

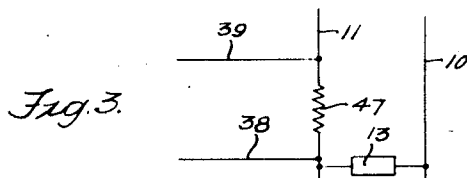
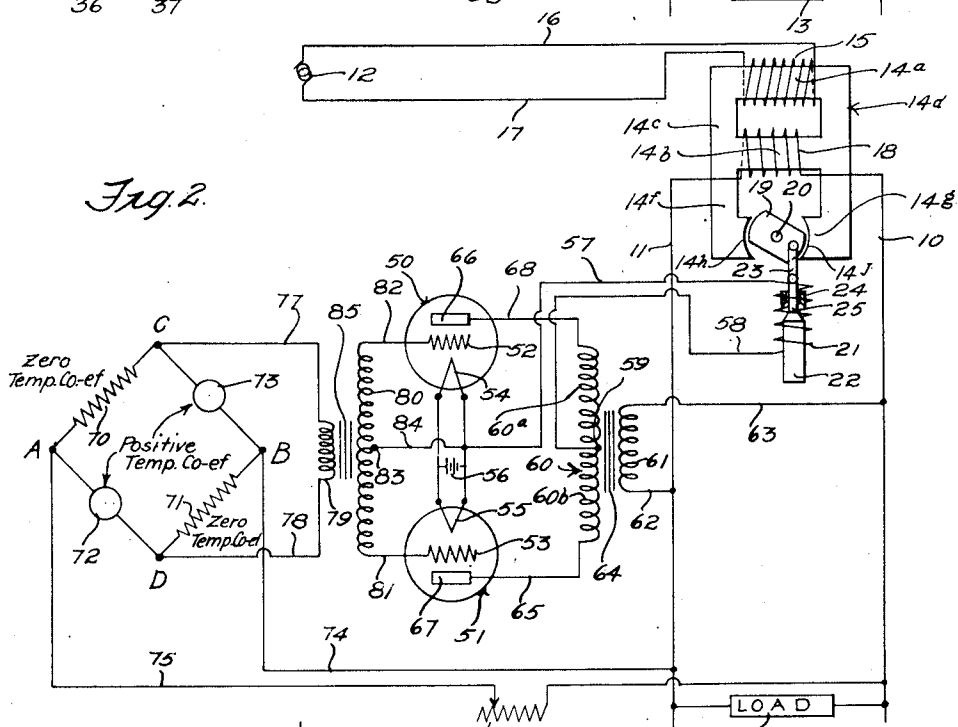
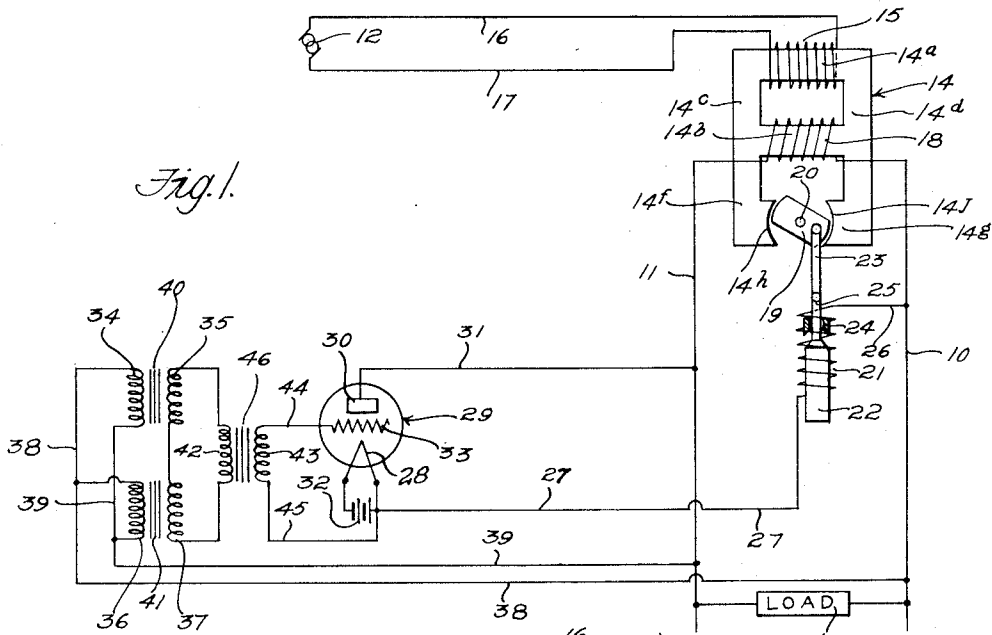
Jan. 16, 1934.

