Nov. 7, 1933. S. WIDMER ET AL 1,934,219

FREQUENCY CHANGING SYSTEM

Filed Sept. 20, 1932 2 Sheets-Sheet 1

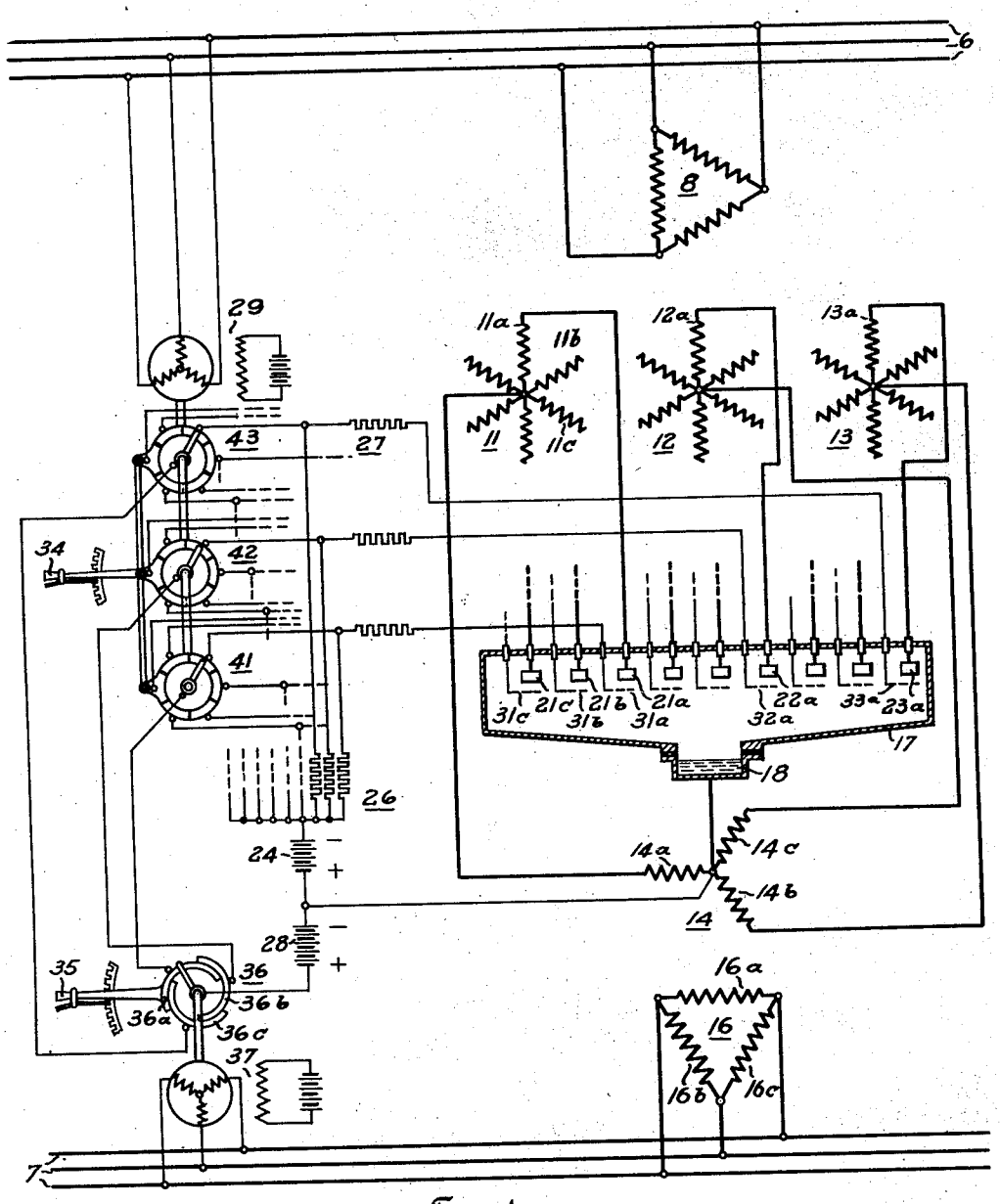


Fig. 1

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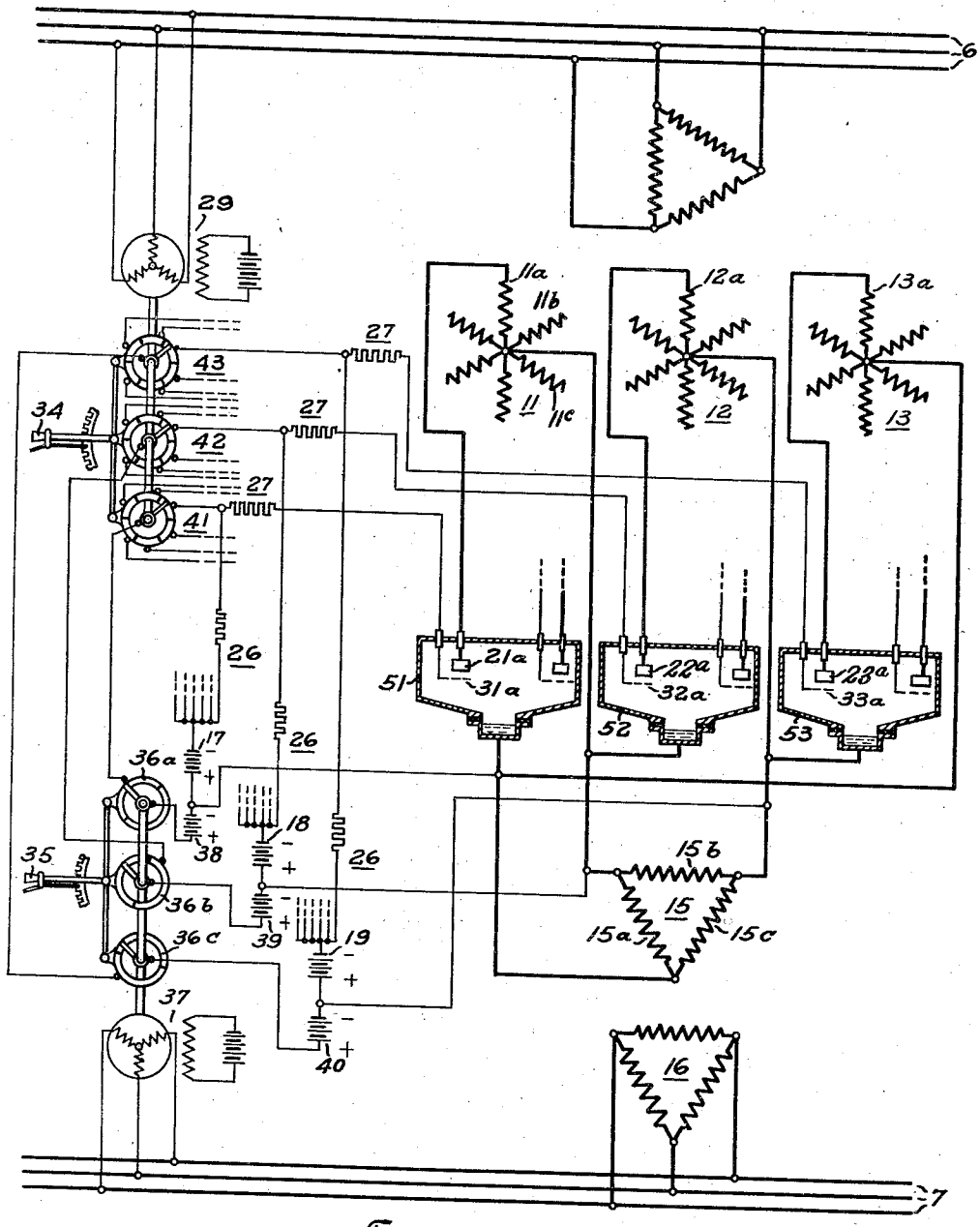


Fig. 2

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Patented Nov. 7, 1933 1,934,219

UNITED STATES PATENT OFFICE

1,934,219

FREQUENCY CHANGING SYSTEM

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Application September 20, 1932, Serial No. 634,055, and in Germany September 25, 1931

12 Claims. (Cl. 172—281)

This invention relates to improvements in alternating current frequency converting systems utilizing electron discharge devices, and more particularly to systems in which a variable amount of in-phase current or of reactive current is to be exchanged in either direction between lines which are not always rigidly maintained in an invariable frequency relation; and is similar in some of its aspects to the system disclosed in the application filed by Charles Ehrensperger, September 20, 1932, bearing Serial No. 634,056.

