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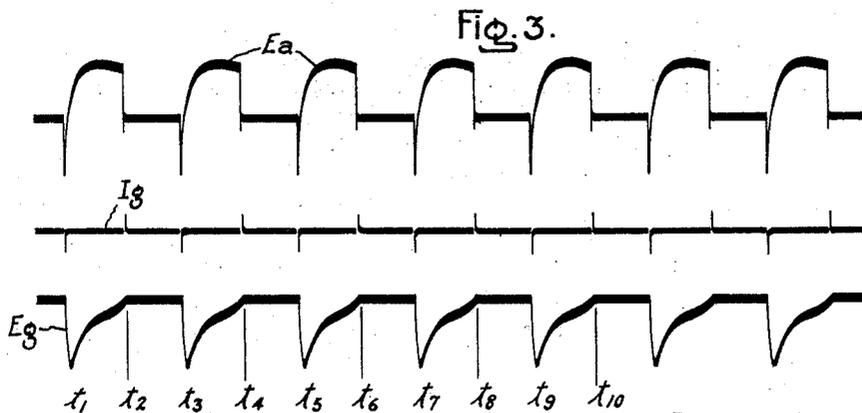
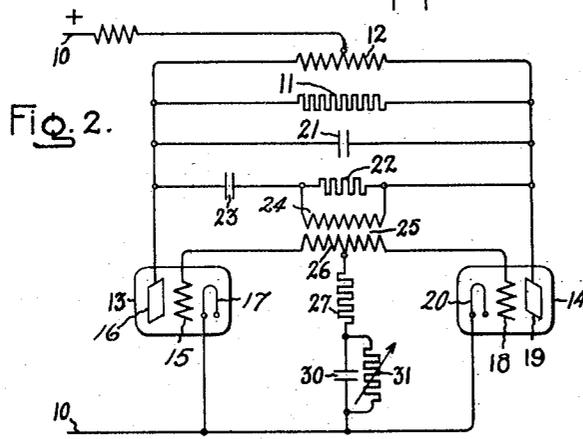
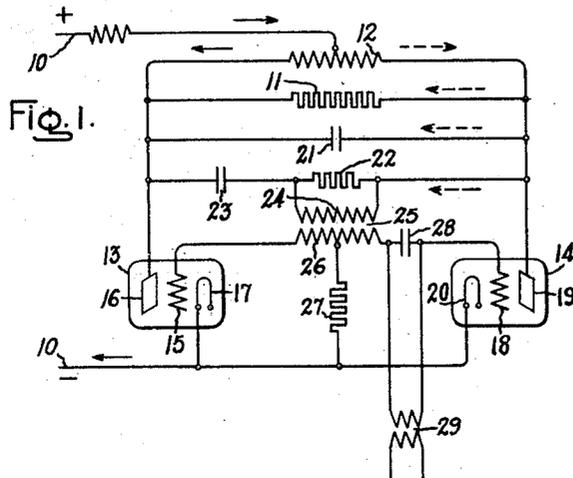
B. D. BEDFORD

1,834,889

POWER TRANSMITTING APPARATUS

Filed April 25, 1930

2 Sheets-Sheet 1



Inventor:  
Burnice D. Bedford,  
by *Charles V. Tuller*  
His Attorney.