L. H. VON OHLSEN ET AL

1,943,463

SYSTEM AND APPARATUS FOR REGULATION

Filed Jan. 13, 1931



INVENTORS:-
Louis H. Von Ohlsen
Frank W. Godsey Jr.
 BY *Jarney, Blair and Curtis,*
 ATTORNEYS

UNITED STATES PATENT OFFICE

1,943,463

SYSTEM AND APPARATUS FOR
REGULATION

Louis H. Von Ohlsen and Frank W. Godsey, Jr.,
New Haven, Conn., assignors to The Safety
Car Heating & Lighting Company, a corpora-
tion of New Jersey

Application January 13, 1931. Serial No. 508,472

20 Claims. (Cl. 171—119)

This invention relates to electric regulation, and more particularly to a system and apparatus for regulating alternating current circuits.

One of the objects of this invention is to provide a simple and thoroughly practical system and apparatus for regulating a function of the alternating current energy in a circuit and, moreover, to provide such a system and apparatus that will be of efficient, accurate and dependable action. Another object is to provide a system and apparatus of the above mentioned character that may be embodied in inexpensive rugged practical form. Another object is to provide a regulating apparatus and system that will be well adapted to meet the exacting and varying conditions of hard practical use. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, and arrangements of parts as will be exemplified in the structure to be hereinafter described and the scope of the application of which will be indicated in the following claims.

In the accompanying drawing, in which are shown several of various possible embodiments of our invention,

Figure 1 shows diagrammatically the apparatus and circuit arrangement of one embodiment of our regulating system,

Figure 2 is a similar diagrammatic illustration of a possible modification, and

Figure 3 is fragmentary diagrammatic view illustrating one of the various possible rearrangements for adapting the system and apparatus of Figures 1 and 2, and shown as achieving regulation of voltage, for the regulation of current, in an alternating current circuit.

Similar reference characters refer to similar parts throughout the several views of the drawing.

Referring now to Figure 1 of the drawing, we have shown a main alternating current circuit 10—11 adapted to be supplied with energy from any suitable source of alternating current illustratively taking the form of an alternator 12, the source being operatively related to the main line 10—11 through a transformer generally indicated at 14. The load connected across conductors 10—11 may take any suitable form and is diagrammatically indicated at 13.

The transformer 14 is provided with two windings, one of which is winding 15, connected to the source 12 by conductors 16—17; the other winding 18 is connected to main line conductors

10—11. Windings 15 and 18 are related to any suitable form of iron core construction and in Figure 1 we have illustrated the latter as of the shell type and having therefor core legs 14^a and 14^b about which are placed windings 15 and 18 respectively, core legs 14^a and 14^b being connected at their ends by core portions 14^c and 14^d. The latter two portions, however, are extended, conveniently in a downward direction as viewed in Figure 1, and as indicated at 14^e and 14^f. Portions 14^e and 14^f are then extended in a direction toward each other and the adjacent end faces are curved as at 14^h and 14ⁱ so as to permit the rotation therebetween of what may be termed a core sector 19, the latter being preferably made of the same material as the remaining portions of the core of transformer 14 and having curved end faces so that member 19, pivoted for rotation at 20, may rotate between the curved end faces of the core portions 14^e and 14^f.

The core portions 14^e and 14^f and the rotatable core sector 19 forming a magnetic shunt or a leakage path for a magnetic flux produced by primary winding 15 of the transformer; this shunt or leakage path is, moreover, variable in that its reluctance may be varied by varying the position of core sector 19 about its axis 20. Assuming the core sector 19 to assume a substantially horizontal position, the leakage path thus provided will be of minimum reluctance and hence a maximum of flux from the primary coil 15 will be by-passed or shunted around or away from the core leg 14^b upon which secondary winding 18 otherwise depends for its linkage with the flux lines produced by winding 15. Were core sectors 17 to assume a vertical position as viewed in Figure 1, the air gap in the above mentioned leakage or shunt path is a maximum, the reluctance of the leakage path is likewise a maximum, and a minimum of magnetic flux is by-passed away from core leg 14^b to which secondary winding 18 is related. In the former instance the voltage induced in secondary winding 18 is a minimum and in the latter instance the voltage produced by winding 18 is a maximum.

