June 18, 1935. D. JOURNEAUX 2,004,952

ELECTRON DISCHARGE DEVICE CONTROL SYSTEM

Filed Aug. 25, 1933 3 Sheets-Sheet 1

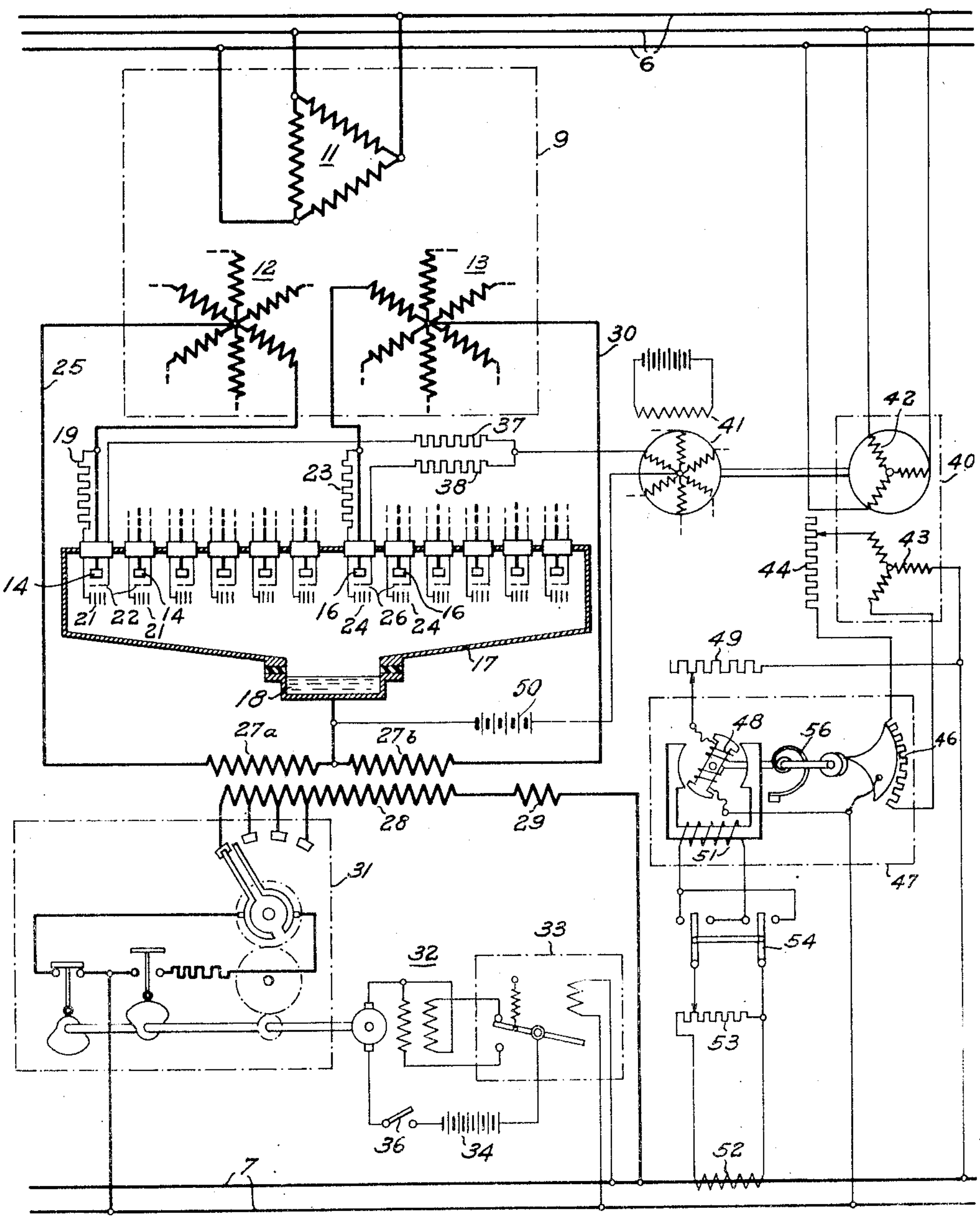

Fig. 1

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June 18, 1935. D. JOURNEAUX 2,004,952

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Filed Aug. 25, 1933 3 Sheets-Sheet 2

