

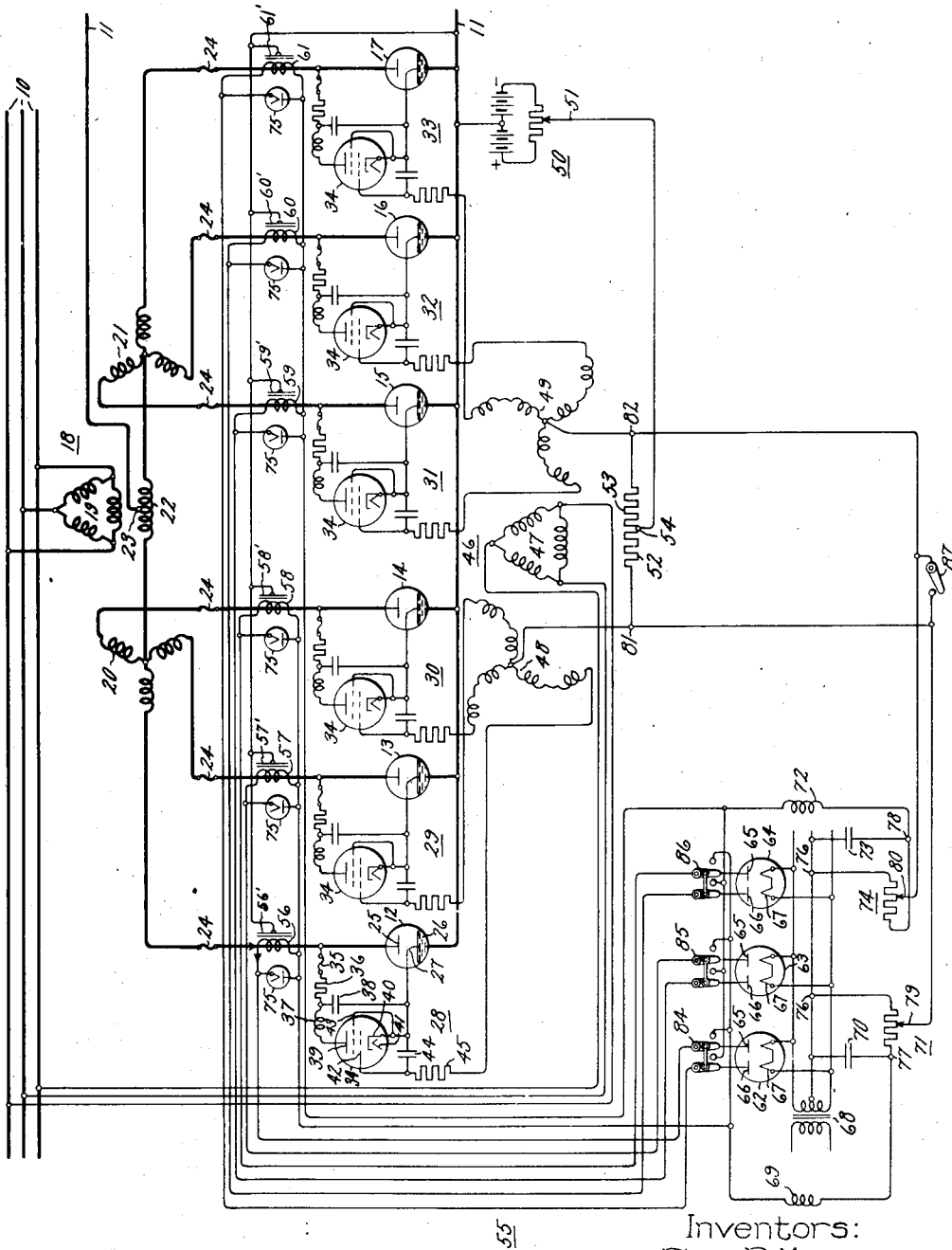
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E. E. MOYER ET AL

2,243,571

ELECTRIC VALVE CONVERTING SYSTEM

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Inventors:
Elmo E. Moyer,
Lysle W. Morton,
August Schmidt, Jr.
by *Harry E. Dunham*
Their Attorney.