The position of core sector 19 and hence the voltage induced in secondary winding 18 is controlled in part by a solenoid winding 21 and in part by related apparatus which controls in turn the action of solenoid coil 21. Coil 21 acts upon a movable core 22 connected by a link 23 to the core sector 19 so that movement of core 22 in a vertical direction is translated into a movement of rotation of core sector 19.

Winding 21 is preferably energized by uni-directional current and, moreover, it is so related to its magnetic circuit and the latter is so constructed that, for a given uni-directional current energization of coil 21, the latter holds core 22 in whatever position it has been moved within the range of movement of the latter. Conveniently core 22 is tapered at its upper end and coacts with a fixed magnetic member 24 provided with a tapered recess with which the upper tapered end of core 22 coacts to achieve the above mentioned coaction with coil 21. Conveniently member 24 is suitably apertured to permit the passage therethrough of the stem 25 of core 22, stem 25 being made of any suitable non-magnetic material such as brass.

Coil 21 is supplied with direct current derived from the alternating current circuit 10—11; more specifically the circuit of coil 21 will be seen to extend from conductor 10, conductor 26, coil 21, conductor 27 to the cathode 28 of an electronic conduction device generally indicated at 29, thence from anode 30 of the device 29 and by way of conductor 31 to the other line 11 of the work or translation circuit 10—11.

Device 29 may be of any desired type or construction and illustratively and preferably takes the form of a three-element thermionic vacuum tube. The cathode 28 therefore may be in the form of a heated filament supplied with heating current from any suitable source, such as a battery 32. In the above described circuit of coil 21, the uni-lateral conductivity of device 29 insures the supply of uni-directional current to winding 21 even though the latter derives its energy from the alternating current circuit 10—11.

As above noted device 29 is preferably of the three-element type of electronic conduction device; it has therefore a control element which, in the above described preferred form of this device, takes the form of a grid 33 which controls the conductivity of the ionic or electronic conduction path between the electrodes 28 and 30.

Control element or grid 33 is made to respond to changes in the voltage across conductors 10—11, in accordance with certain other features of our invention. In this latter connection it might first be pointed out that we provide two transformers 34—35 and 36—37 whose primary windings 34 and 36 are connected in parallel by conductors 38 and 39 which are connected to work circuit conductors 10—11 respectively. The transformer windings are mounted upon a suitable core or cores, the latter being diagrammatically indicated at 40 and 41. These two transformers, moreover, are constructed in any suitable manner to have certain relative characteristics that are described more in detail hereinafter. The secondary windings 35 and 37 are connected in series with each other but in such a way that the potentials thereof are in opposition to each other. These serially connected secondary windings 35 and 37 are connected to the low tension winding 42 of a high ratio step-up transformer whose high tension winding 43 has its one terminal connected by conductor 44 to grid 33 and its other terminal connected by conductor 45 to the cathode 28 of device 29. Windings 42 and 43 are suitably related to a suitable core diagrammatically indicated at 46.

The two transformers 34—35 and 36—37 are constructed dissimilarly, so that, though the primary windings 34 and 36 respond to the same

change or changes in the alternating potential to be regulated, the secondary windings 35 and 37 respond in preferably widely differing degrees to the inductive or electro-magnetic effects caused by the primary windings 34 and 36 respectively. Conveniently the two transformers may be constructed so that the one operates at a different flux density from that of the other.

For example, the transformer 34—35 may be constructed so that, when the primary winding 34 is energized by the normal or intended value of the alternating potential across the line 10—11, the core 40 is substantially saturated or is operating at a point in its saturation curve substantially at or even above the knee. While the transformer 36—37 is constructed so that when the primary winding 36 is energized by the normal or intended value of the alternating potential to be regulated the core 41 is operating at a point in the relatively steep portion of its saturation characteristic, for example, a point below the knee. The secondary windings 35 and 37 have sufficient turns therein so that, under the above described conditions of energization of the primary windings 34 and 36 at the normal alternating potential, the alternating potentials induced therein are equal.

As long therefore as the intended potential exists across conductors 10—11, to which the load 13 is connected, the potentials induced in secondary windings 35 and 37 are equal and opposite in direction and there is effective in winding 42 of transformer 42—43 a zero potential and the same is true of winding 43 of this transformer; as a result grid 33 is at substantially zero potential and normal uni-directional energizing current flows in the circuit of coil 21, the latter holding core 22 in fixed position and thus also holding core sector 19 in a fixed position such that there is such flux leakage by way of the leakage path 14', 19 and 14" as will cause winding 18 of transformer 14 to make effective across conductors 10—11 this intended potential.

