

April 15, 1952

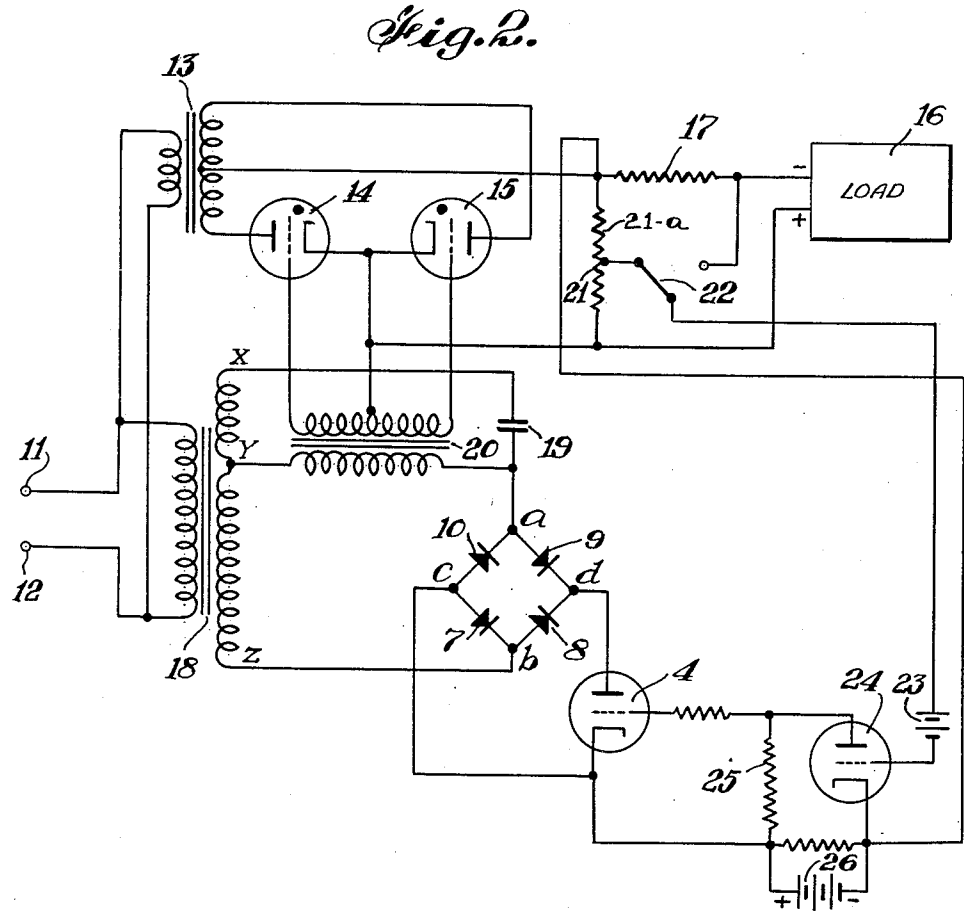
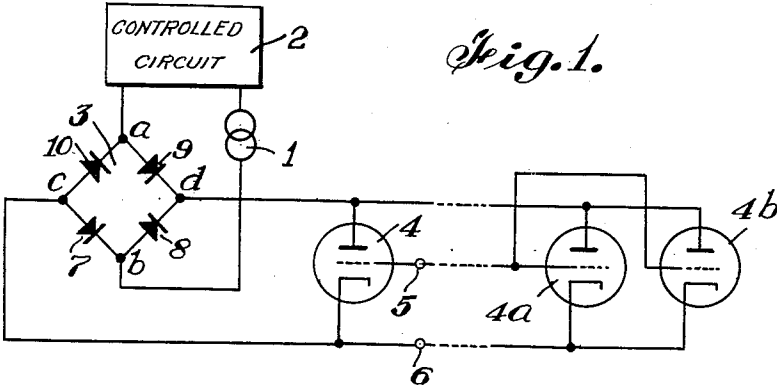
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2,592,615

