

Oct. 23, 1951

H. H. SPENCER

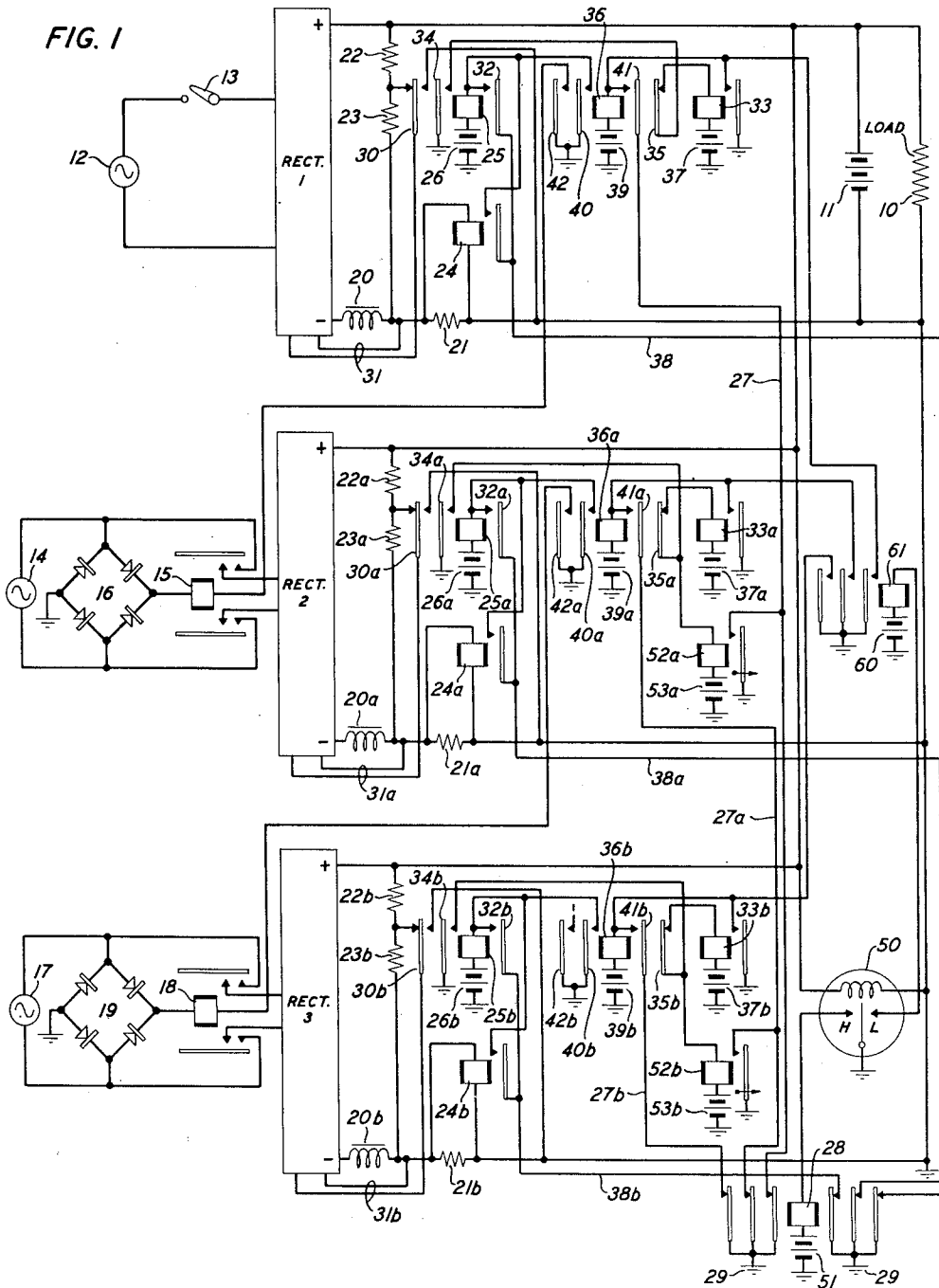
2,572,210

CURRENT SUPPLY APPARATUS

Filed May 11, 1950

2 SHEETS—SHEET 1

FIG. 1



INVENTOR

H. H. SPENCER

BY

Y. F. Heurman

ATTORNEY

Oct. 23, 1951

H. H. SPENCER

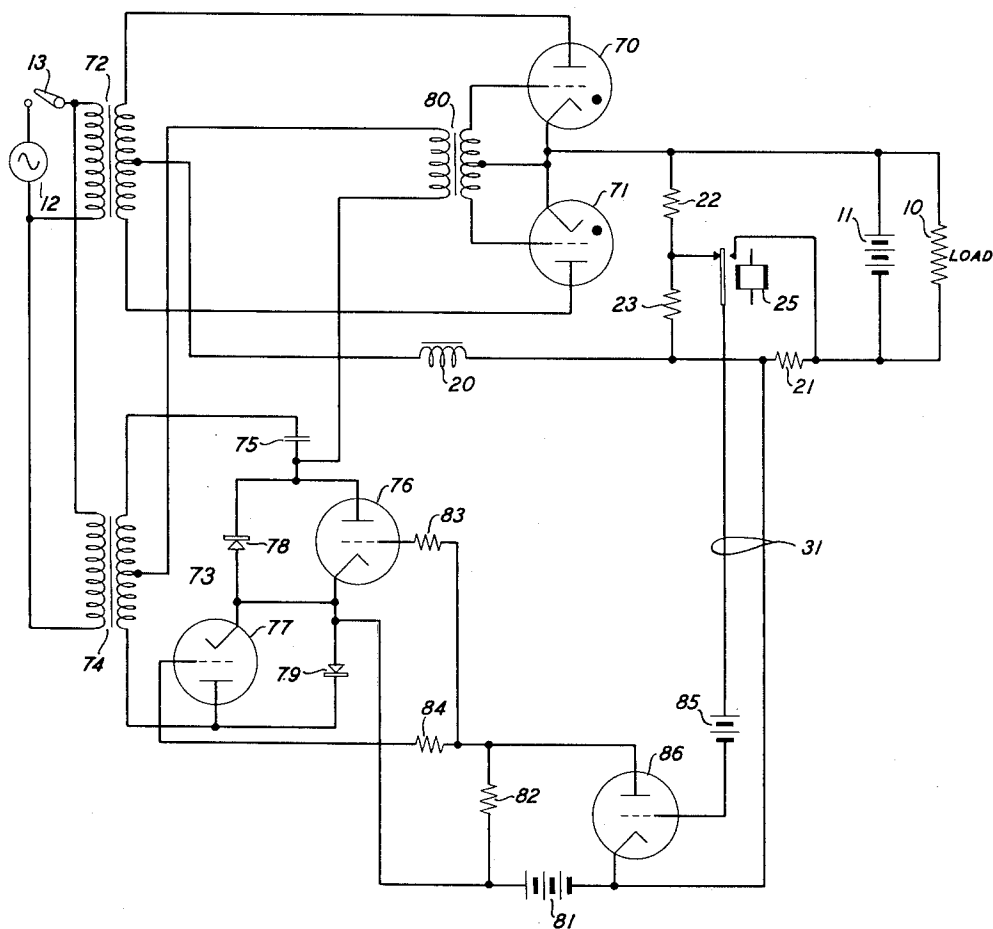
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2 SHEETS--SHEET 2

FIG. 2



INVENTOR
H. H. SPENCER
BY
G. F. Heuerman
ATTORNEY

UNITED STATES PATENT OFFICE

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CURRENT SUPPLY APPARATUS

Harry H. Spencer, Springfield, N. J., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

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5 Claims. (Cl. 171-97)

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This invention relates to a current supply system and more particularly to a system for controlling the supply of current from one or more of a plurality of regulated rectifiers to a common load.

In accordance with a specific embodiment of the invention herein shown and described for the purpose of illustration, there are provided a plurality of rectifiers, the output circuits of which are connected to a common load comprising a storage battery. Each rectifier is of the type which may be conditioned for constant voltage operation or, alternatively, for constant current operation. Means are provided for changing each rectifier from constant voltage to constant current operation when the current output of the rectifier is increased to a predetermined amplitude, and for simultaneously starting a succeeding rectifier in operation by connecting its input to an alternating-current supply source. Thus, as the current required to maintain the load voltage substantially constant increases, additional rectifiers are successively conditioned for supplying current to the load, all of the rectifiers being conditioned for constant current operation except the last to be added which is conditioned for constant current or voltage operation.

When the rectifiers are supplying more current to the load than is required to maintain the load voltage substantially constant, the resulting increase of load voltage causes the last added rectifier which is conditioned for constant voltage operation to be disconnected from its alternating-current supply source and simultaneously causes the preceding rectifier to be changed from constant current to constant voltage operation. This operation is repeated if the load voltage remains too high.

