

Jan. 4, 1938.

B. D. BEDFORD

2,104,690

ELECTRIC VALVE CIRCUITS

Filed April 25, 1936

3 Sheets-Sheet 1

Fig. 1.

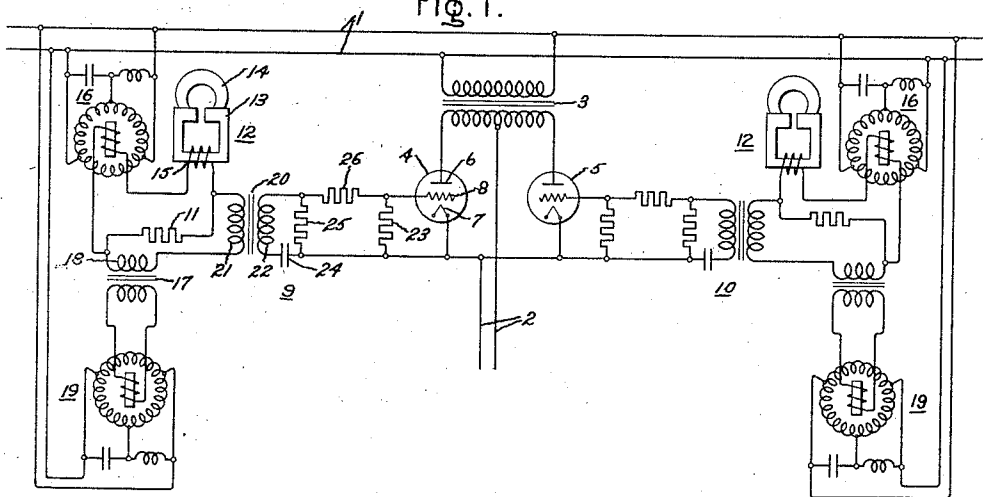


Fig. 2.

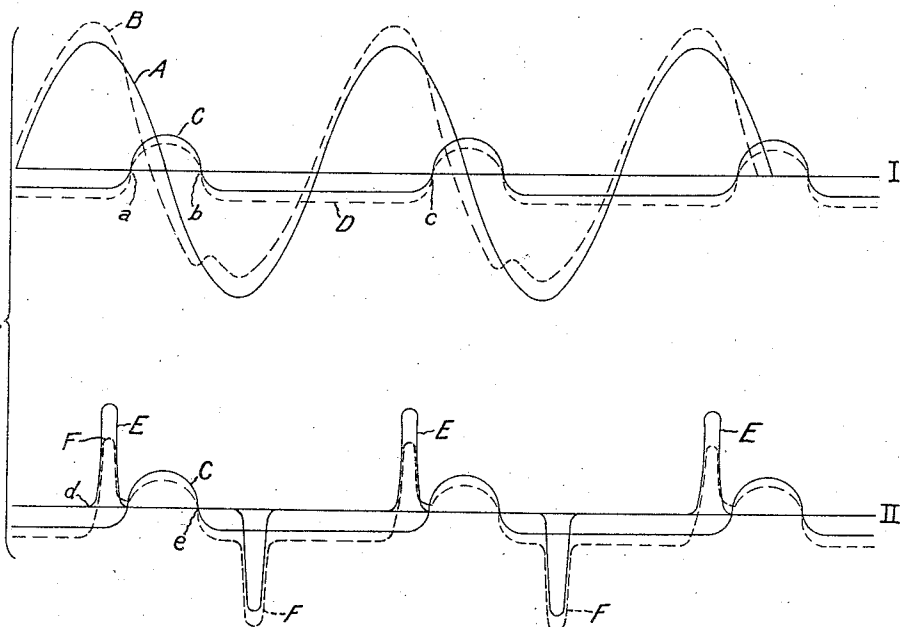
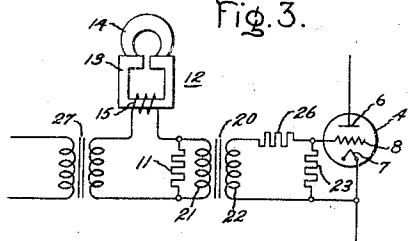


Fig. 3.



