July 12, 1938. H. WINOGRAD 2,123,859

RECTIFIER PROTECTIVE SYSTEM

Original Filed Feb. 13, 1933 5 Sheets-Sheet 1

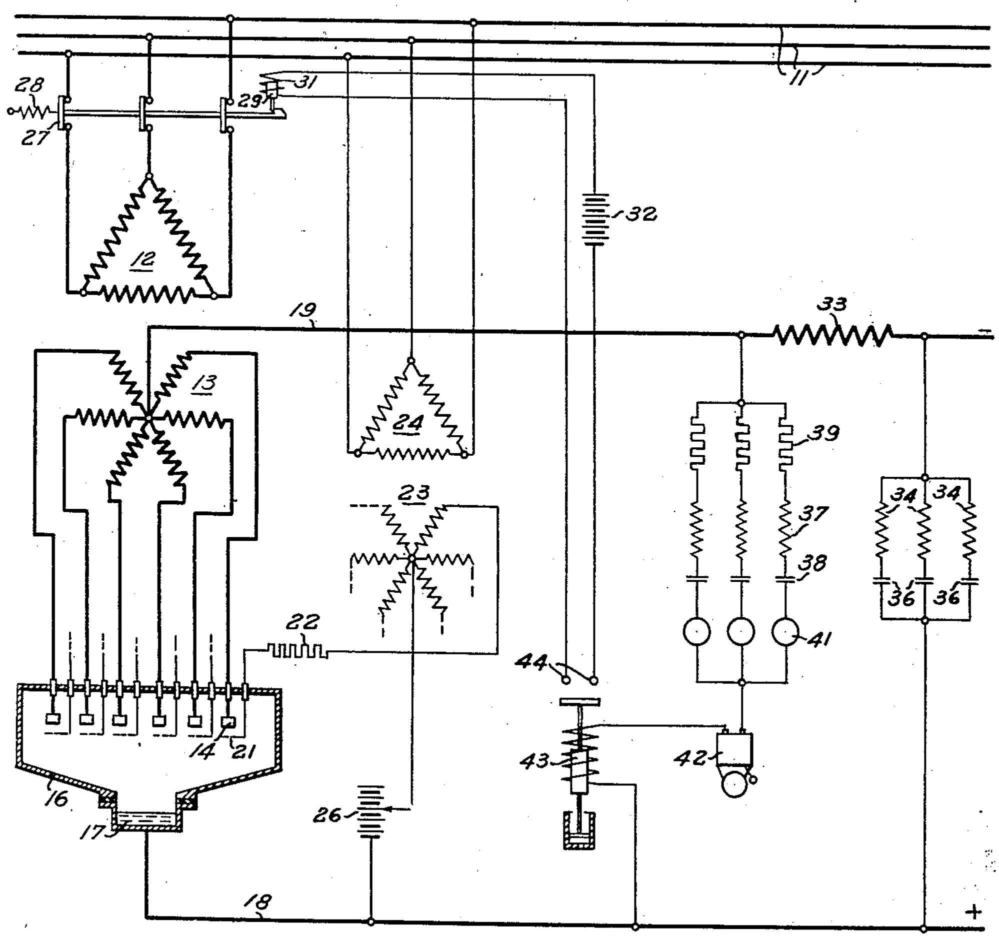

Fig. 1

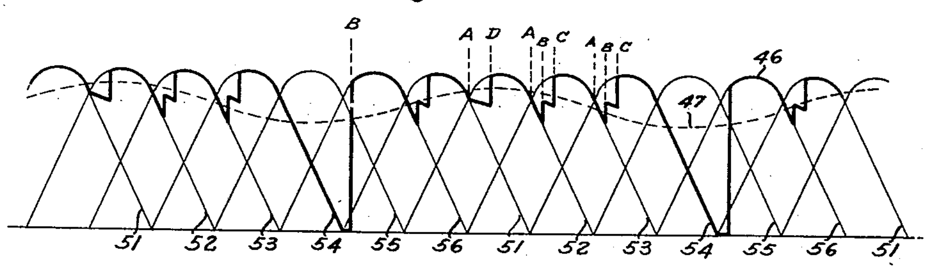

Fig. 2

Inventor
H. Winograd
by [signature]
Attorney

July 12, 1938. H. WINOGRAD 2,123,859

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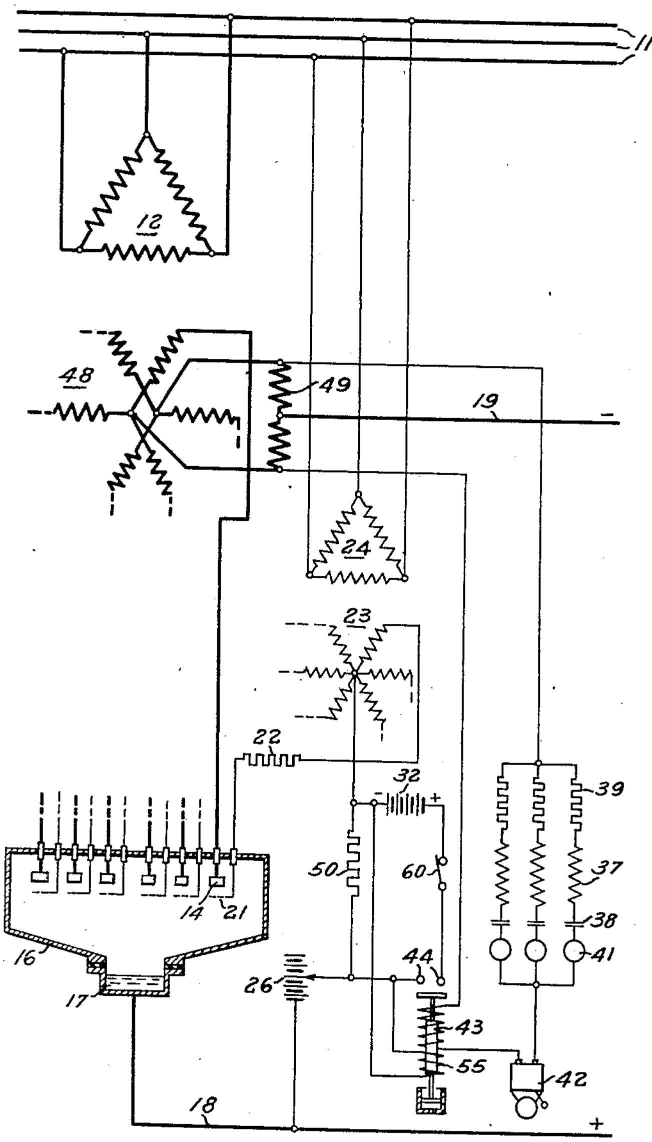

