Dec. 9, 1941. D. JOURNEAUX 2,265,602

ELECTRON DISCHARGE DEVICE SYSTEM

Filed July 31, 1933 3 Sheets-Sheet 1

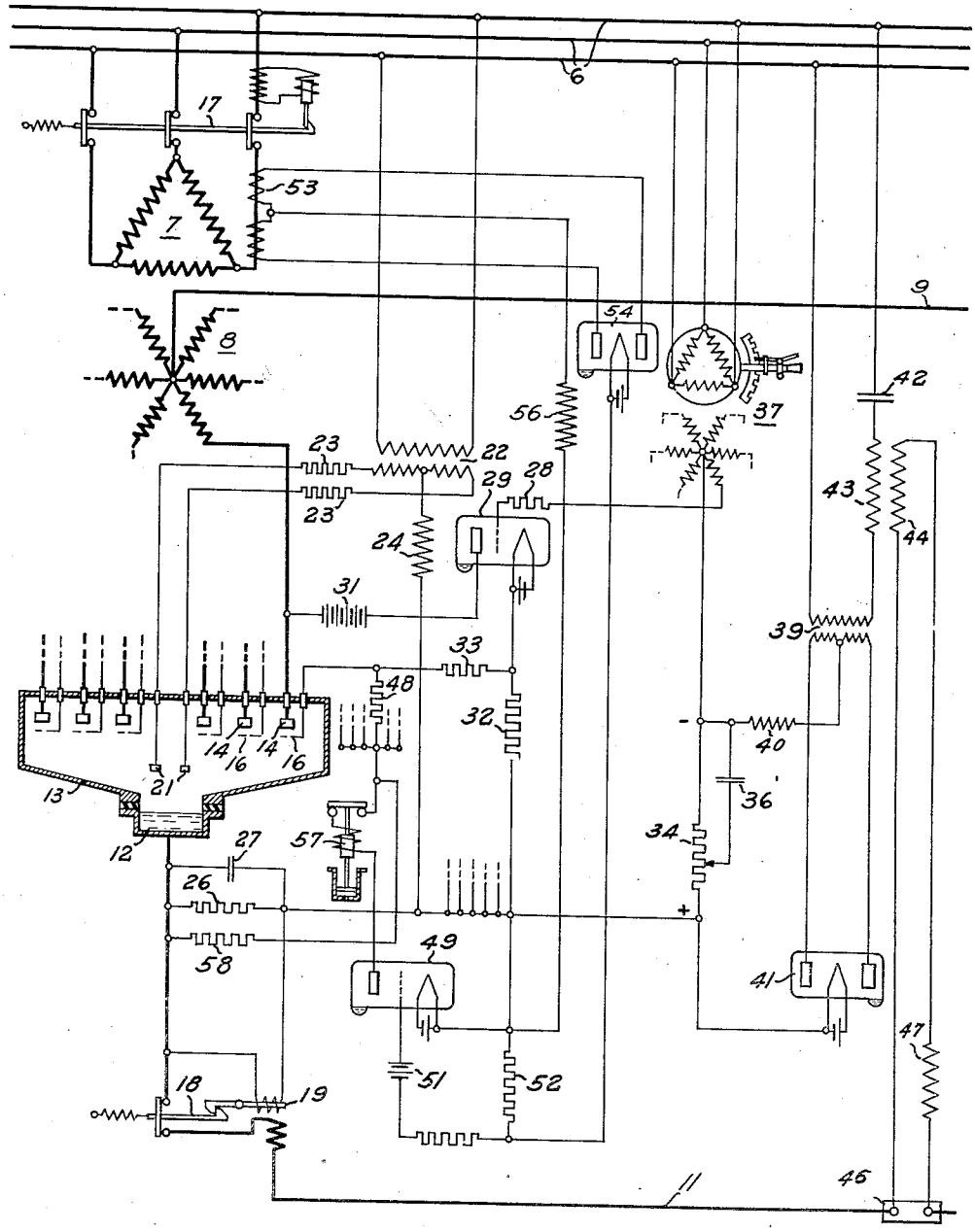


Fig. 1

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Dec. 9, 1941. D. JOURNEAUX 2,265,602