CURRENT SUPPLY APPARATUS

Filed Aug. 19, 1949

2 SHEETS—SHEET 1



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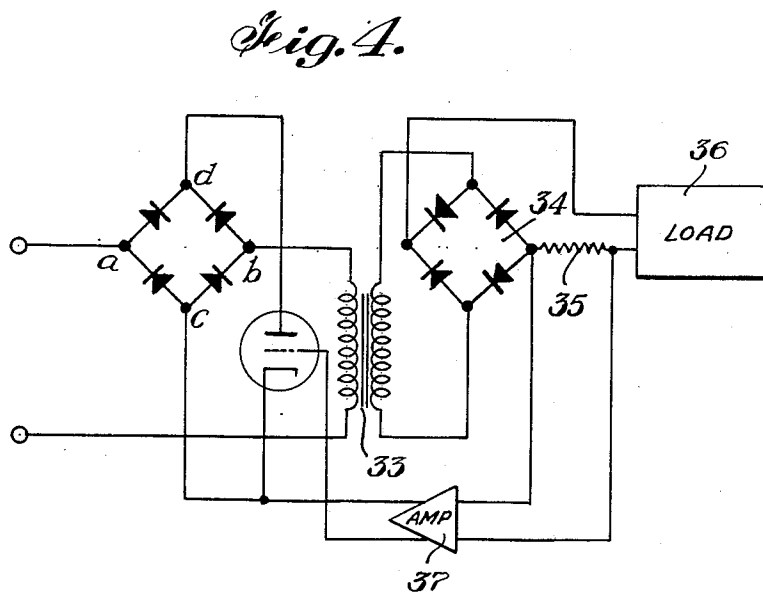
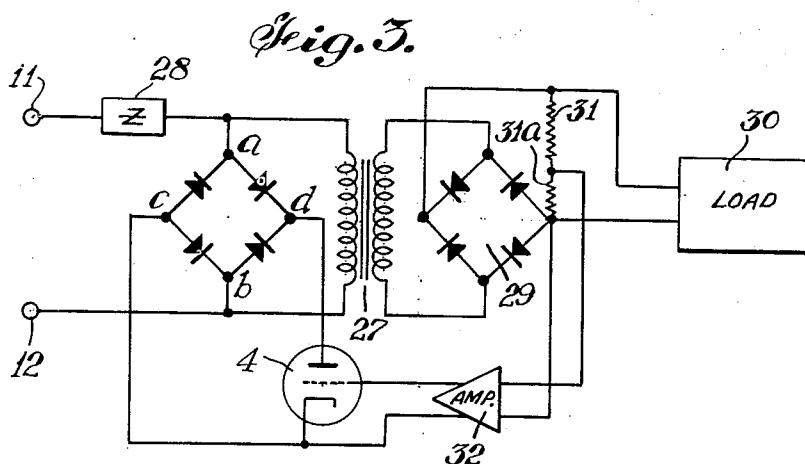
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2 SHEETS—SHEET 2



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CURRENT SUPPLY APPARATUS

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Application August 19, 1949, Serial No. 111,199

12 Claims. (Cl. 321—40)

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This invention relates in general to rectifier type current supply systems and more particularly, to self-controlled, output-regulated rectifier apparatus.

Heretofore, there have been devised innumerable systems for rectifying voltage from an alternating source to supply direct current to a load. Many of such systems have included means for regulating the output of the rectifier in some given manner, providing constant current or constant voltage output to the load. With such systems, however, it is desirable to provide a simple apparatus involving a minimum number of electron discharge devices, and to eliminate the need for mechanically operated servo-controlled circuits with their accompanying moving parts. In accordance with the invention, regulated rectifier type power supplies are provided embodying a controller system having a minimum number of electron discharge devices and associated circuitry therefor, and with no moving parts.

In summary, the invention employs a resistance element having a magnitude varying in accordance with a low voltage, low power, control signal supply thereto. In one circuit according to the invention, this variable resistance element is inserted as one of the arms of a phase-shifting bridge circuit, controlling the relative phase of a voltage supplied to the grid-cathode circuit of a gaseous discharge rectifier system. The control signal for the variable resistance element is derived, through an amplifier, from the output of the gaseous discharge rectifier. A rectifier system employing gaseous discharge rectifiers in somewhat similar manner is shown in copending application of F. W. Anderson, Serial No. 111,208, filed August 19, 1949.