Fig. 3

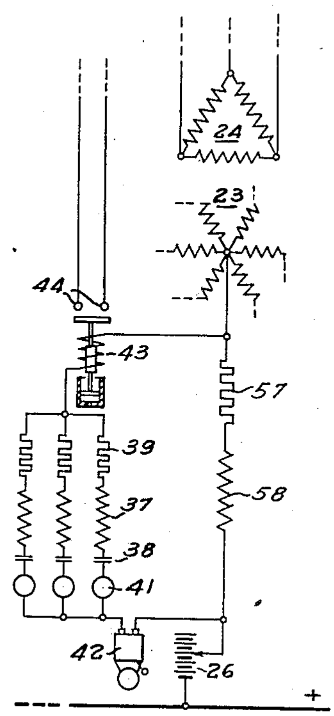

Fig. 4

Inventor
H. Winograd
by
Attorney

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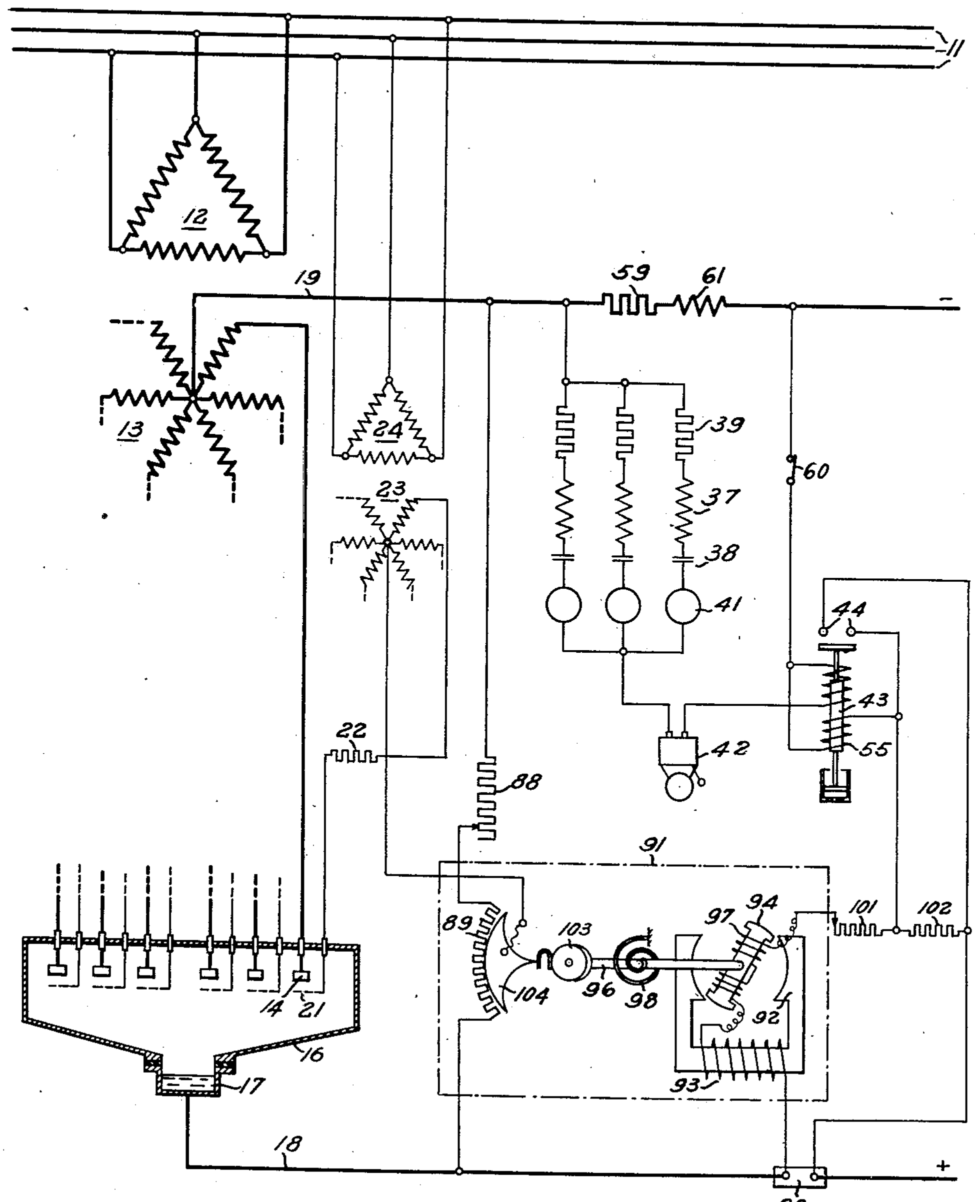

Fig. 5

Inventor
H. Winograd
by [signature]
Attorney

July 12, 1938.