Should, however, such changes take place in the alternating current circuits of the load or source as will cause the potential across conductors 10—11 to increase, the energization of winding 21, which, with this increasing potential is connected in the plate circuit of device 29, correspondingly increases but this action is so accompanied by corresponding increases in the potential applied to the primary windings 34 and 36 of transformers 34—35 and 36—37; due to the above mentioned characteristics of these two transformers, the potential induced in the secondary winding 37 increases at a much more rapid rate than does the potential induced in the winding 35 and there results therefore a potential applied to the winding 42 of transformer 42—43 which is equal to the difference between the potentials induced in secondary windings 35 and 37. The direction of the potential thus applied to primary winding 42 is, moreover, determined by the higher potential of the two induced voltages and hence by the potential of winding 37.

The potential thus applied to winding 42 is stepped-up and amplified by the transformer action of transformer 42—43 and is applied to the control grid 33, the various circuit connections and the phase relations being such that the potential of the grid 33 is raised from zero in a positive direction, thus causing a greatly increased flow of space current between cathode 28 and plate anode 30.

Thus the uni-directional current energizing winding 21 is greatly and rapidly increased, core 22 is moved in an upward direction and core sector 19 is rotated sufficiently to shunt away from core leg 14^b enough flux to cause such a reduction in voltage induced in winding 18 as will bring the potential across work circuit 10—11 back to normal again.

With the return to normal of this potential, the voltages induced in windings 35 and 37 of the differential transformers, the voltages are again equal and opposite and grid 33 restored to zero potential; the energization of coil 21 is also restored to normal but due to the construction and relation of the magnetic circuit of coil 21 with respect to the work which core 22 has to perform in moving and holding core sector 19, core 22 is held in a new fixed position.

Should the alternating potential across circuit 10—11 decrease from its normal value, an action substantially the reverse from that described above takes place. Not only is the energization of winding 21 correspondingly diminished because of its being connected with this diminishing potential, in the plate circuit of device 29, but also grid 33 is made relatively negative because now the voltage induced in secondary winding 35 decreases less rapidly than the voltage induced in the secondary winding 37 and winding 35 becomes preponderate in the circuit of primary winding 42 of transformer 42—43. Hence primary winding 39 is energized by an alternating potential equivalent to the difference between the potentials of windings 35 and 37 by 180° out of phase with respect to the potential that was effective upon winding 42 when the voltage of secondary winding 37 was preponderate of the voltage of winding 35. Grid 33 thus has its potential rapidly changed from zero to a relatively negative value and at a rate increasing with the rate of increase of the difference between the induced potential of the windings 35 and 37. This difference, moreover, is amplified, as will now be clear, by transformer 42—43.

With the grid 33 being thus made relatively negative at a high rate, the space current between cathode 28 and plate anode 30 and hence the current flowing in the circuit of coil 21 is rapidly diminished. The equilibrium theretofore existing between the upward pull of coil 21 and the opposite forces acting upon core 22, such as the weight of core 22 and of related parts or a spring, for example, is disturbed, and core 22 moves downwardly to swing core sector 19 in clockwise direction, as viewed in Figure 1. This movement continues until such an increase in reluctance in the leakage path 14^f, 19 and 14^e has taken place as will bring about the necessary increase in flux through core leg 14^b as will in turn cause the effective output voltage of winding 18 to be restored to normal value. When normal value of this potential across conductors 10—11 is re-established transformer secondary windings 35 and 37 are again balanced and zero potential is effective upon control grid 33, of device 29. Normal energization of winding 21 is thus restored and core 22 and core sector 19 are held in the position in which they have been moved.

In the system and apparatus above described in connection with Figure 1 we have illustrated certain of the features of our invention as operating to maintain constancy of potential in the alternating current circuit 10—11. If, how-

ever, it is desired to achieve constancy of current regulation we may make transformer primaries 34 and 36 of transformers 34—35 and 36—37 of Figure 1 responsive to departures from intended value of current in the circuit 10—11 and this we may achieve by connecting conductors 38—39 across a suitable impedance, such as a relatively low resistance 47 inserted in one of the main line conductors, such as conductor 11, all as is diagrammatically shown in Figure 3. The two differentially acting transformers may be suited to this relatively small potential drop across the impedance 47 or, if desired, this relatively small impedance drop may be stepped-up by an appropriate transformer interposed between it and the two transformer primaries.

