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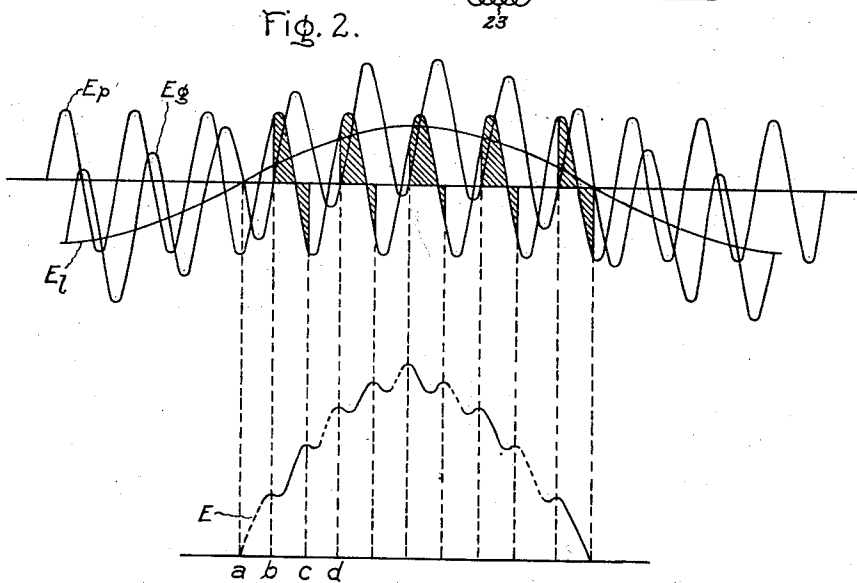
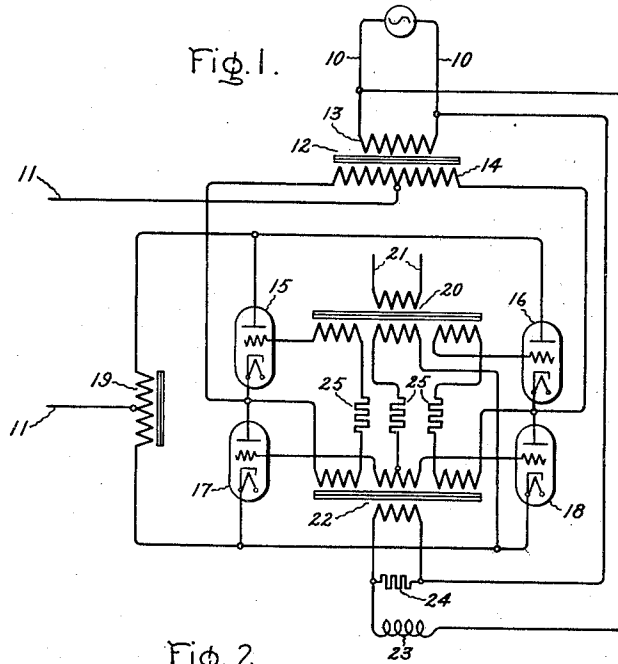
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1,930,302

