Dec. 28, 1937. F. H. GULLIKSEN 2,103,779

ELECTRIC DISCHARGE APPARATUS

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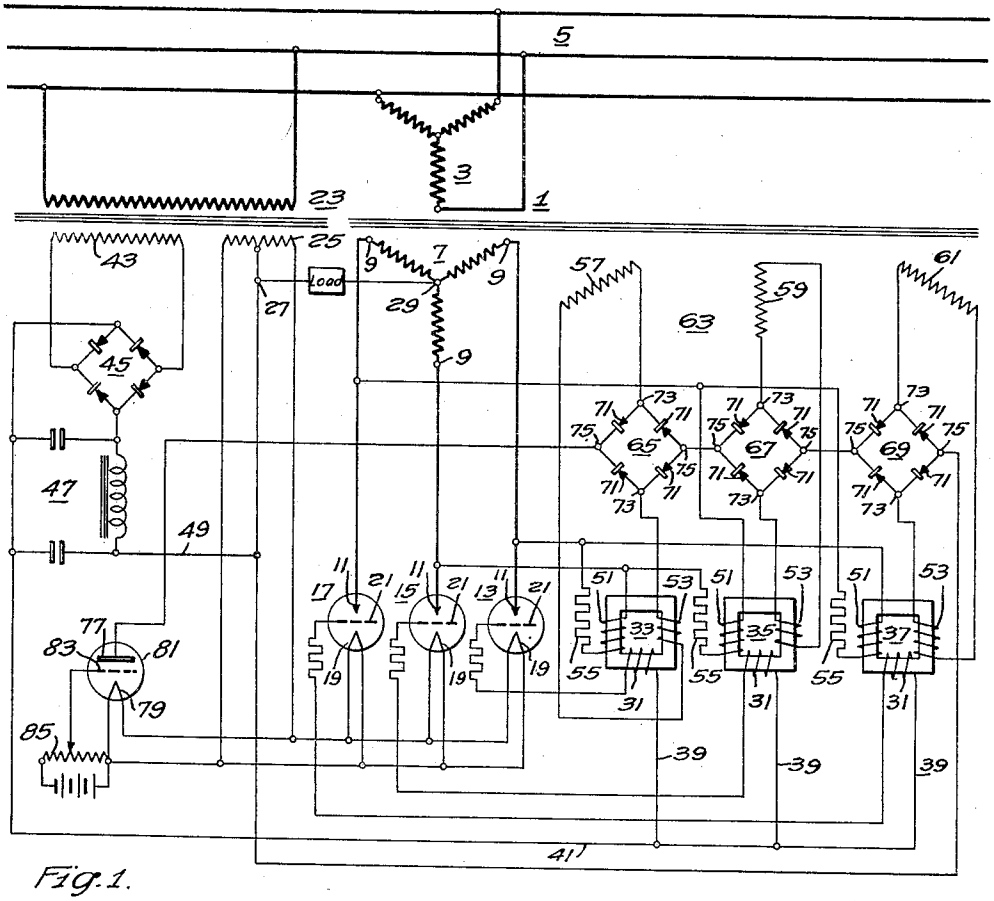


Fig. 1.

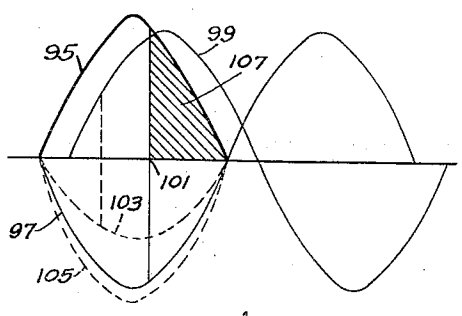


Fig. 3.

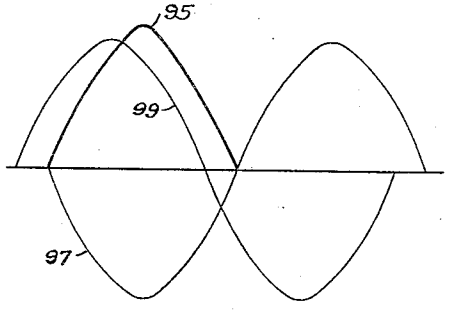


Fig. 4.

WITNESSES:

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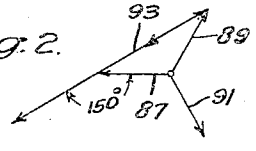


Fig. 2.