In the arrangement of Figure 2, the winding 21, which controls the leakage path of the transformer 14, is connected in circuit with the output circuits of two three-element electronic conduction devices generally indicated at 50 and 51, both being preferably of the thermionic type and having their control grids or elements 52 and 53, respectively, controlled in a manner to be more clearly described hereinafter. The devices 50 and 51 are preferably related in push-pull arrangement; their filament cathodes 54 and 55 are connected in parallel and are supplied with heating current from any suitable source, diagrammatically indicated in the drawing in the form of a battery 56. A conductor 57 leads from the cathodes 54—55 to one terminal of winding 21 and a conductor 58 connects the other terminal of winding 21 to the midpoint 59 of one winding 60 of a transformer, the other winding 61 of which is connected across the main line conductors 10—11 by conductors 62 and 63. Windings 60 and 61 of the transformer are suitably related to any suitable form of magnetic circuit or core and the latter is diagrammatically indicated at 64. The plate anode 66 of device 50 is connected by conductors 68 to one terminal of transformer winding 60 and plate anode 67 of device 51 is connected by conductor 65 to the other terminal of winding 60.

Section 60^a of transformer winding 60 is thus made to provide a suitable plate potential in the circuit of vacuum tube 50 and section 60^b of this winding is thus adapted to provide a suitable plate potential for the plate circuit of the vacuum tube 51, the ratio of transformation of the transformer 60—61 being suitably selected with respect to the operating plate voltage of the vacuum tubes and with respect to the voltage of the circuit 10—11. More particularly, winding 21 is thus made to be energized by a relatively steady uni-directional current derived from the alternating current effective in circuit 10—11.

More specifically, winding 21 finds itself first in the plate circuit of one vacuum tube during one half cycle of the alternating potential effective in circuit 10—11 and during the next half cycle is in the plate circuit of the other vacuum tube. Thus, during one half cycle of alternating potential effective in winding 60, an electronic current flow is caused to take place in a circuit which may be traced as follows:— From terminal 59 of section 60^a, conductor 58, winding 21, conductor 57, cathode 54 of device 50, plate anode 66, and by way of conductor 68 back to the remaining terminal of winding section 60^a. During this half cycle, an electronic

current flow in the circuit, in which is included section 60^b of the transformer winding and the electrodes of device 50, is prevented, due to the uni-directional conductivity of the latter.

During the next succeeding half cycle, the potential effective in circuit 10—11 and also in winding 60 of the transformer is, of course, reversed in direction, and is ineffective to cause an electronic current flow to take place in the circuit immediately above traced because of the uni-lateral conductivity of the device 50. However, an electronic current flow takes place in the circuit of the other device 51 and this circuit may be traced as follows:—From terminal 59 of winding section 60^b, conductor 58, winding 21, conductor 57, cathode 55 of device 51, plate anode 67, and by way of conductor 65 to the remaining terminal of winding section 60^b.

The current flow through winding 21 will thus be seen to be in the same direction for each half cycle of alternating potential effective in the circuits and the above-described cycle of actions is repeated, winding 21 being thus energized by a uni-directional current that is, relatively speaking, very steady, and which may, if desired, be smoothed out by any suitable means. Winding 21 may thus efficiently coact with the magnetic parts 22 and 24 to achieve the intended action as above described in connection with Figure 1.

Control grids 52 and 53 are made to vary this uni-directional energizing current of winding 21 in accordance with departures from the intended value of alternating potential across conductors 10—11 and, furthermore, by an arrangement which greatly multiplies or amplifies such changes in potential. More specifically, control elements 52 and 53 are controlled by what may be termed a Wheatstone bridge made up of two pairs of arms 70—71 and 72—73.

Arms 72—73 of the bridge are made up of resistance units having a temperature coefficient of resistance such that an increase in voltage to which the unit or units are subjected results in such an increase in the resistance that the resultant current increases at a lesser rate than does the voltage; these arms of the bridge may comprise suitable lengths of iron wire, preferably enclosed in an evacuated tube. Arms 70—71 are made up of resistance units having substantially a zero temperature coefficient of resistance.

As illustrative merely of the characteristics of resistance arms 72—73, we may note that each arm may comprise an iron wire resistance in an evacuated tube in which an increase in current of only four percent takes place, though the voltage increases as much as forty percent, as, for example, from fifteen to twenty-one volts.