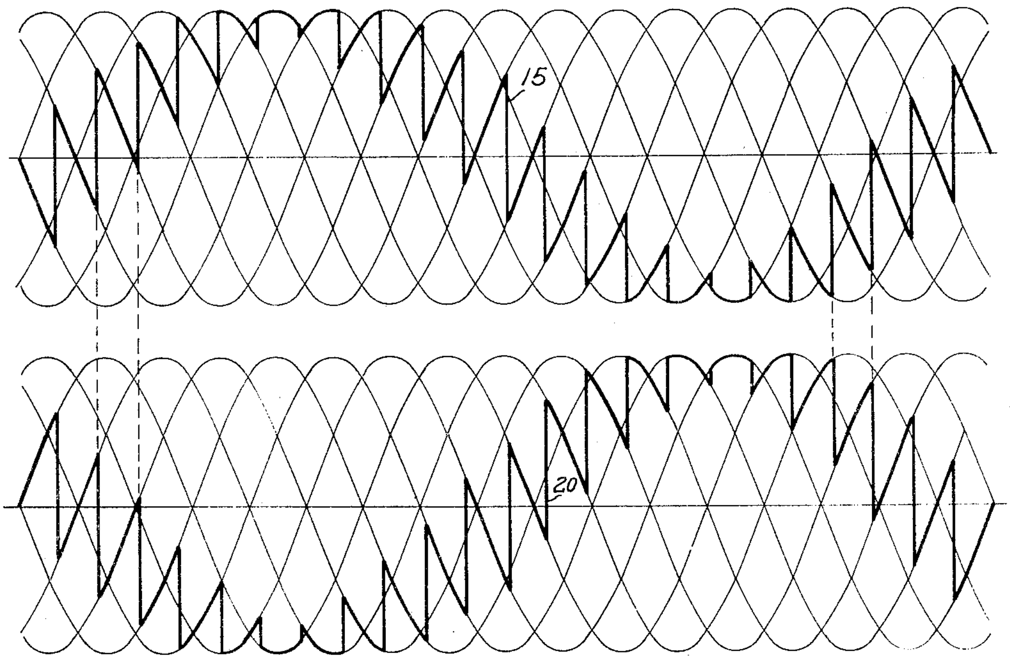

Fig. 2

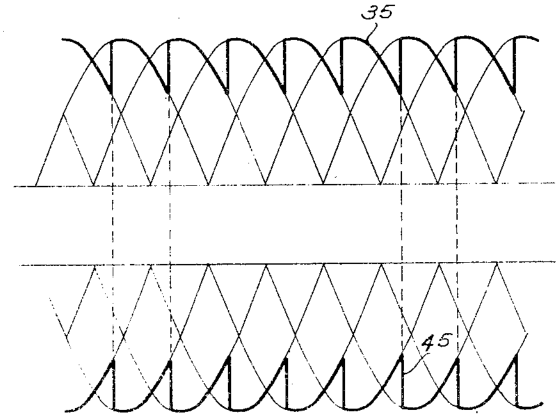

Fig. 4

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ELECTRON DISCHARGE DEVICE CONTROL SYSTEM

Filed Aug. 25, 1933 3 Sheets-Sheet 3

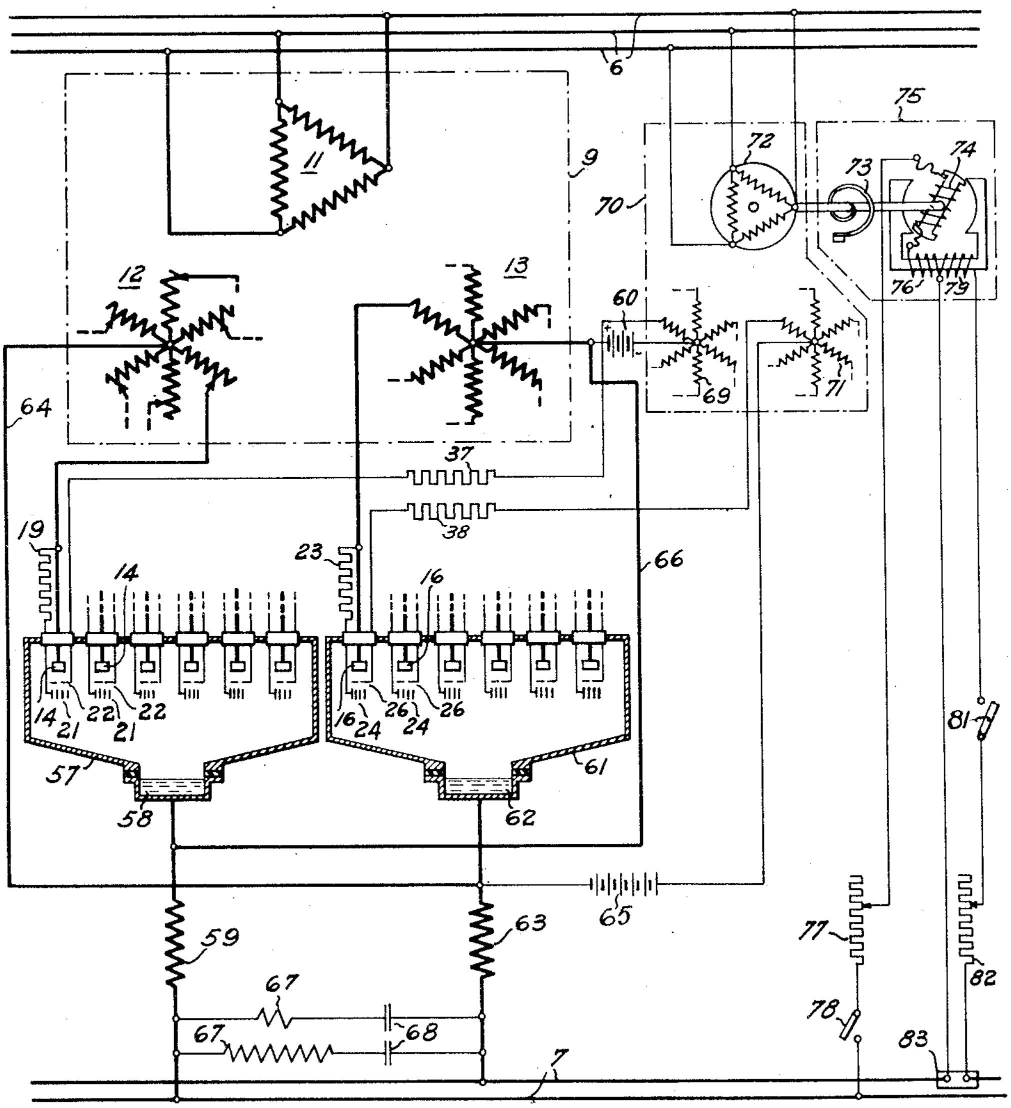

Fig. 3

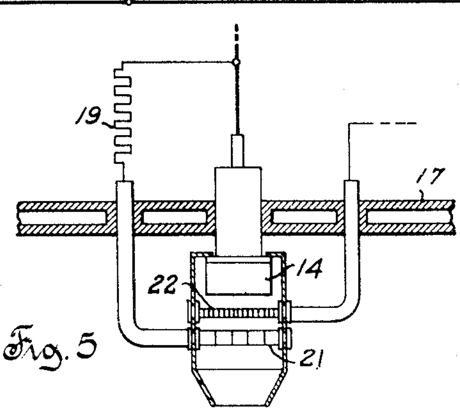

Fig. 5

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UNITED STATES PATENT OFFICE

2,004,952

ELECTRON DISCHARGE DEVICE CONTROL SYSTEM

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Application August 25, 1933, Serial No. 686,700

23 Claims. (Cl. 172—281)

This invention relates to control systems for electron discharge devices and more particularly to means for controlling the flow of current through bi-directional electric current converting systems employing electron discharge devices.

In bi-directional electric current converting systems, i. e. systems in which current may pass in either direction, employing electron discharge devices, it is generally necessary to provide two or more circuits forming separate paths for the transmission of energy in the one and in the other direction between the lines connected thereby. Such paths should be simultaneously conductive to permit the flow of energy in either direction at any instant and consequently such paths then form closed circuits in which circulating or local currents may flow if the several voltages appearing in each circuit do not cancel each other with respect to such circuit. If the discharge means are of the vapor type in which the electron discharge may be released when desired but cannot be voluntarily interrupted by the discharge controlling means, it is generally not possible to so design the circuits that the voltages appearing therein cancel each other for the reason that it is not possible to utilize similar portions of an alternating current voltage wave to obtain the flow of current in each direction, the choice of the portions of the voltage wave to be utilized being restricted by the necessity for always transferring the current from one anode to another at a higher voltage to obtain proper commutation therebetween as is well known in the art. It is, therefore, necessary to utilize electron discharge means, in which the discharge may be interrupted when desired, such as continuously controllable electric valves, or preferably such as valves of the vapor type provided with some particular types of control electrodes to be described hereinafter whereby the voltages in the circuits may be controlled at will and commutation between anode currents may be effected at any desired instant.

It is, therefore, among the objects of the present invention to provide a control system for an electric current converting system employing electron discharge devices in which the flow of energy may occur in either direction at any instant.

Another object of the present invention is to provide a control system for an electric current converting system employing electron discharge devices permitting the flow of energy between lines having instant polarities in any desired relation in time.

Another object of the present invention is to provide a control system for an electric current converting system employing electron discharge devices in which the flow of current through the anodes of the device may be released and interrupted at will.