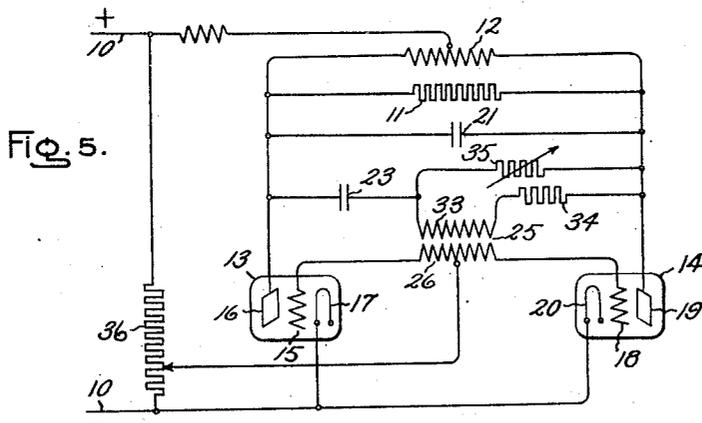
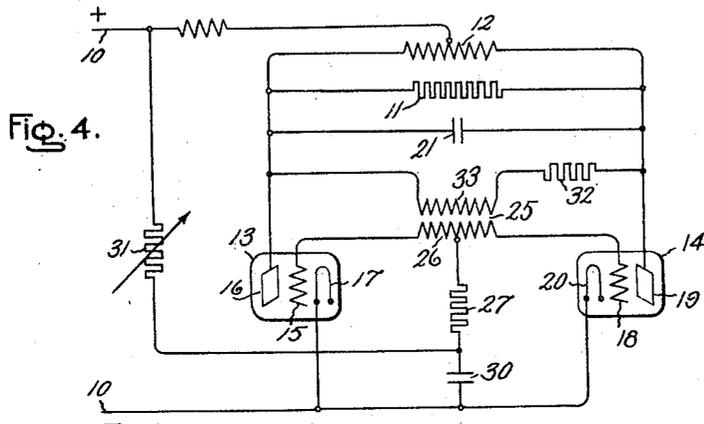
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## UNITED STATES PATENT OFFICE

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## POWER TRANSMITTING APPARATUS

Application filed April 25, 1930. Serial No. 447,406.

My invention relates to the transmission of electric power between direct and alternating current circuits or between alternating current circuits operated at different frequencies, and has for its principal object the provision of an improved arrangement and method of operation whereby electric power is transmitted between such circuits more effectively and over a greater range of frequencies than has heretofore been possible.

Different types of apparatus have been provided in the past for transmitting electric power between direct and alternating current circuits. Some of these apparatus include a transformer and a plurality of electric discharge paths or elements located either in the same device or in different devices.

For satisfactory operation of such apparatus, it is essential that means be provided for commutating the load current, i. e., shifting it from one discharge path to another. The various means heretofore provided for this purpose have not been altogether satisfactory for the reason that deionization of the discharge path is in some cases not rapid enough to permit satisfactory operation of the apparatus especially at high frequencies.

Where the electric discharge path is through a vapor electric device provided with a grid or control electrode, rapid deionization of the discharge path may be produced by subjecting the grid to a bias potential of large negative value. The use of batteries for producing this negative grid bias potential is objectionable due to the expense and inconvenience of maintaining them in suitable operating condition. In accordance with my invention, these difficulties are avoided by the provision of an improved arrangement and method of operation whereby the desired negative bias potential is produced in response to the change in the path of the current transmitted through the apparatus.

My invention will be better understood from the following description when considered in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

Referring to the drawings, Fig. 1 illustrates an apparatus which embodies my in-

vention and is arranged to have its frequency determined by an external source of alternating current; Fig. 2 illustrates a similar apparatus including means for controlling its operating frequency; Fig. 3 is a group of curves relating to the operation of the apparatus illustrated by the previous figure; and Figs. 4 and 5 illustrate modifications of the apparatus shown in Figs. 1 and 2.

The apparatus of Fig. 1 includes a direct current circuit 10 and an alternating current circuit 11 which are interconnected through means including a winding 12 and a pair of electric discharge devices 13 and 14 each provided with a grid or control electrode for controlling the starting of current between its cathode and anode. Thus the device 13 is provided with a grid 15 arranged to control the current transmitted between its anode 16 and cathode 17 and the device 14 is likewise provided with a grid 18 arranged to control the current transmitted between its anode 19 and cathode 20. The devices 13 and 14 are preferably of the vapor electric type and may be so designed that current between the anode and cathode starts when the grid is subjected to zero potential, to a slight positive potential or to a potential of small negative value. It is well known that the grid of such devices is effective to prevent starting of the current but is usually incapable of interrupting this current after it has started.