H. WINOGRAD

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RECTIFIER PROTECTIVE SYSTEM

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5 Sheets-Sheet 4

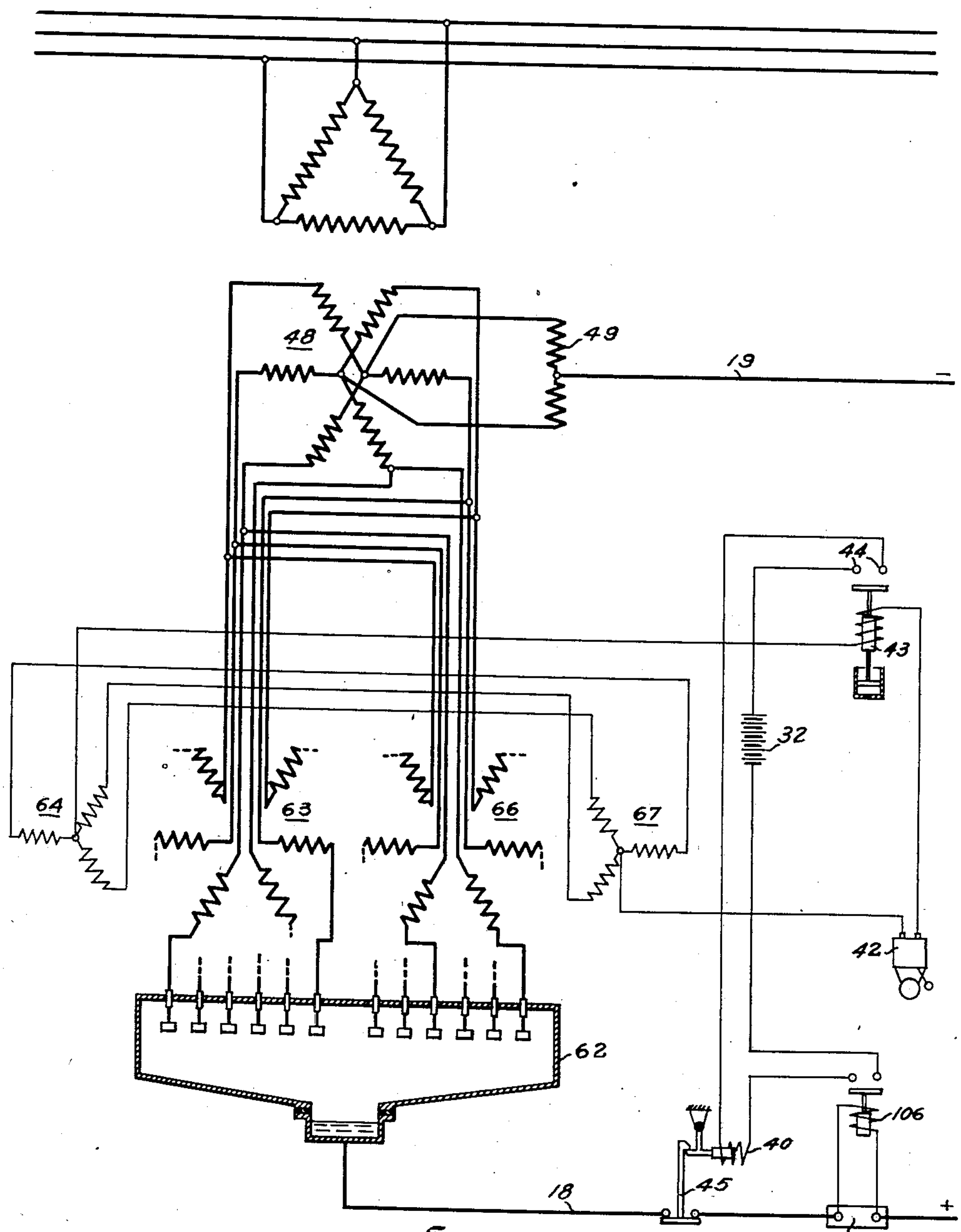

Fig. 6

Inventor

H. Winograd

by G. J. O'Brien

Attorney

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RECTIFIER PROTECTIVE SYSTEM

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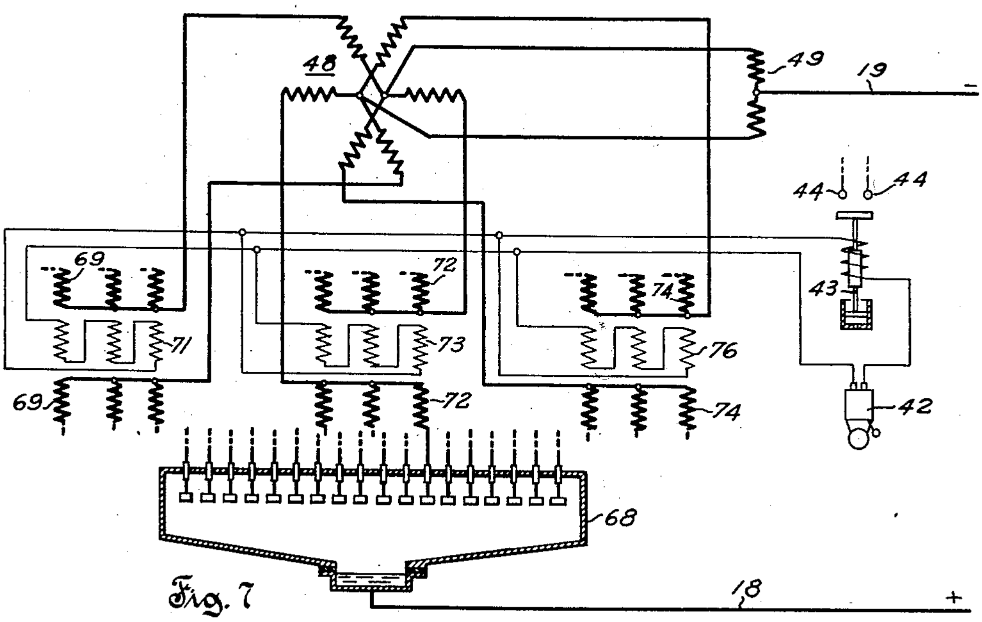

Fig. 7

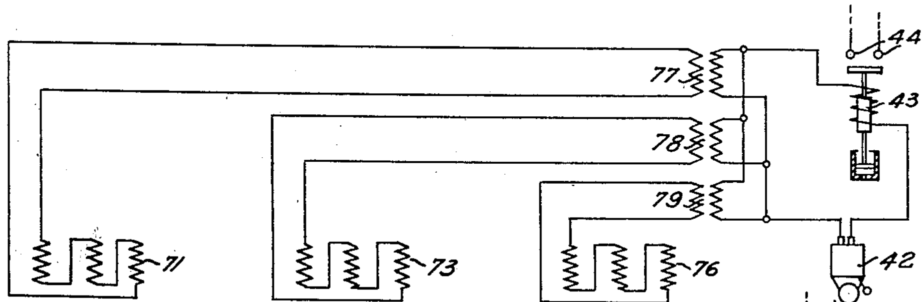

Fig. 8

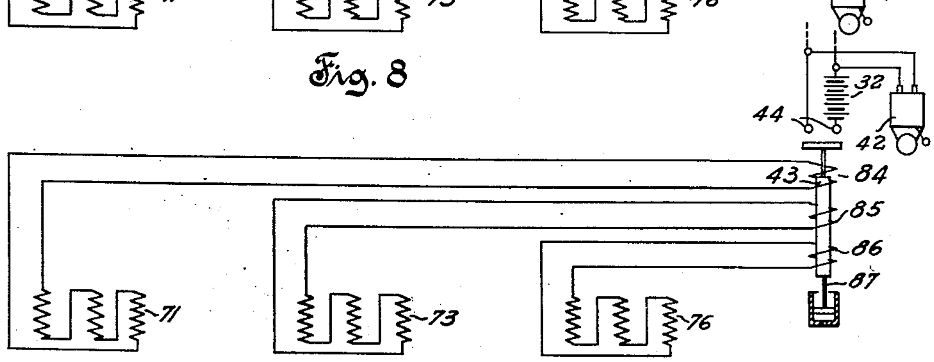

Fig. 9

Inventor
H. Winograd
by [signature]
Attorney

Patented July 12, 1938

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UNITED STATES PATENT OFFICE

2,123,859

RECTIFIER PROTECTIVE SYSTEM

Harold Winograd, Milwaukee, Wis., assignor to Allis-Chalmers Manufacturing Company, Milwaukee, Wis., a corporation of Delaware