Another object of the present invention is to provide a control system for an electric current converting system employing electron discharge devices presenting a plurality of electrically distinct circuits for the flow of current.

Another object of the present invention is to provide a control system for an electric current converting system employing electron discharge devices in which the flow of current occurs through only one of several circuits at any time.

Another object of the present invention is to provide a control system for an electric current converting system employing electron discharge devices presenting a plurality of circuits in which the flow of circulating currents is entirely avoided.

Objects and advantages other than those above set forth will be apparent from the following description when read in connection with the accompanying drawings, in which:

Fig. 1 diagrammatically illustrates a bi-directional frequency changing system in which the power output and the voltage ratio of the several lines in the system may be automatically regulated;

Fig. 2 is a diagram of the terminal voltages of the transformer secondary windings of the embodiment illustrated in Fig. 1;

Fig. 3 diagrammatically illustrates a bi-directional alternating current rectifying and direct current inverting system in which the voltage of the direct current line may be automatically regulated;

Fig. 4 is a diagram of the terminal voltages of the transformer windings of the embodiment illustrated in Fig. 3; and

Fig. 5 diagrammatically illustrates the anode and control electrode structure of the discharge devices employed in the present invention.

It will be understood that although the embodiments shown illustrate different combinations of control elements, elements from each embodiment may be combined into a single system without departing from the spirit of the invention.

Referring more particularly to the drawings by characters of reference, reference numeral **6** represents an alternating current line operating at any desired voltage at any frequency and having any desired number of phases, herein represented as a three phase line. Unless otherwise stated, it will be assumed that line 6 is connected with suitable sources maintaining the voltage thereof at a constant value for the purpose of simplifying the description of the operation of the system. The present system is connected to convert energy between line 6 and a second line 7 which, in the embodiment illustrated in Fig. 1, is assumed to be a single phase alternating current line operating at any voltage and at any desired frequency. The frequency of line 7 may or may not be in definite relation with the frequency of line 6, so that the instant polarities of lines 6 and 7 may be in any relation in time during the operation of the system. It will be understood that the system could also be utilized for converting current between line 6 and a line at any number of phases by suitably modifying the elements shown and by suitably duplicating some of such elements. Line 6 is connected with the primary winding 11 of a transformer 9 having two secondary windings 12 and 13 each comprising a plurality of phase displaced portions connected in star to form a neutral point. The different phase portions of winding 12 are severally connected with anodes 14 of an electron discharge device 17 having a cathode 18. Such device is illustrated as being of the discontinuously controllable vapor type and will be referred to as rectifier 17 for the sake of brevity.