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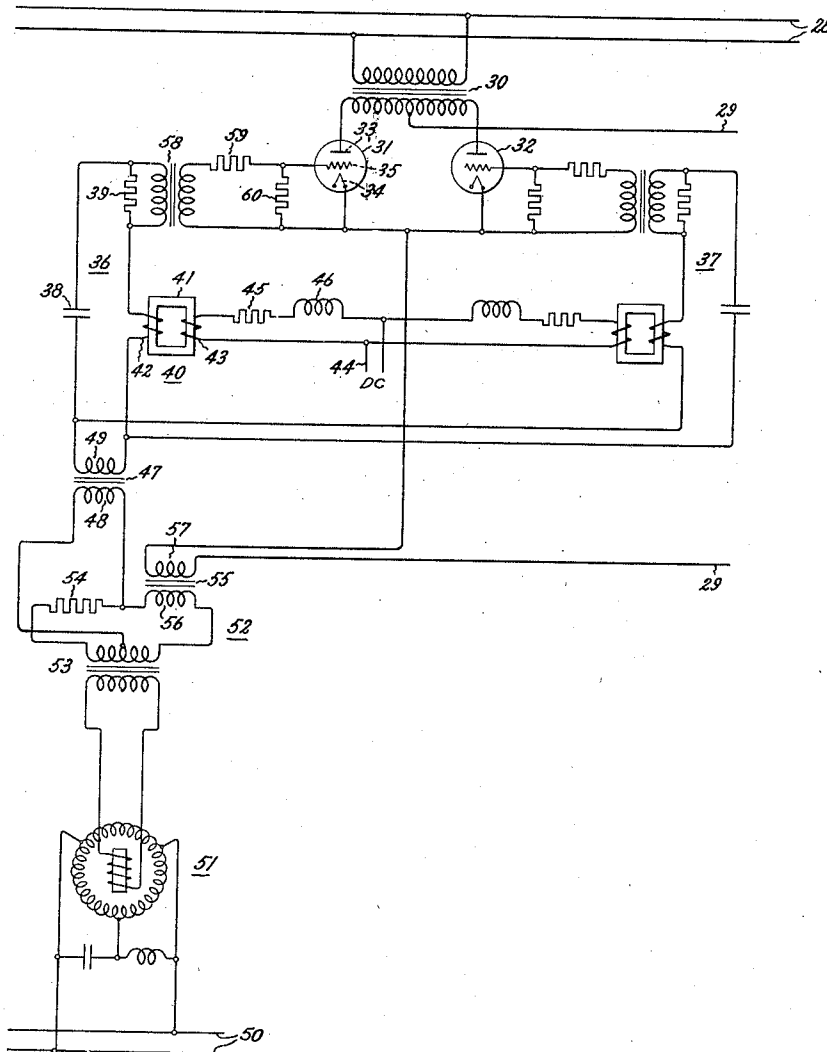
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## ELECTRIC VALVE CIRCUITS

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3 Sheets-Sheet 2

Fig. 4.