In other circuits, according to the invention, the variable resistance element is used to provide control through an impedance inserted between the source of alternating voltage and a conventional rectifier apparatus; in still another circuit the variable resistance element itself produces a voltage drop in series between the alternating voltage source and the rectifier. In the latter two circuits, the control signal for the variable resistance element may be obtained from the output of the rectifier system.

The principal object of the invention is to provide a current supply or rectifier apparatus having its output regulated in accordance with a parameter of the rectifier output and employing a non-mechanical, variable resistance control element.

The objects of the invention may be realized by

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the means described in detail in the following specification:

Fig. 1 shows an electric schematic of a variable resistance element according to the invention;

Fig. 2 shows an electric schematic of a preferred embodiment of the controlled rectifier system according to the invention;

Fig. 3 shows an electric schematic of a further embodiment of a controlled rectifier system according to the invention; and

Fig. 4 shows an electric schematic showing a still further embodiment of a controlled rectifier system according to the invention.

Referring now to Fig. 1, a variable resistance element according to the invention is here shown. A source of alternating voltage 1 is in series with a circuit to be controlled 2, the latter having some value of impedance. Completing the series circuit between the source of alternating voltage 1 and controlled circuit 2, are vertices *a* and *b*, of the variable resistance element. A portion of the variable resistance element is composed of four unidirectional conductors 7, 8, 9 and 10 connected in a bridge circuit 3 and having vertices at points *a*, *b*, *c* and *d*. The polarities in which the unidirectional conductors will permit a flow of current will be later explained. The unidirectional conductors 7, 8, 9 and 10 are shown as metallic disc rectifiers employing some semi-conductive material such as selenium, copper oxide, or barium titanate, but may be of any convenient type such as thermionic discharge tubes or the like. Metallic disc rectifiers so employed are commonly known as varistors, and display a low resistance to the passage of current in a given direction known as the "forward" direction, and a relatively high resistance to the passage of current in the opposite or "back" direction. The limit of values of high and low resistance of such varistors depends, inter alia, upon the physical properties of the semi-conductors employed.

A thermionic discharge tube 4 having a cathode, grid and anode is shown; the anode-cathode circuit of this tube is connected between vertex points *c* and *d*. The controlling signal input is supplied to the thermionic discharge tube 4 between terminals 5 and 6.

In general, the variable resistance element operating between points *a* and *b* is so connected as to modulate or control the flow of alternating current from the supply source 1 as it passes to the controlled circuit 2, in accordance with the magnitude of voltages found at the control signal input terminals 5 and 6.

In the ensuing discussion, the flow of current in

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the circuits will be considered in terms of conventional battery current flow, viz., from positive to negative. Assuming that at a given instant, the polarity of the alternating source 1 is positive at point *b* and negative at the controlled circuit 2, the input at *b* is offered a low forward resistance through varistor 3 to point *d*, but offered a comparatively high back resistance through varistor 7. The current flow, therefore, proceeds through varistor 3 to a point *d* and thence to the anode of thermionic discharge tube 4, a high resistance being offered to current flow from *d* to *a*. Assuming that the cathode of thermionic discharge tube 4 is properly energized, the current flow passes from its anode to the cathode and thence to point *c*. A resistance to the flow of electrons from the anode to the cathode of discharge tube 4 is developed, having a magnitude dependent upon the "anode resistance" of discharge tube 4. This, in turn, depends upon the grid-cathode voltage of discharge tube 4. A more negative voltage on terminal 5 with respect to 6 increases the anode resistance; a less negative voltage decreases the anode resistance. The current will then pass from vertex *c* to *a* through varistor 10 which offers a relatively low resistance to the passage of current in this direction, to *a*. Assuming, therefore, that varistors 3 and 10 offer a negligibly low resistance to current flow from points *b* to *d*, and *c* to *a*, respectively, the resistance presented between vertices *b* and *a* will depend substantially upon the anode resistance of thermionic discharge tube 4. This anode resistance has been shown depending upon the control grid-cathode voltage applied to the tube 4.