As illustrated more clearly in Fig. 5, each anode 14 is provided with a control electrode 22 of a type operable to interrupt the flow of current through anode 14 at will by energization thereof at a suitable potential by means of a suitable source. Such result is obtained if the control electrode is capable of removing the positive charges of the ions present in the space between the anode and the control electrode at a rate greater than the rate of appearance of such ions within such space. Such appearance of ions may be the result of collisions of electrons with vapor atoms or of wandering of the ions from the space outside the control electrode through the openings thereof. In addition to the above mentioned removal of ionic charges, the control electrode should repel the electrons produced at the cathode or in the space outside of the control electrode so that no further transport of charges to the anode can take place. To obtain such result without resorting to the use of a source of such high potential as to introduce disturbances in the operation of the rectifier, it is necessary to employ a control electrode having dimensions maintained within predetermined limits. It has been found, for instance, that the desired result is obtained by means of a control electrode having the openings thereof, which are available for the passage of the discharge, so dimensioned that the ion sheaths formed about the several portions of the control electrode structure entirely fill such openings when the control electrode is unenergized and not traversed by the arc. In addition to the above overlapping of the ion sheaths, the total area of such openings is then preferably made equal to approximately 40% of the area of the anode in contact with the discharge, the distance between the control electrode and the anode is made substantially equal to the mean free path of the electrons, and the area of the control electrode in contact with the space contained between such electrode and the associated anode plus the total area of the surfaces of such control electrode forming the openings thereof is made to exceed two and one-half times the total cross-sectional area of such openings. It will be understood, however, that control electrodes of other dimensions than the above are also suitable for obtaining the desired result. The discharge occurring at each anode 14 is preferably also caused to come in contact with another electrode 21 connected with the anode through a resistor 19, the purpose of such electrode being to carry an uncontrolled current ionizing the discharge path of the anode and also to dissipate the surges appearing at the anode upon interruption of the flow of current therethrough by means of the control electrode. The different phase portions of winding 13 are severally connected with further anodes 16 of rectifier 17, such anodes being similar to anodes 14 and similarly provided with control electrodes 26 and with auxiliary electrodes 24 connected with anodes 16 through resistors 23.

Cathode 18 is connected with the neutral points of windings 12 and 13 through the primary winding 27 of a transformer having a secondary winding 28 connected with line 7. Winding 27 comprises two equal portions 27a and 27b when line 7 is a single phase line as shown in Fig. 1, but comprises a larger number of portions when line 7 is a polyphase line. Winding 12, anodes 14, cathode 18 and winding 27a and the connections therebetween constitute a circuit 25 for the flow of current between lines 6 and 7, and winding 13, anodes 16, cathode 18 and winding 27b and the connections therebetween constitute a second circuit 30 for the flow of current between the lines. Winding 28 is preferably connected with line 7 through a reactor 29 for the purpose of reducing the magnitude of any harmonic components of the current flowing therethrough. The connection of winding 28 with line 7 may be varied by means of a tap changer 31 operated by a reversible motor 32 energized from a suitable source such as a battery 34 through a switch 36 and through the contacts of a relay 33. In the present embodiment relay 33 is shown as being responsive to the voltage of line 7 and controlling the operation of tap changer 31 to maintain such voltage at a constant value.

The control electrodes of rectifier 17 are energized in pairs, each pair comprising one control electrode 22 energized through a resistor 37 and a control electrode 26 energized through a resistor 38, by means of simultaneously operating sources or from a single source such as a generator 41 having the neutral point thereof connected with cathode 18 through a battery 50. Each pair of control electrodes controls the operation of a pair of anodes connected with one phase of winding 12 and with the opposite phase of winding 13 respectively, and therefore receiving voltages which are equal and opposite at every instant from such windings. Generator 41 preferably delivers voltage of a frequency equal to the sum or to the difference of the frequencies of the voltages of lines 6 and 7. To obtain such effect generator 41 may be driven by motor 40 having an armature winding 42 energized from line 6 and a field winding 43 energized from line 7. Winding 43 is of the so-called split phase type having two of the terminals thereof connected with line 7 through a rheostat 44 and through a resistor 46 constituting part of a regulator 47. Line 7 is connected with a movable tap of resistor 46, such tap being displaceable by a torque element having an armature winding 48 connected with line 7 through a rheostat 49 and a field winding 51 energized from a current transformer 52, inserted in one of the conductors of line 7, through a voltage divider 53 and a reversing switch 54. The torque of windings 48 and 51 is opposed by a suitable spring 56, the characteristics of which determine the position taken by the regulator for each value of such torque.