The winding 12 is provided with an intermediate terminal connected to one of the direct current leads 10 and with end terminals connected to the anodes 16 and 19. Connected between the end terminals of the winding are three parallel circuits, one of which is the alternating current circuit 11, another of which includes a capacitor 21, and the other of which includes a resistance element 22 and a capacitance element 23.

The resistance element 22 is connected in shunt to the primary winding 24 of a transformer 25. This transformer includes a secondary winding 26 provided with end terminals connected respectively to the grid 15 and through a capacitance element 28 to the grid 18. Potential for driving the apparatus or determining its operating frequency

may be applied to the capacitance element 28 from a suitable source through a transformer 29. As hereinafter explained, the characteristics of the apparatus are such that a very small voltage applied to the capacitance element 28 is capable of controlling the operating frequency of the apparatus. In cases where the devices 13 and 14 require a positive grid potential in order to initiate a current in them, the secondary winding of the grid transformer 25 may be provided with an electrical midpoint and this point may be connected to the common cathode circuit of the devices 13 and 14 through a resistor 27 whose resistance is preferably high enough to limit any grid current flowing therethrough to a negligible value.

In explaining the operation of the above described apparatus, it will be assumed that one of the devices, for example the device 13, is initially rendered conductive. Current will now flow as shown by the arrows of Fig. 1, the solid line arrows indicating the total current including magnetizing current and the dotted line arrows indicating load current and capacitor current. As will be well understood by those skilled in the art, the capacitors 21 and 23 become charged to substantially twice the potential of the direct current circuit. After these capacitors become substantially completely charged, it will be assumed that the potential applied to the capacitor 28 by means of the grid transformer 29 will reverse the control potential and apply a positive potential to the grid of the device 14 rendering it conductive. It will be assumed that the instant at which the device 14 is rendered conductive corresponds to the time  $t_1$  of Fig. 3 in which the curves  $E_a$ ,  $I_g$ , and  $E_g$ , indicate the anode voltage, the grid current, and the grid voltage, respectively, of the device 13. As is well understood by those skilled in the art, when the device 14 becomes conductive the cathode of the device 13 is made negative with respect to its anode by approximately twice the potential of the direct current circuit due to the fact that the potential across the capacitor 21 cannot change instantaneously. This results in the interruption of current in the device 13 and its establishment in the device 14. The capacitor 21 now rapidly discharges, aiding in the reversal of the magnetizing current of the winding 12, so that the anode potential of the device 13 increases positively at a very rapid rate represented by the initial portion of the curve  $E_a$  between intervals  $t_1$  and  $t_2$  of Fig. 3. During this commutating period, that is, the interval during which the anode potential of the device 13 is negative, the capacitor 23 also tends to discharge but, due to the impedance of the resistor 22 and the grid transformer 25 in its discharge path, its discharge takes place at a very much lower rate. It is seen that the difference in po-

tential between the capacitors 21 and 23 is impressed directly on the resistor 22 which excites the grid transformer 25. In other words, as soon as the device 14 becomes conductive and during the commutating period, the grid of the device 13 in which current has just been interrupted is subjected to a very high negative potential transient. As the potential drop in the device 14 is very low and due to the fact that the impedance of the resistor 27 is sufficiently high that it may be neglected in ordinary operation of the apparatus, the full potential of the secondary winding of grid transformer 25 is impressed upon the grid of the device 13 rather than a half of the potential of the secondary winding as is ordinarily the case with apparatus of this type. It will be noted also that, due to the high impedance of the resistor 27, the only path for the grid current of the device 14 includes the grid-cathode circuit of the device 13. Since grid current flows in the device 13 only during the period of deionization, the positive grid current of the device 14 is limited in magnitude and duration to the ion cleanup current of the device 13 so that any danger of damage to the grid of the device 14 by excessive grid current is avoided. Capacitors 21 and 23 now become charged to an opposite polarity. The potential applied to the capacitor 21 will reverse its polarity at the instant  $t_2$  and the above described half cycle will be repeated with respect to the valve 13 and the current will be successively transferred between the valves 13 and 14 at a frequency determined by the potential applied to the transformer 29. It is to be especially noted that the transformer 29 needs to supply an alternating potential of a magnitude only sufficient to render the devices 13 and 14 conductive during their respective half cycles of positive grid potential and that the negative potential required for deionization of the device in which current has just been interrupted is supplied by means of the transformer 25 in the manner described above.