Upon the subsequent half cycle of output voltage from the alternating source 1, point *b* will become negative and controlled circuit 2 will be positive. The current will flow from the positive lead of source 1 through controlled circuit 2 to point *a*. A high back resistance to the flow of current will be offered from point *a* through varistor 10, but a low forward resistance will be presented to the flow of current through varistor 9 to *d*. Accordingly, the current passes from point *a* to point *d*, thence to the anode of discharge tube 4. As before, the current will pass from anode to cathode of thermionic discharge tube 4; a resistance will be presented to this flow depending upon the relative polarity and magnitude of this control signal voltage provided at points 5 and 6. The current flow will pass from the cathode of discharge tube 4 to point *c* and through the low forward resistance offered by varistor 7 from *c* to *b* and thus to the negative side of alternating source 1.

If the minimum resistance presented by the discharge tube 4 is not sufficiently low for the proper control of current to the circuit, additional thermionic discharge tubes such as 4-a and 4-b may be connected in parallel with discharge tube 4 and in sufficient number so that the net resistance presented by the combination of tubes can be made to obtain any desired value. If a higher resistance is required than may be obtained with thermionic discharge tube 4 as a triode, the higher anode resistance offered if thermionic discharge tube 4 is a pentode may be utilized.

Referring now to Fig. 2, a rectifier employing a variable resistance element is here shown. A source of alternating current is supplied to terminals 11 and 12, thence to the primary of a transformer 13. Transformer 13 supplies alter-

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nating voltages to two gaseous discharge rectifier triodes 14 and 15 connected in full wave. Rectifiers 14 and 15 may be of the "thyatron" type, a name generally indicative of grid-controlled gaseous discharge rectifiers. The output of the full wave thyatron rectifier is supplied between the center tap of the secondary of transformer 13 and the common cathodes of thyatrons 14 and 15, to the load 16.

The amount of current passed by the thyatrons 14 and 15 will be determined by the phase of the grid-cathode voltage with respect to the anode-cathode voltage of the thyatrons. When the grid-cathode voltage applied to thyatrons 14 and 15 is exactly in phase with the anode-cathode voltage, the thyatrons pass the maximum current. As the phase of the grid-cathode voltage is shifted more and more from the in-phase to an out-of-phase condition with respect to the anode-cathode voltage, the current passed by the thyatrons is correspondingly reduced. When the grid voltage and anode-cathode voltage are 180 degrees out of phase, no current will be passed by the thyatrons 14 and 15 and the output will be zero. Grid-controlled thyatrons can be considered as hot cathode, phase sensitive, rectifier tubes, in which a grid or a control electrode has been inserted. This grid serves a function analogous to that of a control grid in an ordinary vacuum tube. However, the grid is able only to initiate the flow of anode current; once current has started, the magnitude of current flow is not fixed by the grid potential nor is any change of the grid potential able to stop the flow of current. Current can be stopped by making the anode zero or negative with respect to the cathode for a short interval of time. By shifting the phase of the grid-cathode voltage, the time at which the anode-cathode current is initiated can be shifted. The time of the cycle during which current passes will therefore be controlled by shifting the point at which the anode-cathode current is initiated.

The alternating voltage supplied to terminals 11 and 12 is also supplied to the primary of a transformer 18. The secondary of this transformer 18 is included as two arms of a phase shifting bridge; one arm extends between *x* and *y*, and a second arm between *y* and *z*. A third arm is presented between points *b* and *a*, which is the variable resistance element previously described in connection with Fig. 1; a fourth arm between points *a* and *x* comprises a reactance 19 which may be a capacitance. The output vertices *y* and *a* of the phase shifting bridge are connected to the primary of a transformer 20.

Two parallel branches are supplied for the flow of current from the secondary of transformer 18. Thus, that portion of the secondary voltage of transformer 18 developed between points *x* and *y* is supplied through capacitance 19 to the primary of transformer 20. The phase of the supply voltage will thus be shifted, providing a leading current to the primary of transformer 20 in the first parallel branch. That portion of the secondary voltage of transformer 18 between points *y* and *z* will be supplied through the variable resistance element at points *b* and *a*; thence to the primary of transformer 20 in the second parallel branch. The flow of current through this second parallel branch has substantially no shift in phase, as the variable resistance element introduces no reactance in this branch.

