

April 14, 1936.

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2,037,567

ELECTRON DISCHARGE DEVICE CONTROL SYSTEM

Filed June 3, 1933

5 Sheets-Sheet 1

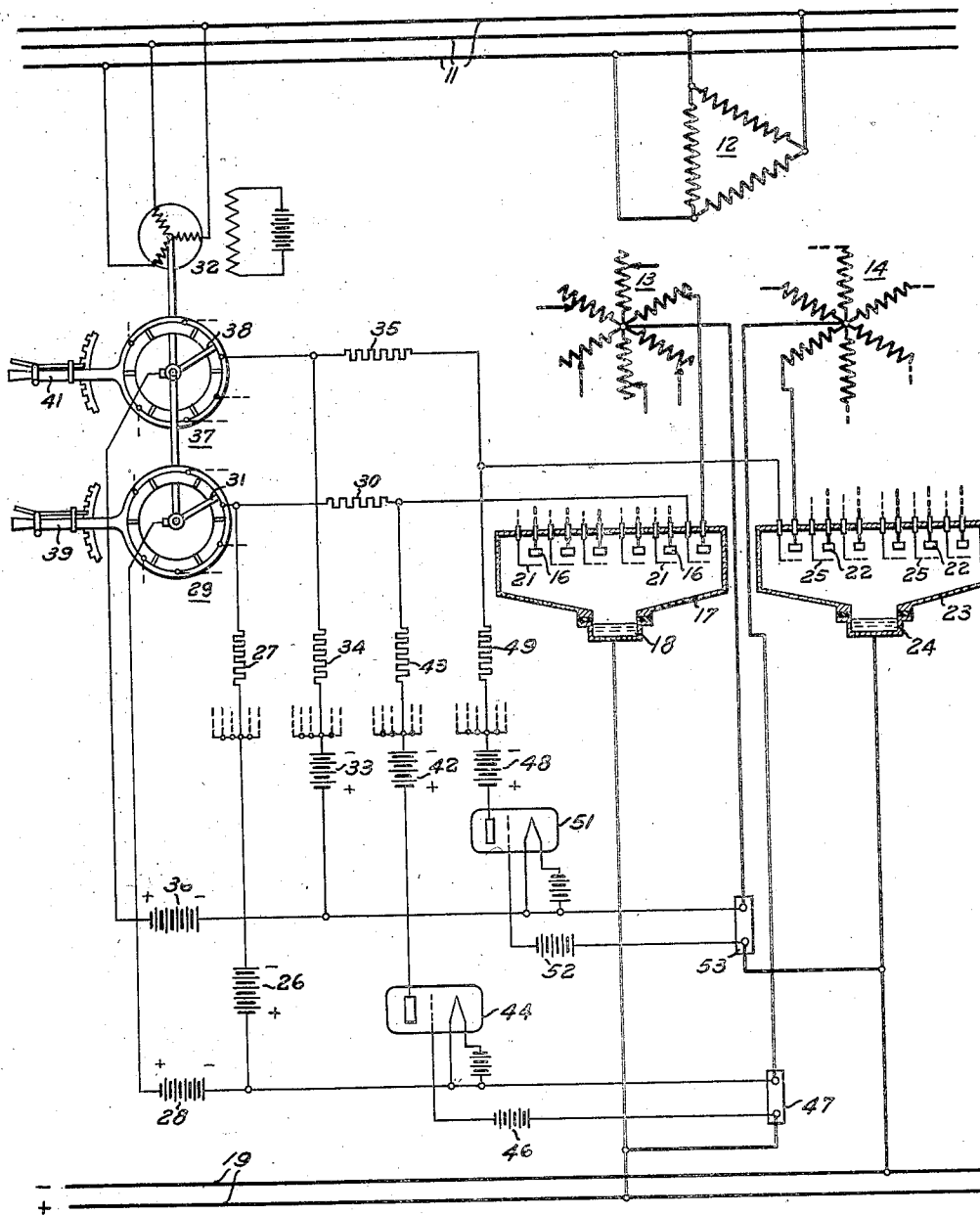


Fig. 1

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5 Sheets-Sheet 2

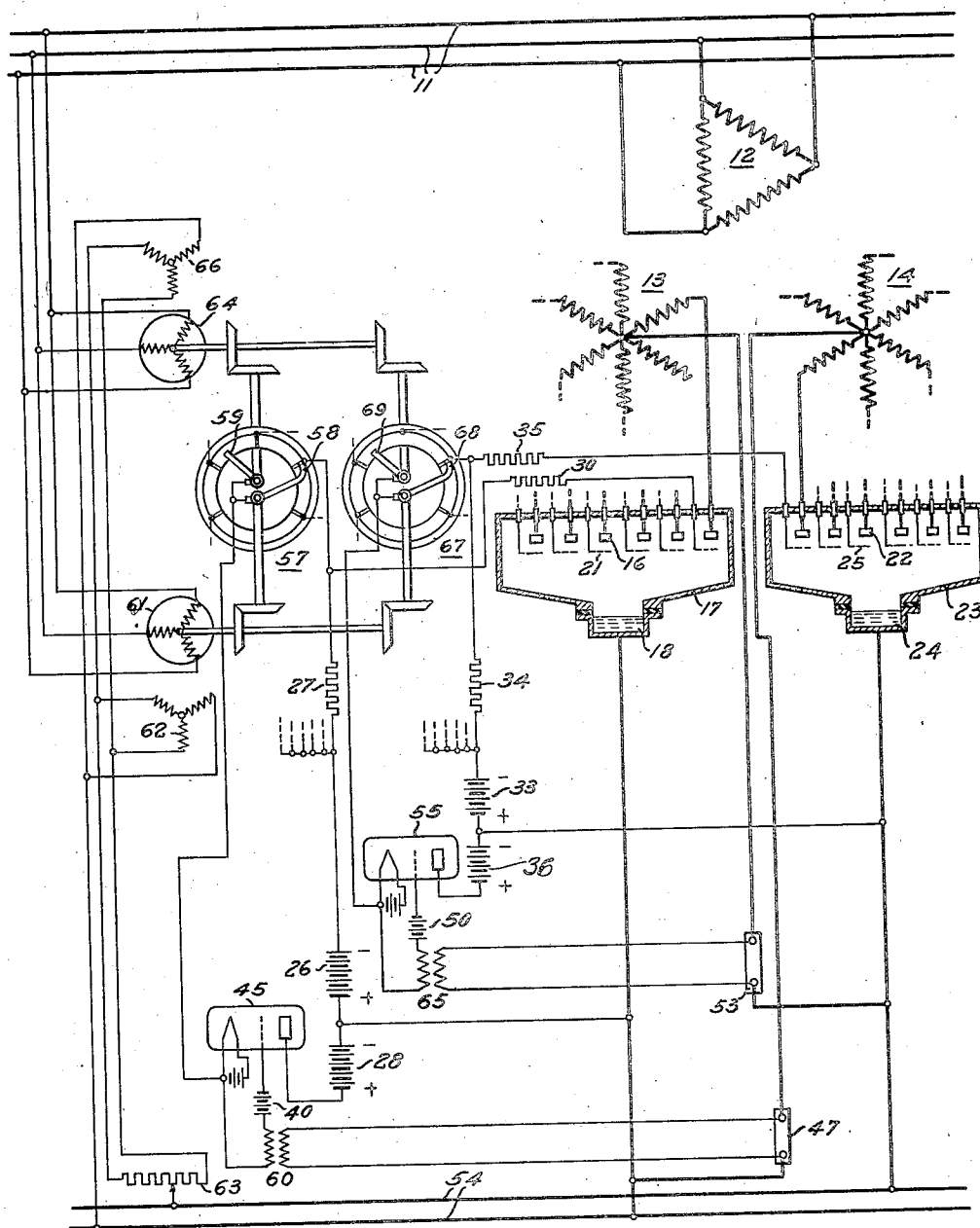


Fig. 2

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5 Sheets-Sheet 3

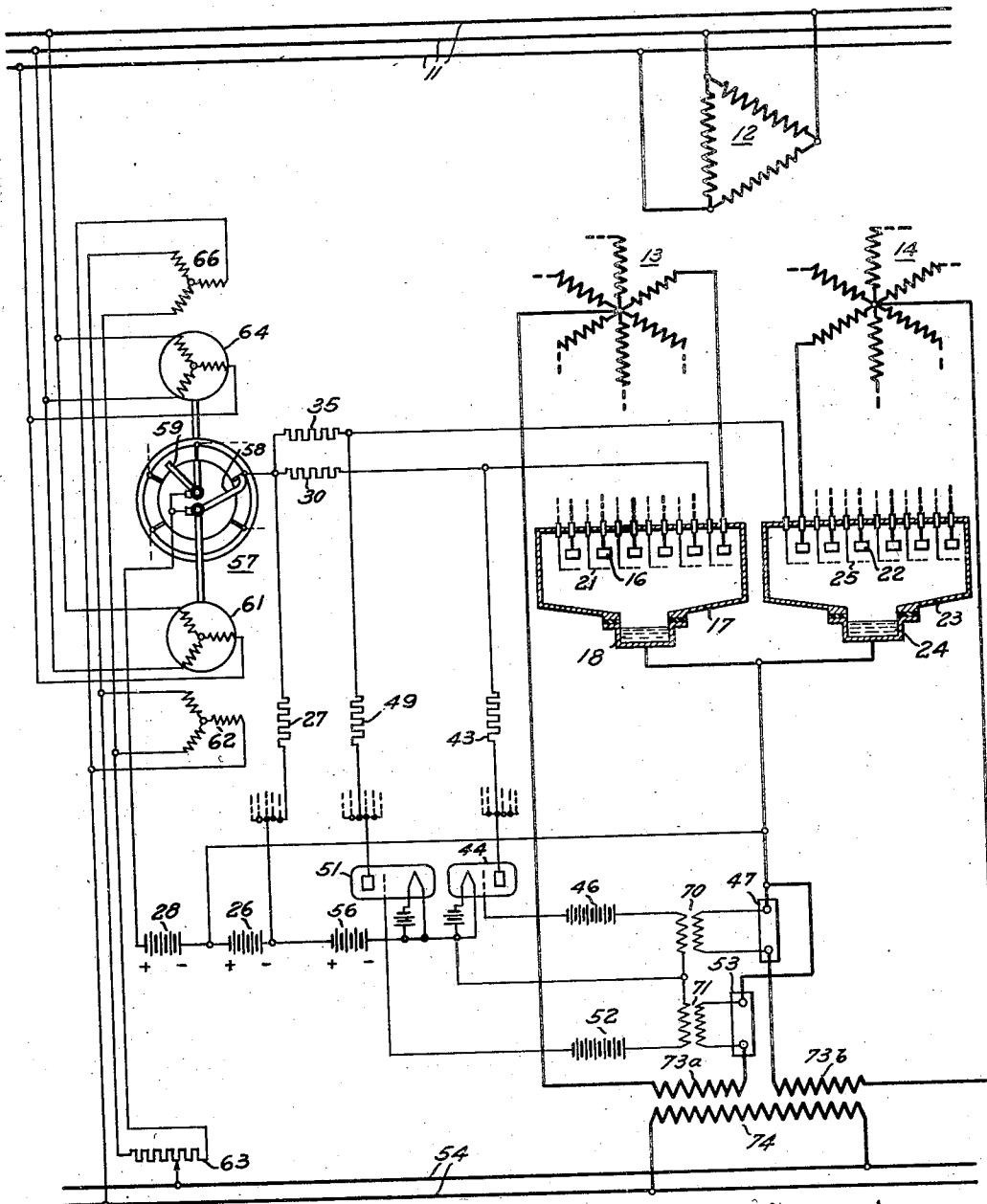


Fig. 3

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5 Sheets-Sheet 4

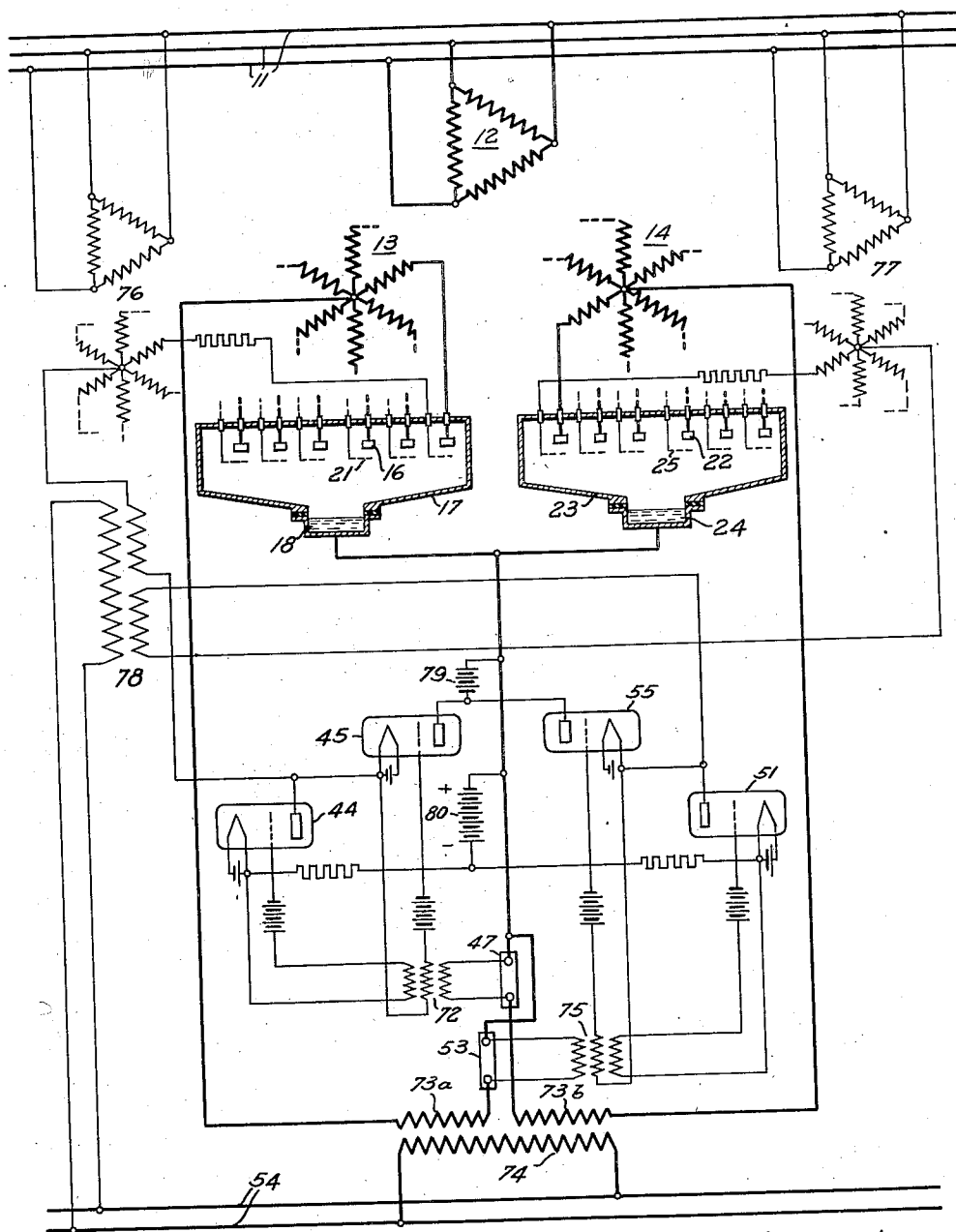


Fig. 4

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ELECTRON DISCHARGE DEVICE CONTROL SYSTEM

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5 Sheets-Sheet 5

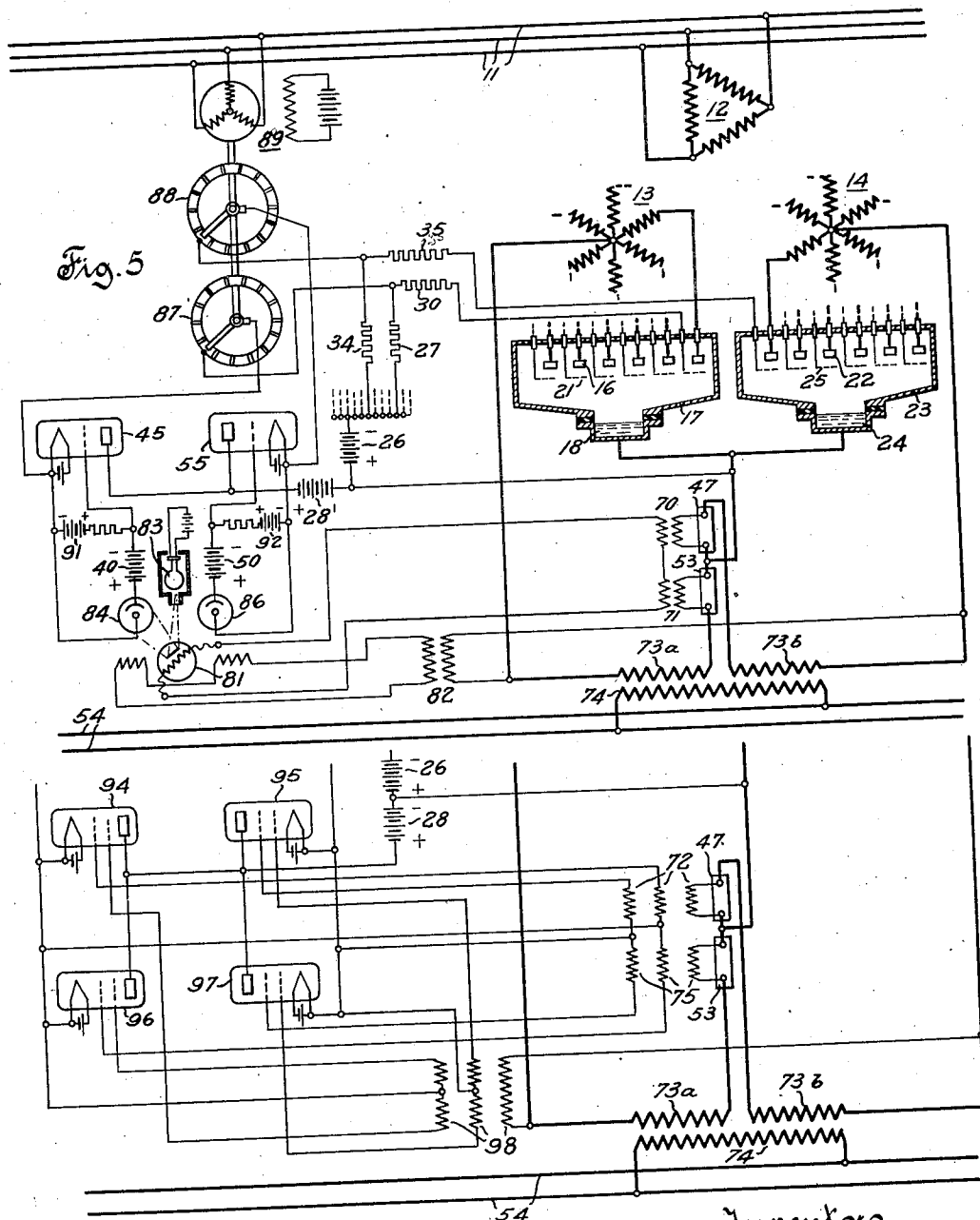


Fig. 6

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UNITED STATES PATENT OFFICE

2,037,567

ELECTRON DISCHARGE DEVICE CONTROL SYSTEM

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In Germany June 17, 1932

14 Claims. (Cl. 171—97)

This invention relates to improvements in reversible electric current converting systems employing electron discharge devices and more particularly to means in connection with such systems for controlling the sequential operation of two or more electrically distinct discharge devices forming portions of such systems.

In reversible electric current converting systems employing electron discharge devices, the current is generally transmitted in one direction through one device and is transmitted in the reverse direction through another device. If one of the lines between which current is to be transmitted is a direct current line, the reversal of the flow of energy occurs infrequently at intervals determined by the variations of the voltages of the lines and by the action of any current regulating means provided therefor. If the two lines are alternating current lines, the flow of energy between the two lines occurs regularly during every cycle of the voltage of one of