The junctions A and B of the bridge are connected across line conductors 10—11 by conductors 74—75, preferably through a variable resistance 76, the purpose and action of which will be described more clearly hereinafter. The opposite junctions C and D of the bridge are connected by conductors 77—78 to a winding 79 of a transformer whose other winding 80 has its one end connected by conductor 82 to control grid 52 of device 50 and its other terminal connected by conductor 81 to control grid 53 of device 51. The midpoint 83 of winding 80 is connected by conductor 84 to the cathodes 54 and 55 of the two vacuum tubes. Windings 79 and

80 are preferably related in any suitable manner to any suitable magnetic circuit or core, diagrammatically indicated at 85.

Giving the resistance units of the bridge such characteristics as those noted above, and with the zero-temperature-coefficient units 70 and 71 each of eighteen ohms resistance, we find that the bridge is balanced when the voltage across points A and B is thirty-six volts; under these conditions the voltage difference between points C and D is zero and there is then no potential effective upon the transformer winding 79. If the circuit 10—11 is to be regulated for a voltage other than thirty-six volts, for example, one hundred and ten volts, variable resistance 76 is suitably increased in ohmic value. It is specifically to be pointed out, however, that the specific figures given with respect to the construction and action of the Wheatstone bridge are given merely by way of illustration and that the bridge may be constructed, if desired, to balance at any voltage other than the above-mentioned illustrative voltage of thirty-six volts.

With a potential of thirty-six volts effective across points A and B, there is, as above noted, zero potential effective in winding 79 of transformer 79—80, and hence control elements 52 and 53 of the vacuum tube are likewise at zero potential. Under these conditions, the pull of winding 21 is in equilibrium with the downward pull of movable core 22 and connected parts, core sector 19 being thus held in a fixed position so that there is such flux leakage in the transformer core circuit as will cause winding 18 to make effective across conductors 10—11 the intended or desired potential.

Should, however, the voltage across conductors 10—11 increase, then the voltage across points A and B of the bridge increases, unbalancing the bridge and causing the production of a voltage difference between points C and D in such a direction that control elements 52 and 53 have impressed upon them a potential which is, relatively speaking, positive. The conductivity of the electronic conduction paths in the devices 52 and 51 is thereupon promptly and greatly increased, the energization of coil 21 being correspondingly promptly and greatly increased to cause the core 22 to be pulled upwardly to swing core sector 19 in counter-clockwise direction to increase the leakage of flux, through leakage path 14', 19 and 14", sufficiently to bring the potential of winding 18, and hence across conductors 10—11, back to normal. The sensitivity of the bridge is such that the potential difference created across points C and D increases at a disproportionately greater rate than the rate of increase of potential across points A and B, transformer 79—80, being preferably a step-up transformer of high ratio, further multiplying this effect. When the intended potential across the circuit 10—11 is re-established, the bridge again becomes balanced, and a state of equilibrium is restored with respect to the pull of winding 21 and the force of the parts moved thereby, core sector 19 being held in the new position into which it was moved.

Should the alternating potential across conductors 10—11 become less than the intended value, then the bridge is again unbalanced but this time in a direction such that the potential effective across points C and D acts in a direction reversed from that in which this potential difference acted when the bridge became unbalanced, due to an increase in the voltage across conduc-

tors 10—11 above the intended value. Correspondingly, the potential effective in winding 79 and also in winding 80 of the transformer 79—80 now acts in reverse direction and control elements or grids 52 and 53 are made relatively negative in potential, thus bringing about a rapid decrease in the conductivity of the electronic conduction paths in the devices 50 and 51 and correspondingly rapidly diminishing the energization of winding 21. This diminished energization of winding 21 disturbs the equilibrium existing between winding 21 and the parts coacting with it and, due to the diminished pull of winding 21, core 22 moves downwardly and rotates core sector 19 in clockwise direction throughout a sufficient extent to increase the reluctance of the leakage path 14^a—19—14^b to an extent in turn to effect a greater flow of flux through core leg 14^b, thus to bring the voltage of winding 18 and conductors 10—11 back to its normal or intended value. When this intended value is thus restored, control grids 52 and 53 are again restored to zero potential and a state of equilibrium between winding 21 and the pull of core 22 and associated parts is re-established.

If it is desired to use the arrangement of Figure 2 for achieving regulation for constancy of current in the circuit 10—11, conductors 74—75 of Figure 2, instead of being connected across conductors 10—11 so as to be responsive to changes in voltage across the circuit 10—11, are connected to be responsive to changes in the voltage drop across a resistance, such as resistance 47 of Figure 3, inserted in one of the line conductors, such as conductor 11, a suitable step-up transformer being utilized, if desired, to suit the balancing voltage of the bridge to the potential drop across the resistance 47 corresponding to the intended value of current to be maintained constant in the circuit 10—11.