The current flowing through the primary of

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transformer 20 will be in part the leading or out-of-phase current supplied through capacitance 19 and in part, the in-phase current supplied to the variable resistance element. If the resistance between points *b* and *a*, the variable resistance element, is made very small, the primary of transformer 20 will be supplied substantially with an in-phase voltage. As the resistance between points *a* and *b* increases, the resistance of the variable resistance element increasing, the proportion of the in-phase current in the primary of transformer 20 becomes increasingly less. Thus, the ratio of out-of-phase current supplied through the capacitance 19 becomes higher, and transformer 19 is supplied a voltage having a larger out-of-phase component.

The grid-cathode voltage of the thyratrons 14 and 15 is obtained respectively on either side of the tapped secondary winding of transformer 20. It will be seen that the phase of the grid-cathode voltage of thyratrons 14 and 15 will depend upon the resistance presented by the variable resistance element between points *b* and *a*.

A voltage divider 21 is connected across the output of the thyatron rectifiers 14 and 15; a voltage proportional to the output voltage will be obtained across segment 21-*a* of the voltage divider 21. Assuming that switch 22 is made to its left-hand contact, a voltage proportional to the output voltage is presented to a direct coupled amplifier utilizing a thermionic discharge tube 24. A fixed bias supply 23 is employed to neutralize a portion of the steady output voltage component of the thyatron rectifier in the grid-cathode circuit of amplifier tube 24. Output voltage variations of the thyatron rectifiers will appear between the grid and cathode of the amplifier tube 24. These variations will be amplified by tube 24 and will appear across the anode resistance 25. The amplified variations are supplied thence to the grid-cathode circuit of thermionic discharge tube 4; corresponding to discharge tube 4 in Fig. 1. As in Fig. 1, discharge tube 4 controls the magnitude of the resistance presented between points *b* and *a* of the variable resistance element.

For example, let it be assumed that the output voltage from the thyratrons 14 and 15 has increased. Such a voltage increase is reflected as a proportionately increasing voltage across the voltage divider segment 21-*a*. The steady component of the voltage across 21-*a* is neutralized or overcome by the bias battery 23 to the extent that a proper operating bias is supplied the grid-cathode circuit of amplifier tube 24. The voltage increase across divider segment 21-*a* will cause an increasingly positive voltage on the grid with respect to the cathode of tube 24. This increasingly positive voltage in turn causes a rise in the anode current of amplifier tube 24; the voltage drop across the anode resistance 25 is increased and the anode voltage will drop. As the potential at the cathode of thermionic discharge tube 4 is fixed at the positive end of supply battery 26, the decreased anode potential of amplifier tube 24 will render the grid of thermionic discharge tube 4 more negative. As the grid of the discharge tube 4 becomes more negative, the resistance introduced by the variable resistance element between points *b* and *a* increases as previously explained. The primary of transformer 20 will be in turn presented with a voltage increasingly out-of-phase and the grid-cathode voltages ap-

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plied to the thyratrons 14 and 15 will also be shifted out of phase with regard to their anode-cathode voltages. The output of the thyatron rectifiers 14 and 15 will thus be reduced, compensating for or minimizing the originally assumed increase in output voltage.

Similarly, it may be shown that a decrease in output voltage is reflected across the segment 21-*a* of the voltage divider 21 and will result in an an-phase shift of the grid-cathode voltage of thyratrons 14 and 15 to minimize the decrease of output voltage of the thyatron rectifiers.

A resistance 17 is inserted in series with the output of thyatron rectifiers 14 and 15 to the load. Assuming now, that switch 22 is made to its right-hand contact, the voltage developed by the load current across resistance 17 will be presented in series with the fixed bias supply 23 to the grid-cathode circuit of amplifier tube 24. Changes in load current vary the voltage drop across resistance 17. Inasmuch as a portion of the voltage developed by normal load current across resistance 17 can be neutralized by the bias supply 23 to provide a proper bias to tube 24, voltages representative of changes in load current will be developed between the grid and cathode of amplifier tube 24.