It is well known to connect two alternating current lines or two portions of a single alternating current line by a frequency converter comprising an input transformer, an electron discharge device and an output transformer, in which current supplied from one line to the input transformer is rectified and reconverted into alternating current by the electron discharge device, and is supplied to the second line through the output transformer. A system of the above character generally permits connection only of lines rigidly maintained in an invariable frequency relation, and does not permit a regulation of the flow of current in either direction. By energizing the control electrodes of the electron discharge device in dependence upon the frequencies of both the input and the output circuits, the system may be made operable for energy transfer in either direction between two lines even when the frequency relation between such lines is variable. The controlling means may further be provided with means for adjustment which permit separate regulation of the direction and of the intensity of the flow of in-phase current and of reactive current between the lines.

It is, therefore, one of the objects of the present invention to provide a frequency converting system utilizing an electron discharge device operable to permit flow of energy in either direction between two alternating current lines which are not rigidly maintained in an invariable frequency relation.

Another object of the present invention is to provide a frequency converting system utilizing an electron discharge device in which the direction of the flow of energy between two alternating current lines which are not rigidly maintained in an invariable frequency relation, may be determined by automatically or manually operated control means.

Another object of the present invention is to provide a frequency converting system utilizing an electron discharge device in which the intensity of flow of in-phase current between two alternating current lines which are not rigidly maintained in an invariable frequency relation, may be determined by automatically or manually operated control means.

Another object of the present invention is to provide a frequency converting system utilizing an electron discharge device in which the intensity of flow of reactive current between two alternating current lines which are not rigidly maintained in an invariable frequency relation, may be determined by automatically or manually operated control means.

Another object of the present invention is to provide a frequency converting system utilizing an electron discharge device in which the voltage induced in the primary windings of the output transformer may be adjusted in phase and in magnitude with respect to the voltage of the output line by automatically or manually operated control means.

Objects and advantages other than those above described will be apparent from the following description when read in connection with the accompanying drawings in which:

Fig. 1 diagrammatically illustrates one embodiment of the present invention for converting polyphase alternating currents at one frequency into polyphase alternating currents at the same or at another frequency, and in which the flow of in-phase current and of reactive current may be separately regulated in direction and in magnitude;

Fig. 2 diagrammatically illustrates a modified embodiment of the present invention differing from that illustrated in Fig. 1 in the use of a plurality of electron discharge devices equal in number to the number of phases of the output circuit.

Referring more particularly to the drawings by characters of reference, the reference numeral 6 designates a polyphase alternating current line which is shown as a 3-phase line because such type of line is most frequently met in practice. Line 6 may be energized at any commercial frequency, but such frequency need not be maintained at a constant value and may present regular or irregular variations. It is assumed that it is desired to transmit energy between line 6 and another polyphase alternating current line 7, also represented as a 3-phase line. Line 7 may be energized at any frequency and such frequency may be without relation with the frequency of the voltages in line 6.

The frequencies of lines 6 and 7 may be substantially equal, as would be the case when such lines are part of electrical systems operated at the same normal frequency. Lines 6 and 7 may also be parts of a single electrical system, in which case their frequencies are identical, but their voltages may or may not be equal in magnitude and/or in phase coincidence. When lines 6 and 7 are portions of the same system, the system described in the present invention is no longer properly speaking a frequency converting system, but becomes a system for producing transfer of energy between different lines of an electrical system independently of the voltage relations in such lines. The frequency converting system will be described assuming that it is desired to obtain a flow of energy from line 6 towards line 7, and the system elements will be designated accordingly. Line 6 supplies current to primary winding 8 of an input transformer having three secondary windings 11, 12 and 13 and line 7 is connected with the secondary winding 16 of an output transformer having a star connected primary winding 14. Windings 11, 12 and 13 comprise star connected portions such as 11*a*, 12*a*, 13*a* severally connected with anodes such as 21*a*, 22*a*, 23*a* of an electron discharge device 17 operable as an electric current rectifier and provided with a cathode 18 which is connected with the neutral point of winding 14. The portions 14*a*, 14*b* and 14*c* of transformer winding 14 are severally connected with the neutral points of windings 11, 12 and 13. Rectifier 17 is provided with control electrodes such as 31*a*, 32*a*, 33*a* which are energized at a negative potential with respect to cathode 18 from a battery 24 through banks of resistances 26 and 27. The control electrodes may also be energized at a positive potential with respect to cathode 18 from a second battery 28 through the segments of a distributor 36 and of three distributors 41, 42 and 43. Distributors 41, 42 and 43 are provided with brushes mounted on the shaft of a synchronous motor 29 energized from line 6 and have their segments spatially adjustable by means of a lever 34. Distributor 41 is provided with six segments connected with control electrodes 31*a*, 31*b*, 31*c*, etc. and has its brush connected with segment 36*a* of distributor 36. Distributors 42 and 43 are similarly connected with the remaining control electrodes of rectifier 17 and have their brushes connected respectively with segments 36*b* and 36*c* of distributor 36. Distributor 36 is provided with a brush energized from battery 28 and rotated by a synchronous motor 37 energized from line 7. The segments of distributor 36 extend so as to be in contact with the associated brushes thereof during one-half of each revolution of the brush and are spatially adjustable by means of a lever 35.