ELECTRIC VALVE CONVERTING SYSTEM

Filed Jan. 12, 1932

3 Sheets-Sheet 1



Inventor:
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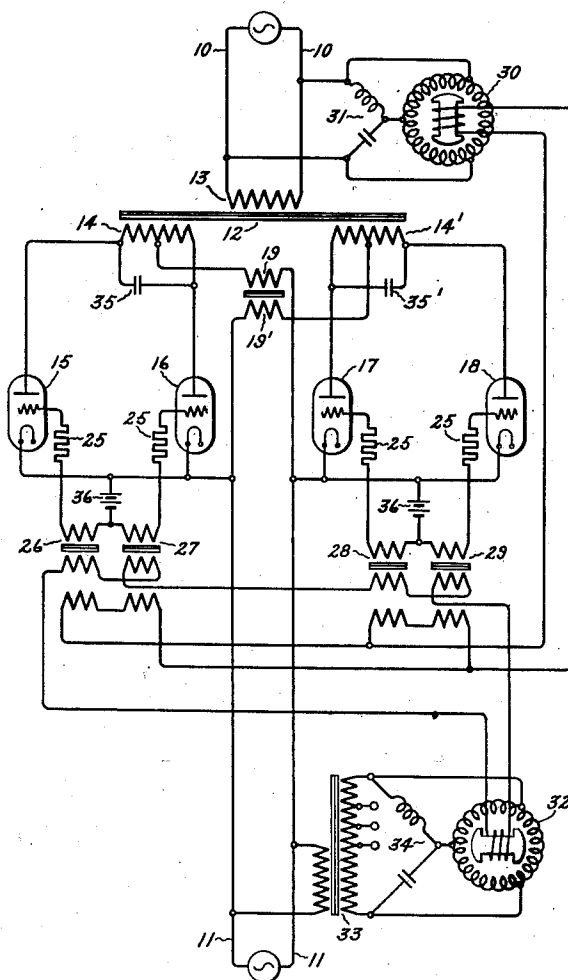
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3 Sheets-Sheet 2

Fig. 3.



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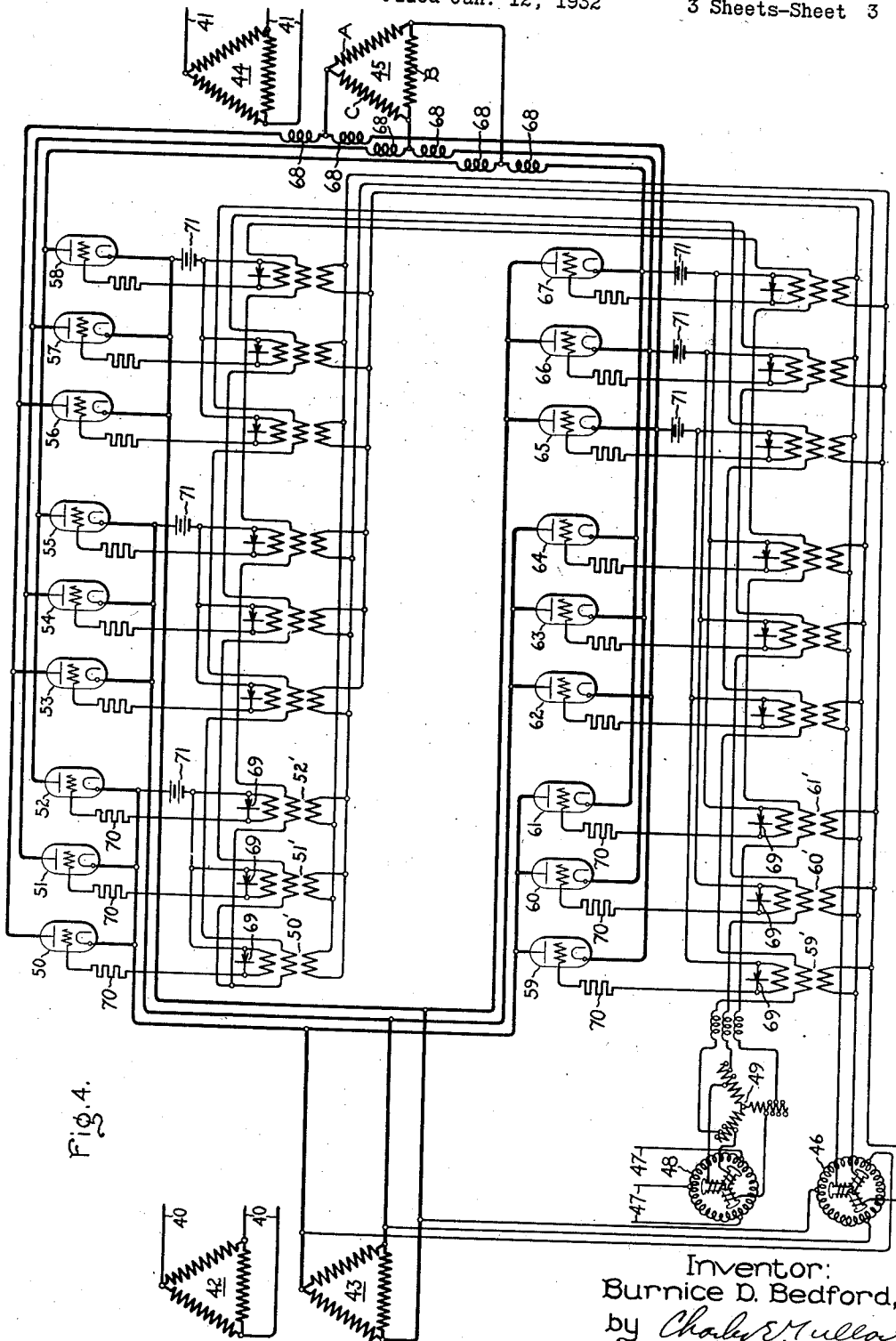
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ELECTRIC VALVE CONVERTING SYSTEM