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ELECTRIC DISCHARGE APPARATUS

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Application February 23, 1935, Serial No. 7,696

12 Claims. (Cl. 175—363)

My invention relates to translating apparatus and it has particular relation to systems incorporating grid-controlled electric discharge devices, that are utilized in converting power supplied by polyphase sources from one form to another.

The present application is a continuation in part of my application Serial No. 621,141, filed July 7, 1932.

In apparatus of the type to which my invention relates gas or vapor filled grid-controlled electric discharge devices are utilized for converting alternating current into direct current, or for converting direct current into alternating current. It is often essential that the alternating current or direct current supplied through the discharge devices be of variable magnitude and the practice has been to vary the current supply by varying the phase relationship between the control potential and the principal potential supplied to the discharge devices.

Since precise operation of the discharge devices is required, the control potential supplied to the discharge devices preferably has a peaked wave form. By impressing a high potential for a short interval of time between the control electrode and the cathode of a discharge device, when it is desired that the discharge device be energized, the discharge device is energized at a point in the positive cycle or principal potential applied thereto which may be predetermined with precision.

In practicing my invention I prefer to supply the peaked grid potential for each discharge device through a saturable transformer. The transformer is provided with a core of saturable iron and with a plurality of windings. One winding, which may be regarded as a primary of the transformer is supplied with alternating current of constant amplitude. Another primary winding is supplied with alternating current of variable amplitude. A further winding which may be regarded as the secondary of the transformer is connected to supply potential or current between the control electrode and one principal electrode of the discharge device. The currents supplied by the former windings are out of phase with each other and a peak occurs in the potential supplied by the secondary winding when the magnitudes of the currents supplied by the primary windings are so related that the flux in the core is zero. The point in the cycle of principal potential impressed on the discharge device at which the peak occurs may be varied by varying the current supplied to the variable-current primary winding. It is with the variation of the current in this winding that I am particularly concerned.

The current which is to be varied is of considerable magnitude and while the interposition of a variable resistor or a grid-controlled gas-filled discharge device in the circuit supplying the variable-current winding might on its face appear to be a simple solution of the problem, the expense involved and the increase in the dimensions of the equipment which is entailed in solving the problem in this manner is a considerable drawback. The disadvantage which arises in this connection is accentuated when a polyphase power system is to be controlled. In such a system one or more discharge devices are provided to correspond to each phase and the control potential of each discharge device must be regulated. To provide separate variable impedances or separate gas-filled discharge devices to control the current supply through the saturable transformer, in this case would not only increase the expense involved in providing such equipment, but would render the equipment so bulky that it would be useless for many purposes.

It is accordingly an object of my invention to provide for a translating system, incorporating discharge devices, in which the control potential is impressed through a saturable transformer, simplified apparatus for controlling the variable current supplied to the transformer.

A further object of my invention is to provide inexpensive and tractable apparatus for controlling the discharge devices in a polyphase converting system, that is, to supply a variable load.

An incidental object of my invention is to provide a contrivance by the operation of which alternating current may be varied by varying an impedance in a direct current circuit.

A further incidental object of my invention is to provide a contrivance by the operation of which alternating current of considerable magnitude may be varied over a wide range by varying direct current power of small magnitude.

More concisely stated, it is an object of my invention to provide a compact rectifying system for polyphase power which is capable of supplying a variable load.

According to my invention, variable alternating current is supplied to the saturable transformers through which control potential is impressed on the discharge devices through a four-arm bridge rectifier. An interesting feature of such a rectifying network is that it is supplied by a simple two-wire system and therefore, continuous

alternating current flows in its input. In accordance with my invention the direct current output of the rectifier supplies a variable impedance. By varying the magnitude of the impedance the input alternating current may be varied.

A bridge rectifier is in the preferred practice of my invention provided for the saturable transformer corresponding to each discharge device of the system. The output terminals of the rectifiers are connected in series with each other and with the variable impedance. By varying the impedance the alternating current supplied to all of the saturable transformers may be varied.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof will best be understood from the following description of a specific embodiment when read in connection with the accompanying drawing in which:

Figure 1 is a diagrammatic view showing a rectifying system constructed in accordance with my invention.

Fig. 2 is a vector diagram illustrating the relationship of the control potentials supplied to a discharge device in the apparatus shown in Fig. 1.