UNITED STATES PATENT OFFICE

2,243,571

ELECTRIC VALVE CONVERTING SYSTEM

Elmo E. Moyer, Scotia, Lysle W. Morton, Schenectady, and August Schmidt, Jr., Niskayuna, N. Y.,
assignors to General Electric Company, a corporation of New York

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13 Claims. (Cl. 175—363)

Our invention relates to electric valve converting systems wherein power is interchanged between two circuits through means comprising an electric discharge apparatus, and more specifically to an arrangement for compensating for or preventing unbalance between the currents flowing in an electric valve converting system.

Unbalancing difficulties due to various causes have been encountered in electric valve converting systems or the like. In certain cases where the electric valve converting systems comprise a main supply transformer including a plurality of secondary windings the reactive voltage of the main supply transformer has tended to cause unequal distribution of the load between the secondary windings especially if the secondary windings are interconnected by an interphase transformer, one of the secondaries being subjected to the larger load when the phase rotation of the main transformer is in one direction and the other secondary having the larger load when the phase rotation of the main transformer is in the other direction. In other cases, the cause of the unbalance has been traced to differences in the voltage drop of the arc discharge paths associated respectively with the transformer secondary windings. The varying grid characteristics of the electric discharge valves also are a cause of unbalance. Other causes, more or less obscure, have been found to contribute to the unbalance.

Various schemes have been suggested to overcome the tendency to unbalance in the above-mentioned power systems including the provision of reactance in the connections associated with that one only of the secondary windings of the main supply transformer, the output of which tended to rise above the output of the other secondary windings. Various other schemes have been employed where an existing degree of unbalance is compensated for or prevented by some initial adjustment. These methods of preventing or compensating for the unbalance have been found to be inadequate in certain cases due to the random shifting of the unbalance from one of the transformer secondaries to the other during the operation. This shifting is due apparently, among other causes, to change in transformer temperature, the balance being impaired after a period of operation on heavy overload. In other cases, the shift is apparently caused by changes in voltage drop through the arc discharge apparatus with age and temperature under which conditions the unbalance between the transformer secondaries tends to be reversed.

In accordance with the present invention the

foregoing difficulties are obviated by means of an arrangement for continuously indicating the currents flowing from the secondary transformer windings and controlling the electric discharge valves in response to any unbalance indicated, thereby to restore balanced conditions or better still to prevent unbalanced conditions.

It is an object of our invention, therefore, to provide an improved electric valve converting apparatus which will overcome the above-mentioned disadvantages of the arrangements of the prior art and which will be simple and reliable in operation.

It is another object of our invention to provide a new and improved electric valve converting apparatus.

A further object of our invention is to provide an electric valve converting apparatus wherein means are provided to prevent unbalance between the currents flowing from the plurality of secondary windings of the transformer of the electric valve converting apparatus.

A still further object of our invention is to provide a current balancing arrangement for an electric valve converting apparatus wherein the balancing arrangement does not compound with current but rather the force tending to restore the balance always tends to be suppressed toward zero.

It is another object of our invention to provide an electric valve converting apparatus wherein the currents flowing from the plurality of secondary windings of the electric valve converting apparatus transformer are compared and any unbalance between these currents is used to control the grid excitation of the electric discharge valves in such a manner as to restore balanced conditions.

In accordance with the illustrated embodiment of our invention we provide an electric valve converting apparatus including a plurality of electric valves and a transformer having a pair of Y-connected secondary windings interconnected by an interphase transformer. In order to balance the currents between the two Y-connected secondary windings current transformers are provided for each anode lead of the main discharge valves so that an indication of the currents flowing from the secondary windings may be obtained and if there is any difference between the average currents flowing a direct current bias potential is applied to the control electrodes of the electric discharge valves associated with the respective Y-connected secondary windings. This bias potential is such as to cause

a decrease in the load carried by the secondary transformer winding and associated discharge valves carrying more than their share of load and simultaneously to cause an increase in the load carried by the secondary transformer winding and associated discharge valves carrying less than their share of load. Switching means are also provided for cutting out the operation of the balancing means on the electric valve converting apparatus, whenever this is desired.

The novel features which we believe to be characteristic of our invention are set forth with particularity in the appended claims. Our invention itself, however, will best be understood by reference to the following description taken in connection with the accompanying drawing in which the single figure thereof diagrammatically represents an embodiment of our invention.