ELECTRON DISCHARGE DEVICE SYSTEM

Filed July 31, 1933 3 Sheets-Sheet 2

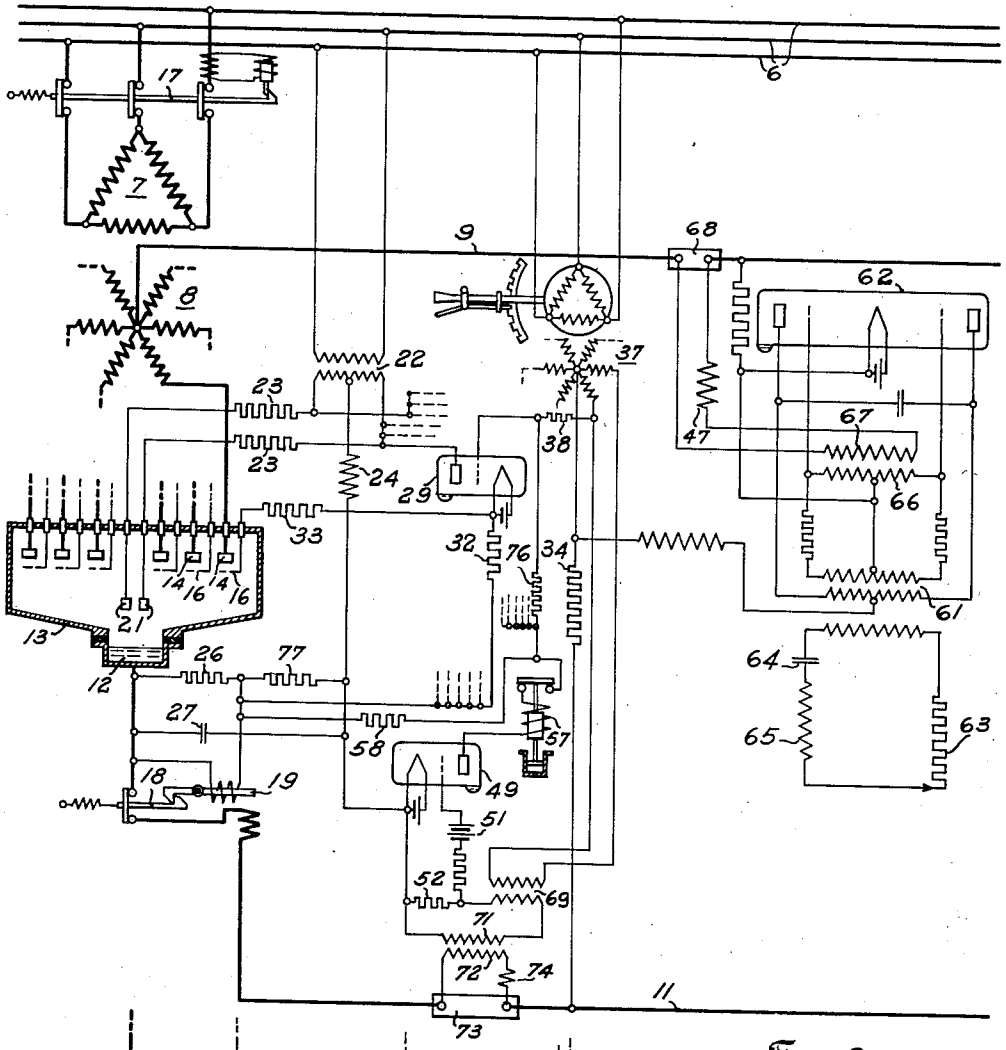


Fig. 2

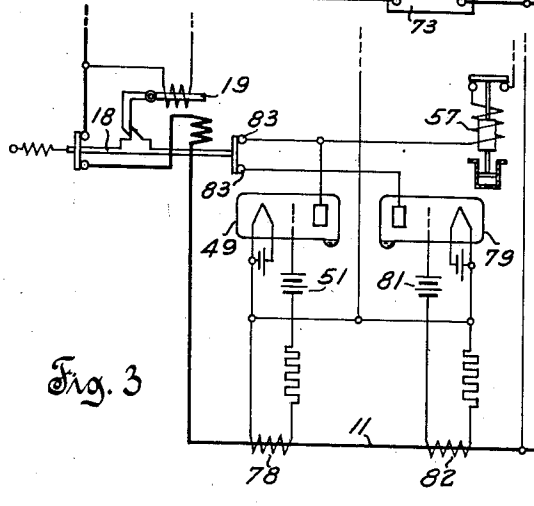


Fig. 3

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Dec. 9, 1941. D. JOURNEAUX 2,265,602