Fig. 3 is a graph illustrating the operation of a system shown in Fig. 3, and

Fig. 4 is a graph illustrating the operation of a modification of the system shown in Fig. 4.

The apparatus shown in Fig. 1 comprises a power supply transformer 1, the primary 3 of which is connected in Y and is supplied from a commercial three-phase power line 5 of the usual type. One secondary 7 of the transformer 1 is Y-connected and to its terminals 9 the anodes 11 of a plurality of discharge devices 13, 15 and 17 are connected. Essentially, my invention relates to apparatus in which the current requirements are considerable and the discharge devices are of the gas or vapor-filled type. The discharge devices may, however, be selected in accordance with the purpose which the apparatus is to serve. If, for example, the power supplied is to be of comparatively high potential, but small current, the discharge devices may be of the high vacuum type. My invention is applicable to apparatus incorporating high-vacuum discharge devices.

Each discharge device is provided with a hot cathode 19, and a control electrode 21 in addition to the anode 11. If the necessity therefore arises, the hot cathode 19 may be replaced by mercury pool cathode and the discharge devices may be consolidated into a single one with a single cathode and a plurality of anodes to each of which a control electrode corresponds. Moreover, in lieu of control electrodes, starting electrodes such as are utilized in the Ignitron tube may be provided. In the latter case, a mercury pool cathode is utilized and a starting electrode composed of a high resistance element such as boron, boron carbide or silicon carbide dips in the mercury. When current is transmitted through the starting electrode a discharge between the anode and the mercury electrode is initiated.

In the apparatus shown in Fig. 1, the hot cathodes 19 of the discharge devices 13, 15 and 17 are supplied from a transformer 23 which is energized from main supply 5. The secondary 25 of the transformer 23 is provided with a central tap 27 which is connected to the neutral point 29 of the Y-secondary 7 of the power supply transformer 1. Hence, between the anode 11 and the cathode 19 of each tube 13, 15 and 17 the potential output of one phase of the source is impressed.

Control potential is supplied to each of the discharge devices 13, 15 and 17 through the secondaries 31 of saturable transformers 33, 35 and 37. Each secondary 31 supplies a series circuit extending from the right hand terminal of the secondary, a conductor 39, a conductor 41, a biasing potential source supplied from the main power supply 5, through a secondary section 43 of the transformer 23, a rectifying system 45 and a filter 47, a conductor 49, the center tap 27 of the cathode-supply secondary 25, a cathode 19, of the discharge devices 13, 15 or 17 to which the secondary corresponds, the corresponding control electrode 21 to the left hand terminal of the secondary. As the potential output of the secondary 31 varies the potential supplied between the control electrode 21 and the cathode 19 of the corresponding discharge device is varied.

The saturable transformers 33, 35 and 37 are each provided with a plurality of primary windings 51 and 53. One primary winding 51 (the constant current winding) of each saturable transformer is connected between two of the terminals 9 of the Y-secondary 7 of the power transformer 1 through a current-limiting resistor 55, while the other windings 53 (the variable current windings) are each supplied with current from the windings 57, 59 and 61 of an auxiliary secondary 63 of the main transformer 1 through bridge rectifying networks 65, 67 and 69. The secondary windings 57, 59 and 61 of the auxiliary transformer 63 are so vented that the currents supplied to the corresponding variable-current primaries 53 are in opposite phase to the potential output of corresponding windings of the main Y-connected secondary 7 and therefore, in opposite phase to the anode-cathode potential supplied to the discharge devices 13, 15 or 17 to which they correspond.

The bridge rectifiers 65, 67 and 69 are of the so-called Graetz-connected type. Each rectifier is composed of a four-arm closed network, in each arm of which a rectifier 71 is connected. The rectifiers 71 are so arranged that if alternating current is supplied to one pair of opposite terminals 73 of the network, direct current may be drawn from the other pair of opposite terminals 75. The interesting feature of the network is that the alternating current is supplied by a two-wire circuit in which, when the rectifier is in operation, alternating current continuously flows. Although rectifiers of other types are applicable, the rectifying elements that are utilized in the networks in accordance with the preferred practice of my invention are discs of the copper-cuprous-oxide type, described in detail in Patent No. 1,640,335 Lars O. Grondahl.