Referring now to the single figure of the drawing, we have illustrated therein a system embodying our invention for transmitting energy from a polyphase alternating current supply circuit 10, having three phases, to a direct current load circuit 11. An electric valve translating apparatus including the main electric discharge valves 12 to 17, inclusive, and a transformer 18 are arranged to transmit the energy between the supply and load circuits 10 and 11, respectively. The transformer 18 may comprise a primary winding 19 and groups of Y-connected secondary windings 20 and 21, the neutrals of which are interconnected by means of an interphase transformer 22 to produce a form of six-phase system of the double Y type. The midpoint 23 of interphase transformer 22 is connected to one side of the direct current circuit 11, while the other side of the direct current circuit is connected to the cathodes of the main electric discharge valves 12 to 17. As indicated, suitable fuses 24 may be connected in series relation with the electric valves 12 to 17, inclusive. The electric valves 12 to 17 are preferably of the type employing an ionizable medium such as a gas or a vapor, and each comprises an anode 25, a cathode of the self-reconstructing type such as a mercury pool cathode 26, and a control member 27 of the make-alive or the immersion ignitor control member type. The immersion ignitor control members 27 are of a material having a substantially greater electrical resistivity than that of the associated mercury pool cathode 26. These control members may be constructed of a suitable material such as boron-carbide and silicon-carbide, or of the material disclosed and claimed in U. S. Letters Patent No. 1,822,742, granted September 8, 1931, on an application of Karl B. McEachron, and assigned to the assignee of the present application. In order to establish an arc discharge between the anode 25 and the cathode 26, it is necessary that a predetermined minimum critical flow of current be transmitted through the immersion ignitor control member 27. The main or power arc discharge path of each of the electric valves 12 to 17, of course, lies between the anode 25 and the cathode 26.

Excitation circuits 28 to 33 are associated with electric valves 12 to 17, respectively, and may be connected to be responsive to the anode-cathode voltage of the associated main power electric valve. Each of the excitation circuits 28 to 33 includes a control electric valve 34 which may be connected between the anode 25 and the immersion ignitor control member 27 of the associated electric valve through a current limiting means such as a fuse 35, a resistance 36

and an inductive reactance 37. The fuses 35 protect the control electric valves 34 while the resistor 36 limits the surge peak current which might flow through the auxiliary control electric valve in the event the main electric discharge valve does not conduct. The inductive reactance 37 combined with capacitor 38 which is connected in parallel with the control electric valves 34 decrease the high frequency oscillations which are undesirable from the standpoint of radio interference. The control electric valves 34 are preferably of the type employing an ionizable medium and each comprises an anode 39, a cathode 40, a filament or cathode heating element 41 therefor, and a control member or grid 42. As described the electric valves 34 may be of the type employing a screen or shield grid 43 which is connected to a point less positive than the anode and may be connected directly to the cathode. A capacitance 44 is connected between the cathode 40 and the control grid 42 to absorb transient voltage variations which may be present in the grid circuit due to the anode circuit. A current limiting resistance 45 may be connected in series relation with the control grid 42 and the grid or excitation circuit described hereinafter. In order to impress on the control grids 42 of electric control valves 34 in excitation circuits 28-33 alternating voltages preferably having a lagging phase displacement relative to the anode-cathode voltages of the respective control electric valves, we employ a transformer 46 having a primary winding 47 and groups of secondary windings 48 and 49. The primary winding 47 of transformer 46 may be energized with alternating potential from any suitable supply which has a fixed phase relationship with said anode supply, and is illustrated as being energized from alternating current supply circuit 10. The secondary windings 48 and 49 of grid transformer 46 are connected in zigzag-Y relationship so that the alternating grid potentials have a lagging phase displacement relative to the potentials of the secondary windings 20 and 21 of the main power transformer 18. This lagging phase displacement should preferably be in the neighborhood of 90 electrical degrees whereby the bias shift method of grid control may suitably be employed as described and claimed in U. S. Letters Patent No. 1,654,987, granted January 3, 1928, upon an application of Albert H. Mittag. By impressing a direct current bias upon the neutrals of the secondary windings 48 and 49 of grid transformer 47, a shift in the phase of the grid potentials of control electric valves 34 relative to the anode cathode voltage of these valves occurs and in this manner the valves may be caused to conduct for longer or shorter intervals of time depending upon whether the grid excitation is advanced or retarded. It will be understood by those skilled in the art that in the arrangement described above a positive direct current bias impressed upon the neutrals of the secondary windings 48 and 49 of grid transformer 46 will advance the phase of the grid excitation of control electric valves 34 and cause them to be conductive for a longer interval during each cycle. Conversely a negative bias will retard the phase excitation and render control electric valves 34 conductive for a shorter period during each cycle. In order to obtain this direct current bias to advance or retard the grid excitation of control electric valves 34 we provide a potentiometer regulator 50 the moving arm 51 of which