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

1,930,302

ELECTRIC VALVE CONVERTING SYSTEM

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New York

Application January 12, 1932. Serial No. 586,106

14 Claims. (Cl. 172—281)

My invention relates to electric valve converting systems and more particularly to such systems adapted to transmit energy between alternating current circuits of different frequencies.

Heretofore there have been devised various electric valve converting apparatus for transmitting energy between alternating current circuits of different frequencies. The use of electric valves of the vapor electric discharge type in such apparatus has been found particularly advantageous because of the relatively large amounts of power which may be handled at ordinary operating voltages. In the arrangements of the prior art, however, when transmitting energy from a relatively high frequency circuit to a relatively low frequency circuit, each half wave of the low frequency alternating potential comprises a group of rectified phase potentials of the high frequency circuit with the result that the wave form of the low frequency current tends to become rectangular with a number of higher harmonics superimposed thereon. On the other hand, when transmitting energy from a relatively low frequency circuit to a relatively high frequency circuit, each half wave of the low frequency current is inverted to a group of cycles of the high frequency current and the amplitude of the high frequency current tends to vary so that its envelope corresponds to the rectified low frequency current. Obviously, either of the above arrangements has the disadvantage of poor wave form with consequent telephone interference and unsatisfactory operation of associated apparatus.

It is an object of my invention therefore, to provide an improved electric valve converting system for transmitting energy between alternating current circuits of different frequencies which will overcome the above mentioned disadvantages of the arrangements of the prior art and which will be simple, economical and reliable in operation.

It is another object of my invention to provide an improved electric valve converting system for transmitting energy between alternating current circuits of different frequencies in which the wave form of the potentials on both alternating current circuits is substantially sinusoidal.

It is a further object of my invention to provide an improved electric valve converting system for transmitting energy between alternating current circuits of different frequencies in which there is included means for controlling the power factor conditions on the low frequency circuit.

It is a still further object of my invention to provide an improved electric valve converting

system for transmitting energy from a high frequency alternating current circuit to a low frequency alternating current circuit by means of which any given signal wave may be reproduced in wave form and phase relation on the low frequency circuit.

In accordance with my invention, alternating current circuits of different frequencies are interconnected by means of one or more pairs of electric valves oppositely connected with respect to the circuit to which energy is being transmitted.

The circuits of different frequencies will be referred to hereinafter as the high frequency circuit and the low frequency circuit, respectively, but it is to be understood that the terms higher and lower are used only in a relative sense and that my invention is not limited to any particular ratios of the frequencies of the respective circuits. However, as the ratio of the frequencies departs from unity, the operation is correspondingly improved. The grids of the electric valves are excited with components of alternating potential of the frequencies of the two alternating current circuits with the result that the conductivities of the valves are successively varied so that the average potentials of the circuits are substantially equal during each of the several intervals in which one of said valves conducts current, as will be explained more fully hereinafter.