the lines if the current is transmitted at unity power factor, and reverses four times during every cycle if the current is transmitted at a leading or a lagging power factor. Such reversals make it necessary to control the two devices in such a manner that both devices be operable to carry current at every instant. In general, the voltage relations in the circuits of the two devices are not symmetrical at every instant with the result that circulating currents flow in the circuits connecting the two devices, thereby producing losses in the circuit and lowering the power factor of the current drawn from the supply line. The flow of such circulating currents may be avoided by controlling the devices in response to the flow of useful current therethrough in such a manner that only the device carrying useful current is made operable by the action of the control means which is such that any other devices are then inoperative to offer a conductive path to the flow of circulating currents. Such control is preferably obtained by means of auxiliary electron discharge devices controlled in response to the flow of useful current.

It is therefore among the objects of the present invention to provide means in a current converting system employing electron discharge devices in distinct circuits by which only one of such devices is operative at any instant.

Another object of the present invention is to provide means in a current converting system employing electron discharge devices in distinct circuits by which only the device which is to carry useful current is operative at any instant.

Another object of the present invention is to provide means in a current converting system employing electron discharge devices in distinct circuits by which such devices are controlled in response to the flow of useful current.

Another object of the present invention is to provide means in a current converting system employing electron discharge devices in distinct circuits by which the flow of circulating current between the devices is prevented.