If, due to some abnormal condition such as the failure of a rectifier, the load voltage should decrease below the normal operating range, means are provided for causing all of the rectifiers to be conditioned for constant current operation. When the load voltage rises above the normal operating range, the last connected rectifier is changed from constant current to constant voltage operation and, if the load voltage continues to be too high the last connected rectifier is de-energized and the preceding rectifier is changed from constant current to constant voltage operation, as described above. It is thus seen that only the last connected rectifier can be conditioned for constant voltage operation, all preceding rectifiers being conditioned for constant current operation.

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The invention will be more fully described with reference to the accompanying drawing in which:

Fig. 1 is a schematic view of a current supply system embodying the invention; and

Fig. 2 is a schematic view of a regulated rectifier of a type which may be used in the supply system of Figs. 1.

Referring to the drawing, there are provided a plurality of regulated rectifiers, such as rectifiers 1, 2 and 3 for supplying rectified current to a load 10 and a battery 11 connected in parallel. The rectifiers 1, 2 and 3 are preferably of the type disclosed in a copending application of F. W. Anderson, Serial No. 111,208, filed August 19, 1949. Another suitable rectifier is disclosed in United States Patent No. 2,155,515 to D. E. Trucksess, April 25, 1939. Alternating current is supplied to rectifier 1 from a supply source 12 when switch 13 is closed; alternating current is supplied to rectifier 2 from a supply source 14 through the armatures and contacts of an electromagnetic relay 15 when its winding is energized by current from an auxiliary rectifier 16 to which alternating current is supplied from source 14 and alternating current is supplied to rectifier 3 from a supply source 17 through the armatures and contacts of a relay 18 when its winding is energized by current from an auxiliary rectifier 19 to which alternating current is supplied from source 17.

Current from rectifier 1 is supplied to the load through a circuit comprising a filter inductance element 20 and a resistor 21 in series. A voltage divider comprising resistors 22 and 23 in series is connected in a shunt path across battery 11. The winding of a relay 24 is connected across resistor 21 so that when the load current flowing through resistor 21 reaches a sufficient amplitude the relay armature is attracted to complete an energizing circuit for a relay 25 which may be traced from grounded battery 26, through the winding of relay 25, the armature and contact of relay 24, lead 27 and through an armature and a contact of a relay 28 to ground at 29. When the armature 30 of relay 25 is released, as shown, the voltage across resistor 23 which is proportional to load voltage is impressed across leads 31 for regulating the output of rectifier 1 to maintain the load voltage substantially constant. When the armature 30 of relay 25 is attracted, the voltage across resistor 21 which is proportional to load current is impressed across leads 31 for regulating the output of rectifier 1 to maintain the load current substantially constant at eight amperes, for example. The means for controlling

the output of rectifier 1 in response to the voltage across resistor 23 or resistor 21 is described in said copending application of F. W. Anderson or in said patent to Truckess, referred to above. In accordance with the disclosure of the Anderson application, as described more fully below in connection with Fig. 2, a voltage proportional to the load voltage or a voltage proportional to the load current is amplified and, after amplification, is used to control the phase of an alternating voltage impressed upon the control grid-cathode circuit of a gaseous space current rectifier to control the output of the rectifier and thereby to maintain the load voltage or the load current, alternatively, substantially constant.

Relay 25, when energized, completes a current path from its winding through its armature 32 to ground at 29 to hold the relay operated. The relay 25, when operated, remains operated until the ground is removed from the circuit by the operation of relay 28. The energization of relay 25 also completes an energizing circuit for a relay 33 which may be traced from the grounded armature 34 of relay 25, through armature 35 and contact of a relay 36 and through the winding of relay 33 to grounded battery 37. Relay 33, when energized, attracts its grounded armature to complete a circuit for energizing relay 36 by current from grounded battery 39. To simplify the drawing, batteries 26, 37 and 39 are shown as being independent of battery 11 connected across the load. If desired, however, the direct current for energizing the various relays may be obtained from battery 11. Relay 36, when operated, completes a circuit from its grounded armature 40 to the winding of relay 25 to hold the relay 25 operated. A holding circuit for relay 36 is completed through its armature 41 to ground at 29. The operation of relay 36 attracts its grounded armature 42 to complete a circuit for supplying current from auxiliary rectifier 16 through the winding of relay 15. The operation of relay 15 causes current from the supply source 14 to be supplied to rectifier 2 which, after a delay period required for heating the cathodes of space discharge devices of rectifier 2 to operating temperature, supplies current to the load circuit in addition to that supplied by rectifier 1.