For a better understanding of my invention together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims. Fig. 1 of the accompanying drawings illustrates an arrangement embodying my invention for transmitting energy from a high frequency source to a low frequency alternating current circuit which is not connected to an independent source of electromotive force; Fig. 2 is a diagram of certain operating characteristics of the arrangement of Fig. 1 to aid in the understanding of my invention; Fig. 3 represents another embodiment of my invention for transmitting energy in either direction between two alternating current circuits of different frequencies, by means of which the power factor conditions on the low frequency circuit may be controlled; while Fig. 4 illustrates an extension of my invention to an arrangement for transmitting energy between two three phase circuits of different frequencies.

Referring now to Fig. 1, there is illustrated an arrangement for transmitting energy from a high frequency alternating current supply circuit

10 to a relatively low frequency alternating current load circuit 11. This arrangement includes a main transformer 12 provided with a primary winding 13 connected to the alternating current circuit 10 and a secondary winding 14 having an electrical midpoint connected to one side of the alternating current circuit 11, and a pair of end terminals connected to the other side of the alternating current circuit 11 through the pairs of electric valves 15 and 17, and 16 and 18 respectively, and the two portions of reactor 19. The electric valves 15—18, inclusive, are each provided with an anode, a cathode, and a control grid and may be of any of the several types well known in the art, although I prefer to use valves of the vapor electric discharge type. In order to control the conductivities of the valves 15—18, inc. and thus the energy transmitted from the high frequency circuit 10 to the low frequency circuit 11, there is provided a grid transformer 20 having a primary winding energized from an alternating current circuit 21 of the frequency wave shape, and relative magnitude which it is desired to supply to the circuit 11, and a grid transformer 22 energized from the alternating current circuit 10 through any suitable arrangement for producing a phase displacement between the potentials thereof, such for example, as a phase shifting circuit comprising a reactor 23 and a resistor 24. Each of the grids of the several electric valves 15—18, inc. is connected to its cathode through a winding of each of the transformers 20 and 22 and a current limiting resistor 25.

The general principles of operation of the above described apparatus will be well understood by those skilled in the art. In brief, during one half cycle on the low frequency circuit 11, energy will be supplied thereto through the transformer 12 and corresponding valves of the two pairs of electric valves, for example, valves 15 and 16, operating as a full wave rectifier and supplying unidirectional current for the duration of this particular half cycle. During the next succeeding half cycle of the low frequency circuit, energy will be supplied thereto through the transformer 12 and electric valves 17 and 18 operating as a full wave rectifier of reverse polarity. The reactor 19, having two portions oppositely connected in the two rectifying circuits, serves to prevent a short circuit upon the alternating current circuit 10 in case the polarity of the low frequency circuit 11 reverses at an intermediate point in the cycle of alternating potential of the circuit 10. Obviously the above described operation might be secured by alternately rendering conductive the valves 15 and 16, and 17 and 18, which could be accomplished merely by exciting their control grids with an alternating potential of the frequency which it is desired to supply the circuit 11. However, as stated above with this type of operation the alternating potential supplied to the circuit 11 is substantially rectangular in wave form with a number of higher harmonics superimposed thereon. In accordance with my invention, however, the grids of the several electric valves are energized from the alternating current circuit 21 with a component of alternating potential of the frequency which it is desired to supply to the circuit 11, and from the grid transformer 22 with an alternating potential of the frequency of the alternating current circuit 10 but retarded in phase with respect thereto by substantially 90 electrical degrees. In Fig. 2 there are represented certain operating characteristics of one of the electric valves, for example, valve 15. In