Another object of the present invention is to provide means in a current converting system employing electron discharge devices in distinct circuits permitting the passage of useful current alternately in each direction of flow through the system.

Another object of the present invention is to provide means in a current converting system employing electron discharge devices in distinct circuits permitting the flow of in-phase and of reactive energy in either direction of flow through the system.

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:

Figure 1 diagrammatically illustrates one embodiment of the present invention applied to the control of a reversible current rectifying-inverting system employing an electron discharge device for the rectifying operation and another such device for the inverting operation.

Figure 2 diagrammatically illustrates another embodiment of the present invention applied to the control of a reverse frequency converting system employing two electron discharge devices in electrically distinct circuits in such manner that the devices are controlled in response to the flow of current through such circuits.

Figure 3 diagrammatically illustrates a modified embodiment of the present invention differing from the embodiment illustrated in Figure 2 in that the cathodes of the two devices are connected at a common point and in that the control electrodes of the two devices are energized by common means.

Figure 4 diagrammatically illustrates another modified embodiment of the present invention differing from the embodiment illustrated in Figure 3 in that the control electrodes of the devices are energized with alternating current.

Figure 5 diagrammatically illustrates another modified embodiment of the present invention differing from the embodiment illustrated in

Figure 3 in that the discharge devices are controlled in response to the direction of the flow of energy current between the two lines.