is connected to the neutral terminals of grid transformer secondary windings 48 and 49 through two equal resistances 52 and 53 the purpose of which will become apparent as this description proceeds. Resistances 52 and 53 are serially arranged and interconnect the neutrals of zigzag Y-connected grid transformer secondary windings 48 and 49. The moving arm 51 of potentiometer regulator 50 is connected to terminal 54 intermediate resistances 52 and 53. The other terminal of potentiometer regulator 50 is connected to the cathodes of control electric valves 34 through cathodes 26 and immersion ignitor type of control electrodes 27 of main electric discharge valves 12 to 17. By providing two secondary grid transformer windings 48 and 49 each associated with a separate group of three electric discharge valves it is possible to impress a different direct current bias potential upon the neutral of secondary winding 48 than upon the neutral of secondary winding 49 so that control electric valves 34 and associated main valves 12, 13 and 14 may be made to carry more or less current than control valves 34 and associated main valves 15, 16 and 17 as will be described in detail hereinafter. However, the direct current bias potential obtained from potentiometer regulator 50 impressed upon terminal 54 will through control valves 34 effect all of the main electric discharge valves 12 to 17 in the same manner. It will of course be understood by those skilled in the art that potentiometer regulator 50 can readily be adapted to automatic operation. For example, the moving arm 51 may be controlled in response to the voltage of the direct current circuit 11 whereby voltage regulation of this direct current circuit may be obtained.

Although we have described the electric valve converting apparatus as transmitting energy from a three-phase alternating current supply circuit 10 to a direct current circuit 11, it will be understood by those skilled in the art that supply circuit 10 may comprise any number of phases and furthermore that energy might equally well be transmitted from direct current circuit 11 to alternating current circuit 10 or even between two alternating current circuits of like or different frequency.

Since actual operation has shown a persistent tendency toward unbalance between the main power currents flowing from the respective secondary transformer windings to the electric discharge valves of electric valve converting apparatus of the type described, we provide, in accordance with our invention, an automatic current balance control 55 by which to maintain a balance between the currents flowing from the respective secondary windings of the main power transformer. In the illustrated embodiment we have provided a current balance control by which a balance is continuously maintained between the currents flowing from the two Y-connected secondary windings 20 and 21 of main power transformer 18. Accordingly, we have provided a plurality of current transformers 56 to 61 arranged so that each has its primary winding connected in series with one of the main anode power supply lines associated with electric valves 12 to 17, respectively. These current transformers are used to indicate the currents flowing through the respective anodes of electric discharge valves 12 to 17, and are provided with cores 56'-61', respectively, insulated from the anode conductors. These cores are connected

to the cathode bus for the purpose of minimizing any capacity effect between the secondary coils and the anode conductor or the core structure. The secondary outputs of current transformers 56, 57 and 58 which are associated with the anode supply lines leading from Y-connected secondary winding 20 of main power transformer 18 are rectified through separate elements of three double-element thermionic rectifier valves 62, 63 and 64, while the secondary outputs of current transformers 59, 60 and 61 associated with the other Y-connected secondary winding 21 are rectified through the remaining separate elements of thermionic electric valves 62, 63 and 64. Each of these thermionic valves is provided with a pair of anodes 65 and 66. Currents flowing from current transformers 56 to 58, respectively, are connected to anodes 65 of thermionic valves 62 to 64 and currents flowing from current transformers 59 to 61 are connected to anodes 66 of thermionic valves 62 to 64. These rectifiers 62 to 64 are each provided with a cathode 67 of the hot cathode type, the filament of which is suitably energized for heating purposes from the filament transformer 68, the primary winding of which is supplied from a suitable source of alternating current. The direct current output of current transformers 56 to 58 when rectified by electric valves 62 to 64 is filtered or smoothed by means of a reactor 69 and a capacitor 70 so that not the peak currents but rather the average currents are metered. A potentiometer 71 is connected across capacitor 70 so that the direct current potential appearing across potentiometer 71 is to all practical purposes proportional to the average anode current flowing through the three anodes associated with the Y-connected secondary winding 20 of transformer 18. Similarly, the output from current transformers 59, 60 and 61 when rectified by thermionic valves 62 to 64, is filtered by reactor 72 and capacitor 73. The potentiometer 74 is connected in parallel with capacitor 73 and the potential appearing across this potentiometer is proportional to the average anode current flowing through the anodes of electric discharge valves 15 to 17 associated with Y-connected secondary winding 21 of transformer 18.