this figure the curve E_p represents the curve of anode potential of the valve 15 supplied from the alternating current circuit 10, the curve E_i represents the low frequency excitation derived from the circuit 21, while the curve E_g corresponds to the resultant grid potential, that is, the low frequency component of excitation E_i with an additional high frequency component of excitation of the frequency of E_p but retarded in phase with respect thereto substantially 90 electrical degrees. The curve E illustrates one half cycle of alternating potential supplied to the circuit 11. For example, if the valve 15 is first rendered conductive at the point b , when the resultant grid potential E_g crosses the zero axis, assuming the valve 15 has substantially a zero grid voltage characteristic, that is, that the valve will be rendered conductive whenever the grid potential is zero or slightly positive with respect to its cathode, current will flow in the valve 15 during the interval $b-c$ indicated by the first shaded area. It will be seen that this current flows during the initial portion of the interval, represented by the shaded area above the zero line, in accordance with the electromotive force of the circuit 10, but that during the second portion of the interval, represented by the shaded area below the zero line, the current is forced through the electric valve 15 against the electromotive force of the circuit 10 by the reactance of the reactor 19. The average potential tending to supply current to the circuit 11 during this interval $b-c$ is, therefore, the difference in the shaded areas above and below the line and may be represented by the solid line portion of the curve E during the interval $b-c$. Valve 15 is again rendered conducting at the point d and conducts current during the succeeding interval, the area under the curve E during this interval again corresponding to a difference in the shaded areas above and below the zero axis. It is thus seen that the point in the cycle of alternating potential of the circuit 10 at which the valve 15 is made conductive is varied in accordance with instantaneous magnitude of the low frequency excitation derived from the circuit 21. During the intermediate half cycles of alternating potential of the circuit 11, it will be obvious that the valve 16 conducts current in a similar manner and the voltage impressed upon the circuit 11 during these intervals is represented by the dotted portions of the curve E of Fig. 2. Obviously, when the shaded area below the zero axis is greater than that above the axis, the difference voltage is in an opposite direction, but, due to the unilateral conductivity characteristics of the valves, this reverse current cannot flow. During these intervals, however, the potential will be in such a direction as to send current through the valves 17 and 18 in the manner described above, and a half cycle of low frequency alternating potential will be supplied of opposite polarity to that illustrated in Fig. 2. In other words, the average conductivity of two oppositely connected rectifiers is controlled in accordance with the instantaneous magnitude of a low frequency excitation, with the result that an alternating potential of substantially the same wave form as the source of low frequency excitation is supplied to the alternating current circuit 11. While I have illustrated the source of low frequency excitation of sinusoidal wave form, which is most suitable for power purposes, it will be apparent that my invention is not limited thereto, but that the low frequency excitation may have any desired wave form and

that this wave form will be reproduced by means of the above described apparatus.

In Fig. 3 there is illustrated a modification of my invention for transmitting energy in either direction between a high frequency alternating current circuit 10 and a low frequency alternating current circuit 11 connected to an independent source of electromotive force for determining its frequency and wave form. In this arrangement, the opposed rectifiers are energized from electrically insulated windings 14 and 14' of the transformer 12, by means of which the number of cathode potentials of the electric valves is reduced from three to two. With this arrangement, the single reactor 19 must be replaced by the reactive windings 19 and 19' inductively coupled but electrically insulated from each other. The grid excitation circuit of this arrangement is modified by providing a separate grid transformer, or a grid transformer with separate magnetic core members for each of the several electric valves. For example, electric valves 15-18, inc. may be energized from the secondary windings of grid transformers 26-29 inc., which are provided with self-saturating magnetic core members. Each of the grid transformers is provided with a primary winding energized from the high frequency alternating current circuit 10 through any suitable phase shifting arrangement such for example as a rotary phase shifting transformer 30, connected to the circuit 10 through a phase splitting arrangement 31, and a second primary winding energized from the low frequency circuit through a rotary phase shifting transformer 32, connected to the low frequency circuit 11 through a voltage regulating transformer 33 and phase splitting circuit 34. In case it is desired to transmit energy from the low frequency circuit 11 to the high frequency circuit 10, and the circuit 10 is not provided with an independent source of electromotive force, commutating capacitors 35 and 35' should be connected across transformer windings 14 and 14' respectively.