Figure 6 diagrammatically illustrates a portion of another modified embodiment of the present invention differing from the embodiment illustrated in Figure 5 in the means utilized for energizing the control electrodes of the discharge devices.

Referring more particularly to the drawings by characters of reference, reference numeral 11 designates an alternating current line of any desired frequency and number of phases herein represented as a three-phase line only for the reason that such type of line is most frequently utilized in practice. Line 11 is connected with the primary winding 12 of a transformer having two secondary windings 13 and 14 each comprising a plurality of phase portions connected to form neutral points for such windings. In the embodiment illustrated in Fig. 1 windings 13 and 14 may deliver either identical or different voltages and the relative value of such voltages may be adjusted by providing one of the windings such as winding 13 with suitable taps. The phase portions of winding 13 are severally connected with the plurality of anodes 16 of an electron discharge device 17 having a cathode 18 connected with the positive conductor of a direct current line 19. Device 17 is provided with control electrodes 21 severally associated with each of the anodes 16 and is also provided with the usual arc igniting and maintaining means known to the art and therefore not shown. The phase portions of winding 14 are similarly connected with the plurality of anodes 22 of an electron discharge device 23 having control electrodes 25 and having a cathode 24 connected with the negative conductor of line 19. Cathode 18 is connected with the neutral point of winding 14 and cathode 24 is connected with the neutral point of winding 13. As a result of the above connections, device 17 may only be so controlled as to be operable as an alternating current rectifier to transmit current from line 11 to line 19, whereas device 23 is operable as a direct current inverter to transmit energy from line 19 to line 11.