In operation, assuming that lines 6 and 7 are energized at their respective operating frequencies, winding 16*a* of the output transformer will be periodically energized at a positive potential from line 7. During each period of positive energization of winding 16*a*, winding 14*a* must also be energized at a postive potential to permit transfer of energy from line 6 to line 7. During such period, the brush of distributor 36 is in contact with segment 36*a* thereof thereby energizing the brush of distributor 41 at a positive potential from battery 28. The brushes of distributors 42 and 43 are disconnected from battery 28 and are thus inoperative, so that the control electrodes associated therewith are energized at a negative potential from battery 24 and prevent flow of current through transformer windings 12 and 13. The brush of distributor 41, being rotated by synchronous motor 29, permits sequential energization of control electrodes 31*a*, 31*b*, 31*c*, etc. from battery 28 through segment 36*a*. Such control electrodes are positively energized in the sequence in which the associated anodes 21*a*, 21*b*, 21*c*, etc. are energized at positive potentials from transformer winding portions 11*a*, 11*b*, 11*c*, etc. Winding portions 11*a*, 11*b*, 11*c*, etc. therefore sequentially carry current during one-sixth of cycle of the voltage of line 6 as is well known in the electric current rectifier art, such currents flowing to the cathode 18 of rectifier 17 and combining to form a single current wave flowing through winding portion 14*a* back to the neutral point of winding 11. Such current will flow during the entire period when winding 16*a* is energized at positive potential and during which time the brush of distributor 36 will remain in contact with segment 36*a*.

During the following third of a cycle of the voltage of line 7, winding 16*b* will be energized at a positive potential. Winding portion 14*b* then receives current from winding 12 by a process similar to that described above for winding portion 14*a*, the flow of such current being controlled by distributor 42. During the period when winding portion 14*b* is energized, the brush of distributor 36 is in contact with segment 36*b* so as to permit connection of battery 28 to the brush of distributor 42. It will be understood that, during a period of one-sixth of a cycle of the voltage in line 7, the brush of distributor 36 will be in contact with two segments 36*a* and 36*b* to permit simultaneous operation of windings 11 and 12, thereby causing simultaneous flow of current in windings 14*a* and 14*b*. Such simultaneous operation corresponds to the common period of flow of currents in successive phases of 3-phase line 7.

By a process similar to that described above, current flows in winding 13 during the remaining third of each cycle of the voltage in line 7 to permit flow of current through windings 14*c* and 16*c*. The above cycle of successive energization of the portions of winding 16 is repeated during each cycle of the voltage in line 7 to permit continuous flow of current from line 6 to line 7. It will be understood that current supplied to winding 8 from line 6 is rectified for one period of time in winding 11, during another period in winding 12, and during a further period in winding 13, the cycle of rectification being repeated during each cycle of the voltage in line 7. Windings 11, 12 and 13 thus intermittently transmit direct current to windings 14*a*, 14*b* and 14*c*, thereby inducing 3-phase alternating currents in windings 16*a*, 16*b* and 16*c*.