The variable-current primaries of each of the saturable transformers 33, 35 and 37 are connected to be supplied through the alternating current terminals 73 of networks 65, 67 and 69, respectively, from winding 57, 59 or 61 of auxiliary secondary 63. The direct current terminals 75 of the networks are connected in series with each other and with the anode 77 and cathode 79 of an auxiliary electric discharge device 81 which is also provided with a control electrode 83. The latter discharge device 81 may be of the high vacuum or gas-filled type depending on the current and potential requirements of the

apparatus. For the ordinary case a high vacuum discharge device is preferred.

A variable potential is impressed between the control electrode 83 and the cathode 79 of the auxiliary discharge device 81 from a potentiometer 85 of suitable character. As the potential supplied between the control electrode 83 and the cathode 79 is varied, the current transmitted between the anode 77 and the cathode 79 is varied and the direct current supplied by the rectifying networks 65, 67 and 69 is varied. The alternating current supplied to each of the networks is therefore, varied and the alternating current transmitted through the variable-current primaries 53 of the saturable transformers 33, 35 and 37 is varied.

The operation of the apparatus is illustrated in Figs. 2 to 4. The potential supplied by the windings of the Y-connected main secondary 7 may be represented vectorially by three vectors 87, 89 and 91 which are at an angle of 120° to each other. Accordingly, the potential supplied between the terminals 9 of two of the windings of the transformer 7 may be represented by a vector 93 connecting the terminals of the vectors 87, 89 and 91, representing the potentials supplied by the individual windings. The latter vector 93 represents, in direction and sense, the current supplied to the constant-current primary 51 of one of the saturable transformers 33, 35 and 37, say the transformer 33. The current supplied to the other two may be represented by vectors drawn between the remaining terminals of the vectors 87, 89 and 91. The sense of the vectors 87, 89 and 91 is the same as the sense of vectors representative of the currents in the variable-current primaries 51 of the saturable transformers 33, 35 and 37. The direction of these vectors is, however, opposite to the current vectors since the current supplied to each variable current primary is in opposite phase to the principal potential of the corresponding discharge device. The discharge device 13 corresponds to the saturable transformer 33. Assume that the horizontal vector 87 represents the principal potential supplied to the discharge device 13. Since the vector 93 is at an angle of 30° to the vector 87 and current supplied to the variable-current winding 53 is represented by a vector of opposite direction to the vector 87, the variable current is out of phase with the current supplied to the constant current winding 51.

The situation is represented graphically in Fig. 3. In this view the potential supplied by the main transformer to a discharge device 13, say, corresponding to the saturable transformer 33 is represented by a half wave 95 of a sine curve. Accordingly, the potential supplied to the variable-current winding 53 of the saturable transformer 33 is represented by the full line sine curve 97, the negative half-cycle of which subtends the half wave 95 representing the principal potential. The current supplied to the constant-current winding 51 of the saturable transformer 33 is represented by a sine wave 99 lagging in the last mentioned wave 97 by 150°.

At a certain point 101 in each half cycle the sum of the two currents and therefore the sum of their corresponding fluxes in the core of the transformer 33 is zero, and at this point a peak occurs in the output potential supplied by the secondary 31 of the saturable transformer. The peak potential is impressed between the control electrode 21 and the cathode 19 of the discharge device 33, and the discharge device is energized. By varying the current supplied to the variable-current primary 53 the point at which the peak occurs may be varied. In Fig. 3 two magnitudes of variable current are illustrated by broken line half waves 103 and 105. The variable magnitudes may be obtained by varying the control potential of the auxiliary discharge device 81.

The discharge devices 13, 15 and 17 are customarily of the gas-filled or mercury pool type and when once energized, they continue in energized condition until sufficient negative potential is supplied between their principal electrodes 11 and 19 to deenergize them. The operation in this connection is represented in Fig. 3 by the shading 107 under the full line curve 95 representing the principal potential. The shaded area is initiated earlier in the opposite half cycle by an amount which increases as the amplitude of the variable current supplied to the primary 53 of the transformer 33 decreases and the total current supplied by the discharge device 13 increases correspondingly. However, since both the variable current and the constant current supplied to the primaries 51 and 53 of the transformer 33 become negative, at the 30° point in the positive half cycle of principal potential, the current which can be supplied through the discharge devices 13, 15 and 17 is limited to a magnitude corresponding to the initiation of the discharge at this point.