Danger of damaging the grids by excessive current is avoided because the grids draw current only during commutation, the ion clean-up of one device being exactly balanced by the electron current of the other device if the resistance 27 is made infinite. With very little grid power input from the transformer 29, deionization equal to that secured with a high voltage grid bias battery is obtained and the load capacity of the apparatus is greatly increased. The application of the alternating driving voltage to the capacitor 28 has the advantage that it permits rapid deionization and does not load the excitation circuit. Due to rapid deionization, the operation of the apparatus at low frequencies is improved and the range of operating frequencies is greatly extended.

The apparatus illustrated by Fig. 2 is similar in many respects to that of Fig. 1 but differs therefrom in that it supplies its own excitation or is self-driven. It includes a capacitor 30 and an adjustable resistor 31 which are common to the grid circuits of the devices 13 and 14 and are connected in parallel with one another.

The excitation circuit including the capacitor 30 and resistance 31 operates in a manner similar to the excitation circuit of Fig. 1. Change in operating frequency is produced by adjustment of the resistance 31, the frequency of oscillation being largely determined by the rate at which the capacitor 30 discharges through the resistance 31. This frequency, however, is dependent to some extent on the magnitude of the load to which the apparatus is subjected for the reason that the charge of the capacitor 30 is dependent on the voltage of the load 11, the transformer ratio, the size of the condenser 23, and the size of the resistances 22 and 27. Where the alternating current load 11 is a synchronous motor, it has been found that a range of speed variation between 500 and 4000 R. P. M. may be readily secured. A marked advantage of the apparatus of Fig. 2 is that it functions as an alternating source of variable frequency and may be readily utilized to energize alternating load circuits located in districts where only direct current is available.

In the case of some tubes which require a positive grid voltage to start in operation, it may be desirable to connect one side of the resistor 31, as indicated in Fig. 2, to the positive direct current line instead of the negative. This arrangement is indicated in Fig. 4. This may be desirable in cases where the mere discharging of the negatively discharged condenser to zero will not be sufficient to start the tubes into operation.

In the arrangement shown in Figs. 1 and 2, a capacitor and resistor are connected in series, the voltage across the resistor being impressed on the grids of the tubes. Similar results can be obtained by the use of a series inductance and resistor 32, as shown in Fig. 4, and by impressing the voltage across the inductance upon the grids of the tubes, the inductance in this case constituting the primary 33 of the transformer 25. With such an arrangement the rapid change in potential of the capacitor 21 occurring when current is commutated from one valve to the other appears largely across the reactor 33 so that a highly negative transient potential is impressed upon the grid of the valve in which current has been interrupted in a manner similar to that described in connection with Fig. 1.

In Fig. 5 I have indicated another form of self-excitation circuit in which the con-

denser 23 and inductance 33 and resistance 34 are connected in series and the variable resistance 35 is connected in shunt to 33 and 34. The potentiometer 36 connected across the direct current circuit will supply positive grid excitation to such tubes as may require it.

In each of the connections which I have shown the polarity of the grid transformers should be such that when one end of the primary is positive with respect to the other end, the corresponding end of the secondary will be negative with respect to the other end.

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

1. The combination of a pair of electric discharge devices each provided with a grid for controlling the starting of current between its cathode and anode, a winding connected between the anodes of said devices and provided with an intermediate terminal, a direct current circuit connected between said terminal and the cathodes of said devices, a capacitor connected between the anodes of said devices, capacitor and resistance elements connected between said anodes in series with one another, and means for subjecting said grids to potentials dependent on the voltage drop of said resistor.