The two circuits comprising devices 17 and 23 then present common connections with line 19, but such circuits may be designated as being electrically distinct for the reason that only one of such circuits carries current at any given instant.

Control electrodes 21 and 25 may be energized by any suitable well known means. In the present embodiment, control electrodes 21 are generally maintained at a negative potential with respect to cathode 18 by means of a battery 26 over resistances such as 27 and 30 and are sequentially charged at a positive potential with respect to cathode 18 by means of a battery 28 connected therewith over resistances such as 30 and the segments of a distributor 29 having a brush 31. Brush 31 is driven at a speed such that all control electrodes 21 will be energized from the battery 28 once during every cycle of the voltage of line 11 and is therefore preferably driven by a synchronous motor 32 directly energized from line 11. In a similar manner to the control of electrodes 21, control electrodes 25 are generally maintained at a negative potential with respect to cathode 24 by means of a battery 33 connected therewith over resistances such as 34 and 35 and are sequentially charged at a positive potential with respect to cathode 24 by means of a battery 36 and of a

distributor 37 having a brush 38 also driven by the motor 32. The times of energization of control electrodes 21 and 25 may be adjusted independently of each other by means of levers 39 and 41 which control the position of the several segments of distributors 29 and 37. Control electrodes 21 may also be continuously maintained at a negative potential with respect to cathode 18 by means of battery 42 over resistance such as 43 and an auxiliary electron discharge device 44 having an anode connected with the battery 42, a cathode connected with cathode 18 and a control electrode connected with the cathode of the device 44 over the bias battery 46 and over a shunt 47 inserted in the connection between cathode 18 and the neutral point of winding 14. Device 44 is such and the voltage of battery 46 is so adjusted that, when no current flows through shunt 47, device 44 is not conductive whereas when a current of any appreciable magnitude flows through shunt 47, device 44 is made conductive by the action of the control electrode thereof and completes the circuit of battery 42. In a similar manner to that described immediately above, control electrodes 25 may be maintained at a negative potential with respect to cathode 24 by means of a battery 48 and over resistances such as 49 and over another auxiliary discharge device 51 having a control electrode connected with a bias battery 52 and connected with a shunt 53 inserted in the conductor between cathode 24 and the neutral point of winding 13.

The operation of the system will be described assuming that the voltage of line 11 is maintained at a constant value but it will be understood that such operation will not be materially different if the voltage of line 11 is variable. Assuming the system to be connected as shown in Figure 1 and assuming that line 11 is energized, control electrodes 21 and 25 are generally maintained at a negative potential with respect to the associated cathode by means of batteries 26 and 33 and are sequentially charged at a positive potential with respect to the associated cathode as a result of the movement of brushes 31 and 38 driven by motor 32. If the voltage of line 19 is below a predetermined value, it will generally be desired to transmit current from line 11 to line 19, such current being rectified in device 17. Lever 39 is therefore so adjusted that each control electrode 21 becomes positive when the associated anode 16 receives, from winding 13, a voltage which is higher than the voltage of line 19. Under such conditions the several anodes of device 17 sequentially become positive with respect to cathode 18 and carry currents which combine to form a direct current flowing from cathode 18 to line 19. When the voltage of line 19 is higher than the predetermined value considered above, it will be desired to convert direct current from line 19 to alternating current for line 11 over device 23 and lever 41 is accordingly adjusted in such a manner that each control electrode 25 is positively energized from battery 36 at a time when the associated anode 22 receives, from winding 14, a negative voltage smaller than the voltage of line 19. As a result of such simultaneous adjustment of levers 39 and 41, devices 17 and 23 permit windings 13 and 14 to impress a voltage on a circuit from the neutral point of winding 13, over winding 13, device 17, winding 14, device 23 back to the neutral point of winding 13, such voltage being the sum of the voltages of the portions of windings 13 and 14 associated with anodes 16 and 22 simultaneously operable to

carry current. In general, the value of such voltage will cause the flow of a pulsating circulating current in the above described circuit in the absence of batteries 42 and 48 and of devices 44 and 51. When device 17 is carrying current, such current flows over shunt 53, thereby bringing the potential impressed on the control electrode of device 51 to a value which makes such device conductive. The negative potential of battery 42 is thereby applied to all control electrodes 25 thereby making all the associated anodes 22 inoperative with the result that a circulating current cannot flow over device 23. In a similar manner to that above described, when device 23 is carrying current, such current flowing over shunt 47, device 44 is thereby made conductive and the negative voltage of battery 42 is applied to all control electrodes 21, thereby making device 17 inoperative to carry a circulating current. By means of the above connections each device is therefore capable only of carrying useful current and the device not carrying current is made inoperative so that the circuit offered to the flow of circulating currents is always interrupted and such current cannot be established.

In the embodiment illustrated in Figure 2, transformer 12, 13, 14 and devices 17 and 23 are operable to convert alternating current between line 11 and a second alternating current line 54. The connections between such lines are then the same as the connections between lines 11 and 19 in Figure 1, but the means for energizing the control electrodes of the devices must be modified to permit the sequential flow of current through devices 17 and 23 during each cycle of the voltage of line 54. In the present embodiment, control electrodes 21 are again generally maintained at a negative potential with respect to cathode 18 by means of battery 26 and are sequentially and periodically brought to a positive potential with respect to cathode 18 by means of battery 28 connected over an auxiliary discharge device 45 and over a distributor 57 having two brushes 58 and 59. Device 45 is similar to devices 44 and 51 utilized in the embodiment of Figure 1, but differs therefrom in being connected with shunt 47 over a transformer 60 having the secondary winding thereof connected in series with a bias battery 40. Battery 40 is adjusted at such a value that when current is not flowing through shunt 47, device 45 is conductive and when a half wave sinusoidal current flows through shunt 47 the control electrode of device 45 is brought to a potential such as to render such device non-conductive. Brush 58 of distributor 57 is driven by the armature 61 of an electric motor having a field winding 62. Armature 61 is connected with line 11 and field 62 is connected with line 54 over a resistance 63 provided with a movable tap, such connection permitting an adjustment of the relative position of the rotating field in winding 62 with respect to the voltage cycle of line 54. As a result of such connections, brush 58 is driven at a speed which may be expressed as a number of revolutions per second which is equal to the frequency of the voltage of line 11 plus the frequency of the voltage of line 54, such frequencies being expressed in cycles per second. Brush 59 is driven by the armature 64 of another electric motor having a field 65, armature 64 being connected with line 11 and field 65 being connected with line 54 over resistance 63 in such a manner that brush 59 is driven at a speed equal to the frequency of the voltage of line 11 minus the frequency of the

voltage in line 54. Brushes 58 and 59 may each engage with contacts of distributor 57 which are of such width as to give only a momentary energization of each control electrode 21 upon engagement of either of the brushes with the distributor segment associated with such control electrodes. As a result of such connection, the output voltage of winding 13 over device 17 is a substantially sinusoidal voltage which is impressed on line 54, and current may flow through device 17 over any portion of such voltage wave depending upon the direction of energy flow between the two lines and upon the power factor of the current transmitted.

