting said holding anode to said excitation circuit, and means comprising a unidirectional conducting device connected in series relation with said control member to permit transmission of only unidirectional impulses of current thereto.

22. In combination, electric valve means having an anode, a cathode and a control member, a source of alternating current, an excitation circuit for producing an alternating voltage having positive portions of greater magnitude and shorter duration than the negative portions and comprising means energized from said source including in series relation a resistance, an inductance and an inductive device, a unidirectional conducting device connected between the said control member and said excitation circuit to impress only the positive portions of voltage on said control member, and a circuit connected between said cathode and said unidirectional conducting device to reduce the magnitude of the negative portions of the voltage appearing across said inductance.

23. In combination, electric valve means having an anode, a cathode and an immersion-ignitor control member associated with said cathode and employing an ionizable medium capable of supporting an arc discharge, a source of alternating current, and an excitation circuit for impressing on said control member a periodic voltage of peaked wave form having positive portions of substantially greater magnitude and shorter duration than the negative portions and comprising in series relation with said source an impedance element and a unidirectionally biased inductive reactance which offers substantially less impedance to the flow of current therethrough during positive half cycles of voltage of said source than that during the negative portions whereby said periodic voltage is produced across said impedance element.

24. In combination, electric valve means having an anode, a cathode and an immersion-ignitor control member associated with said cathode and employing an ionizable medium capable of supporting an arc discharge, a source of alternating current, an excitation cricuit for impressing on said control member a periodic voltage of peaked wave form having positive portions of substantially greater magnitude and shorter duration than the negative portions and comprising in series relation with said source an impedance element, an inductive device and means for connecting said control member to said impedance element, and means for controlling said inductive device to effect a flow of current of unsymmetrical wave form therethrough from said source so that said periodic voltage is produced across said impedance element.

25. In combination, electric valve means having an anode, a cathode and an immersion-ignitor control member associated with said cathode and employing an ionizable medium capable of supporting an arc discharge, a source of alternating current, an excitation circuit for impressing on said control member a periodic voltage of peaked wave form having positive portions of substantially greater magnitude and shorter duration than the negative portions and comprising in series relation with said source an impedance element, an inductive device and means for connecting said control member to said impedance element, and means for controlling the magnetization of said inductive device to offer less impedance to the flow of current during half cycles of voltage of one polarity of said source than during half cycles of voltage of the opposite polarity whereby said periodic voltage is produced across said impedance element.

26. In combination, alternating current cir-

cuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising two groups of electric valves, each electric valve means having a control member for controlling the current conducted thereby, a plurality of excitation circuits each comprising a source of alternating current, a saturable inductive device having a winding connected in series relation with said source and an impedance element connected in series relation with said winding, said inductive device offering an unsymmetrical impedance to the flow of current through said winding to produce a periodic voltage of peaked wave form across said impedance element, and means for controlling said inductive devices of said excitation circuits to control the currents conducted by the two groups of electric valves.

27. In combination, alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising two groups of electric valves, each electric valve means having a control member for controlling the current conducted thereby, a plurality of excitation circuits each comprising a source of alternating current, a saturable inductive device having a winding connected in series relation with said source and an impedance element connected in series relation with said winding, said inductive device offering an unsymmetrical impedance to the flow of current through said winding to produce a periodic voltage of peaked wave form across said impedance element, and means responsive to a predetermined controlling influence for controlling the inductive devices to maintain a predetermined division of load between said groups of electric valves.

28. In combination, alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising a plurality of groups of electric valves, each electric valve means having a control member for controlling the current conducted thereby, a plurality of excitation circuits each comprising a source of alternating current, a saturable inductive device having a winding connected in series relation with said source and an impedance element connected in series relation with said winding, said inductive device offering an impedance which varies abruptly in response to the flow of current through said winding to produce a periodic voltage of peaked wave form across said impedance element, and means responsive to the current conducted by said groups of electric valves to control the magnetization of the inductive devices.

29. In combination, alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising a plurality of inductive networks and a plurality of groups of electric valve means, interphase transforming means connected between said inductive networks, said electric valve means each having a control member for controlling the current conducted thereby, a plurality of excitation circuits each connected to a different one of said electric valve means and each comprising a source of alternating current, an inductive device having a winding connected in series relation with said source and an impedance element connected in series relation with said winding, said inductive device offering an impedance which varies abruptly in response to the flow of current through said winding to produce a periodic voltage of peaked wave form across said impedance element, and means responsive to an electrical condition of said interphase transforming means for controlling the magnetization of the inductive devices to control the division of load among the groups of electric valve means.