It may be shown, for example, that an assumed increase in output current will increase the voltage drop across resistance 17; the grid of amplifier tube 24 will become more positive. This increased positive grid voltage causes a rise in the anode current of tube 24, in turn providing a more negative voltage on the control grid of thermionic discharge tube 4 with respect to its cathode. As has been demonstrated, this causes an increase in resistance of the variable resistance element between points *b* and *a* and a consequent out-of-phase shift in the grid-cathode voltage of thyratrons 14 and 15 results. The out-of-phase shift reduces the output of thyratrons 14 and 15, and compensates for or minimizes the assumed increase in load current.

It may similarly be shown, a decrease in load current will ultimately provide an in-phase voltage shift in the grid-cathode supply voltage to thyratrons 14 and 15, increasing the output current and compensating for or minimizing the assumed decrease in load current.

It follows that by operation of the switch 22, it is possible to maintain the output of the thyatron rectifier system either at a constant output voltage or at a constant output current value.

Referring now to Fig. 3, a source of alternating current is presented to terminals 11 and 12. Terminal 11 is connected in series with a fixed impedance 28, having a given value, to the primary of a transformer 27. The secondary of transformer 27 is connected to the input vertices of a conventional bridge rectifier 29. The output vertices of rectifier 29 connect to a load 30. While rectifier 29 is shown as a full wave, metallic disc rectifier, many types of conventional rectifier arrangements may be used herein.

The variable resistance element is connected between points *b* and *a* in series with the fixed impedance 28, and in parallel with the primary of transformer 27. By varying the resistance offered between points *b* and *a*, at least a portion of the current drawn through the fixed impedance 28 can be caused to vary in a similar manner. The subsequent voltage drop presented by impedance 28 to the transformer 27 can thus be made to vary in accordance with changes in the variable resistance element.

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Assuming that the output voltage of rectifier 29 across voltage divider 31 increases, the voltage across voltage divider segment 31-a will increase proportionately; this increase will be amplified in amplifier 32 and thence presented as an increasingly positive voltage to the control grid of thermionic discharge tube 4. A rise instead of a drop at the control grid of thermionic discharge tube 4 as a result of an assumed voltage increase may be accomplished, for example, by amplifier 32 having an even number of concatenated stages. The assumed increase in the control grid voltage of discharge tube 4 will reduce the resistance presented between points b and a by the variable resistance element and will increase the current drawn through the fixed impedance 28 by the latter. The increase of current through fixed impedance 28 increases the voltage drop across it and reduces the voltage supplied to the transformer 27 and therefore to the input vertices of the rectifier 29. The originally assumed increase in output voltage will thus be minimized.

Similarly, it may be shown that a decrease in output voltage will produce a higher resistance between points b and a of the variable resistance element, reducing the drop across fixed impedance 28 and raising the output voltage across rectifier 29.

The transformer 27, inserted between the variable resistance element and the rectifier 29, will isolate direct currents between the latter two elements, assisting in the operation of the direct coupled amplifier 32.

Referring now to Fig. 4 a source of alternating voltage is supplied to terminals 11 and 12. The primary of transformer 33 is connected in series with the variable resistance element between points a and b to the supply terminals 11 and 12. The secondary of transformer 33 connects to the input vertices of a conventional rectifier 34. Again, this rectifier 34 is shown as a full wave, metallic disc rectifier, but many types of rectifier systems may be employed. The output vertices of rectifier 34 are supplied in series with a fixed resistance 35 to a load circuit 36. Increases or decreases in magnitude of the load current from rectifier 34 will be reflected as increased and decreased voltage drops across the resistance 35. As with transformer 27, transformer 33 provides the function of isolating the direct currents of the system and adjusting the desired output voltage.

For example, an increase in the output current will reflect an increasing voltage drop across resistance 35 and this increasing voltage may be translated and amplified by amplifier 37 to provide a more negative grid voltage to thermionic discharge tube 4. The increasingly negative grid voltage of thermionic discharge tube 4 will increase the resistance presented by the variable resistance element between points a and b; the alternating voltage supplied to the input vertices of rectifiers 34 will be lowered, reducing the output current and compensating for the originally assumed increase in output current.

Similarly, it may be shown that a reduction in the output current of rectifier 34 will produce a corresponding decrease in the resistance presented by the variable resistance element between points a and b, compensating for the originally assumed load current drop.