Device 23 is controlled in a manner similar to the control of device 17, control electrodes 25 being generally maintained at a negative potential with respect to the potential of cathode 24 by means of battery 33 and being sequentially and periodically made positive with respect to cathode 24 by means of battery 36 over discharge device 55 and distributor 67. Device 55 is connected with shunt 53 by means of a transformer 65 and a bias battery 50. Distributor 67 is provided with a brush 68 driven by motor armature 61 and a brush 69 driven by motor armature 64. Winding 14 thus delivers current over device 23 and the output voltage of device 23 is a substantially sinusoidal voltage similar to the voltage of winding 13 and device 17, and is similarly impressed on line 54. Due to the inverted connection of devices 17 and 23, such devices alternate in carrying current and thereby transmit positive and negative half waves of current between lines 11 and 54. When device 17 is carrying current, such current flows over shunt 53, thereby bringing the control electrode of device 55 to a voltage such that device 55 becomes non-conductive, with the result that control electrodes 25 cannot be energized from battery 36 and are maintained negative with respect to cathode 24 by battery 33. As in the embodiment illustrated in Figure 1, the flow of circulating current, which tends to establish itself between the two devices 17 and 23, is thus prevented by the inoperativeness of device 23 over the period considered. During the next half cycle of the voltage of line 54, device 23 is carrying current, such current flowing over shunt 47 with the result that device 45 is made nonconductive and control electrodes 21 are maintained negative with respect to cathode 18 by battery 26. During such period, device 17 is thus inoperative and prevents the flow of a circulating current therethrough. The times at which devices 17 and 23 carry current are dependent upon the direction of the flow of energy between the two lines and upon the power factor of the current transmitted and, as devices 45 and 55 are controlled in response to the flow of such current, such devices will always render either the device 17 or 23 inoperative dependent on which is not required to carry useful current; the flow of circulating currents is thus prevented in the absence of current or in the presence of current at any power factor.

In the embodiment illustrated in Figure 3, cathodes 18 and 24 are connected at a common point and must therefore be connected with the neutral points of windings 13 and 14 over the portions 73a and 73b of the primary winding of a transformer having a secondary winding 74 connected with line 54. Control electrodes 21 and 22 may then all be maintained negative with respect to the associated cathodes by means of battery 26 and may all be sequentially energized at

a positive potential with respect to the associated cathodes by means of battery 28 and distributor 57. Control electrodes 21 and 25 thus being energized by a common means, the positive energization thereof can no longer be controlled by means of devices 45 and 55 as in the embodiment illustrated in Figure 2. In the present embodiment, the control electrodes are maintained negative with respect to the associated cathodes by means of battery 56 and devices 44 and 51 in a manner similar to that illustrated in the embodiment of Figure 1, devices 44 and 51 being however preferably connected with shunts 47 and 53 over transformers 70 and 71. When device 17 is carrying current, such current flows over shunt 53 with the result that device 51 is made conductive and maintains control electrodes 25 negative with respect to cathode 24 with the result that device 23 is inoperative and cannot therefore carry any circulating current. During the next half cycle of the voltage of line 54, device 23 is carrying current, such current flowing through shunt 47 with the result that device 44 is made conductive and control electrodes 21 are maintained negative with respect to the associated cathode 18 by means of battery 56 and device 17 cannot carry any circulating current. The operation of the frequency converting system illustrated in the present embodiment is therefore entirely similar to that of the embodiment illustrated in Figure 2. It will be understood that, in the present and following embodiments, devices 17 and 23 may be replaced by a single device containing anodes 16 and 22, control electrodes 21 and 25, and having a cathode connected with winding 73 over shunts 47 and 53. Such device would however constitute part of two electrically distinct circuits, as the two circuits including windings 13 and 14 and having the cathode of the device in common do not carry current simultaneously at any instant.

In the embodiment illustrated in Figure 4, the control electrodes of devices 17 and 23 receive the voltages, in series, of a battery 79 connected with cathodes 18 and 24, of a transformer 78 energized from line 54, and of transformers 76 and 77 energized from line 11. As is well known, the output voltage of a system comprising such control electrode energizing means is again a substantially sinusoidal voltage, but the control electrode energizing means again controls the operation of the devices in such a manner as to prevent the flow of circulating current therebetween. In the present embodiment, shunt 47 controls the operation of auxiliary devices 44 and 45 over a transformer 72, and shunt 43 similarly controls the operation of auxiliary devices 51 and 55 over a transformer 75. Transformer 72 is the equivalent of transformers 60 and 70 in Figs. 2 and 3 and transformer 75 is the equivalent of transformers 65 and 71 in Figs. 2 and 3. Device 45 is conductive when no current flows through shunt 47 and completes the connection of control electrodes 21 to cause operation of device 17. Device 44 is then non-conductive and does not effect the operation of device 17. When current is flowing through shunt 47, device 45 becomes non-conductive and interrupts the connection of battery 79 with control electrodes 21 whereas device 44 becomes conductive and impresses on control electrodes 21 the negative voltage of a battery 80 which is of sufficient magnitude to maintain control electrodes 21 negative with respect to cathode 18 even when such control electrodes also receive voltages from trans-

formers 76 and 78. In a similar manner, when no current is flowing through shunt 53, device 55 connects battery 79 with control electrodes 25 over transformers 78 and 77, and device 51 is non-conductive. When current is flowing through shunt 53, device 55 becomes non-conductive and device 51 becomes conductive so that control electrodes 25 are energized at the voltage of battery 80 and of transformers 78 and 77, being thus maintained negative with respect to cathode 24. In the present embodiment as in the previously described embodiments, when device 17 is carrying current, device 23 is inoperative; when device 23 is carrying current, device 17 is inoperative and circulating currents therefore cannot flow between the two devices.