It will thus be seen that there has been provided in this invention a system and apparatus in which the various objects hereinbefore noted, together with many thoroughly practical advantages, are successfully achieved.

As many possible embodiments may be made of the above invention and as many changes might be made in the embodiment above set forth, it is to be understood that all matter hereinbefore set forth or shown in the accompanying drawing, is to be interpreted as illustrative and not in a limiting sense.

We claim:

1. In apparatus of the character described, in combination, a source of alternating current, a load, a transformer interposed between said source and said load and having means for varying the flux linkage between its windings, means responsive to departures from intended value of a function of the energy supplied said load for producing a potential in one direction and responsive to departures in opposite direction for producing a potential in opposite direction, and means responsive to directional changes in said potential for controlling said first-mentioned means.

2. In apparatus of the character described, in combination, a source of alternating current, a load, a transformer interposed between said source and said load and having means for varying the flux linkage between its windings, means responsive to departures from intended value of a function of the energy supplied said load for producing a potential in one direction and responsive to departures in opposite direction for

producing a potential in opposite direction, and means including a device having an electronic conduction path affected by directional changes in said potential for controlling said first-mentioned means.

3. In apparatus of the character described, in combination, a source of alternating current, a load, a transformer interposed between said source and said load and having means for varying the flux linkage between its windings, means responsive to departures from intended value of a function of the energy supplied said load for producing a potential in one direction and responsive to departures in opposite direction for producing a potential in opposite direction, and an electronic conduction device having a control element responsive to directional changes in said produced potential for controlling said first-mentioned means.

4. In apparatus of the character described, in combination, a source of alternating current, a load, a transformer interposed between said source and said load and having means for varying the flux linkage between its windings, means responsive to departures from intended value of a function of the energy supplied said load for producing a potential in one direction and responsive to departures in opposite direction for producing a potential in opposite direction, and means for controlling said first-mentioned means and including a three-element thermionic device having its control element connected to be affected by directional changes in said produced potential.

5. In apparatus of the character described, in combination, a source of alternating current, a load, a transformer interposed between said source and said load and having means for varying the flux linkage between its windings, means responsive to departures from intended value of a function of the energy supplied said load for producing a potential in one direction and responsive to departures in opposite direction for producing a potential in opposite direction, electromagnetic means for controlling said first-mentioned means, and amplifying means responsive to directional changes in said produced potential for controlling said electromagnetic means.

6. In apparatus of the character described, in combination, a source of alternating current, a load, a transformer interposed between said source and said load and having means for varying the flux linkage between its windings, means responsive to departures from intended value of a function of the energy supplied said load for producing a potential in one direction and responsive to departures in opposite direction for producing a potential in opposite direction, electromagnetic means for controlling said first-mentioned means, and electronic conduction means having the conductivity of its electronic conduction path affected by changes in said produced potential for controlling said electromagnetic means.

7. In apparatus of the character described, in combination, a source of alternating current, a load, a transformer interposed between said source and said load and having means for varying the flux linkage between its windings, and means for controlling said first-mentioned means and including a plurality of windings, each responsive to a function of the energy supplied to said load and having core means related thereto, one of said windings and said core means having

a different saturation characteristic from said other winding and said core means.

8. In apparatus of the character described, in combination, a source of alternating current, a load supplied thereby and variable reactance means having appreciable leakage reactance for controlling a function of the energy supplied to said load, and means responsive in different degrees to changes in said function for controlling said variable reactance means by changing the leakage reactance thereof.

9. In apparatus of the character described, in combination, a source of alternating current, a load supplied thereby and variable reactance means having appreciable leakage reactance for controlling a function of the energy supplied to said load, and means directionally responsive to increases and decreases in said function for controlling said variable reactance means by changing the leakage reactance thereof.

10. In apparatus of the character described, in combination, a source of alternating current, a load supplied thereby and variable reactance means for controlling a function of the energy supplied to said load, a plurality of means responsive to changes in said function but responsive in different degrees, and means responsive to the differential effect of said plurality of responsive means for controlling said variable reactance means.

11. In apparatus of the character described, in combination, a source of alternating current, a load supplied thereby and variable reactance means having appreciable leakage reactance for controlling a function of the energy supplied to said load, a plurality of resistance elements having different temperature coefficients connected to be responsive to changes in said function, and means controlled by said resistance elements for controlling said variable reactance means by changing the leakage reactance thereof.