In the system above described, rectifier 17 constitutes an electron discharge means having anodes connected in two interconnected circuits 25 and 30 which are electrically distinct. Rectifier 17 is connected with line 6 through transformer 9 and with line 7 through transformer 27, 28. The operation of rectifier 17 is controlled by control electrodes 22 and 26 operable to release and to interrupt the flow of current through the anodes. Generator 41 controls control electrodes 22 and 26 to permit a flow of energy in either direction between the lines by way of only circuit 25 or only circuit 30 at any time to prevent the flow of local currents in such circuits. Generator 41 controls simultaneously the control electrodes severally controlling the flow of current through both circuits 25 and 30. Regulator 47 is responsive to operating conditions of line 7 which are the voltage of such line and the magnitude of the current therein to regulate such voltage at predetermined values and to thereby control or regulate the intensity of the flow of inphase current and, therefore, the flow of energy between the lines. Tap changer 31 controls the operation of transformer 27, 28 to control or regulate the flow of reactive current and, therefore, the direction and the magnitude of the flow of reactive energy between the lines.

In operation, assuming, as a case most generally existant, that lines 6 and 7 are each connected with sources as well as with current consuming devices, such lines will be energized before initiation of the operation of the system and motor 40 will rotate at a speed proportional to, for instance, the sum of the frequencies of the voltages of lines 6 and 7. Generator 41 then impresses, on control electrodes 22 and 26, voltages having a frequency equal to the sum of the frequencies of the voltages of lines 6 and 7 whereas the associated anodes 14 and 16 receive voltages at the frequency of the voltage of line 6 from transformer 9. As a result of such energization control electrodes 22 sequentially release the flow of current through the several anodes 14 at voltages which are portions of the voltage of winding 12 in a manner such that such portions constitute, in time, a voltage of substantially sinusoidal wave shape having the frequency of the voltage of line 7, and represented by curve 15 in Fig. 2. Such voltage constitutes the terminal voltage of winding 12 impressed on winding 27*a* through anodes 14 and cathode 18. In a similar manner, winding 13 impresses on winding 27*b* a terminal voltage represented by curve 20 in Fig. 2, which is equal to the voltage of winding 12 and opposed thereto at every instant, either of voltages inducing a voltage proportional thereto in winding 28 and always substantially in phase with the voltage of line 7 as a result of the opposed connection of winding portions 27*a* and 27*b*. During the above operation, current can be conducted at every instant over one of the anodes 14 and over one of the anodes 16; inphase current transmitted from line 6 to line 7 will flow through the one anode receiving a positive voltage from the associated winding whereas inphase current flowing from line 7 to line 6 will flow over the one anode receiving a negative voltage from the associated winding. Reactive current flowing between the two lines will flow alternately through positively energized anodes and through negatively energized anodes as the flow of energy reverses periodically during the transmission of reactive current.

As a result of simultaneous energization of control electrodes 22 and 26 associated with anodes receiving equal and opposite voltages from windings 12 and 13, the particular anode of a pair carrying load current is always at a potential slightly higher than that of cathode 18 and the anode not carrying current is at a slightly lower potential than cathode 18 and therefore cannot carry any local current. For instance, if an anode 14 receives a positive voltage from the associated portion of winding 12 and is carrying current, such voltage must be equal to the arc drop in rectifier 17 plus the positive voltage of winding portion 27*a*, neglecting the impedance drops in circuit 25, and is therefore greater in magnitude than the voltages of winding portions 27*a* and 27*b*. The corresponding anode 16 then receives, from a portion of winding 13, a negative voltage greater than the voltage of winding portion 27*b* and is, therefore, negative with respect to cathode 18 by the amount of the arc drop in rectifier 17. A similar conclusion will result from analysis of other current conditions in rectifier 17. If anodes 14 and 16, simultaneously made operable by their respective control electrodes, were receiving different voltages, for instance if anode 16 was receiving a negative voltage materially lower than the positive voltage impressed on anode 14 while anode 14 was carrying current, anode 16 would be brought to a materially higher potential than cathode 18 and a flow of current would occur through circuit 30, such flow being limited by the reactance of windings 13 and 27*b* but serving no useful purpose. Even if the control electrodes were energized in pairs releasing the flow of current through anodes receiving equal and opposite voltages and if such control electrodes were of the usual type incapable of interrupting the flow of current; conditions would frequently be such that, while a pair of control electrodes 22 and 26 are energized to release the flow of current through a pair of anodes 14 and 16 at equal and opposite voltages, current would continue to flow through the precedingly operating anode 16 then receiving a different voltage from winding 13, thereby again causing local current to flow through circuit 30. It is, therefore, necessary to utilize the particular type of control electrodes described to cause immediate transfer of the flow of current from one anode to another in a positive manner in response to the energization of the control electrodes. If switches 36 and 54 are open, tap changer 31 and regulator 47 are inoperative and the flow of current between lines 6 and 7 occurs in the one or in the other direction at a rate depending upon the relation between the voltages of lines 6 and 7. If one of the lines is connected with only current consuming devices, the flow of current occurs at a rate depending upon the characteristics of the current consuming devices and upon the voltage of the particular line then operating as a supply line.