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ELECTRIC VALVE CIRCUITS

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3 Sheets-Sheet 3

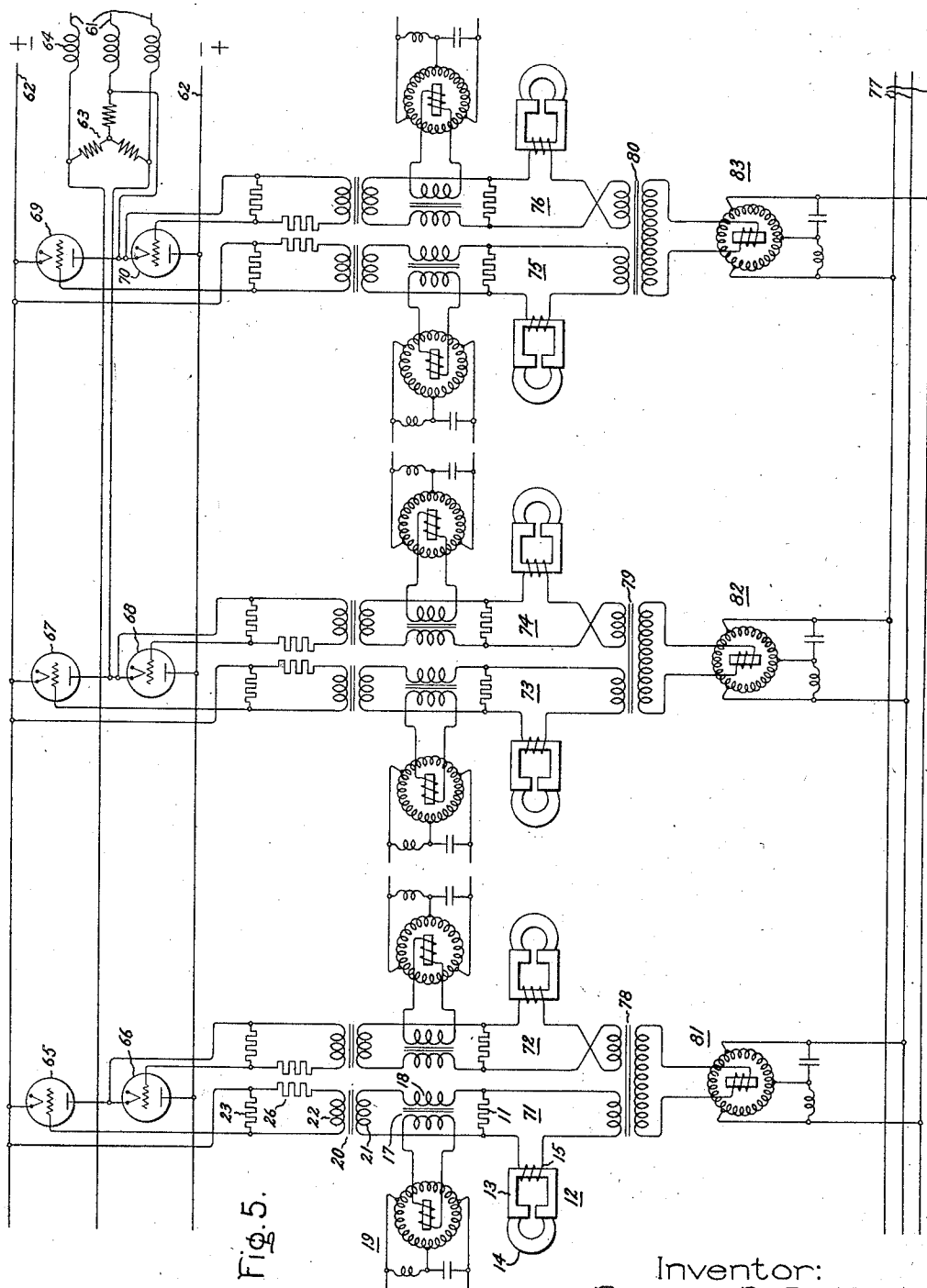


Fig. 5.

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## UNITED STATES PATENT OFFICE

2,104,690

## ELECTRIC VALVE CIRCUITS

Burnice D. Bedford, Schenectady, N. Y., assignor  
to General Electric Company, a corporation of  
New York

Application April 25, 1936, Serial No. 76,450

21 Claims. (Cl. 175—363)

My invention relates to electric valve translating apparatus and more particularly to control or excitation circuits for electric valves.

Heretofore in electric valve circuits, the control or excitation circuits have involved the use of apparatus intricate in construction and arrangement and have required frequent renewals and replacements. Coincidentally with the increased application of electric valve translating apparatus to power transmission and distribution systems, it has become evident that it is highly desirable to employ excitation circuits using only those electrical elements or parts which are susceptible of long life without requiring a disproportionate degree of care and inspection in order to assure a reasonable continuity of service and reliability in operation.

It is an object of my invention to provide a new and improved electric circuit for supplying a periodic potential of predetermined wave form.

It is another object of my invention to provide a new and improved electric valve translating circuit.

It is a further object of my invention to provide a new and improved excitation circuit for controlling electric valve means.

It is a still further object of my invention to provide an excitation circuit for electric valve means which employs only apparatus of a rugged construction and which supplies a potential suitable for controlling electric valves of the type employing ionizable mediums such as gases or vapors.

In accordance with the illustrated embodiments of my invention, I provide excitation circuits for controlling the conductivity of electric valve means which employ electrical elements which are rugged in construction and which are susceptible of long life, such as resistances, capacitances and inductances, arranged and correlated so that suitable control voltages are provided. In one embodiment of my invention, I employ an excitation circuit including a serially-connected impedance element and an inductive device having a winding, a core member and means, such as a permanent magnet, for establishing in the core member a unidirectional flux. Means, such as a transformer, is associated with the impedance element to impress on the control member of an associated electric valve a periodic potential of substantially rectangular wave form having positive portions of relatively short duration and negative portions of relatively greater duration. In another embodiment of my invention, I employ additional means, such

as capacitances and nonlinear resistances, to increase the magnitude of the negative portion of the periodic control potential. In a further embodiment of my invention, I provide an excitation circuit including a serially-connected capacitance, an impedance element and an inductive device having a core member, a winding inductively associated with the core member and a unidirectional magnetizing element for impressing on the control member of an associated electric valve a potential having positive portions of relatively short duration and negative portions of relatively greater duration. In a still further embodiment of my invention, I provide a modification of the above-mentioned excitation circuits in which a potential of peaked wave form is introduced in the excitation circuit to co-operate with the periodic potential of rectangular wave form to provide a resultant control potential of substantially greater magnitude and longer duration than the periodic potential.