ELECTRON DISCHARGE DEVICE SYSTEM

Filed July 31, 1933 3 Sheets-Sheet 3

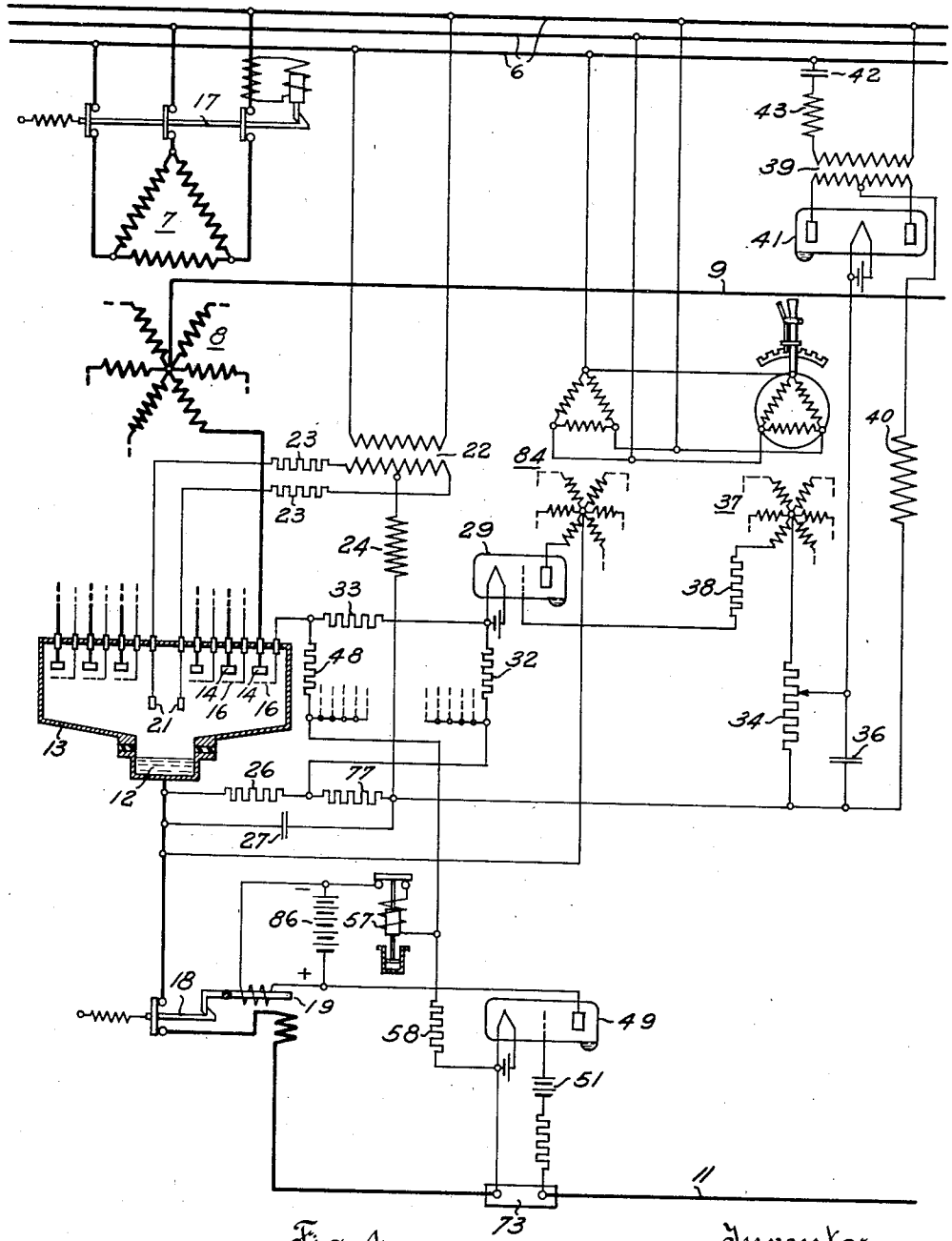


Fig. 4

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Patented Dec. 9, 1941

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UNITED STATES PATENT OFFICE

2,265,602

ELECTRON DISCHARGE DEVICE SYSTEM

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Application July 31, 1933, Serial No. 682,969

16 Claims. (Cl. 175—363)

This invention relates to improvements in systems employing electron discharge means and more particularly to means for controlling the flow of current through the discharge means during normal operation thereof and for interrupting such flow upon occurrence of abnormal conditions in the system.

The operation of electron discharge devices may be regulated and controlled by the action of suitable discharge controlling means which may be electrostatic, electromagnetic or mechanical in nature and which act in response to periodic energization thereof effected at suitable times. In certain types of electron discharge devices such as devices of the vapor type controlled by means of control electrodes, it is generally preferable to apply a negative potential to the discharge controlling means and to instantly substitute for such negative potential, at suitable times, a positive potential of suitable magnitude. Such substitution may be advantageously obtained by means of discontinuously controllable auxiliary electron discharge devices for the reason that such devices may be made to pass instantly from a non-conductive condition to a fully conductive condition by a small change in the potential of their control electrode, such devices thus operating as switches without appreciable operating time. The energization of the control electrodes of the auxiliary devices may be varied to regulate the flow of current through the main device, such variation being preferably controlled by means responsive to the value of the quantity to be regulated. To obtain accurate regulation, the control means should preferably amplify the variations of the quantity to be regulated by static means such as variable resonant means inserted in an alternating current circuit. The protection of the system against disturbances is preferably effected by controlling the discharge controlling means through electron discharge means discontinuously responsive to the magnitude of direct current flowing through a circuit which is part of the system.

It is therefore among the objects of the present invention to provide a system employing an electron discharge device in which system the discharge controlling means of the discharge means are energized through discontinuously controllable auxiliary electron discharge means.

Another object of the present invention is to provide an electron discharge device system in which the discharge controlling means of the discharge means are energized at potentials which are instantly reversed by auxiliary electron discharge means.

Another object of the present invention is to provide a system employing an electron discharge device in which the discharge controlling means of the discharge device are severally energized at a negative direct current potential for which an alternating current potential is substituted by auxiliary electron discharge means.

Another object of the present invention is to provide an electron discharge device system in which the discharge controlling means of the discharge device are energized through means amplifying the variations of a quantity to be controlled.

Another object of the present invention is to provide a system employing an electron discharge device in which system the discharge controlling means of the discharge device are energized at a negative potential upon occurrence of a disturbance by auxiliary electron discharge means.

Another object of the present invention is to provide an electron discharge device system in which current supplied thereto from an alternating current circuit is interrupted by discharge controlling means and current supplied thereto by a direct current circuit is interrupted by circuit interrupting means.

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 one embodiment of the present invention applied to the control of an electron discharge device operable as an alternating current rectifier which is regulated in response to the magnitude of the current in the direct current output circuit thereof;

Fig. 2 diagrammatically illustrates a modified embodiment of the present invention in which the discharge device is regulated in response to the magnitude of both the voltage and the current of the direct current output circuit thereof;

Fig. 3 diagrammatically illustrates the portion of another modified embodiment of the present invention differing from the embodiment illustrated in Fig. 2 in the method of controlling the operation of the discharge controlling means in response to the occurrence of abnormal conditions; and

Fig. 4 diagrammatically illustrates another

embodiment of the present invention to control an electron discharge device operable as a direct current inverter which is regulated in response to the magnitude of the voltage of the alternating current output circuit thereof.

Referring more particularly to the drawings by characters of reference, reference numeral 6 designates an alternating current line or circuit herein represented as a three phase line and which, in the embodiment illustrated in Fig. 1, constitutes the source of supply for the system. Line 6 is connected with the primary winding 7 of a transformer having a secondary winding 8 divided into a plurality of phase displaced portions connected to form a neutral point. The direct current output circuit of the system comprises a conductor 9 connected with the neutral point of winding 8 and a second conductor 11 connected with the cathode 12 of an electron discharge device 13. The potential of cathode 12 will be used as datum and all potentials will hereinafter be referred thereto unless otherwise stated. Any source of electromotive force having a terminal connected with the cathode will then have the other terminal thereof at a potential equal to such electromotive force and the source therefore also functions as a source of potential for any circuit connected therewith. Device 13 may be of any type through which the discharge may be controlled by suitable discharge controlling means and is herein represented as being of the vapor type provided with control electrodes. For the sake of brevity, such device will hereinafter be referred to as rectifier 13. Rectifier 13 is provided with a plurality of anodes 14 severally connected with the different portions of winding 8 and each provided with a control electrode 16. The connection between winding 7 and line 6 is preferably made through a circuit breaker 17 operable, as shown, to interrupt such connection upon occurrence of an excessive flow of current therethrough. Cathode 12 is preferably connected with conductor 11 through another circuit breaker 18 provided with a polarized latch 19 operable to cause opening of the circuit breaker 18 upon occurrence of a flow of current from conductor 11 to cathode 12. Rectifier 13 is provided with the usual discharge igniting means (not shown) and with current maintaining means comprising excitation anodes 21 energized from line 6 through a transformer 22 and resistors 23. The secondary winding of transformer 22 is provided with a midtap connected with cathode 12 through a reactor 24 and a resistor 26. Reactor 24 causes the flow of current through resistor 26 to be maintained at a substantially uniform value, such action being aided if necessary by means of a capacitor 27 connected in parallel with resistor 26.