The polarities of the current transformer windings as indicated by the arrowheads associated with current transformer 56, are such that when current flows through the primary conductors in a direction from anode to cathode of main electric valves 12 to 17, respectively, a secondary current flows from anode to cathode of rectifier valves 62 to 64. Because of the fact that an excessively high inverse voltage appears across the secondary windings of the current transformers 56 to 61, respectively, at the time when the main anode currents of electric discharge valves 12 to 17 cease to flow, we have provided electric discharge valves 75 connected across the secondary winding of each of the current transformers 56 to 61 so as to suppress the inverse peak and also to eliminate the high frequency oscillations which would otherwise appear across the secondary windings of the current transformers. These electric discharge valves 75 are connected so as to become conductive in a reverse direction with respect to valves 62, 63 and 64. It will be understood by those skilled in the art that valves 75 could be replaced by means of large resistors, although in this latter case a certain amount of current would continually flow through the resistors and the necessity of call-

bration of the arrangement would occur in the interest of more accurate metering of the main anode currents.

In order to compare the direct current potentials proportional to the average currents flowing from secondary transformer windings 20 and 21 potentiometers 71 and 74 have a common positive terminal 76 and isolated negative terminals 77 and 78, respectively. If the currents flowing from each Y-connected secondary winding 20 and 21 are equal then the potentials appearing across potentiometers 71 and 74, assuming the constants of the circuit to be identical, are equal and no potential difference should exist between terminals 77 and 78. If, however, the currents flowing through electric discharge valves 12, 13 and 14 are greater than the currents flowing through electric discharge valves 15, 16 and 17, then the potential difference between terminals 76 and 77 will be greater than the potential difference between terminals 76 and 78 and terminal 77 will be at a negative potential relative to terminal 78. Conversely, if the currents flowing through electric discharge valves 12, 13 and 14 are less than those flowing through electric discharge valves 15, 16 and 17 then the potential difference between terminals 76 and 77 will be less than the potential difference between terminals 76 and 78 and the potential of terminal 77 will be negative with respect to the potential of terminal 78. Potentiometers 71 and 74 are provided with adjustable sliders 79 and 80, respectively, for purposes of adjustment which will be described in detail hereinafter and the potential difference between terminal 76 and slider 79 is used instead of the potential difference between terminals 76 and 77. Similarly, the potential difference between terminal 76 and slider 80 is used instead of the potential difference between terminals 76 and 78. Slider 79 of potentiometer 71 is connected to terminal 81 of resistance 52 while slider 80 of potentiometer 74 is connected to terminal 82 of resistance 53. In view of the above description it will be understood by those skilled in the art that when the current flowing through main electric discharge valves 12, 13 and 14 equals the current flowing through main electric discharge valves 15, 16 and 17 there will be no potential difference between sliders 79 and 80 assuming that they are initially placed in the same position on potentiometers 71 and 74, respectively, and similarly, terminals 81 and 82 of resistances 52 and 53, respectively, will be at the same potential. The grid excitation circuits of all of the control electric valves 34 therefore will have the same direct current bias potential impressed upon them by virtue of potentiometer regulator 50 acting through terminal 54 intermediate resistances 52 and 53. If, however, more current flows through main electric discharge valves 12, 13 and 14 than through electric discharge valves 15, 16 and 17 a negative direct current potential will appear at terminal 81 of resistance 52 relative to the direct current potential of terminal 82 of resistance 53. This bias potential will retard the phase of the grid excitation of the auxiliary control valves 34 associated with main electric discharge valves 12, 13 and 14 and at the same time the opposite potential appearing at terminal 82 will tend to advance the phase of the grid excitation of the control valves associated with main discharge valves 15, 16 and 17, thereby tending to restore a balance between the currents flowing from the respective secondary transformer windings 20

and 21. Thus it is observed that if unbalanced currents exist, equal and opposite bias potentials are applied to the respective excitation circuits in order to cause some electric discharge valves to carry more current while others are caused to carry less current so as to restore balanced conditions.