The operation of the above described apparatus for transmitting energy from the high frequency circuit 10 to the low frequency circuit 11 is substantially identical to that described above in connection with Fig. 1. In this arrangement, however, the grid excitation of the several electric valves comprises an alternating potential of peaked wave form, the peak of which varies in phase in order to control the conductivities of the valves. The manner in which the alternating potential of peaked wave form variable in phase is obtained, may be more readily understood by again referring to Fig. 2 of the drawings, in this case considering the curve E_p as the anode potential of one of the electric valves as before, and the resultant curve E_g as the resultant magnetomotive force of the associated grid transformer. It is well understood by those skilled in the art that the secondary voltage of a self-saturating transformer which is operating considerably beyond saturation, comprises a sharp peak at each zero point in the cycle of magnetomotive force. In other words, each time the curve E_g crosses the zero axis there is induced in the secondary winding of the corresponding grid transformer, a short impulse of grid potential sufficient to turn on the electric valve. The negative bias batteries 36 serve to maintain the valves non-conductive during the remaining portions of each cycle. However, the feature of supplying the several vapor electric discharge valves with alternating potentials of peaked wave form comprises no part of

my invention but is disclosed and broadly claimed in my copending application, Serial No. 485,335, filed September 29, 1930, and assigned to the same assignee as the present application, while the feature of providing an alternating potential of peaked wave form variable in phase by combining a plurality of magnetomotive forces in a self-saturating transformer, forms the subject matter of my copending application, Serial No. 564,623, filed September 23, 1931, also assigned to the same assignee as the present application.

In the above described arrangement, it is seen that no problem of commutation arises since the current in a given electric valve automatically stops at the end of the particular half cycle of high frequency current in which the low frequency current reverses polarity, the reactor 19 serving to prevent any short circuit during these fractions of a half cycle of high frequency current. However, when transmitting energy in the other direction from the low frequency circuit 11 to the high frequency circuit 10, some means for commutating the current between the valves 15 and 16 or 17 and 18 must be provided.

Referring again to Fig. 2, it is seen that, in case the amplitude of the low frequency excitation E_i should be decreased, the average value of the curve E would be correspondingly decreased; that is, the energy transmitted between the circuits would be decreased. This may be accomplished by means of the tap changing transformer 33 interposed between the circuit 11 and the low frequency grid excitation, as shown in Fig. 3. It will be apparent also, that the power factor conditions on the low frequency circuit 11 and the energy exchanged between the circuits may be varied by varying the phase and magnitude of the low frequency excitation, as for example by operating the rotary phase shifting transformer 32 and the tap changing transformer 33.

In Fig. 4 there is illustrated an extension of the arrangement shown in Fig. 3 for transmitting energy from a three phase high frequency circuit 40 to a three phase low frequency circuit 41. This arrangement includes a three phase transformer comprising a three phase primary network 42 connected to the circuit 40 and a three phase secondary network 43 interconnected with the primary network 45 of a three phase transformer, the secondary winding 44 of which is connected to the load circuit 41. Each terminal of the network 43 is connected to each of the several terminals of the network 45 through one of the valves of the group 50-58, inc., and one of the valves of the group 59-67, inc., the valves of each group being similarly connected; that is, as "positive" or "negative" valves. The several electric valves 50-67, inc. are provided with separate self-saturating grid transformers 50', 51', 52', etc., each of which is energized with a component of high frequency excitation from the transformer network 43 through a rotary phase shifting transformer 46, and with a component of low frequency excitation derived from a control circuit 47, of the frequency which it is desired to supply to the circuit 41, through a rotary phase shifting transformer 48 and a regulating autotransformer 49. Unilaterally conductive devices, such for example as contact rectifiers 69 are preferably connected across the secondary windings of the several grid transformers, in order to short circuit the negative impulses produced by the saturable transformers, which might be reflected in some of the other grid circuits, due to their mutual coupling. Each of the grid circuits also includes a current limiting

resistor 70 and a negative bias battery 71. The reactors 68 are included in the connections from each terminal of the network 45 to the groups of positive and negative valves in order to eliminate momentary short circuits on the high frequency circuit.