For a better understanding of my 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 of the accompanying drawings diagrammatically illustrates an embodiment of my invention as applied to an electric valve translating circuit; Fig. 2 shows certain operating characteristics of the illustrated embodiments of my invention; Fig. 3 diagrammatically represents a simplified embodiment of the invention shown in Fig. 1; Fig. 4 diagrammatically shows another embodiment of my invention as applied to an electric valve translating circuit for transmitting energy between an alternating current circuit and a direct current circuit and in which means are provided for controlling the excitation circuits in accordance with an electrical condition of one of the power circuits; and Fig. 5 diagrammatically shows another embodiment of my invention as applied to an electric valve translating system for transmitting energy between a polyphase alternating current circuit and a direct current circuit.

Referring now to Fig. 1 of the accompanying drawings, my invention is diagrammatically illustrated as applied to an electric valve translating circuit for transmitting energy between an alternating current circuit 1 and a direct current circuit 2 through a transformer 3 and electric valves 4 and 5, preferably of the type employing ionizable mediums such as gases or vapors. Each of the electric valves 4 and 5 is pro-

vided with an anode 6, a cathode 7 and a control member 8. To control the conductivity of electric valves 4 and 5, I provide excitation circuits 9 and 10, respectively; each of these excitation circuits includes a serially-connected impedance element, such as a resistance 11, and an inductive device 12 having a core member 13, a unidirectional magnetizing element, such as a permanent magnet 14, and a winding 15 inductively associated with the core member 13. The excitation circuits 9 and 10 may be energized from any suitable source of alternating potential of substantially sinusoidal wave form. In the arrangement diagrammatically shown in Fig. 1, the excitation circuits 9 and 10 are energized from the alternating current circuit 1 through any conventional phase shifting arrangement, such as the rotary phase shifters 16. Where it is desirable to introduce in the excitation circuits 9 and 10 additional voltages to assure more positive control of the electric valves 4 and 5, I provide transformers 17 having secondary windings 18. These transformers are preferably of the type designed to provide a voltage of substantially peaked wave form and are energized from any suitable source of alternating potential, such as the alternating current circuit 1, through any conventional phase shifting arrangement, such as the rotary phase shifter 19. In order to impress on the control members 8 of electric valves 4 and 5 a potential which varies in accordance with an electrical condition such as the voltage, of the impedance element 11 and which is also responsive to the voltage of the secondary winding 18 of transformer 17, I provide in each of the excitation circuits 9 and 10 a transformer 20 having a primary winding 21 and a secondary winding 22. The primary winding 21 of transformer 20 and the secondary winding 18 of transformer 17 are serially-connected relative to each other and are connected across the impedance element 11. A nonlinear resistance 23, which may be of the material described and claimed in United States Patent No. 1,822,743, granted September 8, 1931, on an application of K. B. McEachron, and assigned to the assignee of the present application, is connected between the cathode 7 and control member 8 of the associated electric valve 4, and serves to suppress electrical transients.

Where it is desirable to provide means for increasing the magnitude of the negative portions of the periodic potential impressed on the control member 8, I provide a serially-connected capacitance 24 and a resistance 25 which are connected across the secondary winding 22 of transformer 20. The resistance 25 may be of the type having a nonlinear volt-ampere characteristic. A current limiting resistance 26 is connected in series with the control member 8 of the associated electric valve 4.

The operation of the embodiment of my invention diagrammatically shown in Fig. 1 may be explained by considering the electric valve translating circuit when energy is being transmitted from the alternating current circuit 1 to the direct current circuit 2. In the manner well understood by those skilled in the art, electric valves 4 and 5 will be rendered conductive alternately to supply unidirectional current to the circuit 2. The operating characteristics of the arrangement shown in Fig. 1 are represented in Fig. 2 where in Diagram I, curve A represents the sinusoidal alternating potential impressed on the excitation circuits by circuit 1 through the

phase shifters 16; curve B represents the voltage appearing across the winding 15 of inductive device 12 and curve C represents the potential appearing across the impedance element 11, while curve D represents the potential C as modified by the serially-connected capacitance 24 and the resistance 25. In Diagram II, curve E represents the periodic potential of peaked wave form which is introduced in the excitation circuit 9 by transformer 17; and curve F represents the resultant potential as modified by the serially-connected capacitance 24 and resistance 25 and which is impressed on the control members 8 when the peaking transformers 17 are energized.