In order that any one of the rectifier valves 62, 63 or 64 may be replaced in case it should become defective and without affecting the operation of the current balancing means to any great extent we have provided that the secondary windings of the current transformers associated with diametrically opposite electric discharge valves, insofar as the firing period is concerned, both feed into the same two-element rectifier. For example, the secondary winding of current transformer 56 associated with main electric discharge valve 12 is connected to the anode 65 of rectifier valve 62 while current transformer secondary winding 61 associated with main electric discharge valve 17 is connected to anode 66 of the same rectifier valve 62. The same relationship is true with respect to the remaining current transformer secondary windings and rectifiers 63 and 64. By this arrangement it is possible to remove thermionic rectifier 62, 63 or 64 from the circuit without greatly affecting the operation as far as balancing the currents flowing from the two Y-connected secondary windings 20 and 21 is concerned other than to change the sensitivity. It has been found that even with only a single one of the thermionic rectifiers 62, 63 or 64 connected in the circuit a considerable balancing effect is obtained which is improved when two rectifier valves are used and of course is much better when all of the currents flowing from the secondary windings 20 and 21 of transformer 18 are used.

In order that the electric valve converting apparatus may be operated without the current balancing means we provide double pole, double throw switches 84, 85 and 86, preferably of the "make-before-break" type, which are connected in series with the anode leads of the thermionic rectifiers 62, 63 and 64, respectively. A single pole switch 87 is also provided in order to short circuit terminals 81 and 82 of resistors 52 and 53 and place them at the same potential when the current balancing means is cut out of the circuit. When switches 84, 85 and 86 are moved to the right the secondary windings of current transformers 56 to 61 are short circuited and the current balancing means is cut out of operation. These switches have been provided not only that the electric valve converting apparatus may be operated without the current balancing means but also to facilitate the replacement of the thermionic rectifiers 62, 63 or 64 without appreciably affecting other than the sensitivity of the current balancing means in case one of these rectifiers should become defective.

The operation of the embodiment of our invention diagrammatically shown in the single figure of the accompanying drawing will be understood by those skilled in the art in view of the detailed description given above but will be briefly described by considering first the electric valve converting apparatus when operating with balanced currents flowing from the secondary windings 20 and 21 of main power transformer 18. The main electric discharge valves 12 to 17 are rendered conductive in the proper sequence due to the action of the control electric valves 34 and the grid excitation circuits 28 to 33 as-

sociated therewith. The output of the electric valve converting apparatus may be controlled by varying the position of movable arm 51 of potentiometer regulator 50 thereby varying the direct current bias applied to control electric valves 34 and either advancing or retarding the grid excitation thereby increasing or decreasing the power output. If the average currents flowing from secondary transformer winding 20 are equal to the average currents flowing from secondary transformer winding 21 there will be no potential difference between sliders 79 and 80 of potentiometers 71 and 74, respectively, associated with current balancing means 55 and hence no change in the operation of the electric discharge valves will occur, assuming that the sliders 79 and 80 are in the same relative positions on their respective potentiometers. If, however, the average currents flowing from secondary transformer winding 20 are greater than the average currents flowing from secondary transformer winding 21, a positive bias potential will be impressed on the neutral of secondary grid transformer winding 49 while an equal and opposite bias potential is impressed on the neutral of grid transformer secondary winding 48, whereby main electric discharge valves 12, 13 and 14 will be caused to carry less current and main electric discharge valves 15, 16 and 17 will be caused to carry more current thereby restoring the balance. It will be understood by those skilled in the art that a small amount of unbalance between the currents is necessary to produce a direct current potential difference between terminals 81 and 82 of resistors 52 and 53, respectively, to force a balance between the respective anode currents. With the sliders 79 and 80 in the same relative positions and the system having a normal tendency to unbalance, the currents flowing will never become balanced. For this reason sliders 79 and 80 are initially adjusted relative to one another so that the apparatus will have a slight initial correction. Instead of sliders 79 and 80 it will be understood by those skilled in the art that this initial correction could be produced by means of a fixed bias of proper magnitude and direction. It is desirable that the potentials obtained from potentiometers 71 and 74 are as large as possible in order to minimize the degree of unbalance that must be tolerated. The heavier the load carried by the electric valve converting apparatus the better will be the operation of the current balancing means due to the fact that a larger direct current bias potential will be available at terminals 81 and 82 for causing a phase shift in the grid excitation relative to the anode potential of control electric valves 34.

Although we have shown and described a particular embodiment of our invention as applied to an electric valve converting apparatus embodying a main transformer including a pair of Y-connected secondary windings interconnected by an interphase transformer, it will be understood by those skilled in the art that our current balancing means may equally well be embodied in connection with many other types of electric valve converting apparatus.