In the embodiment illustrated in Fig. 1, each control electrode 16 is connected with the associated anode 14 through a discontinuously controllable auxiliary discharge device of any suitable type herein shown as an electric valve of the vapor type 29. Each anode 14 is connected with the anode of the associated valve 29 either directly or through a source of direct current such as a battery 31. The cathode of each valve 29 is connected with resistor 26 through a resistor 32 and is connected with the associated control electrode 16 through another resistor 33. Resistor 26 is connected through a resistor 34 and a capacitor 36 with the neutral point of the star connected secondary winding of a control transformer 37 having a primary winding energized from line 6. The different secondary winding portions of transformer 37 are severally connected with the control electrodes of valves 29 through resistors 28. Transformer 37 may be so constructed as to have the voltages of the secondary winding thereof in invariable or in variable phase relation with the voltages of the primary winding thereof and is therefore represented as having the primary winding thereof adjustable in space. Resistor 34 receives a variable flow of direct current from line 6 through a transformer 39 having the secondary winding thereof provided with a neutral point connected with resistor 34 through a current smoothing reactor 40 and through a suitable rectifying device such as valve 41. The flow of such current is controlled by means of a capacitor 42 and a reactor 43 inserted in series with the primary winding transformer 39. The inductance of reactor 43 may be varied by means of a saturating direct current winding 44 connected across a shunt 46 and receiving current from line conductor 11. A flow of alternating current by transformer action from winding 43 through winding 44 and shunt 46 is prevented by means of reactor 47 in series therewith. Reactor 43 is so adjusted as to be in resonance with capacitor 42 for the frequency of the voltage of line 6 when the current flowing through shunt 46 is approximately at the desired value, or is preferably at a slightly higher value. The different control electrodes 16 of rectifier 13 are severally connected through resistors 48 with the anode of another discontinuously controllable auxiliary electron discharge device such as a valve 49 which is similar to valve 29. The cathode of valve 49 is connected with the control electrode thereof through a suitable bias battery 51 and through a resistor 52. Resistor 52 receives a continuous flow of direct current from a current transformer 53 inserted in one of the connections of winding 7 with circuit 6, the current of such current transformer being rectified through a suitable rectifying device such as a valve 54 and rendered substantially uniform by means of a reactor 56. It will be understood that the rectified current supplied to resistor 52 could also be obtained from all the connections between winding 7 and circuit 6 by providing the system with additional current transformers inserted in the remaining connections connected with additional anodes of valve 54. The connection between the anode of valve 49 and resistors 48 is preferably effected through a time delay relay 57 which interrupts such connection after current has passed therethrough during a predetermined length of time. The operation of valve 49, when in the conductive condition, may be stabilized by permitting the flow therethrough of current flowing over a resistor 58 of high resistance value.

In a system connected as above described, the current maintaining means for rectifier 13 therefore comprise transformer 22, resistors 23, anodes 21, cathode 12, resistor 26 and reactor 24. Resistor 26, being connected with cathode 12 and as a result of the flow therethrough of excitation current, constitutes a source of negative potential with respect to the potential of cathode 12, such potential being applied on control electrodes 16 by means of resistors 32 and 33. Circuit 6 is utilized as a source of alternating current connected with control electrodes of valves 29 through transformer 39, resistor 34 and a number of other circuit elements to be hereinafter specifically mentioned. Winding 8, which is con-

nected with cathode 12 through circuit 9, 11, is also used as a source of alternating current for the control electrodes. Valves 29 constitute discontinuously controllable electron discharge means connected with all the above sources and with the control electrodes, such valves being periodically operative to sequentially connect the several control electrodes with the respective anodes associated therewith and with the associated portions of winding 8 to regulate the flow of current through rectifier 13. Such action is controlled by the application of potential on the control electrodes of valves 29 by means of resistor 26, resistor 34 and transformer 37 which each constitute sources of potential, with the result that the potentials of winding 8 are periodically caused to sequentially overcome or suppress the action of the potential obtained from resistor 26 and applied on the several control electrodes 16. The potential of winding 8 is instantly impressed on a control electrode 16 each time a valve 29 becomes conductive, thereby instantly reversing, in sequence, the potential of the several control electrodes in response to the voltage cycle of circuit 6. Capacitor 42 and reactor 43 constitute variably resonant means controlling the operation of control electrodes 16 to regulate the flow of current through rectifier 13 and, therefore, through the system. Such resonant means are disproportionally or non-linearly responsive to the flow of the current in conductor 11 due to the action of shunt 46, reactor 47 and coil 44. Valve 49 operates in response only to the abnormal flow of direct current in resistor 52 to cause the flow of current from circuit 6 through rectifier 13 to be interrupted, such direct current resulting from the production of an alternating current proportional to the current flowing in rectifier 13 in current transformer 53, which current is rectified in valve 54 to cause appearance of a potential proportional to all of such currents at the terminals of resistor 52. Any current flowing through rectifier 13 from conductor 11 is then interrupted by circuit breaker 18.