In connection with the manner in which the inductive element 12 and the serially-connected impedance element 11 co-operate to provide the periodic control potential as represented by the curve C, it is to be noted that during those half cycles in which the alternating potential furnished by phase shifter 16 tends to establish in the core member 13 of inductive device 12 a flux which is in the same direction as the flux established by the permanent magnet 14, the current which flows in the excitation circuit will have a wave form substantially as that indicated during the interval *a-b*. It will be noted that the wave form of the current is substantially rectangular and that the positive portion is substantially less than 180 electrical degrees. Furthermore, it is to be noted that when the voltage impressed on each of the excitation circuits is in a direction tending to establish a flux opposing that established by the permanent magnet 14, the current flowing in the excitation circuit and hence the voltage appearing across the resistance 11 may be represented by the portion of the curve C lying between points *b* and *c*. Since the nonlinear or disproportionate current variation occurs at or near the maximum value of the flux wave which lags the applied voltage by 90 electrical degrees (not shown), the disproportionate increase in current as represented by the portion of curve C during the interval *a-b* will occur substantially as shown relative to the curve A. Of course, the curve A also represents the potentials impressed on the associated excitation circuits. Neglecting, for the present, consideration of the effect of the peaking transformer 17, the voltage impressed on the primary winding 21 of transformer 20 and hence the voltage appearing across the terminals of secondary winding 22 may be represented by the curve C.

The serially-connected capacitance 24 and the resistance 25 serve to decrease the magnitude of the potential impressed on control member 8 as represented by the portion of curve D during the interval *a-b* but effect an increase in the magnitude of the negative portion of this curve lying between the points *b* and *c*. This feature is of considerable importance in those applications where it is desirable to provide an increased negative bias voltage for use where electric valves of the gaseous or vapor type are employed and where it is desirable to effect rapid deionization of the valves after the valves have completed the normal periods of conduction.

Where it is desired to provide a potential which is greater in magnitude than the potential appearing across the impedance element 11, the transformer 17 is employed and the phase of the peaked voltage is adjusted to occur in substantially the phase position shown by curve E in Diagram II of Fig. 2. This arrangement is particularly advantageous in those applications

where it is desirable to assure positive starting by the application of a relatively large voltage of perpendicular wave front on the control member of the associated electric valve and where it is desirable to continue the application of a relatively large positive potential to the control member after the electrical discharge has been initiated in the electric valve. Referring to Diagram II, it is to be noted that during interval *d—e* this relation of voltages is obtained by adjusting the phase of the peaked voltage *E* so that it occurs immediately preceding the positive portion of the rectangular potential represented by curve *C*.

In Fig. 3 of the accompanying drawings, there is shown a simplified embodiment of the excitation circuit disclosed in Fig. 1, and corresponding elements have been assigned like reference numerals. An additional element, a transformer 27, is employed to impress an alternating potential on the excitation circuit. It should be understood that suitable phase shifting arrangement, corresponding to the rotary phase shifter 16 of Fig. 1, may also be associated with the modified embodiment in Fig. 3 to control the phase of the potential impressed on the control member 8 relative to the potential impressed on the anode 6.

The operation of the embodiment of my invention shown in Fig. 3 is substantially the same as that described above in connection with Fig. 1. A potential of substantially sinusoidal wave form, which may be represented by curve *A* in Diagram I of Fig. 2, is impressed on the excitation circuit of Fig. 3 by means of the transformer 27. The wave form of the voltage appearing across the impedance element 11 will be substantially that as represented by curve *C* in Diagram I of Fig. 2, and this curve also represents the wave form of the voltage impressed on the control member 8 of electric valve 4. In this manner, the excitation circuit of Fig. 3 provides a periodic potential having positive portions of substantially rectangular wave form and of relatively short duration, and having negative portions also of substantially rectangular wave form but of substantially greater duration than that of the positive portions.

Referring now to Fig. 4 of the accompanying drawings, a further embodiment of my invention is diagrammatically shown as applied to an electric valve translating circuit for transmitting energy between an alternating current circuit 28 and a direct current circuit 29 through a transformer 30 and electric valves 31 and 32. Each of the electric valves 31 and 32 is provided with an anode 33, a cathode 34, and a control member 35, and is preferably of the type employing an ionizable medium such as a gas or a vapor.