If the maximum magnitude is desired, the phase relationships of the potentials should be adjusted to correspond to the graph shown in Fig. 4. In this view, the principal potential and the constants and variable currents supplied to the saturable transformers are represented as in Fig. 3. However, it is to be noted that the phase relationship of the quantities is so arranged that the current supplied through the discharge devices may be varied from a value corresponding to excitation during the complete positive half cycle to a value corresponding to excitation only during the last 30° of the half cycle.

As will be apparent from the above discussion, by controlling the small potential supplied to the auxiliary discharge device the current supplied to the variable windings of the saturable transformers may be varied and in a corresponding manner the control potential supplied to the discharge devices 13, 15 and 17 may be varied. Thus the current supplied by the system may be controlled.

In the embodiment described hereinabove, my invention is shown as preferably carried out with four-arm bridge rectifying networks 65, 67 and 69. The bridges may be replaced by ordinary three-wire input full-wave rectifiers (i. e., center-tap transformer or center-tap resistor rectifiers). In this case the variable-current primaries 53 are connected in series with the alternating-current input of the rectifiers and with the center tap element whether it be a resistor or a transformer.

Although I have shown and described a certain specific embodiment of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. In combination a source of power, electric discharge means to be supplied from said source, said means comprising a plurality of pairs of electrodes between which a discharge is to be transmitted and means, independently associated with each pair of electrodes, for controlling the dis-

charge between said pairs of electrodes, means for controlling the supply of power to said controlling means, the last said means including an element coupled to the controlling means associated with each pair of electrodes, the operation of which is dependent on variation in the current supplied thereto and means for varying the supply of current to each of said elements said means comprising a rectifying network having a pair of terminals to which alternating current is supplied through said elements and a pair of terminals from which direct current may be supplied, a unitary impedance supplied from the direct current terminals of all of said elements and means for varying said impedance.

2. In combination a source of power, electric discharge means to be supplied from said source, said means comprising a plurality of pairs of electrodes between which a discharge is to be transmitted and means, independently associated with each pair of electrodes, for controlling the discharge between said pairs of electrodes, means for controlling the supply of power to said controlling means, the last said means including an element coupled to the controlling means associated with each pair of electrodes the operation of which is dependent on variation in the current supplied thereto and means for varying the supply of current to each of said elements said means comprising a rectifying network comprising a plurality of arms connected in series with each other to form a closed network and a rectifying element in each of said arms, said network having a pair of terminals to which alternating current is supplied through said elements and a pair of terminals from which direct current may be supplied, a unitary impedance supplied from the direct current terminals of all of said elements and means for varying said impedance.

3. In combination a source of power, electric discharge means to be supplied from said source, said means comprising a plurality of pairs of electrodes between which a discharge is to be transmitted and means, independently associated with each pair of electrodes, for controlling the discharge between said pairs of electrodes, means for controlling the supply of power to said controlling means, the last said means including an element coupled to the controlling means associated with each pair of electrodes the operation of which is dependent on variation in the current supplied thereto and means for varying the supply of current to each of said elements said means including a rectifying network comprising a plurality of arms and a rectifying element of the copper-cuprous-oxide type connected in each of said arms, said network having a pair of terminals to which alternating current is supplied through said elements and a pair of terminals from which direct current is supplied, a unitary impedance supplied from the direct current terminals of all of said elements and means for varying said impedance.

4. In combination a source of power, electric discharge means to be supplied from said source, said means comprising a plurality of pairs of electrodes between which a discharge is to be transmitted and means, independently associated with each pair of electrodes, for controlling the discharge between said pairs of electrodes, means for controlling the supply of power to said controlling means, the last said means including an element coupled to the controlling means associated with each pair of electrodes the operation of which is dependent on variation in the current supplied thereto and means for varying the supply of current to each of said elements, said means including a rectifying network comprising four arms connected in series with each other to form a closed network and a rectifying element in each of said arms, said network having a pair of terminals to which alternating current is supplied through said elements and a pair of terminals from which direct current is supplied, a unitary impedance supplied from the direct current terminals of all of said elements and means for varying said impedance.