In operation, assuming line 6 to be energized and the system being connected as shown, the discharge in rectifier 13 is first ignited by the ignition means usually provided and therefore not shown. A current then flows from line 6 through transformer 22, resistors 23 and anodes 21 to form a direct current flowing from cathode 12 through resistor 26 and reactor 24 back to transformer 22. Transformers 37 and 39 also receive current from line 6, transformer 39 supplying current which is rectified in valve 41, such rectified current flowing through resistor 34 and causing the appearance of a voltage across the terminals thereof. The flow of such current is given the desired degree of uniformity by means of reactor 40 and capacitor 36. Control electrodes 16 are generally maintained at a negative potential from resistor 26 through resistors 32 and 33. The control electrodes of valves 29 are generally maintained negative with respect to the associated cathodes by the amount of the direct current voltage drop across the terminals of resistor 34 and receive in addition alternating potentials from the secondary winding of transformer 37.

Assuming that one of the anodes 14 is brought to a positive potential by the associated portion of winding 8, the flow of current through such anode may then be released. At the time now considered, the anode of the associated valve 29 is positive with respect to the cathode of valve 29 by the amount of the positive potential of anode 14, plus the voltage drop in resistor 26 and the voltage of battery 31. Such valve 29 is therefore positively operable to carry current and transformer 37 is so adjusted that, at the time considered, the control electrode of valve 29 becomes positive with respect to the cathode of the valve. Valve 29 instantly becomes fully conductive and the associated control electrode 16 instantly receives a positive potential equal to the potential of anode 14 plus the voltage of battery 31 less the discharge drop in valve 29, from winding 8 through battery 31, valve 29 and resistor 33, such potential instantly overcoming or suppressing the potential previously received by control electrode 16 from resistor 26 through resistors 32 and 33. Anode 14 therefore then carries current and, after a predetermined length of time, anode 14 becomes negative with respect to cathode 12 and the flow of current therethrough ceases to be then transferred to another anode of rectifier 13. Control electrode 16 also becomes negative and ceases to carry current so that the control electrode of valve 29 may render such valve nonconductive upon being again negatively energized with respect to the associated cathode from resistor 34 and transformer 37. The above process of operation is periodically repeated for the several anodes and control electrodes of rectifier 13 in sequence to thereby control the flow of current from circuit 6 to circuit 9, 11.

The flow of current through shunt 46 causes winding 44 to give a predetermined degree of saturation to the core of reactor 43 and thereby controls the degree of resonance of reactor 43 with capacitor 42 for the frequency of the voltage of line 6. If the current through rectifier 13 decreases below the desired value, the current in coil 44 likewise decreases and the combined impedance of capacitor 42 and reactor 43 increases, such increase being in much greater proportion than the decrease of the current in conductor 11, so that a small change of current in conductor 11 will cause a large change in the flow of current through capacitor 42 and reactor 43. The direct current flowing through resistor 34 and the voltage across the terminals thereof decreases correspondingly, and the positive energization of the control electrodes of valves 29 is advanced. The energization of control electrodes 16 is therefore similarly advanced and the flow of current through rectifier 13 increases, such action continuing until such flow of current is restored to the desired value. If the current flowing in rectifier 13 is greater than the desired value, such current is returned to the desired value by an operation opposite to that above described.

During such operation, the flow of current through current transformer 53, valve 54 and resistor 52 is small and the voltage across resistor 52 is insufficient to render the control electrode of valve 49 positive and such valve remains nonconductive. Upon occurrence of a disturbance such as a short circuit in line 9, 11 or of a backfire in rectifier 13, a large current flows in the connection between line 6 and winding 7 and a correspondingly high current flows through resistor 52. The control electrode of valve 49 is thereby made positive with respect to the cathode of the valve and establishes a second connection of resistor 26 with the control electrodes 16 by way of valve 49, relay 57 and the several resistors 48. By virtue of this second connection

of the resistor 26 with the control electrodes 16 the negative potential impressed on the control electrodes is no longer overcome by the positive potential sequentially impressed on the control electrodes from winding 8 through valves 29 and resistors 33. Control electrodes 16 do not carry current and, in order to stabilize the discharge in device 49, a flow of current therethrough is caused to occur due to the connection of resistor 58. As pointed out above resistor 58, if used at all, is of high value and the flow of current therethrough is limited to such a low value as to be without material effect on the operation of the control electrodes 16. The negative energization of control electrodes 16 causes the flow of current in rectifier 13 received from line 6 to be interrupted before circuit breaker 17 has time to open. Should the control electrodes fail in such action for any reason, circuit breaker 17 will then interrupt such flow of current. When the disturbance is a backfire in rectifier 13, and if line 9, 11 is connected with generators, a flow of current will then occur from conductor 11 to cathode 12, one of the anodes 14, winding 8 to conductor 9. Such flow of current cannot be interrupted by control electrodes 16 and is interrupted by opening of circuit breaker 18. After the flow of current in rectifier 13 is interrupted, the control electrode of valve 49 again becomes negative with respect to the associated cathode but current continues to flow through such valve until relay 57 opens the contacts thereof thereby, interrupting such flow of current. The control electrode of valve 49 then regains control of the valve and returns such valve to the non-conductive condition. During a disturbance in rectifier 13, the flow of current through excitation anodes 21 may be accidentally interrupted, but the negative potential of resistor 26 is maintained for a sufficient length of time by the discharge of capacitor 27 to permit control electrodes 16 to complete the interruption of the current through rectifier 13.