To control the conductivity of electric valves 31 and 32, I provide excitation circuits 36 and 37, respectively. Each of these excitation circuits includes a serially-connected capacitance 38, an impedance element such as a resistance 39, and an inductive device 40 having a core member 41, a winding 42 and a unidirectional magnetizing element such as a winding 43 energized from any suitable source, such as the direct current circuit 44, through a resistance 45 and a smoothing reactor 46. The capacitance 38 of Fig. 4 serves substantially the same purpose as the capacitance of Fig. 1; that is, it functions to increase the magnitude of the negative portions of the periodic voltage appearing across the impedance element 39. To impress on the excitation circuits

36 and 37 potentials of substantially sinusoidal wave form, I employ a transformer 47 having a primary winding 48 and a secondary winding 49 which is energized from any suitable source of alternating potential, such as the auxiliary circuit 50, through any conventional phase shifting arrangement, such as the rotary phase shifter 51 and the automatic phase shifting circuit 52. The excitation circuits may be energized from circuit 28 if desired. The automatic phase shifting circuit 52, illustrated as of the impedance type, comprises a transformer 53, a resistance 54 and a saturable inductance 55 having a primary winding 56 and a secondary winding 57. The primary winding of transformer 47 is energized in accordance with the voltage appearing between resistance 54 and saturable inductance 55 and an electrical mid-connection of a secondary winding of transformer 53. The secondary winding 57 of saturable inductance 55 is connected in series with the direct current load circuit 29 and provides an arrangement for controlling the inductance of the reactor 55 in accordance with an electrical condition such as the current of the direct current circuit 29. In order to impress on the control member 35 of electric valves 31 and 32 a potential which varies in accordance with an electrical condition of impedance element 39, I provide a transformer 58 and a current limiting resistance 59 connected in series with the control member 35 and the secondary winding of transformer 58. A nonlinear resistance 60 is connected across the cathode 34 and control member 35 to suppress high voltage transients.

It will be observed that the excitation circuit just described is substantially the same as the arrangement shown in Fig. 1, except that the bias of the reactor 40 is provided by the direct current circuit 44 rather than a permanent magnet, and the capacitance 38 is introduced in series relation with the impedance element 39; and the current responsive impedance phase shifting circuit 52 is interposed between the source of alternating potential and the excitation circuit.

The general principles of operation of the embodiment of my invention diagrammatically shown in Fig. 4 are substantially the same as those explained in connection with the operation of the arrangement shown in Fig. 1. By virtue of the inductive device 40 and the associated unidirectional magnetizing element or winding 43, the current flowing in the excitation circuit, comprising capacitance 38, impedance element 39 and winding 42 of inductive device 40, will have a wave form such that the positive portions are substantially rectangular and of relatively short duration while the negative portions will also be rectangular but will be of substantially greater duration than that of the positive portions. The phase shifter 51 may be arranged, by the design of the saturable inductance 55, to control the phase of the potential impressed on the control members 35 of electric valves 31 and 32 to effect control of the voltage of the direct current circuit 29. By suitable design of this circuit, the voltage of direct current circuit 29 may be maintained substantially constant or the voltage may be caused to increase or decrease in accordance with a predetermined variation in the current of circuit 29. Let it be assumed that the saturable inductance 55 is designed so that at no load the inductance of winding 57 is such that the voltages impressed on the control members 35 of electric valves 31 and 32 lag the voltages impressed on the anodes 33 of these

valves. As the load current in circuit 29 increases, effecting thereby saturation of the reactor 55, the inductance of winding 56 will be decreased. This change in inductance may be utilized to advance the phase of the potential impressed on the control members 35 to effect an increase in the voltage impressed on the circuit 29.

In Fig. 5 of the accompanying drawings, I have diagrammatically illustrated a further embodiment of my invention as applied to an electric valve translating system for transmitting energy between a polyphase alternating current circuit 61 and a direct current circuit 62 through a transformer 63 and smoothing reactors 64. Electric valves 65-70, inclusive, are provided to obtain full wave rectification of the alternating current supplied by circuit 61. Excitation circuits 71-76, inclusive, are associated with electric valves 65-70, respectively. The excitation circuits 71-76, inclusive, are substantially similar to the excitation circuits 9 and 10 of the embodiment of my invention shown in Fig. 1, distinguishing from those circuits only by the omission of capacitive elements in the circuits. Corresponding elements have been assigned like reference numerals. The excitation circuits 71-76, inclusive, are energized from any suitable three-phase alternating current system, such as alternating current circuit 77, by means of transformers 78, 79, and 80, and through conventional phase shifting arrangements such as the rotary phase shifters 81, 82, and 83, respectively.

The operation of the excitation circuits 71-76 diagrammatically shown in Fig. 5 of the accompanying drawings will be substantially the same as that explained in connection with the operation of excitation circuits 9 and 10 of Fig. 1. The potentials impressed on the control members of electric valves 65-70 will have wave forms corresponding to the resultant potential as obtained by the addition of curves E and C in Diagram II of Fig. 2. The manner in which electric valves 65-70 operate to supply unidirectional current to the load circuit 62 from the polyphase alternating current circuit 61 will be well understood by those skilled in the art.