While the circuit with reference to Fig. 3 has been shown as providing constant output voltage regulation, and with respect to Fig. 4, has been

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shown as providing constant output current regulation, it will be obvious to those skilled in the art that either constant output voltage or constant output current may be maintained by an appropriate choice of voltage dividers or series load resistances in either circuit as shown.

It is obvious that the scope of the invention is not limited to the specific embodiments described, and that the invention may be employed in arrangements other than those given by way of example.

What is claimed is:

1. In an electric regulator apparatus for regulating the flow of a source of alternating current in series with an impedance, the circuit comprising, a plurality of unidirectional conductors coupled in a full wave bridge and having input and output vertices, means to couple the input vertices of said bridge in series with the source of alternating current and impedance, a thermionic discharge tube having a cathode, anode and grid, means to couple the anode-cathode circuit of the said thermionic discharge tube to the output vertices of the said bridge, means to derive a signal voltage having a magnitude varying according to a portion of the flow of the said source of alternating current, and means to couple the said signal voltage to the control grid-cathode circuit of the said thermionic discharge tube.

2. In a rectifier having a grid-controlled gaseous discharge tube and energizing circuits therefor, a regulator comprising a phase shifting circuit having means to derive an alternating potential having two components with displaced phase relation, means to vary the magnitude of one of the components, said latter means comprising a plurality of asymmetrically conducting varistors connected as a full wave bridge and having input vertices and a positive and negative output vertex, a thermionic discharge tube having an anode, cathode and grid, means to connect the positive and negative output vertices of the said varistor bridge to the said anode and cathode, respectively, means to apply the said alternating potential to the grid of the gaseous discharge tube, means to derive a signal voltage varying in accordance with the output of the gaseous discharge tube, and means to impress the said signal voltage on the grid-cathode circuit of the said thermionic discharge tube.

3. In a direct current power supply system having a grid-controlled gaseous discharge tube and energizing circuits therefor to supply a direct current to a load from a source of alternating current, the regulator comprising, a phase shifting circuit having means to derive a first alternating potential component in phase with the source of alternating current and a second alternating potential component in displaced phase with the said source of alternating current, means to vary the magnitude of the first said component, said latter means comprising first, second, third and fourth asymmetrically conducting varistors connected as a full wave bridge and having input vertices and a positive and negative output vertex, a thermionic discharge tube having an anode, cathode and grid, means to connect the positive and negative output vertices of the said varistor bridge to the said anode and cathode, respectively, means to combine the said two potential components vectorially and to supply the vectorial sum to the grid of the gaseous discharge tube, means to derive a signal voltage varying in accordance with a portion of the output voltage of the gaseous discharge tube, and means to impress the said

signal voltage on the grid-cathode circuit of the said thermionic discharge tube.

4. In a direct current power supply system having a grid-controlled gaseous discharge tube and energizing circuits therefor to supply a direct current to a load from a source of alternating current, the regulator comprising, a phase shifting circuit having means to derive a first alternating potential component in phase with the source of alternating current and a second alternating potential component in displaced phase with the said source of alternating current, means to vary the magnitude of the first said component, said latter means comprising first, second, third and fourth asymmetrically conducting varistors connected as a full wave bridge and having input vertices and a positive and negative output vertex, a thermionic discharge tube having an anode, cathode and grid, means to connect the positive and negative output vertices of the said varistor bridge to the said anode and cathode, respectively, means to combine the said two potential components vectorially and to supply the vectorial sum to the grid of the gaseous discharge tube, means to derive a signal voltage varying in accordance with a portion of the output current of the gaseous discharge tube, and means to impress the said signal voltage on the grid-cathode circuit of the said thermionic discharge tube.