In the embodiment illustrated in Fig. 2, rectifier 13 is again operable to convert current from line 6 to line 9, 11, but the anodes of valves 29 are no longer connected with the associated anodes 14. The anodes of three of the valves 29 are connected with one terminal of the secondary winding of transformer 22 and the anodes of the other three valves are connected with the other terminal of such winding. The connection is effected in a manner such that the anode of each valve 29 receives, from the transformer 22, a positive potential when the associated anode 14 becomes positive. Such result is possible because each terminal of the secondary winding of transformer 22 is positive during substantially one-half cycle of the voltage of line 6 and is therefore positive while three of the anodes 14 successively become positive at intervals of one-sixth of the cycle of the voltage of line 6. The positive terminal of resistor 34 is connected with conductor 11, the current flowing therethrough being converted into alternating current by means of a transformer 61 and of a valve 62 having the operation thereof controlled by means of control electrodes and having a cathode connected with conductor 9. The output circuit of transformer 61 comprises an adjustable load resistor 63, a capacitor 64 and a reactor 65. The core of reactor 65 is at a degree of saturation such that reactor 65 and capacitor 64 become resonant for the frequency of the output voltage of transformer 61 when such voltage is at a value corresponding to a value of the direct current voltage of line 9, 11 which is somewhat greater than desired. The operation of transformer 61 and valve 62 is well known in the art and may be varied by varying the value of the inductance of reactor 66 bridging the control electrodes of valve 62 to thereby change the frequency of the output voltage of transformer 61. Such variation is preferably obtained by providing the core of reactor 66 with a saturating winding 67 receiving direct current from shunt 68 in conductor 9, thereby effecting such variation in response to the value of the flow of current through conductor 9. Such variation of the frequency of the voltage of transformer 61 causes reactor 65 and capacitor 64 to become resonant at different voltages depending upon the value of such frequency. In the present embodiment, resistor 52 receives current from a transformer 69 energized from any suitable source of alternating current such as transformer 37. The flow of current through resistor 52 is controlled by reactor 71 provided with a saturating winding 72 connected with a shunt 73 in conductor 11 through a reactor 74. The anode of valve 49, relay 57 and resistor 58 are serially connected with the control electrodes of valves 29 through resistors 76. The cathode of valve 49 is connected with a resistor 77 inserted in series with resistor 26 in the excitation circuit of rectifier 13.

In the present embodiment therefore, transformer 22 is utilized for supplying alternating current potentials to the control electrodes of rectifier 13 through valves 29. Transformer 61 and valve 62 convert direct current from line 9, 11 into alternating current and also supply current to valves 29. Capacitor 64 and reactor 65 constitute variably resonant means having the same function as the means 42, 43 in the embodiment of Fig. 1. In the present embodiment, however, such means are responsive to the voltage of line 9, 11 because the output voltage of transformer 61 is proportional to the voltage of the line. Such means are also responsive to the magnitude of the current flowing through rectifier 13 by being responsive to the value of the frequency of the voltage of transformer 61 which in turn is controlled by the magnitude of the current in rectifier 13. Shunt 73 provides a direct current potential proportional to the current flowing through rectifier 13 and valve 49 is discontinuously responsive to the magnitude of such potential. Transformer 69 constitutes a source of alternating current connected with valve 49 and causing such valve to operate when the current in shunt 73 reaches a predetermined value, due to the controlling action of reactor 71 on the flow of current in resistor 52 in response to the flow of current through shunt 73.

In operation, rectifier 13 is controlled by means of valves 29 in a manner similar to that above described for the embodiment illustrated in Fig. 1. The voltage of transformer 61 is proportional to the voltage of line 9, 11 and reactor 65 and condenser 64 are tuned to resonance for a voltage of transformer 61 corresponding to a voltage of line 9, 11 slightly higher than the desired voltage. If the voltage of line 9, 11 is too low, reactor 65 and capacitor 64 depart from the resonant condition and their combined impedance increases. The flow of current through resistor 34 and transformer 61 therefore decreases, the voltage drop across resistor 34 also decreases, with the result that the times of energization of the control electrodes of valve 29 and of rectifier

13 are advanced, thereby causing the output voltage of rectifier 13 to be increased. Such action continues until such output voltage is restored to the value desired therefor. If the voltage of line 9, 11 is higher than desired, a controlling action opposite to the above action takes place. Such action is modified in response to the flow of current through shunt 68 and in winding 67. When such current increases, winding 67 saturates the core of reactor 66 and the voltage impressed on the control electrodes of valve 62, which is equal to the voltage drop in reactor 66, is thereby advanced. The frequency of the voltage of winding 61 accordingly becomes higher and capacitor 64 and reactor 65 becomes resonant to a higher voltage of transformer 61, thereby imparting a compounding effect to the regulating system. It will be understood, however, that, by suitable modifications of the connections, the frequency of transformer 61 may be made to decrease at increasing values of a current in shunt 68 to impart to the system a drooping voltage characteristic.

During such operation, the flow of current in winding 72 is insufficient to saturate the core of reactor 71, so that the reactance of reactor 71 is high and only a small current flows through resistor 52. Bias battery 51 then maintains the control electrode of valve 49 negative relative to its associated cathode, and valve 49 remains non-conductive. Upon occurrence of an excessive flow of current in shunt 73, winding 72 saturates the core of reactor 71 and transformer 69 produces a large flow of alternating current through resistor 52. The control electrode of valve 49 therefore becomes intermittently positive with respect to the cathode of the valve and, having once become positive, causes valve 49 to become conductive and to impress on the control electrodes of valves 29 a negative voltage equal to the voltage drop in resistor 77 which overcomes the voltage drop of resistor 34 and the voltage of transformer 37. As in the embodiment of Fig. 1, current then flows through resistor 58, relay 57 and valve 49 and is interrupted upon opening of the contacts of relay 57. All valves 29 become non-conductive, so that all control electrodes 16 remain negatively energized from resistor 26 and the flow of current from line 6 through rectifier 13 is interrupted. Circuit breaker 18 then interrupts the flow of current from conductor 11 to cathode 12.