Although in the above disclosed embodiments I have chosen to describe my invention as applied to electric valve translating circuits for transmitting energy between an alternating current circuit and a direct current circuit, it should be understood that my invention in its broader aspects may be applied to electric valve translating circuits generally for transmitting energy between single phase or polyphase alternating current circuits and direct current circuits or between alternating current circuits of the same or different frequencies.

While I have shown and described my 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 my invention, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. In combination, a source of alternating potential, an impedance element, an inductive device having a core member, a unidirectional magnetizing element and a winding connected in

series with said impedance element across said source, and means responsive to an electrical condition of said impedance element for supplying a periodic electrical quantity having positive portions of substantially shorter duration than the negative portions.

2. In combination, a source of alternating potential, an inductive device having a winding and a unidirectional magnetizing element, means comprising an impedance element connected in series with said winding across said source for supplying a periodic potential having positive portions of relatively short duration and having negative portions of a duration substantially greater than 180 electrical degrees, and means for controlling the phase relationship of said positive portions and said alternating potential.

3. In combination, an electric valve means having a control member, and an excitation circuit comprising a source of alternating potential, an inductive device having a core member, a unidirectional magnetizing element for establishing a unidirectional flux in said core member and a winding inductively associated with said core member, and means including an impedance element connected in series with said winding across said source for impressing on said control member a periodic potential.

4. In an excitation circuit for an electric valve means having a control member, the combination of a source of alternating potential, an impedance element, an inductive device having a core member, a unidirectional magnetizing element and a winding, said winding being connected in series with said impedance element across said source, and means responsive to an electrical condition of said impedance element for impressing on said control member a periodic potential.

5. In combination, a supply circuit, a load circuit, electric translating apparatus interconnecting said circuits including an electric valve means having a control member, and an excitation circuit comprising a source of alternating potential, an impedance element, an inductive device having a core member, a winding and a unidirectional magnetizing member, said impedance element and said winding being connected in series relation across said source, and means responsive to an electrical condition of said impedance element for impressing on said control member a periodic control potential.

6. In an excitation circuit for an electric valve means having a control member, the combination of a source of alternating potential, an impedance element, means comprising an inductive element having a core member, means for establishing a unidirectional flux in said core member and a winding inductively associated with said core member, said impedance element and said winding being connected in series relation across said source for producing a periodic electrical quantity having positive portions of substantially shorter duration than that of the negative portions, and means for impressing on said control member a periodic potential which varies in accordance with said periodic electrical quantity.

7. In combination, a supply circuit, a load circuit, electric translating apparatus interconnecting said circuits including an electric valve means having a control member, and an excitation circuit comprising a source of alternating potential, an impedance element and an inductive device having a core member, a permanent magnet biasing member for establishing a unidirectional flux

in said core member and a winding inductively associated with said core member, said impedance element and said winding being connected in series relation across said source, and means responsive to an electrical condition of said impedance element for impressing on said control member a periodic control potential.

8. In combination, a supply circuit, a load circuit, electric translating apparatus interconnecting said circuits including an electric valve means having a control member, and an excitation circuit comprising a source of alternating potential of substantially sinusoidal wave form, an impedance element and an inductive device having a winding, a core member and means for establishing a unidirectional flux in said core member, said impedance element and said winding being connected in series relation across said source, and means responsive to an electrical condition of said impedance element for impressing on said control member a periodic potential having positive portions of relatively short duration and having negative portions of substantially greater duration than that of said positive portions.

9. In combination, a source of alternating potential, a circuit arranged to be energized from said source for producing a periodic electrical quantity having positive portions of substantially shorter duration than the negative portions, and means energized in accordance with said electrical quantity comprising a serially-connected capacitance and resistance for increasing the magnitude of the portions of like sign of said periodic electrical quantity.

10. In combination, a source of alternating potential, a circuit arranged to be energized from said source for producing a periodic potential having positive portions of substantially shorter duration than that of the negative portions, and means energized in accordance with said periodic potential comprising a serially-connected capacitance and a nonlinear resistance for increasing the magnitude of the negative portions of said periodic potential.

11. In combination, an electric valve having a control member, a source of alternating potential, an impedance element, an inductive device having a unidirectional magnetizing element and a winding connected in series relation with said impedance element across said source, means responsive to an electrical condition of said impedance element for impressing on said control member a periodic potential having positive portions of substantially shorter duration than that of the negative portions, and means responsive to said periodic potential for increasing the magnitude of portions of like sign of said periodic potential.