12. In apparatus of the character described, in combination, a source of alternating current, a load supplied thereby and variable reactance means having appreciable leakage reactance for controlling a function of the energy supplied to said load, and means for controlling said variable reactance means by changing the leakage reactance thereof and including an electrical bridge having two points thereof connected to be responsive to changes in said function, said bridge being adapted to be balanced as long as said function remains at its intended value and adapted to make effective potential differences acting in a direction depending upon the direction of departure of said function from its intended value.

13. In apparatus of the character described, in combination, a source of alternating current, a load supplied thereby and variable reactance means having appreciable leakage reactance for controlling a function of the energy supplied to said load, means for controlling said variable reactance means by changing the leakage reactance thereof and including an electrical bridge having two points thereof connected to be responsive to changes in said function, said bridge being adapted to be balanced as long as said function remains at its intended value and adapted to make effective potential differences acting in a direction depending upon the direction of departure of said function from its intended value; and a transformer having one winding connected to be responsive to said potential differences and having its other winding

connected to affect said variable reactance means.

14. In apparatus of the character described, in combination, a source of alternating current, a load supplied thereby and variable reactance means for controlling a function of the energy supplied to said load, means for controlling said variable reactance means and including an electrical bridge having two points thereof connected to be responsive to changes in said function, said bridge being adapted to be balanced as long as said function remains at its intended value and adapted to make effective potential differences acting in a direction depending upon the direction of departure of said function from its intended value, and an electronic conduction device affected by said potential differences interposed between said bridge and said variable reactance means.

15. In apparatus of the character described, in combination, a source of alternating current, a load supplied thereby and variable reactance means for controlling a function of the energy supplied to said load, means for controlling said variable reactance means and including an electrical bridge having two points thereof connected to be responsive to changes in said function, said bridge being adapted to be balanced as long as said function remains at its intended value and adapted to make effective potential differences acting in a direction depending upon the direction of departure of said function from its intended value, a transformer having one winding connected to be responsive to said potential differences, and an electronic conduction device having its conductivity affected by the other winding of said transformer and being interposed between said other winding and said variable reactance means.

16. In apparatus of the character described, in combination, a source of alternating current, a load supplied thereby and variable reactance means for controlling a function of the energy supplied to said load, means for controlling said variable reactance means and including an electrical bridge having two points thereof connected to be responsive to changes in said function, said bridge being adapted to be balanced as long as said function remains at its intended value and adapted to make effective potential differences acting in a direction depending upon the direction of departure of said function from its intended value, and an electronic conduction device interposed between said bridge and said variable reactance means and having its conductivity varied in response to said potential differences.

17. In apparatus of the character described, in combination, a source of alternating current, an alternating current load supplied with alternating current energy from said source, a transformer interposed between said source and said load and having a shunt magnetic path associated with its magnetic circuit, and means including an electronic conduction device responsive to changes in a function of the energy supplied to said load for controlling the reluctance of said shunt magnetic path.

18. In apparatus of the character described, in combination, a source of alternating current, a load, a transformer interposed between said source and said load and having a variable shunt associated with its magnetic circuit, a plurality of means connected to be responsive to changes in a function of the energy supplied

to said load but each responding in different degree to changes in said function, means including an electronic conduction device for controlling said variable shunt, and means effecting change in conductivity of said device in response to the different degrees of response of said plurality of means.

19. In apparatus of the character described, in combination, a source of alternating current, a load, a transformer interposed between said source and said load and having a variable shunt associated with its magnetic circuit, a plurality of means connected to be responsive to changes in a function of the energy supplied to said load but each responding in different degree to changes in said function, and means responsive to the differential effects of said differing degrees of response of said plurality of means for controlling said variable shunt.

20. In apparatus of the character described, in combination, a source of alternating current, a load supplied thereby and variable reactance means for controlling a function of the energy supplied to said load, and means for controlling said variable reactance means and including a plurality of windings, each responsive to a function of the energy supplied to said load and having core means related thereto, one of said windings and said core means having a different saturation characteristic from another of said windings and its core means, whereby said windings respond in different degree to changes in said function, and means responsive to the differential effects of said differing degrees of response of said plurality of windings for affecting said variable reactance means.

FRANK W. GODSEY, JR.
LOUIS H. VON OHLSEN.

80

85

90

95

100

105

110

115

120

125

130

135

140

145

150

20

25

30

35

40

45

50

55

60

65

70

75