If switch 54 is closed to connect winding 51 in the one or in the other manner with voltage divider 53, windings 48 and 51 produce a torque proportional to the magnitude of the flow of power in line 7. If such flow of power occurs, for instance, from line 6 to line 7 and is greater than the value desired therefor, the torque of windings 48 and 51 overcomes the action of spring 56 and causes the regulator to displace the tap of resistor 46. The distribution of the flow of current through the several portions of winding 43 is thereby varied with the result that the magnetic axis of such winding is displaced in space. As a result of such displacement, armature 42 and the rotor of generator 41 are caused to lag, thereby retarding the moments of positive energization of control electrodes 22 and 26. The output voltages of windings 12 and 13 through rectifier 17 are thereby caused to lag with respect to the voltage of line 7 with the result that the flow of power between lines 6 and 7 decreases. Such action continues until such flow of power is reduced to the desired value, at which time regulator 47 becomes stationary and remains in the position reached thereby until some change in operating condition again causes the flow of power to depart from the desired value. If such flow of power was below the desired value regulator 47 would return such flow of power to the desired value in a manner opposite to that described above. If, in addition to closure of switch 54 as above, switch 36 is closed relay 33 will energize motor 32 to cause rotation of such motor in the one or in the other direction depending upon the magnitude of the voltage of line 7. If the voltage of line 7 is greater than the value desired therefor, relay 33 closes one of the contacts thereof thereby energizing motor 32 which drives tap changer 31 in a manner such that the number of turns of winding 28 in circuit is reduced. Such action continues until the voltage of line 7 is restored to the value desired, at which time relay 33 opens the contact thereof and tap changer 31 remains stationary. If the voltage of line 7 is below the value desired, relay 33 will close the other contact thereof to cause tap changer 31 to increase the effective number of turns of winding 28.

If only current consuming devices are connected with line 7, such devices are accordingly supplied with current at a constant voltage. If, however, the voltage of line 7 tends to be maintained by suitable sources at a predetermined value different from the value for which relay 33 is adjusted, tap changer 31 will maintain winding 28 adjusted in a manner such that a flow of reactive current will occur between line 6 and line 7.

In the embodiment illustrated in Fig. 3, line 7 is assumed to be a direct current line operating at an average voltage depending upon the voltage of line 6 and upon the characteristics of transformer 9. Anodes 14 are then assembled in a separate rectifier 57 having a cathode 58 connected with the negative conductor of line 7 through a reactor 59. Anodes 16 are similarly assembled in a second separate rectifier 61 having a cathode 62 connected with the positive conductor of line 7 through a second reactor 63. The neutral point of winding 12 is connected with cathode 62 by a conductor constituting, with winding 12 and with rectifier 57, a circuit 64 for the flow of energy from line 7 to line 6. The neutral point of winding 13 is similarly connected with cathode 58 by a conductor completing a circuit 66 comprising winding 13 and rectifier 61 for the flow of energy from line 6 to line 7. A plurality of reactors 67 associated with capacitors 68 may be inserted between the conductors of line 7 to cooperate with reactors 59 and 63 in reducing the magnitude of any alternating components of the current flowing between line 6 and line 7. In the present embodiment, control electrodes 22 and 26 must receive voltages which are alternately positive and negative with respect to cathodes 58 and 62 respectively and, as such cathodes are at different potentials, control electrodes 22 and 26 are preferably energized by means of separate sources such as secondary windings 69 and 71 of a transformer or phase shifter 70 having a primary winding 72 energized from line 6. Windings 69 and 71 are connected with cathodes 58 and 62 through batteries 60 and 65 respectively. Winding 72 is preferably adjustable in space by means of a torque motor 75 to vary the phase relation between the voltages of winding 72 and windings 69 and 61. Torque motor 75 is provided with an armature winding 74 connected in series with a field winding and across the conductors of line 7 through a rheostat 77 and a switch 78. The field of motor 75 may be provided with a second winding 79 energized through a switch 81 and a rheostat 82 from a shunt 83 inserted in one of the conductors of line 7.

In the present embodiment the conversion of current is obtained by discharge means consisting of rectifiers 57 and 61 which are connected with line 7 either directly or by means of reactors 59 and 63. Phase shifter 70 performs the same functions as generator 41 in the embodiment of Fig. 1. In the present embodiment, circuits 64 and 66 constitute electrically distinct circuits forming paths for the flow of local currents but load current flows only through one circuit when energy is transmitted in one direction from one line to the other. Torque motor 75 has the same function as regulator 47, and rheostat 77 has the same functions as switch 54 as will appear hereinafter.

In operation, assuming switches 78 and 81 to be open, torque motor 75 is inoperative and the voltages of windings 72 and 69, 71 remain in invariable phase relation. In the present embodiment, the control electrodes are so energized that each control electrode 26 becomes positive when the associated anode 16 receives a positive voltage from winding 13 and simultaneously a control electrode 22 becomes positive associated with an anode receiving, from winding 12, a negative voltage equal to the positive voltage received by the anode 16. The terminal voltages of windings 12 and 13, through rectifiers 57 and 61, are then undulating direct current voltages of average values substantially equal to the voltage of line 7. The positive terminal voltage of winding 13 through rectifier 61 is represented by curve 35 in Fig. 4, and the negative terminal voltage of winding 12 through rectifier 57 is represented by curve 45. Either of such voltages may be both impressed on line 7 in the same direction as a result of the opposed connections of the windings and of the rectifiers with such line. Such voltages have equal average values if the voltages of the portions of windings 12 and 13 are equal, and, in addition, are equal at every instant because they are constituted by similar portions of the voltage waves of windings 12 and 13. If the terminal voltage of winding 13 through rectifier 61 is greater than the voltage of line 7, anodes 16 sequentially carry currents which combine at cathode 62 to form a direct current flowing from such cathode through reactor 63, line 7 and the load consuming device connected therewith, reactor 59, winding 13, and anodes 16. If the terminal voltage of winding 13 is lower than the voltage of line 7 energy will be transmitted from line 7 to line 6 from the sources connected with line 7 through reactor 63, winding 12, anodes 14, cathode 58 and reactor 59 back to line 7.