The embodiment illustrated in Fig. 3 is identical with the embodiment of Fig. 2 with regard to the elements controlling the normal operation of rectifier 13 which are therefore not shown. In the present embodiment, the control electrode of valve 49 is connected with the associated cathode through battery 51 and a current transformer 78 inserted in conductor 11, such current transformer being so connected that the control electrode of the valve becomes positive with respect to the cathode when a flow of current from conductor 11 to cathode 12 is established at a rate exceeding a predetermined value, such as would occur upon occurrence of a backfire in rectifier 13. A second valve 79 is connected in parallel with valve 49 and has the control electrode thereof connected with the associated cathode through a battery 81 and a second current transformer 82. Transformer 82 is so connected that the control electrode of valve 79 becomes positive with respect to the associated cathode when the current flowing from cathode 12 to conductor 11 increases at a rate exceeding a predetermined value such as would occur upon occurrence of a short circuit in line 9, 11. Valves 49 and 79 may be adjusted to be responsive to different rates of increase of current in the respective directions through conductor 11. The anode of valve 79 is connected with the anode of valve 49 through auxiliary contacts 83 of circuit breaker 18 so that, when current is first established through the system by the closure of circuit breaker 18, such current has reached the steady state value thereof before contacts 83 have closed and valve 79 is therefore not permitted to negatively energize the control electrodes of valves 29 in response to the rate of increase of the current established by closure of circuit breaker 18. If the current flow through the system is established instead by closure of circuit breaker 17, it will be understood that contacts 83 will be transferred to circuit breaker 17.

In the embodiment illustrated in Fig. 4, rectifier 13 is assumed to be operable to convert energy from line 9, 11 to line 6. To obtain this effect, it is assumed that line 6 is connected with suitable frequency determining means as is well known in the art. Transformer 37 is then so adjusted as to cause energization of the control electrodes 16 during the suitable part of the voltage cycle of line 6. In the present embodiment, control electrodes 16 receive alternating potentials through valves 29 from the secondary winding of a control transformer 84 having the primary winding thereof energized from line 6. The connections of transformer 39 and valve 41 with resistor 34 are herein reversed from the connections illustrated in Fig. 1 and the voltage drop across resistor 34 therefore opposes the voltage drop in resistor 26 to form a resultant bias voltage for the control electrodes of valve 29. In the present embodiment, current flows in line 9, 11 only in one direction and the latch 19 is therefore adjusted to be responsive only to the flow of excessive currents from conductor 11 to cathode 12. The cathode of valve 49 is connected with the associated control electrode through battery 51 and through shunt 73 inserted in conductor 11 in such a manner that the control electrode becomes positive when the flow of current through shunt 73 becomes excessive. Upon occurrence of a short circuit in line 6 or of a backfire in rectifier 13, transformer 22 is no longer available as a source of potential for the system and the potential to be impressed on the control electrodes through valve 49 is preferably supplied from a separate source such as a battery 86. In the present embodiment, reactor 43 is not provided with a saturating winding and the resonant condition of capacitor 42 and reactor 43 varies only in response to the magnitude of the voltage of line 6, and the source of alternating potentials for the control electrodes 16 is constituted by transformer 84 but the functions of the other elements of the figure are the same as for the embodiments illustrated in Fig 1.

In operation, valves 29 impress on the control electrodes 16 positive potentials from transformer 84 instead of from winding 8 or from transformer 22, but the operation of such valves is otherwise similar to the operation of the valves illustrated in the other figures. Rectifier 13 operating as an inverter in the present embodiment, it is necessary that the periods of positive energization of control electrodes 16 be of short duration, as is well known. Transformer 84 is therefore so connected that each control electrode 16 receives, through the associated valve 29, a decreasing posi-

tive voltage which becomes negative after a small fraction of a cycle. Reactor 43 and capacitor 42 are tuned to resonance for a voltage slightly higher than the voltage desired for line 6. If the voltage of line 6 is too low, the combined impedance of capacitor 42 and reactor 43 increases, the flow of current therethrough decreases, and the direct current bias voltage impressed on the neutral point of the secondary winding of transformer 37 becomes decreasingly positive or even increasingly negative. The times of energization of the control electrodes of valves 29 and of rectifier 13 are therefore retarded and the output voltage of line 6 is therefore increased. Such action continues until the voltage of line 6 is restored to the value desired therefor. If the voltage of line 6 is higher than the normal value thereof, an action opposite to that above described will take place to restore such voltage to the normal value thereof.

Upon occurrence of a backfire in rectifier 13, an excessive flow of current occurs through shunt 73, thereby causing the control electrode of valve 49 to become positive with respect to the associated cathode. Valve 49 becomes conductive and impresses, on control electrodes 16, a negative potential from battery 86 thereby causing interruption of any flow of current through rectifier 13 from line 6. Circuit breaker 18 interrupts the flow of current occurring through rectifier 13 from line 9, 11. Upon occurrence of a short circuit in line 6, the energization of the control electrodes is without effect and circuit breaker 18 interrupts the flow of current through rectifier 13 from line 9, 11 which is the only current then present.

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 system for controlling the flow of electric current, electron discharge means having an anode with an associated control electrode and a cathode, current maintaining means for said discharge means operable to supply a negative potential with respect to the potential of the cathode, means for impressing on the control electrode a negative potential from the second said means, electron discharge means operable to impress on the control electrode a potential from the anode, and means responsive to an electrical condition of said system controlling the second said discharge means to cause the last said potential to be instantly impressed on the control electrode.

2. In a system for controlling the flow of electric current, electron discharge means having an anode with an associated control electrode and a cathode, current maintaining means for said discharge means operable to supply a negative potential and alternating potentials with respect to the potential of the cathode, means for impressing on the control electrode a negative potential from the second said means, electron discharge means operable to impress on the control electrodes an alternating potential from the second said means, and means responsive to an electrical condition of said system controlling the second said discharge means to cause said alternating potential to be instantly impressed on the control electrode.

3. In a system for controlling the flow of electric current, electron discharge means having a plurality of anodes with associated control electrodes and having a cathode, current maintaining means for said discharge means, means for impressing on the control electrodes potential from the second said means, and electron discharge means operable to sequentially impress on the several control electrodes potential from the respective anodes associated therewith to overcome the action of the first said potential.