30. In combination, alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising a plurality of groups of electric valve means for transmitting power between said circuits and each including a control member for controlling the current conducted thereby, a plurality of excitation circuits each connected to a different one of said electric valve means and each comprising a source of alternating current and a saturable inductive device having a winding connected in series relation with said source and having a control winding, an impedance element connected in series relation with said winding and said source, said inductive device offering an impedance which varies abruptly in response to the flow of current through the first mentioned winding from said source to produce a periodic voltage of peaked wave form across said impedance element, and means for variably energizing the control windings of the inductive devices associated with the electric valves of said groups to control the division of load current thereamong.

31. In combination, alternating current circuit, a direct current circuit, electric translating apparatus connected between said circuits and comprising an electric valve means having a control member for controlling the current conducted thereby, an excitation circuit comprising a source of alternating current, a saturable inductive device having a winding connected to be energized from said source and an impedance element connected in series relation with said winding and said source, said inductive device offering an impedance which varies abruptly in response to the flow of current through said winding to produce a periodic voltage of peaked wave form across said impedance element, a phase shifting circuit of the static impedance type comprising an impedance element to vary the phase of the voltage of said source in response to the variable amounts of reactive current consumed by said excitation circuit in accordance with the magnetization of said saturable inductive device.

32. In combination, alternating current circuit, a transformer having a primary winding and a secondary winding, a saturable inductive device having a winding connected in series relation with an impedance element and said secondary winding, means for controlling the magnetization of said inductive device to offer an impedance which varies abruptly in response to the flow of current through the associated winding to produce a periodic voltage of peaked wave form across said impedance element, and a static impedance phase shifting circuit connected between said alternating current circuit and said transformer to vary the phase of the voltage impressed across said primary winding in response to the current transfitted through the winding of said inductive device.

33. In comination, alternating current circuit, a transformer having a primary winding and a secondary winding, a saturable inductive device having a winding connected in series relation with an impedance element and said secondary winding, means for controlling the magnetization of

said inductive device so that it offers an impedance which varies abruptly in response to the flow of current through said associated winding to produce a periodic voltage of peaked wave form across said impedance element, and a static impedance type phase shifting circuit connected between said alternating current circuit and said primary winding to vary the phase of the voltage impressed across said primary winding relative to the voltage of said alternating current circuit in response to the current transmitted through said secondary winding, the winding of said inductive device and said impedance element.

34. In combination, a three-phase alternating current circuit, a transformer having a three phase primary winding and having a secondary winding, a saturable inductive device having a winding connected in series relation with an impedance element and said secondary winding, means for controlling the magnetization of said inductive device so that it offers an impedance which varies abruptly in response to the flow of current therethrough thereby producing across said impedance element a voltage of peaked wave form, a capacitance connected across said secondary winding, and a plurality of resistances connected between said alternating current circuit and said primary windings responsive to the current transmitted by said secondary winding to control the phase of the voltage impressed across said primary winding relative to the voltage of said alternating current circuit.

35. In combination, a three-phase alternating current circuit comprising three conductors, transforming means including a primary winding and a secondary winding, means energized from said secondary winding comprising an inductive device having a winding connected in series relation with said secondary winding and an impedance element, means for controlling the magnetization of said inductive device so that it offers an impedance which varies abruptly in response to the flow of current through the associated winding thereby producing across said impedance element a periodic voltage of peaked wave form, a capacitance connected across said primary winding and having one terminal connected to one conductor of said alternating current circuit, a second capacitance and a resistance connected to the other terminal of said capacitance and each connected to a different one of the other two conductors of said alternating current circuit.

36. In combination, a source of alternating current, an inductive device having a core member and having a winding and a control winding, an impedance element connected in series relation with said source and said winding, said inductive device offering an impedance which varies abruptly in response to the flow of current through said first mentioned winding to produce across said impedance element a periodic voltage of peaked wave form, and means for controlling the energization of said control winding to control the phase of said periodic voltage relative to the voltage of said source.

37. In combination, an electric valve means having an anode, a holding anode, a cathode, a control member of the immersion-ignitor type associated with said cathode and employing an ionizable medium capable of supporting an arc discharge, a source of alternating current, an excitation circuit for producing a control voltage having positive portions of substantially greater magnitude and shorter duration than the negative portions and comprising means energized from said source and including a serially connected saturable inductive device and an inductance, means for connecting said control member to be energized in accordance with the voltage appearing across said inductance, and means for connecting said holding anode to said excitation circuit.

38. In combination, an electric valve means having an anode, a holding anode, a control member of the self-reconstructing type, an immersion-ignitor control member associated with said cathode and employing an ionizable medium capable of supporting an arc discharge, a source of alternating current, an excitation circuit for producing a control voltage having positive portions of substantially greater magnitude and shorter duration than the negative portions and comprising means energized from said source and including in series relation a saturable inductive device and an inductance, means including a resistance for connecting said control member to be energized in accordance with the voltage appearing across said inductance, and means for connecting said holding anode to said excitation circuit to effect transfer of the current from said control member to said holding anode upon initiation of an arc discharge within said electric valve means occasioned by the energization of said control member.

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