To avoid unnecessary repetition, elements associated with rectifier 2 similar to elements associated with rectifier 1 and performing a similar function have been designated by the same numerals followed by the latter "a." When the relay 25a is deenergized, as shown in the drawing, sufficient current is supplied by rectifier 2 in addition to that supplied by rectifier 1 to maintain the load voltage substantially constant. When the output current of rectifier 2 flowing through resistor 21a is increased to a predetermined value, relays 24a and 25a operate to change the rectifier 2 from constant voltage to constant current regulation under which condition rectifier 2 supplies a substantially constant current of eight amperes, for example, to the load circuit comprising load 10 and battery 11. Under the constant current operation of rectifier 2, relay 36a also operates to complete a circuit for supplying current from auxiliary rectifier 19 to the winding of relay 18 to cause alternating current from source 17 to be supplied to rectifier 3 which then similarly supplies additional current to the load circuit.

Elements associated with rectifier 3 similar to elements associated with rectifier 1 and performing a similar function have been designated by

the same numerals followed by the letter "b." When the current supplied by rectifier 3 to the load circuit is increased to a predetermined amplitude, the various relays are energized to change rectifier 3 from constant voltage to constant current operation and, if additional rectifiers are provided, the next rectifier is connected to a source of alternating current and it supplies additional current to the load circuit, as described in connection with rectifiers 1 and 2.

There is provided a voltmeter relay 50 having its winding connected across the load 10 and battery 11. It is seen that as many rectifiers are conditioned for operation, one at a time in succession, as are required to bring the voltage of battery 11 to the predetermined normal voltage. The last rectifier to be added is conditioned for constant voltage regulation and all preceding rectifiers are conditioned for constant current regulation. If the total output current of the rectifiers which are conditioned for constant current regulation exceeds the charge load required to maintain the battery voltage at the normal voltage, the voltage regulated rectifier will supply zero output current to the load circuit and the battery voltage will rise. As a result a circuit for energizing relay 28 by current from grounded battery 51 will be completed through a contact and the grounded armature of relay 50. There are also provided a relay 52a which is energized by current from grounded battery 53a when relay 25a attracts its grounded armature 34a and a relay 52b which is energized by current from grounded battery 53b when relay 25b attracts its armature 34b.

Assume that rectifiers 1 and 2 operating on constant current regulation are together supplying sixteen amperes to the load circuit comprising load 10 and battery 11 in parallel and that the current supplied to the load 10 per se is ten amperes. Assume further that rectifier 3 is operating on voltage regulation for which condition the relays including relay 52b associated with rectifier 3 are released. When the battery voltage has increased to 140 volts, for example, relay 50 will operate to close a circuit for operating relay 28, thereby removing ground from lead 27a. As a result, relay 36a releases to open the energizing circuit for relay 18, thereby disconnecting rectifier 3 from its alternating-current supply source 17. Relay 25a also releases and, as a result, rectifier 2 is changed from constant current regulation to constant voltage regulation, thereby reducing to zero the current supplied by rectifier 2 to the load circuit. Relay 24a thus also releases. The reduction of the current supplied to the load circuit from the initially assumed sixteen amperes to eight amperes, causes the battery voltage to decrease sufficiently to cause relay 50 to open the energizing circuit for relay 28, thereby reconnecting ground to lead 27. Relay 52a also releases in response to the deenergization of relay 25a but it is slow enough to release to maintain ground connected to lead 27 during the period required for operating and subsequently releasing relay 28 due to the closing and subsequent opening of the energizing circuit for relay 28 by the operation and release, respectively, of relay 50. Since relay 36 and the other relays associated with rectifier 1 are thus maintained operated, relay 15 is also maintained operated to maintain rectifier 2 in operation. Rectifier 1 now operates on constant current regulation and rectifier 2 operates on constant voltage regulation to supply

sufficient current to the load circuit to maintain the load voltage substantially constant.