As is well known, when two alternating current generators or converters are supplying current to the common output line, both generators may be considered as supplying current to the current consuming devices (not shown) connected with the output circuit and as also producing the flow of circulating currents within their own windings and in the line. When the voltages of the generators are different, a reactive current of a magnitude determined by the difference in the generator voltages and by the reactances of the generator windings will circulate through the windings. When the voltages of the two generators are out of phase, a

circulating current will again be present, such current then being in phase with the line voltage and of a magnitude determined by the phase differences of the generator voltages and by the generator winding reactances. Similarly, in frequency converting systems such as described above, the flow of reactive current between the two lines will be determined by the differences in the induced voltages in the primary windings of the output transformer thereof and in the line voltage. The magnitude of such induced voltage may be controlled by adjustment of the segments of distributors 41, 42 and 43, by means of lever 34. As is well known, adjustment of such distributors will cause a change in the output voltage of rectifier 17, which output voltage is applied sequentially to winding portions 14*a*, 14*b*, and 14*c*, and is substantially equal to the induced voltage in such windings. Similarly, adjustment of distributor 36 by means of lever 35 will vary the time of the alternating current cycle of line 7 at which the output voltage of rectifier 17 is applied to winding portions 14*a*, 14*b* and 14*c* thereby adjusting the phase angle of the induced voltage in such windings with respect to the voltages in line 7. Such adjustment permits regulation of the flow of in-phase current between the two lines.

When it is desired to reverse the transfer of current between the two lines, it being impossible to reverse the current through rectifier 17, it therefore becomes necessary to produce the transfer of current when the voltages in lines 6 and 7 are negative instead of positive, such reversal of the voltages then determining the reversal of direction of the flow of energy. Such reversal is obtained by shifting the segments of distributors 41, 42 and 43 by 180 degrees thereby shifting the energization of the control electrodes associated therewith by 180 electrical degrees relative to the voltage in line 6. The segments of distributor 36 are simultaneously displaced by 180 degrees, thereby shifting the energization of the brushes of distributors 41, 42 and 43 by 180 electrical degrees relative to the voltage of line 7. The process of current transfer from line 7 to line 6 then becomes similar to the process described above for the transfer of current from line 6 to line 7. Such current transfer occurs through a winding portion such as 14*a* when such winding is energized at a negative potential and through winding portions such as 11*a*, 11*b* and 11*c*, when such portions are also at a negative potential less than the negative potential of winding 14*a*, so that the anodes such as 21*a*, 21*b* and 21*c* of rectifier 17 are again at a positive potential with respect to cathode 18 to permit flow of current therethrough.

In the embodiment illustrated in Fig. 2 rectifier 17 is replaced by three separate rectifiers 51, 52 and 53. The anodes and control electrodes of rectifiers 51, 52 and 53 are similar to the anodes and control electrodes of rectifier 17 in Fig. 1, and are distributed in such a manner that the anodes and electrodes associated with the portions of a single secondary winding of the input transformer are assembled in a single rectifier. The cathodes of rectifiers 51, 52 and 53 are interconnected with the neutral points of windings 11, 12 and 13 and are also connected with the several portions of the primary winding of the output transformer herein illustrated as a delta connected winding 15. As is well known, the energization of the control electrodes in a rectifier must be relative to the potential of the rectifier cathode and the different rectifier cathodes in the present embodiment are at different potentials, it is no longer possible to energize all of the control electrodes from a single pair of batteries 24 and 28. The control electrodes must therefore be connected in groups associated respectively with windings 11, 12 and 13 and respectively receiving negative potentials with respect to the associated cathodes from batteries 17, 18 and 19 and positive potentials from batteries 38, 39 and 40. Each segment of distributor 36 must therefore receive current from a separate brush connected with one of batteries 38, 39 and 40. The operation of the present embodiment is similar to that of the embodiment illustrated in Fig. 1, current impulses being sequentially transmitted from line 6 to winding portion 15*a* over winding 11 and rectifier 51, through winding portion 15*b* over winding 12 and rectifier 52 and through winding portion 15*c* over winding 13 of rectifier 53.

Although but two embodiments of the present invention have been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims.

It is claimed and desired to secure by Letters Patent:

1. In a system for transmitting energy between polyphase alternating current lines at different electrical conditions, a transformer having a primary winding connected with one of the lines and a plurality of secondary windings each having a neutral point, an electron discharge device having anodes with associated control electrodes and a cathode, the terminals of the secondary windings of said transformer being connected with the anodes, a polyphase transformer connected with another of the lines and having a winding connected with the cathode and with the neutral points of the secondary windings of the first said transformer, a source of potential arranged for connection with the control electrodes of said device, and means for controlling the connection of said source with the control electrodes to control the energy flow between the lines.