Application February 13, 1933, Serial No. 656,524
Renewed October 1, 1937

15 Claims. (Cl. 175—363)

This invention relates to improvements in protective systems and more particularly to systems for interrupting or reducing the flow of current in an electron discharge device when one or more of the electrodes of the device cease to function in the manner which is normal for the connections thereof.

In electron discharge devices provided with a plurality of electrodes, and operable to function as rectifiers, inverters, frequency converters, current interrupters, etc., one or more of the electrodes may fail to function in the manner desired and which is normal for the connections thereof, such failure being possible as a result of one or more of various accidental causes. An anode may fail to carry current because the conditions of vapor pressure and temperature within the space between such anode and the cathode are such that ionization is not sufficiently readily established in such space at the voltage appearing between the anode and the cathode. Such failures occur particularly easily in electron discharge devices operating in parallel with other converting equipment and also in electron discharge devices in which groups of several electrodes are operated in parallel. In devices so connected, the potential of any anode generally becomes positive with respect to the potential of the cathode by an amount which is only slightly greater than the value of the arc drop and which may therefore be insufficient for ionizing the arc path under unfavorable conditions. When the functioning of the anodes is controlled by the action of control electrodes, the deterioration or failure of one of such control electrodes or a defect in the connection thereof may cause the anode associated with such control electrode to carry current prematurely, tardily or not at all during each normal cycle of operation thereof depending upon the nature of the deterioration and upon the method of energization of the control electrode. Some of the anodes of the device may also fail to be energized because of the failure of a phase in the source supplying such device or in other apparatus included in the alternating current circuit. Such condition may arise, for instance, upon breakage of one of the alternating current conductors or upon failure of one phase of a circuit breaker or as a result of an open connection within the windings of a supply transformer.

The operation of an electron discharge device in which only part of the electrodes carry current is highly detrimental to the safety of the device as the operative electrodes are more or less severely overloaded by such operation. All operative electrodes are then overloaded as the several phase voltages of the device must be increased to obtain the same average output voltage as when all electrodes are functioning. In addition, the electrodes preceding and following the inoperative electrode during the normal cycle of operation thereof are even more severely overloaded as they must carry current over the period during which the inoperative electrode is normally functioning. If a group of several electrodes are operated in parallel on one phase of the device, the operative electrodes of the group must carry the current of the inoperative electrodes in addition to the current normally carried. Such overloads may result in a serious deterioration or even complete destruction of the electrodes, and may also result in the deterioration of the associated transformer windings by overheating. In addition to the detrimental results above mentioned, the circuits connected with the device then receive voltage and current components apt to cause interference in communication circuits, train control circuits, etc. by electromagnetic or electrostatic induction.

No indication of the failure of some of the electrodes is given by the usual type of ammeter and voltmeter inserted in the input or output circuit of the device as such meters only indicate the average values of voltages and currents. Such failure could be detected by inserting suitable ammeters in the circuits of each main electrode and control electrode of the device. When the number of electrodes of the device is large, the number of such ammeters becomes large and the installation becomes complicated and excessive in cost. Such ammeters cannot be used directly to control or to give an audible or visible signal or for controlling the disconnection of the device upon failure of one of the electrodes to function because such failure results in unequal ammeter readings rather than in any particular value of such readings.

A simpler, more dependable, and less expensive method consists in utilizing some of the voltage and current components which appear in the circuits associated with the device and in the circuits of any electrode-paralleling device associated therewith, upon failure of one or more electrodes to function, such components not being present when all electrodes carry substantially equal amounts of current. Such components may thus be directly utilized for controlling the disconnection of the device upon the appearance of the components and resonant filters may be used for segregating such components from current and voltage components of other frequencies which may be present in the circuits under all conditions of operation and to which the control and indicating system should not be responsive.

It is accordingly among the objects of the present invention to provide a protective system for electron discharge devices whereby the flow of current within such a device may be interrupted or reduced upon failure of one or more of the electrodes thereof to function in the normal manner thereof.

Another object of the present invention is to provide a protective system for electron discharge devices whereby the flow of current within such a device may be interrupted or reduced upon failure of one or more of the electrodes thereof to carry current.

Another object of the present invention is to provide a protective system for electron discharge devices whereby such a device may be disconnected from the supply line or from the output line upon failure of one or more of the electrodes thereof to carry substantially the same amount of current as is carried by other similarly connected electrodes.

Another object of the present invention is to provide a protective system for electron discharge devices whereby such a device may be disconnected from the supply line or from the output line upon failure of one or more of the electrodes thereof to carry substantially the same amount of current as is carried by electrodes connected in parallel therewith.

Another object of the present invention is to provide a protective system for electron discharge devices whereby such a device may be disconnected from the supply line or from the output line upon faulty controlling operation of one or more of the control electrodes thereof.

Another object of the present invention is to provide a protective system for electron discharge devices whereby such a device may be disconnected from the supply line or from the output line in response to the appearance of current or voltage components occurring upon failure of one or more of the electrodes thereof to function in the normal manner.

Another object of the present invention is to provide a protective system for electron discharge devices whereby such a device may be disconnected from the supply line or from the output line, and in which the system is selectively responsive to sustained voltage or current components in a circuit connected with the device when such components are due to accidental or abnormal operation of the device.

Another object of the present invention is to provide a protective system for electron discharge devices whereby such a device may be disconnected from the supply line or from the output line, and in which the system is selectively responsive to the flow of sustained voltage or current components accidentally appearing in the circuit of an electrode-paralleling device.