If, for example, rectifier 1 should fail at a time when it alone is supplying current to the load circuit, with the control arrangement as thus far described, the relay 24 could not be operated to effect the starting of additional rectifiers so as to tend to maintain the battery voltage substantially constant. So also, if rectifier 1 is operating on constant current regulation and rectifier 2 should fail when it is conditioned for constant voltage operation, relay 24a could not operate to start rectifier 3 in operation. Under either of the above abnormal conditions, the battery voltage would decrease to 132 volts, for example, to cause voltmeter relay 50 to close its low voltage or right-hand contact, as viewed in the drawing. A circuit is thus completed for supplying energizing current from grounded battery 60 to the winding of a relay 51. The operation of relay 61 completes energizing circuits for operating the relays 36, 36a and 36b. Thus, assuming that rectifier 1 has failed, rectifiers 2 and 3 will be energized to supply current to the battery and load, these rectifiers operating at constant current regulation. As the battery voltage increases, the armature of relay 50 first opens the energizing circuit for relay 61 and subsequently, if the battery voltage is sufficiently high, completes an energizing circuit for relay 28 to remove ground 29 from leads 27a and 38a, and 27b and 38b. Removing the ground from leads 27b and 38b causes relay 25b to release to change rectifier 3 from constant current to constant voltage operation. If relay 28 remains energized after the current from rectifier 3 has been reduced, relay 52b will also release to remove its ground from lead 27a. Relay 36a will then release to interrupt the energizing circuit for relay 18, thereby disconnecting rectifier 3 from alternating-current source 17, and relay 25a will release to change rectifier 2 from constant current to constant voltage operation.

The rectifier 1 of Fig. 1, for example, is shown in Fig. 2 and is briefly described as follows: The rectifier comprises two gas-filled, space current rectifying devices 70 and 71 the anodes of which are connected to the end terminals, respectively, of the secondary winding of a transformer 72 the primary winding of which is connected to alternating-current supply source 12 when switch 13 is closed. The cathodes of tubes 70 and 71 are connected to the positive terminal of load 10 and battery 11 while the mid-terminal of the secondary winding of transformer 72 is connected through inductive reactor 20 and resistor 21 in series to the negative terminal of load 10 and battery 11. There is provided a phase shift bridge circuit 73 having four impedance arms. Two of the impedance arms connected in series between the input bridge terminals are the half portions, respectively, of the secondary winding of a transformer 74, the primary winding of which is connected to alternating-current source 12 when switch 13 is closed. A condenser 75 is in a third arm of the bridge. The fourth bridge arm comprises the space current paths of space current triodes 76 and 77 and asymmetrically conducting varistors or rectifying elements 78 and 79. Varistor 78 is poled so that current passes therethrough in its forward or low resistance direction when the anode of triode 77 is positive with respect to its cathode so that it conducts space current. Varistor 79 is poled so that current passes therethrough in its forward or low

resistance direction when the anode of triode 76 is positive with respect to its cathode so that it conducts space current. The output terminals of bridge circuit 73 are connected to the primary winding of a transformer 80. The end terminals of the secondary winding of transformer 80 are connected to the control grids of rectifier tubes 70 and 71, respectively, the mid-terminal of the secondary winding being connected to the cathodes of tubes 70 and 71.

The phase of the output voltage of bridge circuit 73 is controlled by varying the resistances of the space current paths of triodes 76 and 77. The times at which current conduction is initiated in rectifier tubes 70 and 71 is thus controlled to regulate the current supplied by the rectifier to the load 10, 11. To control the resistances of the space current paths of triodes 76 and 77 there is provided an amplifying circuit comprising a space current triode 86. Space current is supplied to triode 86 from a direct-current source such as battery 81 through a circuit comprising a resistor 82. One terminal of resistor 82 is connected through a resistor 83 to the control electrode of tube 76 and through a resistor 84 to the control electrode of tube 77. The other terminal of resistor 82 is connected to the cathodes of tubes 76 and 77. The cathode of tube 86 is connected to the common terminal of resistors 21 and 23. The control electrode of tube 86 is connected through a biasing voltage source, such as battery 85, to the armature of relay 25.