In the embodiment illustrated in Fig. 5, the control of the control electrodes 21 and 25 is common, such control electrodes being maintained negative with respect to cathodes 18 and 24 by means of battery 26 and being positively energized by means of battery 28 over two distributors 87 and 88 having the brushes thereof driven at a suitable speed by means of a synchronous motor 89 connected with line 11. Distributors 87 and 88 are each provided with a number of segments depending upon the ratio of the frequencies of the voltages of lines 11 and 54, such segments being suitably connected with all of control electrodes 21 and 25. The control electrodes are energized by distributors 87 and 88 in such a manner as to permit the associated anodes to carry current in phase with the voltage of line 54, such current being carried alternately by devices 17 and 23 over successive half cycles of the voltage of line 54, thus providing for the transmission of in-phase energy from line 11 to line 54. Distributor 88 is provided with the same number of segments as distributor 87 but the connections between such segments and control electrodes 21 and 25 are such that the control electrodes permit devices 17 and 23 to carry current in phase opposition with the voltage of line 54 thus providing for the transmission of in-phase energy from line 54 towards line 11. The connection of battery 28 with the brush of distributor 87 is effected over auxiliary device 45 and the connection of such battery with the brush of distributor 88 is effected over device 55. In the present embodiment, devices 45 and 55 are generally maintained conductive by the action of batteries 91 and 92 connected between the cathode and the control electrode of each of said devices. Devices 45 and 55 may be made non-conductive by the action of bias batteries 40 and 50 over photo-electric tubes 84 and 86. Tubes 84 and 86 are alternately made conductive upon receiving a beam of light from a suitable source such as a lamp 83 by reflection from the mirror of a wattmeter 81. Wattmeter 81 is of the oscillating type and is provided with an oscillatory armature connected with shunts 47 and 53 over transformers 70 and 71 and provided with fixed field coils connected with winding 73 over a transformer 82. As a result of such connection the armature of wattmeter 81 oscillates in response to the flow of energy between lines 11 and 54.

The direction of such flow of energy remains the same as long as the current transmitted between the two lines is in phase coincidence or in phase opposition with the voltage of line 54 but the direction of such flow reverses four times during every cycle of the voltage of line 54 when the current transmitted is leading or lagging because the flow of energy occurs in one direction

during the intervals over which the current is in phase with the voltage and occurs in the reverse direction during the intervals over which the current is in phase opposition with respect to the voltage. During the intervals over which the current is in phase with the voltage, wattmeter 81 reflects the beam of light received from source 83 on photo-electric tube 86, thereby making device 55 non-conductive and interrupting the connection between battery 28 and distributor 88. During such time battery 28 is connected with distributor 87 over device 45 which is conductive and the control electrodes of devices 17 and 23 are controlled by means of distributor 87. When the current is in phase opposition with the voltage of line 54 wattmeter 81 reflects the beam of light from source 83 on photo-electric tube 84 thereby rendering device 45 non-conductive and interrupting the connection between device 87 and battery 28. During such interval, distributor 33 is connected with battery 28 over device 55 and controls the control electrodes of devices 17 and 23. In the present embodiment, only one of the control electrodes of devices 17 and 23 is energized at any instant over distributor 87 or distributor 88 so that only one of anodes 16 or 22 is operable to carry current at any instant. Such anode then carries the useful current transmitted between line 11 and line 54, and as all the other anodes of devices 17 and 23 are then inoperative, no path is offered to the flow of circulating currents between such devices.

In the embodiment partly illustrated in Fig. 6, devices 44 and 55 and wattmeter 81 are replaced by discharge devices 94, 95, 96 and 97 each provided with an anode, a cathode and two control electrodes. One control electrode of each of devices 94 to 97 is energized in response to the flow of current between the two lines by means of shunts 47 and 53 and transformers 72 and 75. The second control electrode of each device is energized in response to the voltage of winding 73 by means of a transformer 98. Devices 94 to 97 are conductive when the control electrodes thereof are not energized from any of transformers 72, 75 and 98, and also when both control electrodes of the device are positively energized from the associated transformers. When either control electrode of any of devices 94 to 97 is negatively energized from the associated transformers, the device is non-conductive. When the current transmitted between the two lines is in phase with the voltage of line 54 and the current and the voltage are both positive, both control electrodes of device 94 are positive and such device connects battery 28 with the brush of distributor 87. At least one control electrode of each of the other devices 95, 96 and 97 is then negative and such devices are then non-conductive. When the voltage and the current are both negative, both control electrodes of device 96 are positive and such device connects battery 28 with distributor 87. When the current and the voltage are in phase opposition, and the voltage is positive and the current is negative, battery 28 is connected with the brush of distributor 83 over device 97, and during the intervals over which the current is positive and the voltage is negative, battery 28 is connected with distributor 88 over device 95. The connections between battery 28 and distributors 87, 88 are thereby effected at the same time as by the means illustrated in Fig. 5 and the operation of the system illustrated in Fig. 6 is thus identical with that of the system illustrated in Fig. 5.

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 reversible electric current converting system, an electric current line, a second electric current line, a plurality of electrically distinct electron discharge devices each having anodes with associated control electrodes and a cathode, means for connecting said discharge devices with each of said lines, a source of control potential, means for connecting said source with the control electrodes of one of said devices, and means responsive to the flow of current through another of said devices to interrupt the connections of the second said means with the said control electrodes of the said one of said devices.

2. In a reversible electric current converting system, an electric current line, a second electric current line, a plurality of electrically distinct electron discharge devices each having anodes with associated control electrodes and a cathode, means for connecting said discharge devices with each of said lines, a source of control potential, means for connecting said source with the control electrodes of one of said devices, a source of negative potential connected with the cathode of said one of said devices, and means responsive to the flow of current through another of said devices to connect said source of negative potential in parallel with said source of control potential and with the second said means to prevent flow of current through said one of said devices.