While we have described what we at present consider the preferred embodiment of our invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from our invention, and we, therefore, aim in the appended claims to cover all such changes and modifications as

fall within the true spirit and scope of our invention.

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

1. In combination, an alternating current supply circuit, a direct current load circuit, a plurality of electric discharge valves interconnecting said circuits, a control electrode and an excitation circuit therefor for each of said electric discharge valves, means for obtaining a measure of the current flowing through said electric discharge valves comprising a control circuit including energy storage means for producing a direct current bias potential proportional to the difference between the average currents flowing through said valves, said bias potential being impressed upon said excitation circuits of said electric discharge valves to control the operation thereof in such a manner as to prevent any substantial unbalance between the currents flowing through said valves.

2. In combination a supply circuit, a load circuit, electric translating apparatus connected between said circuits and including a transformer and a plurality of electric discharge valves, said transformer including a primary winding and a plurality of secondary windings, a control circuit for preventing unbalance between the currents flowing from said secondary transformer windings comprising means including a plurality of current transformers for obtaining a measure of the current flowing from said transformer secondary windings, and means for controlling the operation of said electric discharge valves in response to any tendency toward unbalance indicated by said measured currents.

3. In an electric valve converting apparatus an alternating current supply circuit, a direct current load circuit, electric translating apparatus connected between said circuits and including a power transformer and a plurality of electric discharge valves, said transformer being provided with a primary winding and a plurality of Y-connected secondary windings, an excitation circuit for each of said discharge valves, and means for maintaining a balance between the currents flowing from the Y-connected secondary transformer windings, said last mentioned means comprising means for producing direct current potentials proportional to the average currents flowing from said Y-connected secondary windings, and means for impressing any difference between said direct current potentials on the excitation circuits of the respective discharge valves associated with said Y-connected windings for restoring a balance between the currents flowing therefrom.

4. In combination a supply circuit, a load circuit, electric translating apparatus connected between said circuits and including a plurality of electric discharge valves, means for balancing the currents flowing between said valves, said last mentioned means including a plurality of current transformers and associated rectifiers for obtaining an indication of the currents flowing through said valves, and means for modifying the operation of said valves in response to unbalance between said currents.

5. In combination a supply circuit, a load circuit, electric translating apparatus connected between said circuits and including a plurality of electric discharge valves arranged in groups, means for balancing the currents flowing between said groups of valves, said last mentioned means including means for obtaining an indica-

tion of the currents flowing through certain valves of each group, means for controlling the operation of said valves in response to the unbalance between said currents, and switching means for changing the connections of said balancing means so that said balancing means may respond to the current conducted by any number of valves of each of said groups of valves.

6. In an electric valve converting apparatus, an alternating current circuit, a direct current circuit, means including a plurality of groups of electric discharge valves interconnecting said circuits, a control circuit for balancing the currents flowing through said groups of valves comprising means including a plurality of current transformers for obtaining an indication of the currents transmitted by each of said groups of valves, and means responsive to said indicated currents for controlling the operation of said groups of valves to eliminate current unbalance between said groups of valves.

7. In combination, an alternating current supply circuit, a direct current load circuit, electric translating apparatus connected therebetween and including groups of electric valve means each having an anode, a cathode and a control member, an excitation circuit for energizing said control member, means including a plurality of current transformers for obtaining an indication of the average current flowing in the anode circuits of certain of said electric discharge valves, and means responsive to any unbalance between the current flowing in certain of said valves for impressing a potential on the excitation circuit of certain of said valves to restore balanced conditions.

8. In an electric valve converting apparatus an alternating current supply circuit, a direct current load circuit, electric translating apparatus connected between said circuits and including a power transformer and a plurality of electric discharge valves, said transformer being provided with a primary winding and a pair of secondary windings each of said secondary windings being associated with a group of electric discharge valves, an excitation circuit for said plurality of electric discharge valves including an excitation transformer having a pair of secondary windings one of which is associated with each of said groups of electric discharge valves, means for maintaining a balance between the currents flowing from said pair of secondary windings of said power transformer comprising capacitance means, means for charging said capacitance means in accordance with the current conducted by the valves associated with both of said secondary windings of said power transformer, and means for impressing the voltage of said capacitance means on the secondary windings of said excitation transformer to reduce the conductivity of the valves associated with the transformer winding carrying more than its share of the current and to increase the conductivity of the valves associated with the transformer winding carrying less than its share of the load in order to restore balanced current conditions between said groups of electric discharge valves.