5. In combination a source of power, electric discharge means to be supplied from said source, said means comprising a plurality of pairs of electrodes between which a discharge is to be transmitted and means, independently associated with each pair of electrodes, for controlling the discharge between said pairs of electrodes, means for controlling the supply of power to said controlling means, the last said means including an element coupled to the controlling means associated with each pair of electrodes the operation of which is dependent on variation in the current supplied thereto and means for varying the supply of current to each of said elements, said means including a rectifying network comprising four arms connected in series with each other to form a closed network and a rectifying element of the copper-cuprous-oxide type in each of said arms, said network having a pair of terminals to which alternating current is supplied through said elements and a pair of terminals from which direct current is supplied, a unitary impedance supplied from the direct current terminals of all of said elements and means for varying said impedance.

6. In combination a source of power, electric discharge means to be supplied from said source, said means comprising a plurality of pairs of electrodes between which a discharge is to be transmitted and means, independently associated with each pair of electrodes, for controlling the discharge between said pairs of electrodes, means for controlling the supply of power to said controlling means, the last said means including an element coupled to the controlling means associated with each pair of electrodes the operation of which is dependent on variation in the current supplied thereto and means for varying the supply of current to each of said elements, said means including a rectifying network having a pair of terminals to which alternating current is supplied through said elements and a pair of terminals from which direct current is supplied, an electric discharge device having a control electrode and a plurality of principal electrodes, means for connecting said principal electrodes to the direct-current terminals of said networks, means for impressing a potential between said control electrode and one of said principal electrodes and means for varying said potential.

7. Apparatus according to claim 6 characterized by that the direct current terminals of the network are connected in series with each other and with the principal electrodes of the discharge device.

8. In combination a closed network having four arms, an alternating current source, translating means to be supplied with variable current connected in series with said source, means for connecting the circuit comprising said source and said translating means in series with one set of opposite terminals of said network, an

impedance of the type having the property of asymmetric conductivity, means for connecting said impedance in series with another set of opposite terminals in said network, rectifying means in each arm of said network, said rectifying means being so connected in said arms that alternating current is transmitted through said translating means and direct current is transmitted through said impedance and means for setting the magnitude of said impedance at more than two different values to vary the alternating current transmitted through said translating means.

9. In combination a polyphase source of power, electric discharge means comprising a plurality of pairs of electrodes between which a discharge is to be transmitted and means, independently associated with each pair of electrodes, for controlling the discharge between said pairs of electrodes, means for connecting a pair of said electrodes to each phase of said source, means for controlling the supply of power to said controlling means, the last said means including an element coupled to the controlling means associated with each pair of electrodes the operation of which is dependent on variation in the current supplied thereto and means for varying the supply of current to each of said elements, said means comprising a rectifying network having a pair of terminals to which alternating current is supplied through said elements and a pair of terminals from which direct current is supplied, a unitary impedance supplied from the direct current terminals of all of said elements and means for varying said impedance.

10. In combination a plurality of closed networks, each of said networks having four arms, a plurality of alternating current sources, translating means the current through which is to be varied connected in series with each of said sources, means for connecting each circuit comprising one of said sources and said translating means in series with one set of opposite terminals of each of said networks, a unitary impedance, means for connecting said impedance and the other opposite terminals of said networks in series with each other, rectifying means so connected in the arms of said network that alternating current is transmitted through said translating means and direct current is transmitted through said impedance and means for varying the impedance to vary the alternating current transmitted through said translating means.

11. In combination an alternating current source, an alternating current load, a full wave rectifying network having a pair of direct-current terminals and a pair of alternating current terminals, means for connecting said source to said alternating current terminals through said load, an electric discharge device having a control electrode and a plurality of principal electrodes, means for connecting said principal electrodes to said direct current terminals and means for supplying a variable potential between said control electrode and one of said principal electrodes, to vary the current between said principal electrodes and thereby to vary the power supplied to said load.

12. In combination a closed network having four arms, an alternating current source, translating means to be supplied with variable current connected in series with said source, means for connecting the circuit comprising said source and said translating means in series with one set of opposite terminals of said network, an impedance, means for connecting said impedance in series with another set of opposite terminals of said network, rectifying means in each arm of said network, said rectifying means being so connected in said arms that alternating current is transmitted through said translating means and direct current is transmitted through said impedance and means for varying said impedance to vary the alternating current transmitted through said translating means; said impedance comprising a discharge device having an anode, a cathode and a control electrode, said anode and cathode being connected to the opposite terminals of said network and means for varying the potential impressed between the control electrode and the other electrodes.

FINN H. GULLIKSEN.