4. In a system for controlling the flow of electric current, electron discharge means having a plurality of anodes with associated control electrodes and having a cathode, current maintaining means for said discharge means operable to supply a negative potential with respect to the potential of the cathode, means for impressing on the control electrodes a negative potential from the second said means, electron discharge means operable to severally impress on the respective control electrodes potentials from the anodes associated therewith, and means responsive to an electrical condition of said system controlling the second said discharge means to cause the last said potentials to be instantly impressed in sequence on the respective control electrodes.

5. In a system for controlling the flow of electric current, electron discharge means, discharge controlling means for said means, a direct current circuit connected with said discharge means, a source of alternating current, electron discharge means controlling the second said means connected with said source and discontinuously responsive to the magnitude of the current flowing in the connections between the second said electron discharge means and said source of current, and means responsive to the magnitude of the current flowing in said direct current circuit controlling the magnitude of the current flowing in the connection between said source and the second said discharge means.

6. In a system for controlling the flow of electric current, electron discharge means having an anode with an associated control electrode and a cathode, current maintaining means for said discharge means, means for impressing on the control electrode a potential from the second said means, and electron discharge means operable to impress on the control electrode a potential from the anode to overcome the action of the first said potential.

7. In a system for controlling the flow of electric current, an alternating current circuit, electron discharge means connected with said circuit, a direct current circuit connected with said means, discharge controlling means for said means, means for applying potential to said discharge controlling means comprising means for converting current supplied from said direct current circuit into alternating current, and means variably resonant in dependence on the magnitude of the voltage of said alternating current circuit for controlling the flow of current through the first said means.

8. In a system for controlling the flow of electric current, an alternating current circuit, electron discharge means connected with said circuit, a direct current circuit connected with said means, discharge controlling means for said means, means for applying potential to said discharge controlling means comprising means for converting current supplied from said direct cur-

rent circuit into alternating current, means responsive to the magnitude of the flow of current through said system controlling the frequency of the voltage of the said alternating current, and variably resonant means responsive to the magnitude and to the frequency of said voltage controlling the application of said potential to said discharge controlling means.

9. In a system for controlling the flow of electric current, electron discharge means, discharge controlling means for said means, means for producing an alternating current in magnitude proportional to the magnitude of the current flowing through said discharge means, means for rectifying said alternating current, and electron discharge means discontinuously responsive to the magnitude of the rectified alternating current controlling the second said means.

10. In combination with an alternating current supply circuit, a direct current load circuit, an electron discharge means interconnecting said circuits and operable to convert current supplied thereto from the first said circuit and the supply thereof to the second said circuit, and means comprising an element of the first said means and a source of current operable to control the converting operation of the first said means, of means comprising a discontinuously controllable electron discharge device operable to control the said operation of the second said means, and means comprising an electron discharge device operable responsive to abnormal flow of current in one of said circuits for controlling the second said means in such sense as to interrupt the said converting operation of the first said means.

11. The combination with an electric current supply circuit, an electric current load circuit, an electron discharge device having an anode and a cathode inter-connecting said circuits and forming spaced electrodes for the flow of current by way of arcs when established therebetween, and a control electrode constituting an element of said device for controlling the moments of establishment of said arcs, of means for applying a potential to said control electrode of such sign and magnitude as to prevent the establishment of said arcs, means comprising a discontinuously controllable electron discharge device for applying a potential to said control electrode of such sign and magnitude as to overcome the first said potential to thereby permit establishment of said arcs, and means operable responsive to abnormal flow of current in one of said circuits for controlling the operation of the second said device to thereby prevent the application of the second said potential to the said control electrode.

12. In a system for controlling the flow of current, electron discharge means comprising a cathode, an anode, and a control electrode, means for exciting said control electrode in such sense as to render the first said means conductive for the flow of current therethrough by way of said anode and cathode, means for exciting said control electrode in such sense as to prevent the said flow of current, means for controlling the third said means comprising a second electron discharge means, and means for controlling the second said electron discharge means comprising means for producing an alternating current of magnitude proportional to the magnitude of the current flowing through the first said means and including means for rectifying said alternating current.

13. An excitation circuit for an electric valve of the gaseous type having an anode, a cathode and a control member comprising an electronic discharge means energized in accordance with the voltage appearing across said anode and cathode of said electric valve, and means for controlling the conductivity of said electronic discharge means to energize said control member in accordance with two different predetermined electrical conditions.

14. The combination with an electric current supply circuit, an electric current load circuit, and electron discharge means comprising an anode and a cathode interconnecting said circuits and constituting spaced electrodes for the transfer of energy therebetween, of means for controlling said transfer of energy comprising an element of said discharge means, a source of potential for energizing said element, auxiliary electron discharge means controlling the operative connection of said source of potential to said element, and means for controlling the conductivity of said auxiliary electron discharge means comprising means variably resonant in accordance with concurrent electrical conditions of said circuits.

15. In a system for controlling the flow of electric current, the combination with an alternating current supply circuit, an electric current load circuit, and electron discharge means comprising an anode and a cathode interconnecting said circuits and constituting spaced electrodes for the flow of current therebetween, of means for controlling said flow of current comprising a reactor and a capacitor serially connected together and energized from said supply circuit, and means for varying the inductance of said reactor comprising means responsive to the magnitude of said flow of current in said load circuit.

16. The combination with an electric current supply circuit, an electric current load circuit, and electron discharge means comprising an anode and a cathode interconnecting said circuits and constituting spaced electrodes for transfer of energy therebetween, of means for controlling said transfer of energy comprising an element of said discharge means, a source of potential for energizing said element, auxiilary electron discharge means controlling the operative connection of said source of potential to said element, and means for controlling the conductivity of said auxiliary discharge means comprising means variably resonant in accordance with an operating condition of one of said circuits.

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