9. In an electric valve converting apparatus an alternating current supply circuit, a direct current load circuit, electric translating apparatus connected between said circuits and including a power transformer and a plurality of electric discharge valves, said transformer being provided with a primary winding and a plurality of

secondary windings, an excitation circuit for each of said discharge valves, means for balancing the currents flowing from the plurality of secondary windings, said last mentioned means comprising a plurality of current transformers and associated rectifiers for producing direct current potentials proportional to the average currents flowing from each of said secondary windings, means for impressing any difference between said direct current potentials on the excitation circuits of the respective discharge valves associated with said secondary windings in such a manner as to restore balanced conditions between the currents flowing therefrom, and switching means for cutting out the operation of said balancing means.

10. In an electric valve converting apparatus an alternating current supply circuit, a direct current load circuit, electric translating apparatus connected between said circuits and including a main power transformer and a plurality of electric discharge valves, said transformer being provided with a primary winding and a pair of secondary windings, an excitation circuit for said electric discharge valves including a grid transformer having a pair of secondary windings provided with neutral terminals, means for maintaining a balance between the currents flowing from said main transformer secondary windings comprising means for producing a direct current bias potential responsive to the average currents flowing from one of said pair of secondary windings of said main power transformer, means for producing a direct current bias potential proportional to the average currents flowing from said other secondary winding of said main power transformer, and means for comparing said bias potentials and impressing the difference across the neutral terminals of said grid transformer secondary windings in order to restore balanced current conditions.

11. In combination an alternating current supply circuit, a direct current load circuit, an electric translating apparatus connected between said circuits and including a power transformer having a primary winding connected to said alternating current circuit, and a pair of secondary windings each associated with a plurality of electric discharge valves for transmitting energy from said alternating current circuit to said direct current circuit, a grid transformer having a pair of secondary windings one of which is associated with the electric discharge valves connected to the other secondary winding of said main power transformer while the other is associated with the electric discharge valves connected to the other secondary winding of the main power transformer, means for balancing the currents flowing from said main transformer secondary windings comprising capacitance means responsive to the difference between the average currents flowing from one of said main power secondary windings and the average currents flowing from the other of said main power transformer secondary windings for impressing a direct current bias potential on the excitation circuits of the electric discharge valves as will advance the phase of the grid excitation of certain of said valves while retarding the phase of the grid excitation of others of said valves.

12. In an electric valve converting apparatus, a supply circuit, a load circuit, electric translating apparatus connected between said circuits and including a plurality of inductive windings

and a plurality of groups of electric discharge valves, each group of said valves being associated with one of said inductive windings, an excitation circuit for each of said groups of electric discharge valves, means for maintaining balanced conditions between the currents flowing in said inductive windings including a plurality of current transformers and associated rectifiers for producing unidirectional potentials proportional to the currents flowing in said inductive windings, and means for comparing said unidirectional potentials to obtain a resultant potential of such magnitude and polarity as to shift the phase of the excitation of said groups of electric discharge valves in such a manner as to restore balanced current conditions.

13. In an electric valve converting apparatus, an alternating current supply circuit, a load circuit, electric translating apparatus connected between said circuits including a plurality of

inductive windings and a plurality of groups of electric discharge valves, each of said groups of valves being associated with one of said windings, an excitation circuit for said electric discharge valves, a control circuit for preventing unbalance between the currents flowing from each of said inductive windings including means for producing direct current potentials responsive to the current flowing from each of said inductive windings, potentiometers for comparing said direct current potentials so as to obtain a resultant potential if any unbalance exists, and means for impressing such resultant potential upon the excitation circuit of said electric discharge valves to restore balanced current conditions.

ELMO E. MOYER.
LYSLE W. MORTON.
AUGUST SCHMIDT, Jr.

CERTIFICATE OF CORRECTION.

Patent No. 2,243,571.

May 27, 1941.

ELMO E. MOYER, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, second column, line 48, for "winding 71" read --winding 21--; page 5, first column, line 20, for "gerater" read --greater--; page 6, first column, line 62, claim 8, for "shart" read --share--; and second column, line 54, claim 11, for "the other secondary winding" read --one of said secondary windings--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 15th day of July, A. D. 1941.

(Seal)

Henry Van Aradale,
Acting Commissioner of Patents.

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