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

Fig. 1 diagrammatically illustrates one embodiment of the present invention which comprises means selectively responsive to components accidentally appearing in the output direct current voltage of a six phase electron discharge device operable as an alternating current rectifier, and is designed for the purpose of disconnecting such device from the supply line thereof;

Fig. 2 is a diagram of the direct current output voltage of the device illustrated in Fig. 1 in which it is assumed that one anode and one control electrode have become inoperative;

Fig. 3 diagrammatically illustrates another embodiment of the present invention in which the voltage responsive circuits of the system are energized at voltages appearing at the terminals of an interphase transformer associated with the main transformer secondary winding supplying the electron discharge device, and are connected to cause the main current to be interrupted by the action of the control electrode of the device;

Fig. 4 diagrammatically illustrates a portion of a modified embodiment of the present invention differing from the embodiment illustrated in Fig. 1 in that the voltage responsive circuits of the system are energized at voltages appearing in the circuit of the control electrode energizing means;

Fig. 5 diagrammatically illustrates another embodiment of the present invention responsive to the flow of components accidentally appearing in the direct current output line of the device to cause the main current to be reduced or interrupted by the action of the control electrodes of the device.

Fig. 6 diagrammatically illustrates a portion of another modified embodiment of the present invention applied to the control of a six-phase 12-anode electron discharge device operable as an alternating current rectifier, the control system operating in response to the flow of current in the neutral connection between the secondary windings of two anode paralleling transformers;

Fig. 7 diagrammatically illustrates a portion of another modified embodiment of the present invention applied to the control of a six-phase 18-anode electron discharge device operable as an alternating current rectifier, the protective system operating in response to the appearance of residual current in the connection of the secondary windings of three anode paralleling transformers;

Fig. 8 diagrammatically illustrates a modification of the control circuits of the embodiment illustrated in Fig. 7 and,

Fig. 9 illustrates a further modification of the control circuits of the embodiment illustrated in Fig. 7.

Referring more particularly to the drawings by characters of reference, reference numeral 11 designates an alternating current supply line herein shown as a three phase line for the reason that such type of line is most frequently utilized in practice. Line 11 energizes the primary winding 12 of a supply transformer having a secondary winding 13 comprising a plurality of phase displaced portions which are star-connected to form a neutral point. The different phase portions of winding 13 are severally connected with the anodes 14 of an electron discharge device 16 provided with a cathode 17 and operable as an alternating current rectifier. To obtain such operation, cathode 17 is connected with the positive conductor 18 of a direct current output line of which the negative conductor 19 is connected with the neutral point of winding 13. Device 16 is provided with a plurality of control electrodes 21 severally associated with the anodes 14 and each energized through a resistance 22 from one of the star-connected secondary winding portions of a control transformer or phase shifter having a secondary winding 23 and having a primary winding 24 energized from line 11. The neutral point of winding 23 may be connected with conductor 18 in any one of a number of different known ways such as through a battery 26. In the present embodiment, winding 13 is operable to supply six phase currents and device 16 is therefore of the six phase type provided with six anodes and with six control electrodes associated therewith which are energized from winding 23 at six phase voltages. Winding 12 is connected with line 11 by means of a circuit breaker 27 which opens under the action of a spring 28 and is maintained in the closed position thereof against the action of the spring by a latch 29. A solenoid 31 is operable to lift latch 31 upon energization from a suitable source such as battery 32 in a manner to be described hereinafter.

It is generally desired to remove, from the direct current output voltage of the rectifier, the alternating current components introduced therein as a result of the method of connection of the rectifying equipment. Such components, as is well known, have frequencies which are six times the frequency of the voltages of line 11 and all the integer multiples of six times such frequency. Such components are removed by bridging the line by a plurality of resonant filters tuned to the frequencies of the voltages to be removed and each consisting of a reactor 34 in series with a condenser 36. The flow of current in such filters is limited by insertion of a series reactor 33 in conductor 13 or in conductor 19. The voltage of the components filtered out then appear across the terminals of the reactor. To provide a path for the selective flow of any other voltage component appearing in the direct current output circuit and producing a ripple in the output as is well known, another resonant filter is connected between conductors 18 and 19 preferably on the rectifier side of reactor 33. Such path comprises a reactor 37 and a condenser 38 tuned to the frequency of the particular component for which the circuit must provide a path. The flow of current at such frequency is limited by a resistance 39 and is indicated by an ammeter 41 preferably provided with a pointer retaining the maximum deflection given thereto or provided with suitable recording means. It may be desired to provide several paths tuned for several frequencies, each path being then provided with the elements recited above for one such path. The current flowing through the several tuned paths may be conducted over visible or audible signalling means such as a bell 42 and over the coil of a relay 43. Such relay is preferably of the time delay type operable to close its contacts 44 upon flow of current of predetermined value through the coil thereof for a predetermined length of time. Contacts 44 are arranged to complete the circuit of battery 32 to solenoid 31 to release latch 29 and cause circuit breaker 27 to open under the action of spring 28.

The operation of the system will be apparent from a consideration of Fig. 2 in which sine curves 51 to 56, drawn in light lines, represent the positive portions of the voltages of the several portions of winding 13. In the absence of control electrodes in device 16, the direct current output voltage appearing between cathode 17 and the neutral point of winding 13 would comprise the peaks of successive curves 51 to 56 intersecting at points such as points A. Under the action of the control electrodes, each anode will begin to carry current at a later moment represented by a point such as point B, so that the preceding anode continues to carry current alone over the interval AB. Due to the inductance of the supply transformer, the two anodes carry current in parallel over the following interval BC, after which the second anode carries current alone. If all anodes and control electrodes are operating normally, the direct current output voltage will consist of the peaks of curves 51 to 56 each extending from a point such as C to a point such as the following point B and each peak is followed by an indentation over an interval such as BC. Such voltage contains alternating components which have the same values recurring during the period of operation of each succeeding anode and accordingly comprise a fundamental component having a frequency equal to six times the frequency of the voltages of line 11 and, generally, all the harmonics of such component.