The operation of the above described circuit is similar in all respects to that of the circuit shown in Fig. 3 with the exception that the successive phase windings A, B, and C of the network 45 are successively energized by means of the network 43 and the group of valves 50—67 operating as a plurality of rectifiers. For example, assume that the phase of the alternating potential supplied by the circuit 47 is such that a positive half wave of low frequency excitation is supplied to the grid transformers associated with electric valves 50, 53 and 56, and 61, 64 and 67. The network 43, together with these six valves, comprises a full wave rectifier with the phase winding A of the network 45 connected in its direct current circuit. A half cycle of potential of substantially sine wave form will be supplied to the phase winding A during this interval, as explained above. During the next interval of time the positive valves 50, 53 and 56 will become non-conducting and the valves 51, 54 and 57 will be excited similarly to supply a portion of a sinusoidal wave of potential to the phase winding B. In this manner the phase windings A, B and C are successively energized and a three phase alternating potential of substantially sine wave form is supplied to the alternating current circuit 41.

While I have described what I at present consider preferred embodiments of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention, and I therefore aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In an electric valve converting system, the combination of two alternating current circuits having frequencies of different orders of magnitude, a pair of oppositely connected electric valves interconnecting said circuits, each of said valves being provided with a control electrode excited to render the valve conductive during intermittent intervals, and means for successively varying the excitation of the control electrodes of said valves so that the average potentials of said circuits are substantially equal during each of the several intervals in which one of said valves conducts current.

2. In an electric valve converting system, the combination of an alternating current circuit, a second alternating current circuit of a frequency substantially lower than that of said first circuit, a pair of electric valves interconnecting said circuits for transmitting energy therebetween, said valves being oppositely connected with respect to the circuit to which energy is being transmitted, and means for successively varying the conductivities of said valves in response to the instantaneous magnitude of the potential of the low frequency circuit.

3. In an electric valve converting system, the combination of an alternating current circuit, a second alternating current circuit of a frequency substantially lower than that of said first circuit, a pair of oppositely connected electric valves interconnecting said circuits, and means for varying the conductivity of each of said valves

in response to the instantaneous magnitude of half cycles of a given polarity of the potential of said low frequency circuit.

4. In an electric valve converting system, the combination of an alternating current circuit, a second alternating current circuit of a frequency substantially lower than that of said first circuit, a pair of oppositely connected grid controlled electric valves interconnecting said circuits, and a grid circuit for said valves including two sources of alternating potential each of the frequency of one of said alternating current circuits.

5. In an electric valve converting system, the combination of an alternating current circuit, a second alternating current circuit of a frequency substantially lower than that of said first circuit, a pair of oppositely connected grid controlled electric valves interconnecting said circuits, and a grid circuit for said valves including a source of alternating potential of the frequency of said first circuit and displaced in phase with respect to the potential thereof and a source of alternating potential of the frequency of said second alternating current circuit.

6. In an electric valve converting system, the combination of an alternating current circuit, a second alternating current circuit of a frequency substantially lower than that of said first circuit, a pair of oppositely connected grid controlled electric valves interconnecting said circuits, and a grid circuit for said valves including a source of sinusoidal alternating potential of the frequency of said first circuit and substantially in quadrature with respect to the potential thereof, and a source of sinusoidal alternating potential of the frequency of said second alternating current circuit.