With the armature of relay 25 released, as shown, when the load voltage rises, for example, the control electrode of tube 86 is made relatively more positive with respect to its cathode to increase the space current flowing through resistor 82. As a result the control grids of tubes 76 and 77 are made relatively more negative with respect to their cathodes to cause the resistance of the fourth arm of phase shift bridge 73 to increase. The output of the bridge circuit is thus shifted in phase in a direction to cause a decrease of current supplied through rectifier tubes 70, 71 to the load 10, 11. The initially assumed rise of load voltage is thus minimized. When the armature of relay 25 is attracted and when an increase of current supplied through rectifier tubes 70 and 71 to the load occurs, for example, the control circuit likewise functions to shift the phase of the control electrode-cathode voltage impressed upon rectifier tubes 70 and 71 in a direction to decrease the current supplied through the rectifier tubes 70 and 71 to the load, thereby minimizing the initially assumed rise of current supplied through rectifier tubes 70 and 71 to the load. It is seen, therefore, that when relay 25 is deenergized the rectifier is conditioned for constant voltage operation, that is, the output voltage of the rectifier tends to remain constant. Similarly, when the relay 25 is energized, the rectifier is conditioned for constant current operation, that is, the current supplied from the output of the rectifier tends to remain constant.

What is claimed is:

1. In combination, a first and a second rectifier each having an output circuit connected to a common load and an input circuit, means for connecting the input circuit of said first rectifier to an alternating-current supply source, regulating means which may be controlled for conditioning said first rectifier for constant voltage or constant current operation alternatively, switching means for connecting the input of said

second rectifier to an alternating-current supply source in response to the energization of said switching means, an electromagnetic relay having a winding connected across said load, and means responsive to the operation of said relay when the load voltage decreases to a predetermined voltage for causing the energization of said switching means and for substantially simultaneously controlling said regulating means to condition said first rectifier for constant current operation.

2. In combination, a first and a second rectifier each having an output circuit connected to a common load and an input circuit, means for connecting the input circuit of said first rectifier to an alternating-current supply source, regulating means for said rectifiers respectively for conditioning said rectifiers respectively for constant voltage or constant current operation alternatively, switching means for connecting the input of said second rectifier to an alternating-current supply source in response to the energization of said switching means, and electromagnetic relay means responsive when the load voltage decreases to a predetermined voltage for causing the energization of said switching means and for substantially simultaneously controlling the regulating means for both said rectifiers to condition said rectifiers for constant current operation.

3. In combination, a first and a second rectifier each having an output circuit connected to a common load and an input circuit, two switching means for completing circuits for supplying alternating currents to said rectifiers respectively in response to the energization of said switching means, two regulating means for said rectifiers respectively for conditioning said rectifiers respectively for constant voltage or constant current operation alternatively, and electromagnetic relay means responsive when the load voltage decreases to a predetermined voltage for causing the energization of both said switching means and for substantially simultaneously controlling both said regulating means to condition said first and second rectifiers for constant current operation.

4. In combination, a first and a second rectifier each having an output circuit connected to a common load and an input circuit, means for supplying alternating current to the input circuit of said first rectifier, switching means for completing a circuit for supplying alternating current to the input circuit of said second rec-

tifier when said switching means is energized, regulating means for conditioning said first rectifier alternatively for constant voltage or constant current operation, means responsive to an increase of output current of said first rectifier to a predetermined amplitude for causing the operation of said regulating means to change said first rectifier from constant voltage to constant current operation and for substantially simultaneously causing the energization of said switching means, and means responsive to a decrease of load voltage to a predetermined voltage for causing the operation of said regulating means to change said first rectifier from constant voltage to constant current operation and for substantially simultaneously causing the energization of said switching means.

5. In combination, a first and a second rectifier each having an output circuit connected to a common load and an input circuit, means for supplying alternating current to the input circuit of said first rectifier, regulating means for conditioning said first rectifier alternatively for constant voltage or constant current operation, a first relay means for controlling said regulating means to change said first rectifier from constant voltage to constant current operation in response to the energization of said first relay means, a second relay means for completing a circuit for energizing said first relay means in response to an increase of output current of said first rectifier to a predetermined amplitude, a third relay means, means for completing a circuit for energizing said third relay means in response to the energization of said first relay means, means responsive to the energization of said third relay means for completing a second circuit for energizing said first relay means, a fourth relay means for completing a circuit for supplying alternating current to the input of said second rectifier when said fourth relay means is energized, means responsive to the energization of said third relay means for completing a circuit for energizing said fourth relay means, a fifth relay means for causing the completion of a second circuit for energizing said third relay means in response to the operation of said fifth relay means, and means for impressing the load voltage across said fifth relay means to cause its operation when the load voltage decreases to a predetermined voltage.

HARRY H. SPENCER.

No references cited.