5. In a direct current power supply system including first and second grid-controlled gaseous discharge rectifiers having each a cathode, grid and anode for supplying a direct current to a load from a source of alternating current having a given phase, said alternating current being applied to the anode-cathode circuits of the said rectifiers in push-pull, the regulator circuit comprising, a transformer having a split secondary winding and a primary winding connected to the source of alternating current, means to derive a current in phase quadrature with the source of alternating current, said latter means comprising a reactance in series with a portion of the secondary of the said transformer, means to derive a variable current in phase with the alternating source, said latter means comprising first, second, third and fourth asymmetrically conducting varistors connected in a full wave bridge and having input vertices and positive and negative output vertices, a thermionic discharge tube having a cathode, grid and anode, means to connect the positive and negative output vertices of the said varistor bridge to the said anode and cathode, respectively, and means to connect the input vertices of the varistor bridge in series with the free portion of the secondary of the said transformer to provide the said variable current, means to derive a voltage resultant from the vectorial sum of the said phase quadrature and variable in-phase currents, means to supply the derived voltage to the grid-cathode circuit of the grid-controlled gaseous discharge rectifiers in push-pull, means to derive a control voltage in accordance with the output of the said grid-controlled gaseous discharge rectifiers, and means to apply the said derived control voltage to the grid-cathode circuit of the said thermionic discharge tube.

6. In a power supply system according to claim 5 wherein the said means to derive a control voltage includes means responsive selectively to the output voltage and load current of the said grid-controlled gaseous discharge rectifiers.

7. In a power supply system according to claim 5 including a plurality of thermionic discharge

tubes having each a cathode, grid and anode, means to couple the said plurality of thermionic discharge tubes together in parallel and in parallel with the said first-mentioned thermionic discharge tube.

8. In a power supply having a rectifier for providing direct current output to a load from an input source of alternating current, a regulating circuit comprising, a plurality of unidirectional conductors connected as a full wave bridge and having input vertices and positive and negative output vertices, a space current device having an anode, cathode and control electrode, means for connecting the positive and negative output vertices of the said bridge respectively to the anode and cathode of the said space current device, an impedance, direct current isolating means to couple the input vertices of the said bridge in parallel with the rectifier input, means to couple the input vertices of the said bridge in series with the said impedance and source of alternating current, means to derive a signal voltage varying in accord with the output of the rectifier, and means for impressing the said signal voltage on the control electrode of the said space current device.

9. In a power supply having a rectifier for providing direct current output to a load from an input source of alternating current, a regulating circuit comprising, a first, a second, a third and a fourth asymmetrically conducting varistor connected as a full wave bridge and having input vertices and positive and negative output vertices, a thermionic discharge tube having an anode, cathode and grid, means for connecting the positive and negative output vertices of the said bridge respectively to the anode and cathode of the said thermionic discharge tube, an impedance, transformer means to couple the input vertices of the said bridge in parallel with the rectifier input, means to couple the input vertices of the said bridge in series with the said impedance and source of alternating current, means to derive a signal voltage responsive selectively to the output voltage and load current of the rectifier, and means for impressing the said signal voltage on the grid of the said thermionic discharge tube.

10. In a power supply having a rectifier for providing direct current output to a load from an input source of alternating current, a regulating circuit comprising, a plurality of unidirectional conductors connected as a full wave bridge and having input vertices and positive and negative output vertices, a space current device having an anode, cathode and control electrode, means for connecting the positive and negative output vertices of the said bridge respectively to the anode and cathode of the said space current device, means to couple the input vertices of the said bridge in series with the rectifier input and the source of alternating current, means to derive a signal voltage responsive to the output of the rectifier, and means for impressing the said signal voltage on the control electrode of the said space current device.

11. In a power supply system according to claim 10 wherein the said means to couple the input vertices of the said bridge in series with the rectifier input and the source of alternating current includes a direct current isolation transformer interposed between the input vertices of the said bridge and the rectifier.

12. In a power supply having a rectifier for providing direct current output to a load from

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a source of alternating current, a regulating circuit comprising a first, a second, a third and a fourth asymmetrically conducting varistor connected as a full wave bridge and having input vertices and positive and negative output vertices, a thermionic discharge tube having an anode, cathode and grid, means for connecting the positive and negative output vertices of the said bridge respectively to the anode and cathode of the said thermionic discharge tube, means to couple the input vertices of the said bridge in series with the rectifier input and the source of alternating current, means to derive a signal voltage responsive selectively to the output volt-

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age and load current of the rectifier, and means for impressing the said signal voltage on the grid of the said thermionic discharge tube.

JOHN R. STONE.

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