2. In a system for transmitting energy between polyphase alternating current lines at different electrical conditions, a transformer having a primary winding connected with one of the lines and a plurality of secondary windings each having a neutral point, an electron discharge device having anodes with associated control electrodes and a cathode, the terminals of the secondary windings of said transformer being severally connected with the anodes, a polyphase transformer connected with another of the lines and having a winding with a neutral point connected with the cathode, the terminals of the last mentioned winding being severally connected with the neutral points of the secondary windings of the first said transformer, a source of potential arranged for connection with the control electrodes of said device, and means for controlling the connection of said source with the control electrodes to control the energy flow between the lines.

3. In a system for transmitting energy between polyphase alternating current lines at different electrical conditions, a transformer having a

primary winding connected with one of the lines and a plurality of secondary windings each having a neutral point, an electron discharge device having anodes with associated control electrodes and a cathode, the terminals of the secondary windings of said transformer being severally connected with the anodes, a polyphase transformer connected with another of the lines and having a winding with a neutral point connected with the cathode, the terminals of the last mentioned winding being severally connected with the neutral points of the secondary windings of the first said transformer, a source of potential arranged for connection with the control electrodes of said device, an intermediate potential point of said source being connected with the cathode of said device, and means for controlling the connection of said source with the control electrodes of said device to control the energy flow between the lines.

4. In a system for transmitting energy between polyphase alternating current lines at different electrical conditions, a transformer having a primary winding connected with one of the lines and a plurality of secondary windings each having a neutral point, an electron discharge device having anodes with associated control electrodes and a cathode, the anodes being divided into groups, the anodes of each group being severally connected with the terminals of the several secondary windings of said transformer, a polyphase transformer connected with another of the lines, a source of potential arranged for connection with the control electrodes of said device, and means for controlling the connection of said source with the control electrodes of said device to control the direction of the energy flow between the lines.

5. In a system for transmitting energy between polyphase alternating current lines at different electrical conditions, a transformer having a primary winding connected with one of the lines and a plurality of secondary windings each having a neutral point, an electron discharge device having anodes with associated control electrodes and a cathode, the anodes being divided into groups, the anodes of each group being severally connected with the terminals of the several secondary windings of said transformer, a polyphase transformer connected with another of the lines, and having a winding with a neutral point connected with said cathode, the terminals of the last said winding being severally connected with the said neutral points of the secondary winding of the first said transformer, a source of potential arranged for connection with the control electrodes of said device, means associated with each group of control electrodes of said device and responsive to the electrical conditions of one of the lines to control the sequential energization of the control electrodes, and means responsive to the electrical conditions of another of the lines to control the connection of the positive terminal of said source with the first said means thereby controlling the operation of said device.

6. In a system for transmitting energy between polyphase alternating current lines at different electrical conditions, a transformer having a primary winding connected with one of the lines and a plurality of secondary windings each having a neutral point, an electron discharge device having anodes with associated control electrodes and a cathode, the anodes being divided into groups, the anodes of each group being severally connected with the terminals of the sevaral secondary windings of said transformer, a polyphase transformer connected with another of the lines, and having a winding with a neutral point connected with said cathode, the terminals of the last said winding being severally connected with the neutral points of the secondary winding of the first said transformer, a source of potential arranged for connection with the control electrodes of said device, a plurality of distributors operating in response to the electrical conditions of one of the lines, each of said distributors controlling the energization of the control electrodes associated with one group of anodes, and a distributor responsive to electrical conditions of another of the lines to control the connection of said source with the said plurality of distributors thereby controlling the intensity of the energy flow between the lines.

7. In a system for transmitting energy between polyphase alternating current lines at different electrical conditions, a transformer having a primary winding connected with one of the lines and a plurality of secondary windings each having a neutral point, an electron discharge device having anodes with associated control electrodes and a cathode, the anodes being divided into groups, the anodes of each group being severally connected with the terminals of the several secondary windings of said transformer, a polyphase transformer connected with another of the lines and having a winding with a neutral point connected with said cathode, the terminals of the last said winding being severally connected with the neutral points of the secondary winding of the first said transformer, a source of potential arranged for connection with the control electrodes of said device, a plurality of distributors each controlling the energization of the control electrodes associated with one group of anodes, a distributor controlling the connection of said source with the first said distributor, means responsive to the electrical conditions of one of the lines for operating the said plurality of distributors, and means responsive to the electrical conditions of another of the lines for operating the second said distributor.