7. In an electric valve converting system, the combination of an alternating current circuit, a second alternating current circuit of a frequency substantially lower than that of said first circuit, a pair of oppositely connected grid controlled electric valves interconnecting said circuits, a pair of mutually coupled inductive windings included in the connections of said valves to said low frequency circuit, and means for successively varying the conductivities of said valves so that the average potentials of said circuits are substantially equal during each interval in which one of said valves conducts current.

8. In an electric valve converting system, the combination of an alternating current circuit, a second alternating current circuit of a frequency substantially lower than that of said first circuit, two pairs of electric valves interconnecting said circuits, the valves of each pair being oppositely disposed with respect to one of said circuits and corresponding valves of said pairs being oppositely disposed with respect to the other of said circuits, a pair of mutually coupled inductive windings, each being included in the connection from said low frequency circuit to two of said valves similarly disposed with respect to said low frequency circuit, and means for successively varying the conductivities of said valves so that the average potentials of said circuits are substantially equal during each interval in which one of said valves conducts current.

9. In an electric valve converting system, the combination of an alternating current circuit, a second alternating current circuit of a frequency substantially lower than that of said first circuit and provided with an independent source of elec-

tromotive force connected thereto, a pair of oppositely connected grid controlled electric valves interconnecting said circuits, a grid circuit for said valves including two sources of alternating potential, each of the frequency of one of said alternating current circuits, and means for varying the phase and voltage of said low frequency grid potential with respect to that of said low frequency circuit to vary the power factor conditions thereof.

10 10. An alternating current frequency changing system comprising an alternating current supply circuit, an alternating current load circuit of a frequency substantially lower than that of said supply circuit, a pair of oppositely connected electric valves interconnecting said circuits, and means for successively varying the conductivities of said valves during successive half cycles of said load circuit so that the average potential impressed upon the load circuit by said supply circuit during each interval in which one of said valves is conductive is substantially equal to the average potential of the load circuit during the corresponding interval.

25 11. An alternating current frequency changing system comprising an alternating current supply circuit, an alternating current load circuit of a frequency substantially higher than that of said supply circuit, a pair of electric valves oppositely disposed with respect to said higher frequency circuit, a source of commutating potential interposed between said valves and said higher frequency circuit, and means for successively varying the conductivities of said valves so that the average potential impressed upon the load circuit by said supply circuit during each interval in which one of said valves is conductive is substantially equal to the average potential of the load circuit during the corresponding interval.

40 12. An alternating current frequency changing system comprising an alternating current supply circuit, an alternating current load circuit of a frequency substantially higher than that of said

supply circuit, two pairs of electric valves interconnecting said circuits, the valves of each pair being oppositely disposed with respect to one of said circuits and corresponding valves of said pairs being oppositely disposed with respect to the other of said circuits, a capacitor connected between the valves oppositely disposed with respect to said load circuit for commutating the current therebetween, and means for successively varying the conductivities of said valves so that the average potential impressed upon the load circuit by said supply circuit during each interval in which one of said valves is conductive is substantially equal to the average potential of the load circuit during the corresponding interval.

13. In an electric valve converting system, the combination of an alternating current circuit, a second alternating current circuit of a frequency substantially lower than that of said first circuit, a pair of oppositely connected grid controlled electric valves interconnecting said circuits, a self-saturating grid transformer winding for exciting each of said valves, and means for energizing each of said transformer windings with alternating potentials of the frequencies of said circuits.

14. In an electric valve converting system, the combination of an alternating current circuit, a second alternating current circuit of a frequency substantially lower than that of said first circuit, a pair of electric valves oppositely connected with respect to one of said circuits and interconnecting said circuits, a self-saturating transformer winding for exciting each of said electric valves and means for energizing each of said transformer windings including a source of alternating current of the frequency of said first circuit and substantially in quadrature with respect to the potential thereof and a source of alternating current of the frequency of said second circuit and variable in phase with respect to the potential thereof.

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