During the transmission of energy in either direction between the lines, circuits 64 and 66 are continuously conductive and are connected in series to form a path comprising winding 13, anodes 16, cathode 62, winding 12, anodes 14 and cathode 58 back to winding 13. At any instant considered, however, the positive voltage of winding 13 and the negative voltage of winding 12, which are connected in series through anodes rendered operative by the control electrodes, are equal in magnitude and opposite in sign so that such voltages cancel each other in such path and do not result in the flow of useless currents therethrough. To actually obtain a transmission of energy between lines 6 and 7, the difference between the voltage of winding 12 or of winding 13 and the voltage of line 7 must exceed the arc drop in rectifier 57 or in rectifier 61 and energy is therefore not transmitted if such difference is smaller than the value of such arc drop. When it is desired to obtain a transmission of energy under such circumstances, winding 12 is provided wtih taps to reduce the voltage thereof to a value which may be less than the value of the voltage of winding 13 by the sum of the arc drops in rectifiers 57 and 61. Under such conditions the flow of energy will always occur through one of the rectifiers but no circulating currents will flow through circuits 64 and 66 because the resultant voltage impressed on such path, equal to the difference between the positive voltage of winding 13 and the negative voltage of winding 12, is then not sufficient to overcome the arc drops in rectifiers 57 and 61 inserted in series in such path. If it is desired, the voltage of winding 13, instead of the voltage of winding 12, may be reduced and therefore made smaller than the voltage of winding 12 to any desired extent and the flow of circulating currents in circuits 64 and 66 then cannot occur as a result of the valve action of rectifiers 57 and 61 which do not permit flow of current in the direction in which such flow then tends to occur.

If switch 78 is closed, torque motor 75 produces a torque opposed to that of spring 73, thereby adjusting the position of winding 72 in response to the value of such torque to cause the voltage of line 7 to be maintained at a value depending upon the characteristics of spring 73. If, in addition to closure of switch 78, switch 81 is closed, the action of torque motor 75 is varied to modify the voltage of line 7 in dependence upon the magnitude of the current flowing therethrough and through shunt 83.

If line 7 is assumed to be an alternating current line as in the embodiment illustrated in Fig. 1, the connections of rectifiers 57 and 61 with lines 6 and 7 may be retained but control electrodes 22 and 26 must then be energized in dependence upon the frequency of the voltages of both lines 6 and 7. This may be obtained by energizing each group of control electrodes by a generator similar to generator 41, such generators preferably having the armatures thereof jointly driven by motor 40.

Although but a few embodiments of the present invention have been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims.

It is claimed and desired to secure by Letters Patent:

1. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes, means for connecting said discharge means with said line, a second electric current line, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, and means operable in each adjustment thereof for controlling the last said means to cause the flow of energy in either direction between said lines by way of said anodes.

2. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes connected in a plurality of electrically distinct circuits, means for connecting said discharge means with said line, a second electric current line, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, and means operable in each adjustment thereof for controlling the last said means to release the flow of energy in either direction between said lines by way of only one of said circuits at any time.

3. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes, means for connecting said discharge means with said line, a second electric current line, the instant polarities of said lines being in any relation in time, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, and means operable in each adjustment thereof for controlling the last said means to cause the flow of energy in either direction between said lines by way of said anodes dependent upon the relative voltage conditions of said lines.

4. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes connected in a plurality of electrically distinct circuits, means for connecting said discharge means with said line, a second electric current line, the instant polarities of said lines being in any relation in time, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, and means controlling the last said means to cause the flow of energy in either direction between said lines by way of a different one of said circuits for each direction of energy flow.

5. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes connected in a plurality of interconnected circuits forming paths for the flow of local currents therethrough, means for connecting said discharge means with said line, a second electric current line, the instant polarities of said lines being in relation of any kind in time, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, and means controlling the last said means to permit the flow of energy in either direction between said lines in a

manner such as to prevent the flow of local currents in said circuits.

6. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes connected in a plurality of parallel interconnected circuits forming paths for the flow of local current therethrough, means for connecting said discharge means with said line, a second electric current line, the instant polarities of said lines being in relation of any kind in time, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, and means simultaneously controlling the discharge controlling means severally controlling the flow of current through the different parallel circuits to permit the flow of energy in either direction between said lines.

7. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes connected in a plurality of interconnected circuits forming paths for the flow of local current therethrough, means for connecting said discharge means with said line, a second electric current line, the instant polarities of said lines being in any relation in time, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, and means controlling the last said means to cause the flow of energy in either direction between said lines in a manner such as to introduce in said circuits only voltages causing flow of current through only one of said circuits at a time.

8. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes, means for connecting said discharge means with said line, a second electric current line, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, means operable in each adjustment thereof for controlling said discharge controlling means to release the flow of energy in either direction between said lines, and means responsive to an operating condition of one of said lines controlling the last said means.

9. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes, means for connecting said discharge means with said line, a second electric current line, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, means controlling said discharge controlling means to cause the flow of energy in either direction between said lines, and means responsive to the magnitude of the flow of current in one of said lines controlling the last said means.

10. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes, means for connecting said discharge means with said line. a second electric current line, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, means controlling energization of said discharge controlling means to release the flow of energy in either direction between said lines, and means responsive to the magnitude of the voltage of one of said lines controlling the last said means.

11. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes, means for connecting said discharge means with said line, a second electric current line, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, means controlling energization of said discharge controlling means to release the flow of energy in either direction between said lines, and means controlling the last said means for regulating the voltage of one of said lines to predetermined values.

12. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes, means for connecting said discharge means with said line, a second electric current line, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, means controlling said discharge controlling means to release the flow of energy in either direction between said lines, and means responsive to the flow of energy and controlling the last said means to control the direction of the flow of energy between said lines..

13. In a bi-directional electric current converting system, an electric current line, electron discharge means having a plurality of anodes, means for connecting said discharge means with said line, a second electric current line, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, means controlling energization of said discharge controlling means to release the flow of energy in either direction between said lines, and means responsive to the flow of energy and controlling the last said means to control the intensity of the flow of energy between said lines.

14. In a bi-directional electric current converting system, an alternating current line, electron discharge means having a plurality of anodes, means for connecting said discharge means with said line, a second alternating current line, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, means controlling energization of said discharge controlling means to release the flow of energy in either direction between said lines, and means responsive to the flow of energy and controlling the last said means to control the intensity of the flow of in-phase current between said lines.

15. In a bi-directional electric current converting system, an alternating current line, electron discharge means having a plurality of anodes, means for connecting said discharge means with said line, a second alternating current line, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, means controlling energization of said discharge controlling means to release the flow of energy in either direction between said lines, and means for controlling the

operation of the third said means to control the flow of reactive current between said lines.

16. In a bi-directional electric current converting system, an alternating current line, electron discharge means having a plurality of anodes, means for connecting said discharge means with said line, a second alternating current line, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, means controlling operation of said discharge controlling means to cause the flow of energy in either direction between said lines, and means for controlling the operation of the third said means to control the magnitude of the flow of reactive current between said lines.

17. In a bi-directional electric current converting system, an alternating current line, electron discharge means having a plurality of anodes, means for connecting said discharge means with said line, a second alternating current line, means for connecting said discharge means with the second said line, discharge controlling means operable to release and to interrupt the flow of current through said anodes, means controlling operation of said discharge controlling means to cause the flow of energy in either direction between said lines, and means for controlling the operation of the third said means to control the direction of the flow of reactive energy between said lines.

18. In a bi-directional electric current converting system, an electric current line, an electron discharge device of the vapor type having a plurality of anodes with associated control electrodes operable to interrupt the flow of current through said device, a transformer connecting said line and said discharge device, a second electric line, means for connecting said discharge device with the second said line, means operable only in one direction to energize the control electrodes to release energy flow in either direction between said lines, and means automatically responsive to the magnitude of the energy flow in the second said line to control the second said means.

19. In a bi-directional electric current converting system, an electric current line, an electron discharge device of the vapor type having a plurality of anodes with associated control electrodes operable to interrupt the flow of current through said device and a cathode, a transformer connecting said line and said discharge device, a second electric line, means for connecting said discharge device with the second said line, a source of potential related to the cathode potential of said device, means operable only in the same direction to control application of said source to the control electrodes to release energy flow in either direction between said lines, and means responsive to the magnitude of the energy flow in the second said line to control the second said means.

20. In a bi-directional electric current converting system, an electric current line, an electron discharge device of the vapor type having a plurality of anodes with associated control electrodes operable to interrupt the flow of current through said device and a cathode, a transformer connecting said line and said discharge device, a second electric line, means for connecting said discharge device with the second said line, a source of potential related to the cathode potential of said device, a motor jointly energized from said lines to control application of said source to the control electrodes to release energy flow in either direction between said lines, and means responsive to the magnitude of the energy flow in the second said line to control the second said means.

21. In a bi-directional electric current converting system, an electric current line, an electron discharge device of the vapor type having a plurality of anodes with associated control electrodes operable to interrupt the flow of current through said device and a cathode, a transformer connecting said line and said discharge device, a second electric line, means for connecting said discharge device with the second said line, a source of potential related to the cathode potential of said device, a motor jointly energized from said lines to control application of said source to the control electrodes to release energy flow in either direction between said lines, a rheostat connected with said motor for varying the operation thereof, and means responsive to the magnitude of the energy flow in the second said line to control variation of said rheostat.

22. In a bi-directional electric current converting system, an electric current line, an electron discharge device of the vapor type having a plurality of anodes with associated control electrodes operable to interrupt the flow of current through said device, a transformer connecting said line and said discharge device, a second electric line, a tapped transformer connecting said discharge device with the second said line, means for automatically changing the connections of the last said transformer with the second said line, means operable only in one direction to energize the control electrodes to release energy flow in either direction between said lines, and means automatically responsive to the magnitude of the energy flow in the second said line to control the second said means.

23. In a bi-directional electric current converting system, an electric current line, an electron discharge device of the vapor type having a plurality of anodes with associated control electrodes operable to interrupt the flow of current through said device, a transformer connecting said line and said discharge device, a second electric line, a tapped transformer connecting said discharge device with the second said line, a tap changing mechanism for changing the connections of the last said transformer with the second line in response to the potential condition of the second said line, means operable only in one direction to energize the control electrodes to release energy flow in either direction between said lines, and means automatically responsive to the magnitude of the energy flow in the second said line to control the second said means.

DIDIER JOURNEAUX.