12. In combination, a supply circuit, a load circuit, electric translating apparatus interconnecting said circuits including electric valve means having a control member and an excitation circuit for impressing on said control member a periodic potential having positive portions of substantially rectangular wave form and negative portions of substantially greater duration than said positive portions comprising a source of alternating potential, a serially-connected impedance element and an inductive device having a core member, and means for establishing a unidirectional flux in said core member, means responsive to an electrical condition of said impedance element and means energized in accordance with said electrical condition of said impedance element for increasing the magnitude

of the negative portions of said periodic potential.

13. In combination, a supply circuit, a load circuit, electric translating apparatus interconnecting said circuits including electric valve means having a control member, and an excitation circuit comprising a source of alternating potential, an impedance element, an inductive device having a core member, means for establishing a unidirectional flux in said core member and a winding inductively associated with said core member and connected in series relation with said impedance element, means responsive to an electrical condition of said impedance element for providing a periodic potential having positive portions of substantially shorter duration than that of the negative portions and means comprising a serially-connected capacitance and a nonlinear resistance energized in accordance with said periodic potential for increasing the magnitude of said negative portions of said periodic potential.

14. In combination, a source of alternating potential, and means energized from said source for supplying a periodic electrical quantity having positive portions of substantially shorter duration than negative portions comprising in series relation, a capacitance, an impedance element and an inductive device having a unidirectional magnetizing element.

15. In combination, an electric valve having a control member, a source of alternating potential, and an excitation circuit energized from said source for impressing on said control member a periodic potential comprising in series relation, a capacitance, an impedance element and an inductive device having a unidirectional magnetizing element.

16. In combination, an electric valve having a control member, a source of alternating potential, an excitation circuit comprising in series relation a capacitance, an impedance element and an inductive device comprising a core member, a winding inductively associated with said core member and means for establishing a unidirectional flux in said core member, and means responsive to an electrical condition of said impedance element for impressing on said control member a periodic potential.

17. In combination, a supply circuit, a load circuit, electric translating apparatus interconnecting said circuits including electric valve means having a control member and an excitation circuit for impressing on said control member a periodic potential having positive portions of substantially rectangular wave form and negative portions of substantially greater duration than that of said positive portions comprising a source of alternating potential, a capacitance, an inductive device having a core member, a unidirectional magnetizing winding for establishing a unidirectional flux in said core member and a winding inductively associated with said core member, and an impedance element connected in series with said capacitance and said winding, a source of direct current for energizing said magnetizing winding of said inductive device, and means responsive to a voltage appearing across said impedance element connected to energize said control member.

18. In combination, a supply circuit, a load circuit, electric translating apparatus interconnecting said circuits including electric valve means having a control member and an excitation circuit for impressing on said control member a

periodic potential comprising a source of alternating potential, a serially-connected impedance element and an inductive device connected to said source, said device having a core member and means for establishing a unidirectional flux in said core member, means responsive to an electrical condition of said impedance element for energizing said control member, and means for controlling the phase of said periodic potential in accordance with an electrical condition of one of said first-mentioned circuits.

19. In combination, a supply circuit, a load circuit, electric translating apparatus interconnecting said circuits including an electric valve means having a control member, and an excitation circuit for said control member comprising means for supplying a periodic voltage having positive portions of a duration substantially less than 180 electrical degrees and means for producing in said excitation circuit a periodic potential of peaked wave form to provide a resultant periodic potential of a wave form having positive portions of substantially perpendicular wave front.

20. In combination, a supply circuit, a load circuit, electric translating apparatus interconnecting said circuits including an electric valve means having a control member, and an excita-

tion circuit comprising a source of alternating potential, an impedance element and an inductive device having a winding, said impedance element and said winding being connected in series relation across said source, means for introducing in said excitation circuit a periodic potential of peaked wave form and means responsive to an electrical condition of said impedance element and responsive to said first-mentioned means for impressing on said control member a periodic potential having a wave form with positive portions of substantially perpendicular wave front.

21. In combination, a supply circuit, a load circuit, electric translating apparatus interconnecting said circuits including an electric valve means having a control member, and an excitation circuit for said control member comprising means for supplying a periodic voltage having positive portions of a duration substantially less than 180 electrical degrees, means for producing in said excitation circuit a periodic potential of peaked wave form to provide a resultant periodic potential of a wave form having positive portions of substantially perpendicular wave front and means for increasing the magnitude of the negative portions of said resultant periodic potential.

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