For the purpose of illustrating the operation of the system, it will be assumed that the anode receiving voltage 55 fails to carry current for any reason and also that the control electrode associated with the anode receiving voltage 52 fails to retard the flow of current in such anode past the point of intersection A of curves 51 and 52. The direct current output voltage of the rectifier is then represented by heavy line 46. Such line shows a pronounced dip recurring once during each cycle of the voltages of line 11 at the times when the inoperative anode should be carrying current. Curve 46 therefore presents, in addition to the components mentioned above, a number of alternating components of predetermined frequencies and of predetermined magnitudes. The largest of such components is an alternating voltage having the frequency of the voltages of line 11 and represented by dotted line 47. If one of the filters 37, 38 is tuned to the line frequency, a current of predetermined value will then flow through such filter, through indicator 41, signal 42 and relay 43. After a predetermined time delay, relay 43 closes contacts 44 and thereby causes circuit breaker 27 to disconnect device 16 from line 11. An analysis of curve 46 will reveal that such curve will contain alternating components at all the harmonic frequencies of the frequency of component 47. Such frequencies also have predetermined magnitudes so that additional filters tuned to such frequencies will receive currents of predetermined values.

If more than one anode fails to carry current, some of the voltage components may have values differing from the values obtained when only one anode fails, or may be altogether nonexistent. For example, if two anodes normally operating in phase opposition simultaneously fail to function, no component of line frequency will appear in the output voltage and the major component then has a frequency equal to twice the line frequency and is of a predetermined value. An examination of the readings of indicators 41 during the period of the disturbance will thus reveal the number of anodes which have ceased functioning and also the phase relation between the voltages of such anodes. Failure of one control electrode to control the operation of the associated anode causes the serration occurring over period AB to be absent from the output voltage over the period corresponding to the operation of such anode, such as the peak portion of curve 52 in Fig. 2 as indicated at AD. Such failure causes the appearance, in the output voltage, of an alternating component at line frequency but of a considerable smaller magnitude than the component caused by failure of one anode to function. Such component will again cause flow of current in filter 37, 38 tuned to line frequency, the magnitude of such current permitting distinction between the effect of an inoperative control electrode and the effect of an inoperative anode. When an anode and a control electrode are simultaneously inoperative, so as to result in an output voltage curve such as 46, the fundamental component due to the failure of the anode of curve 55 alone is slightly reduced as a result of the failure of the control electrode and is then represented by curve 47; some of the other components may also be altered, thereby permitting ascertaining of the nature of the trouble within the device 16.

Upon occurrence of a short circuit in line 18, 19 or of a backfire in device 16, the voltage present between line conductors 18, 19 suddenly falls to a low value and condensers 38, which during normal operation are charged at the voltage of the line 18, 19, suddenly discharge through indicators 41, signal 42, relay 43, conductor 18, the point of fault or device 16, conductor 19, resistances 39 and reactors 37. Such flow of discharge current through the coil of relay 43 causes such relay to close contacts 44, thereby causing operation of circuit breaker 27 and interruption of the flow of current through device 16.

In the embodiment partially illustrated in Fig. 3, it is assumed that the supply transformer is provided with a six phase secondary winding 48 having two neutral points connected with conductor 19 over the usual type of interphase transformer 49. Upon failure of one of the anodes or of one of the control electrodes of device 16 to function, voltage components similar to those appearing in the direct current output circuit will appear across the terminals of interphase transformer 49. Filters 37, 38, indicators 41, signal 42 and relay 43 are therefore connected across the terminals of interphase transformer 49 to receive voltages appearing at the terminals of such interphase transformer during abnormal operation only. The alternating current voltages normally appearing across such terminals will not cause the flow of any appreciable current through signal 42 and relay 43 due to the tuning of the filters 37, 38 to frequencies other than those of such normal voltages. Battery 26 is herein shown as connected with winding 23 over a resistance 50 having the terminals thereof connected with contacts 44 of battery 32. During normal operation, the current drawn by the control electrodes produces, in resistance 50, a small ohmic drop which is taken into consideration when adjusting phase shifter 23, 24. Upon closure of contacts 44 of relay 43, battery 32 impresses on all control electrodes an additional negative voltage sufficient for continuously maintaining the control electrodes at a negative potential with respect to cathode 17, thereby causing interruption of a current flowing through device 16. As in the embodiment illustrated in Fig. 1, relay 43 is provided with a time delay device so as to preclude operation of such relay upon temporary failure of functioning of one of the electrodes of device 16, as such temporary faulty operation would not cause deterioration of the device 16. Such time delay device also prevents relay 43 from closing upon occurrence of transient surges in the direct current circuit which surges may contain components to which one of the filters 37, 38, 39 is tuned and which may therefore cause the flow of a transient current in the coil of relay 43. In either case signal 42 will operate and one or more of indicators 41 will record the transient flow of current so that the attendant may be cognizant of such transient condition although the device was not disconnected from the supply line. When current flowing through device 16 has been interrupted, current no longer flows in the coil of relay 43 and contacts 44 are thereafter maintained closed by a holding coil 55 provided on relay 43. A switch 60 permits resetting relay 43 by momentarily opening the circuit of battery 32.

It will be understood that, by a suitable adjustment of phase shifter 23, 24, device 16 may be operable to function as an inverter for converting direct current from line 18, 19 into alternating current supplied to line 11, without thereby affecting the operation or the usefulness of the system described.

In the embodiment illustrated in Fig. 4, the operation of relay 43 is shown as being responsive to the flow of current components of predetermined frequencies in the neutral connection of winding 23 resulting from the failure of one of the control electrodes 21 to function. To obtain such effect suitable impedance means such as a resistance 57 and a reactor 58 are inserted between the neutral point of winding 23 and battery 26 and the voltage drop across resistance 57 and reactor 58 is impressed on a plurality of filters 37, 38, indicators 41, signal 42 and the coil of relay 43. As is well known, control electrodes 21 function in a manner similar to that of anodes 14 so that the current in the neutral lead of winding 23 normally has a wave shape resembling the wave shape of the output direct current of device 16. Such current therefore normally contains harmonic components of predetermined frequency to which filters 37, 38 should not be tuned. Failure of one of the control electrodes to function causes the appearance, in the current of the neutral lead of the control transformer, of alternating components of predetermined frequencies and magnitudes which cause flow of current through filters 37, 38, indicators 41, signal 42 and coil of relay 43 as set forth in relation to the embodiment illustrated in Fig. 1.