2. The combination of a pair of electric discharge devices each provided with a grid for controlling the starting of current between its cathode and anode, a winding connected between the anodes of said devices and provided with an intermediate terminal, a direct current circuit connected between said terminal and the cathodes of said devices, a capacitor connected between the anodes of said devices, capacitor and resistance elements connected between said anodes in series with one another, means for subjecting said grids to potentials dependent on the voltage of said resistor, and a resistance element common to the grid circuits of said devices.

3. The combination of a pair of electric discharge devices each provided with a grid for controlling the starting of current between its cathode and anode, a winding connected between the anodes of said devices and provided with an intermediate terminal, a direct current circuit connected between said terminal and the cathodes of said devices, a capacitor connected between the anodes of said devices, a plurality of impedance means connected between said anodes in series with one another, means for subjecting said grids to potentials dependent on the voltage drop of one of said impedance means, and an impedance element common to the grid circuits of said devices.

4. The combination of a pair of electric discharge devices each provided with a grid for controlling the starting of current between its cathode and anode, a winding connected between the anodes of said devices

and provided with an intermediate terminal, a direct current circuit connected between said terminal and the cathodes of said devices, a capacitor connected between the anodes of said devices, a plurality of impedance means connected between said anodes in series with one another, means for subjecting said grids to potentials dependent on the voltage drop of one of said impedance means, an impedance element common to the grid circuits of said devices, and frequency control common to said grid circuits.

5. The combination of a pair of electric discharge devices each provided with a grid for controlling the starting of current between its cathode and anode, a winding connected between the anodes of said devices and provided with an intermediate terminal, a direct current circuit connected between said terminal and the cathodes of said devices, a capacitor connected between the anodes of said devices, capacitance and resistance elements connected between said anodes in series with one another, means for subjecting said grids to the potential across said resistor, and means common to said grid circuits for controlling the frequency at which current is transferred from one to another of said devices.

6. The combination of a pair of electric discharge devices each provided with a grid for controlling the starting of current between its cathode and anode, a winding connected between the anodes of said devices and provided with an intermediate terminal, a direct current circuit connected between said terminal and the cathodes of said devices, a capacitor connected between the anodes of said devices, capacitance and resistance elements arranged to subject the grid circuits of said devices to potentials dependent on the voltage of said windings, and means including capacitance and resistance elements common to said grid circuits for controlling the frequency at which current is transferred from one to another of said devices.

7. Apparatus for transmitting energy from a direct current supply circuit to an alternating current load circuit comprising an inductive winding, means for interconnecting the circuits through said winding including a pair of electric discharge devices each provided with a control grid, means associated with said discharge devices for commutating the current therebetween, and means for exciting said grids to successively render said discharge devices alternately conductive and nonconductive and for accelerating the deionization of said discharge devices during the commutating period.

8. Apparatus for transmitting energy from a direct current supply circuit to an alternating current load circuit comprising an inductive winding, means for interconnect-

ing the circuits through said winding including a pair of electric discharge devices each provided with a control grid, means associated with said discharge devices for commutating the current therebetween, and means for exciting said grids to successively render said discharge devices alternately conductive and non-conductive and for impressing a transient of negative potential on each control grid immediately after current has been interrupted in its associated device.

9. Apparatus for transmitting energy from a direct current supply circuit to an alternating current load circuit comprising an inductive winding, means for interconnecting the circuits through said winding including a pair of electric discharge devices each provided with a control grid, means including a capacitor associated with said discharge devices for commutating the current therebetween, means for exciting said grids to successively render said discharge devices alternately conductive and non-conductive, and means responsive to the discharge of said capacitor during the commutating period for impressing a transient negative potential upon the grid of the device from which current has been commutated.

In witness whereof, I have hereunto set my hand this 24th day of April, 1930.

BURNICE D. BEDFORD.