8. In a system for transmitting energy between polyphase alternating current lines at different electrical conditions, a transformer having a primary winding connected with one of the lines and a plurality of secondary windings each having a neutral point, an electron discharge device having anodes with associated control electrodes and a cathode, the anodes being divided into groups, the anodes of each group being severally connected with the terminals of the several secondary windings of said transformer, a polyphase transformer connected with another of the lines and having a winding with a neutral point connected with said cathode, the terminals of the last said winding being severally connected with the neutral points of the secondary winding of the first said transformer, a source of potential arranged for connection with the control electrodes of said device, a plurality of distributors each controlling the energization of the control electrodes associated with one group of anodes, a distributor controlling the connection of said source with the first said distributor, means responsive to an electrical condition of one of the lines for operating the said plurality of distributors, means responsive to an electrical condition of another of the lines

for operating the second said distributor, and means for varying the operation of said distributors by variation of the relations in space thereof.

9. In a system for transmitting energy between polyphase alternating current lines of different voltage frequencies, a transformer connected with one of said lines and having a plurality of windings each divided into a plurality of phase displaced sections having connections forming a neutral point, electron discharge means having a plurality of anodes divided into a plurality of groups and a plurality of control electrodes severally associated with said anodes, the anodes of each group thereof being severally connected with the phase displaced sections of the several said windings, a second transformer connected with another of said lines and having a winding divided into a plurality of phase displaced sections severally connected with the neutral points of the first said windings, and means for affecting said control electrodes in such manner and during such recurring periods as to induce the conversion of current supplied from the said one of said lines to the first said means by way of the first said windings and said anodes into polyphase alternating current having the voltage frequency of the said another of said lines and the supply thereof thereto.

10. In a system for transmitting energy between polyphase alternating current lines of different voltage frequencies, a transformer connected with one of said lines and having a plurality of windings each divided into a plurality of phase displaced sections having connections to form a neutral point, electron discharge means having a plurality of anodes forming a plurality of groups, the anodes of each group thereof being severally connected with the phase displaced sections of the several said windings, a second transformer connected with another of said lines and having a winding divided into a plurality of phase displaced sections severally connected with the neutral points of the first said windings, control means associated with said anodes, and means for affecting said control means in such manner and during such recurring periods as to induce the conversion of current supplied from the said one of said lines to the first said means by way of the first said windings and said anodes into polyphase alternating current having the voltage frequency of the said another of said lines and the supply thereof thereto.

11. In a system of the character described, a plurality of polyphase alternating current lines of different voltage frequencies, electron discharge means comprising a plurality of anodes and a plurality of control electrodes severally associated with said anodes, a transformer connected with one of said lines and having a plurality of windings each divided into a plurality of phase displaced sections connected to form a neutral point and being severally connected with said anodes, a second transformer connected with another of said lines and having a winding divided into a plurality of phase displaced sections severally connected with the said neutral points of the first said windings, a source of current connectable with said control electrodes, and means operable responsive to and in dependence upon the voltage frequencies of the said one and another lines for controlling the sequential connection of said source of current with said control electrodes at such recurring periods as to control the operation of said electron discharge means to convert current received from the said one of said lines by way of the first said windings and the said anodes into polyphase current having the voltage frequency of the said another of said lines and the supply thereof thereto by way of the said second transformer.

12. In a system for transmitting energy between polyphase alternating current lines of different voltage frequencies, a transformer connected with one of said lines and having a plurality of windings each divided into a plurality of phase displaced sections having connections forming a neutral point, a plurality of electron discharge devices each comprising a cathode, a plurality of anodes and a plurality of control electrodes severally associated with said anodes, the anodes of each said device being severally connected with the phase displaced sections of the several said windings, a second transformer connected with another of said lines and having a winding divided into a plurality of phase displaced sections severally connected with the cathodes of said devices and with the neutral points of the several first said windings, a plurality of sources of current severally arranged for connection with the control electrodes of the several said devices, means severally associated with the control electrodes of the several said devices operable responsive to and in accordance with the voltage frequency of the said one of said lines to control the sequential connections of said sources of current with said control electrodes during such recurring periods as to induce the conversion of current supplied from the said one of said lines to said devices by way of the first said windings and said anodes into polyphase alternating current having the voltage frequency of the said another of said lines and the supply thereof thereto, and means severally associated with the first said means operable responsive to and in accordance with the voltage frequency of the said another of said lines for controlling the recurrent connections of said sources of current with the first said means whereby the voltage frequency and the intensity of the current supplied to the said another of said lines may be varied.

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