3. In a reversible electric current converting system, an electric current line, a second electric current line, a plurality of electrically distinct electron discharge devices each having anodes with associated control electrodes and a cathode, means for connecting said discharge devices with each of said lines, a source of control potential, means for connecting said source with the control electrodes of one of said devices, a source of negative potential connected with the cathode of the said one of said devices, and means responsive to the flow of current through another of said devices to connect said source of negative potential in series with said source of control potential and the second said means to prevent flow of current through the said one of said devices.

4. In a reversible electric current converting system, an electric current line, a second electric current line, a plurality of electrically distinct electron discharge devices each having anodes with associated control electrodes and a cathode, means for connecting said discharge devices with each of said lines, a source of control potentials, means for connecting said source with the control electrodes of said devices, and means responsive to the momentary direction of the flow of energy between said lines for controlling the second said means.

5. In a reversible electric current converting system, an electric current line, a second electric current line, a plurality of electrically distinct electron discharge devices each having anodes with associated control electrodes and a cathode, means for connecting said discharge devices with

each of said lines, a source of control potentials, means for connecting said source with the control electrodes of said devices, and means responsive to the flow of current between said lines and responsive to the voltage of one of said lines for controlling the second said means.

6. In a reversible electric current converting system, an electric current line, a second electric current line, electron discharge means comprising a plurality of electrically distinct circuits, means for connecting said discharge means with each of said lines, means for controlling the operation of said discharge means, and means controlling the third said means to prevent the flow of circulating currents between said circuits.

7. In a reversible electric current converting system, an electric current line, a second electric current line, a plurality of electrically distinct electron discharge devices each having anodes with associated control electrodes and a cathode, means for connecting said discharge devices with each of said lines, means for energizing the control electrodes of said devices, and means controlling the second said means to prevent the flow of circulating currents between said devices.

8. In a reversible electric current converting system, an electric current line, a second electric current line, a plurality of electrically distinct electron discharge devices each having anodes with associated control electrodes and a cathode, means for connecting said discharge devices with each of said lines, means for energizing the control electrodes of said devices, and electron discharge means controlling the second said means to prevent all but one of said devices from carrying current at any instant.

9. In a reversible electric current converting system, an electric current line, a second electric current line, a plurality of electrically distinct electron discharge devices each having anodes with associated control electrodes and a cathode, means for connecting said discharge devices with each of said lines, means for energizing the control electrodes of said devices, and electron discharge means controlling the second said means to prevent the flow of circulating currents between said devices.

10. In a reversible electric current converting system, an electric current supply circuit, an electric current load circuit, a plurality of electrically distinct electron discharge devices each comprising a plurality of anodes with associated control electrodes and a cathode, means for connecting said devices with each of said circuits, a source of control potential, means for connecting said source with said control electrodes, and wattmetric means responsive to the momentary direction of the flow of energy between said circuits for controlling the second said means.

11. The combination with an electric current supply circuit, an electric current load circuit, and a pair of electrically distinct electron discharge devices each comprising a cathode and a plurality of anodes interconnecting said circuits and constituting spaced electrodes for the flow of energy therebetween, of means for controlling said flow of energy comprising a plurality of control electrodes severally associated with said anodes, means comprising a source of current having connection with each of said control electrodes and continuously imparting thereto potential of such sign and magnitude as to prevent the initiation of said flow of energy by way of the associated anodes, means comprising a second source of current for imparting to said control

electrodes potential of such sign and magnitude as to permit the initiation of said flow of energy, means for sequentially connecting the said second source of current simultaneously with the control electrodes associated with the anodes of each said device, and wattmetric means responsive to the flow of energy by way of an anode of either one of said devices for preventing the flow of energy by way of the anodes of the other of said devices.

12. In a system of the character described, electric current converting means comprising a plurality of anodes divided into groups, a plurality of control electrodes severally associated with said anodes, an alternating current input circuit connected with said means and supplying current thereto, an alternating current output circuit connected with said means and supplied with current therefrom by way of said anodes, means connected with each of said control electrodes and imparting thereto potential of such sign and magnitude as to prevent the initiation of said flow of current by way of said anodes, a source of control current, means comprising electron discharge means for sequentially connecting said source of control current simultaneously with the control electrodes associated with each said group of anodes of such sign and magnitude and during such recurring moments as to permit the initiation of said flow of current, and means operable responsive to the said flow of current by way of the anodes of any one of said groups thereof for controlling said electron discharge means in such sense as to prevent the connection of said source of control potential with the control electrodes associated with any other group of said anodes.

13. The combination with an electric current supply circuit, an electric current load circuit, and means interconnecting said circuits comprising a pair of electron discharge devices each having a cathode and a plurality of anodes constituting spaced electrodes for the flow of current between said circuits, of means for controlling the said flow of current comprising a plurality of control electrodes severally associated with said anodes, means comprising a source of current connected with each of said control electrodes and continuously exciting the same in such sense as to prevent the initiation of said flow of current, means comprising a second source of current for sequentially exciting the said control electrodes in such sense and during such recurring moments as to permit the initiation of said flow of current, electric valve means controlling the operative connection of the said second source of current with said control electrodes, and means operable responsive to the flow of current by way of the cathode and an anode of either one of said devices for controlling the said valve means in such sense as to prevent the connection of the said second source of current with the control electrodes associated with the anodes of the other of said devices.

14. In combination, an electric current supply circuit, an electric current load circuit, electron discharge means interconnecting said circuits and comprising a plurality of groups of anodes constituting electrodes for the flow of energy between said circuits, a plurality of control electrodes severally associated with said anodes, means comprising a source of current connected with said control electrodes and continuously exciting the same in such sense as to prevent the initiation of flow of current between said circuits by way of said anodes, means comprising a second source of current for sequentially imparting potential

5 simultaneously to said control electrodes associated with each said group of anodes of such sign and magnitude and during such recurring moments as to permit the initiation of said flow of energy between said circuits by way of said anodes, electric valve means controlling the third said means, and means operable responsive to said flow of energy by way of the anodes of either

of said groups thereof for rendering ineffective the third said means with respect to the control electrodes associated with any other of the said groups of anodes.

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