If the rectifying system utilizing device 16 supplies current to a line also receiving current from other converting equipment such as rotary converters, the voltage of the direct current line is maintained at a substantially uniform value by such converters. Reactor 33 and filters 34, 36 may then be omitted, and the alternating voltage components appearing in the embodiment illustrated in Fig. 1 then no longer appear in the rectifier output voltage. It is then necessary to utilize the alternating components of predetermined frequencies appearing in the current delivered by device 16, and which were not utilized in the preceding embodiments. As shown in Fig. 5, such current components may be utilized in a manner similar to that illustrated in Fig. 4 by inserting, in one of the direct current conductors such as 19, suitable impedance means such as resistance 59 and reactor 61. The voltage drop across such impedance means is then impressed on the same circuits as in the embodiment illustrated in Fig. 4 in which filters 37, 38 are tuned to frequencies of alternating components present during abnormal operation and absent during normal operation of the device.

In the present embodiment, battery 26 is omitted and the control electrodes receive a negative direct current voltage component from a voltage divider comprising rheostats 88 and 89 connected in series between conductors 18 and 19. Automatic control of energization of the control electrodes to maintain the current within device 16 at a constant value is obtained by constructing rheostat 89 as part of a regulator such as a regulator 91 of the rocking contact type. Regulator 91 includes a stator core 92 energized by means of a winding 93, and an armature 94 rotatable on a spindle 96 and carrying a winding 97 connected in series with winding 93. Windings 93 and 97 are energized in response to the variations of the current in conductor 18 by means of a shunt 99 over a regulating rheostat 101 and a resistance 102. The torque of spindle 96 resulting from such current flow is opposed by a spring 98 or by a combination of springs having a constant torque over the range of motion of the regulator. Spindle 96 carries a hub 103 serving as a fulcrum for a rocking sector 104 which moves either in direct contact with resistance 89 or over a separate contact path comprising a plurality of conductive segments (not shown) severally connected with the portions of resistance 89. Sector 104 is connected with the neutral point of winding 23, so that movement of such sector causes the connection of such neutral point with portions at different potentials of resistance 89.

When the current flowing through the device is lower than desired, spring 98 rotates spindle 96 and sector 104, thereby causing the point of contact of sector 104 with resistance 89 to move toward conductor 18. The negative voltage equal to the voltage drop in the portion of resistance 89 between the point of contact and conductor 18 decreases, thus causing the control electrodes to become positive with respect to cathode 17 at an earlier moment of the voltage cycle of line 11 and to thereby cause a large flow of current through device 16. When the current through the device becomes too large, armature 94 rotates spindle 96 against the action of spring 98 to produce a current reduction by a process opposite to that above described, the value of current thus automatically maintained may be adjusted by means of rheostat 101.

In the present embodiment, when the relay 43 closes contacts 44, resistance 102 is short circuited, thereby adjusting the setting of regulator 91 in such a manner as to cause such regulator to maintain the flow of current within device 16 at a lower value, which will not cause the anodes remaining in operation to become overloaded.

In the embodiment illustrated in Fig. 6, winding 48 is assumed to be utilized in conjunction with an electron discharge device 62 provided with 12 anodes. The current from each portion of winding 48 is then preferably conducted to two of the anodes of device 62 and additional means must be provided to cause a substantially equal division of current between such anodes. Such means preferably consist of a six phase paralleling transformer having a primary winding 63 and a three phase secondary winding 64 and a second similar paralleling transformer having a primary winding 66 and a secondary winding 67. As is well known, the division of current between the anodes connected with each portion of winding 63 and the anodes connected with each portion of winding 66 is effected by the flow of three phase currents between windings 64 and 67. During normal operation, if the neutral points of windings 64 and 67 are conductively connected, such connection will not receive any current. The coil of relay 43 and signal 42 may therefore be inserted in such connection and will not receive any current during normal operation of device 62. If one of the anodes of device 62 fails to carry current the currents circulating between windings 64 and 67 will no longer be balanced so that a residual current will flow between the neutral points of such windings over the coil of relay 43 and signal 42.

In the present embodiment, relay 43 is assumed to have contacts 44 thereof arranged to connect battery 32 with the trip coil 40 of a circuit breaker 45 inserted in conductor 18. Upon closure of contacts 44, circuit breaker 45 opens and disconnects device 62 from the output line, so that the device no longer carries current as if such device were disconnected from the supply line in the manner illustrated in Fig. 1. The circuit of trip coil 40 is completed over the contacts of a relay 106 energized in response to the flow of current in device 62 by means of a shunt 107. The circuit of trip coil 40 is then not completed and circuit breaker 45 does not open if the current in device 16 has a value which will not cause the anodes remaining in operation to become overloaded. It will be understood also, that, in the present embodiment, relay 43 may be utilized for controlling the opening of a circuit breaker in the supply circuit of the device as previously illustrated and described.

In the embodiment illustrated in Fig. 7, winding 48 is assumed to supply current to an electron discharge device 68 provided with eighteen anodes. Each portion of winding 48 is then preferably connected to supply current to three anodes of device 68 which anodes then operate in parallel; the equal division of current between the parallel anodes is obtained by means of three single phase paralleling transformers each having a double primary winding 69, 72, or 74 and a secondary winding 71, 73, or 76. During normal operation, the currents in windings 71, 73, and 76 constitute a balanced three phase system of currents so that the three windings may be connected in parallel with each other to a circuit comprising the coil of relay 43 and signal 42. During such normal operation there will not be any flow of residual current through coil of relay 43 and signal 42. Upon failure of one of the anodes of device 68 to function the currents of windings 71, 73, 76 no longer constitute a balanced three phase system of current and a residual current will flow through the coil of relay 43 and signal 42 to give a signal and cause circuit breaker 27 to disconnect winding 12 from line 11.

It may be desired not to connect windings 71, 73, 76 in a conductive manner so as to relieve the stress on the insulation between the primary and secondary windings of the several paralleling transformers resulting from such conductive connection. Windings 71, 73, and 76 may then be connected with the circuit of the coil of relay 43 and signal 42 over a plurality of current transformers 77, 78, and 79 having their secondaries connected in parallel as shown in Fig. 8.

Relay 43 may also be provided with a plurality of operating coils 84, 85, 86 as shown in Fig. 9, which are severally connected with windings 71, 73, and 76 and which act on a single armature 87. In this manner the relay will close contacts 44 only upon occurrence of an unbalance between the currents flowing in coils 84, 85, and 86. In the present embodiment, signal 42 is preferably connected in parallel with solenoid 31 and is operated from battery 32 upon closure of contacts 44.

Features specific to certain of the herein disclosed embodiments of the present invention are claimed in a divisional application filed August 13, 1937 and having Serial No. 158,843; and although but a few embodiments thereof 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 protective system for electron discharge devices, an alternating current supply line, an electron discharge device connected with said line, a direct current output line connected with said device, means for interrupting flow of electric current through said device, and means receiving and operating in response to alternating current components appearing in said output line only upon abnormal operation of said device to cause operation of said interrupting means.

2. In a protective system for electron discharge devices, a supply line, an electron discharge device connected with said line, an output line connected with said device, means for interrupting flow of electric current through said device, and means receiving and operating in response to harmonic current components appearing upon abnormal operation of said device, said means causing operation of the first said means.

3. In a protective system for electron discharge devices, a supply line, an electron discharge device connected with said line, an output line connected with said device, means for interrupting flow of electric current through said device, and means receiving and operating in response to harmonic current components of predetermined frequencies appearing in the system only upon abnormal operation of said device, said means causing operation of the first said means.

4. In a protective system for electron discharge devices, a supply line, an electron discharge device connected with said line, an output line connected with said device, means for interrupting flow of electric current through said device, and means receiving and operating in response to alternating current components of predetermined frequencies appearing in one of said lines only upon abnormal operation of said device to cause operation of said interrupting means.

5. In a control system for electron discharge devices, a source of alternating current, an electron discharge device connected with said source, circuits connected with said device and receiving currents of predetermined frequencies relative to the frequency of said source only upon abnormal operation of said device, means for interrupting the flow of current through said device, and means operable upon energization of any of said circuits to cause operation of said interrupting means.

6. In a protective system for electron discharge devices, a supply line, an electron discharge device connected with said line, an output line connected with said device, means for interrupting flow of electric current through said device, and means receiving and operating in response to harmonic current components appearing in said output line upon abnormal operation of said device, said means causing operation of the first said means.

7. In a control system for electron discharge devices, an alternating current line, a transformer connected with said alternating current line, an electron discharge device connected with said transformer, a direct current line connected with said device, a circuit breaker for interrupting the flow of current through said device, circuits tuned to predetermined frequencies appearing in said direct current line only upon abnormal operation of said device, and means operable upon energization of any of said circuits to cause opening of said circuit breaker.

8. In combination with direct and alternating current circuits, an electron discharge device interconnecting said circuits comprising a plurality of electrodes forming asymmetric conductors for transforming current received from one of said circuits and the supply thereof to the other of said circuits, and a plurality of control electrodes severally associated with said conductors, of means including a regulator connected with and continuously applying to said control electrodes potential of such sign and magnitude as to prevent initiation of flow of current through said device by way of said conductors, means having connections with and periodically applying potential to said control electrodes of such sign and magnitude and during such recurring periods as to permit and control the moments of initiation of flow of current sequentially through said conductors, the said regulator having connections with and being responsive to the magnitude of flow of current in said other of said circuits during normal operation of said device to vary within predetermined limits the magnitude of said potential continuously applied to said control electrodes, and means receiving current from the said other of said circuits only during abnormal operation of said device for causing the said regulator to vary the magnitude of said potential continuously applied to said control electrode beyond said predetermined limits.

9. The combination of a supply circuit, a distribution circuit, electron discharge means interconnecting said circuits and comprising a plurality of asymmetric conductors for transforming current received from one of said circuits and the supply thereof to the other of said circuits, means operable to limit the said current to values within predetermined maximum and minimum limits during normal operation of the first said means, and means operable responsive to abnormal operation of the first said means for affecting the operation of the second said means in such sense as to thereby limit said current to a value below said minimum limit.

10. The combination of a supply circuit, a distribution circuit, electron discharge means interconnecting said circuits and comprising an asymmetric conductor for transforming current received from one of said circuits and the supply thereof to the other of said circuits, means comprising an electrode associated with said conductor for controlling the operation thereof, means operable responsive to operation of the first said means during normal operation thereof for affecting the operation of the second said means in such sense as to thereby limit said current to values within predetermined maximum and minimum limits and operable responsive to abnormal operation of the first said means for affecting the operation of the second said means in such sense as to thereby limit said current to a value below said minimum limit.

11. The combination of a supply circuit, a dis-

tribution circuit, electron discharge means interconnecting said circuits and comprising a plurality of asymmetric conductors for transforming current received from one of said circuits and the supply thereof to the other of said circuits, means operable during normal operation of the first said means for regulating the value of said transformed current, and means operable responsive to abnormal operation of the first said means for affecting the operation of the second said means in such sense as to modify the said regulating action thereof.

12. The combination of a supply circuit, a distribution circuit, electron discharge means interconnecting said circuits and comprising an asymmetric conductor for transforming current received from one of said circuits and the supply thereof to the other of said circuits, means operable responsive to operation of the first said means during normal operation thereof for regulating the value of said transformed current, and means operable responsive to abnormal operation of the first said means for affecting the operation of the second said means in such sense as to modify the said regulating action thereof.

13. The combination of an alternating current supply circuit, a direct current output circuit, electron discharge means interconnecting said circuits and comprising an asymmetric conductor for transforming current received from the said supply circuit and the supply thereof to the said output circuit, means operable during normal operation of the first said means for regulating the value of said transformed current, and means operable responsive to alternating current components appearing in the said output circuit upon abnormal operation of the first said means for affecting the operation of the second said means in such sense as to modify the said regulating action thereof.

14. The combination of an alternating current supply circuit, a direct current output circuit, electron discharge means interconnecting said circuits and comprising an asymmetric conductor for transforming current received from said supply circuit and the supply thereof to the said output circuit, means operable during normal operation of the first said means for regulating the value of said transformed current, and means connected with said output circuit and receiving alternating current components of predetermined frequencies relative to the voltage frequency of said supply circuit upon abnormal operation of the first said means for affecting the operation of the second said means in such sense as to thereby modify the said regulating action thereof.

15. The combination of an alternating current supply circuit, a direct current output circuit, electron discharge means interconnecting said circuits and comprising an asymmetric conductor for transforming current received from said supply circuit and the supply thereof to said output circuit, means operable to limit the said current to values within predetermined maximum and minimum limits during normal operation of the first said means, and means connected with said output circuit and receiving alternating current components of predetermined frequencies relative to the voltage frequency of said supply circuit upon abnormal operation of the first said means for affecting the operation of the second said means in such sense as to thereby limit the said current to a value below said minimmu limit.

HAROLD WINOGRAD.