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SYSTEM AND APPARATUS FOR REGULATION

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Fig. 1.

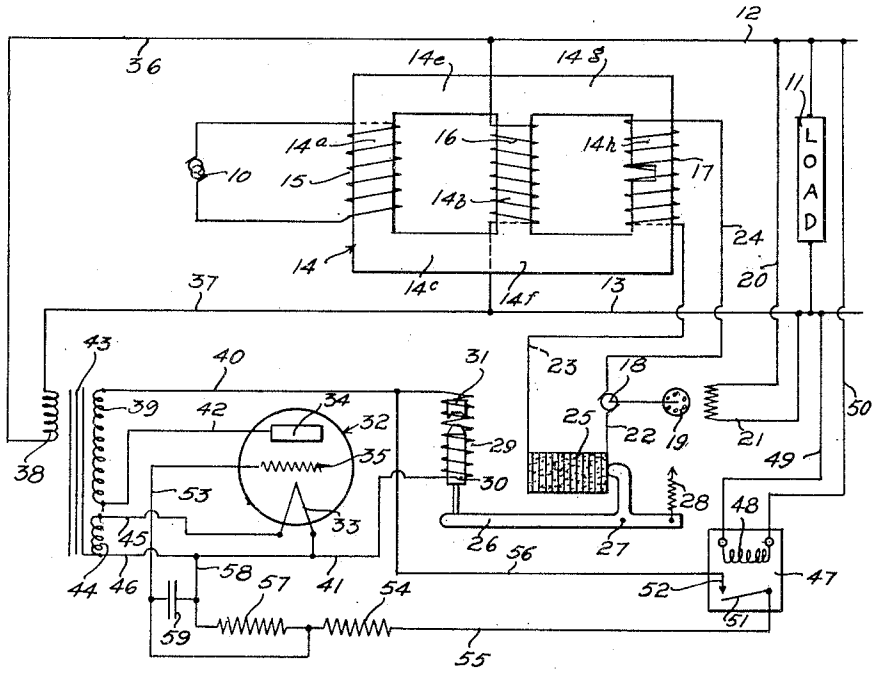


Fig. 2.

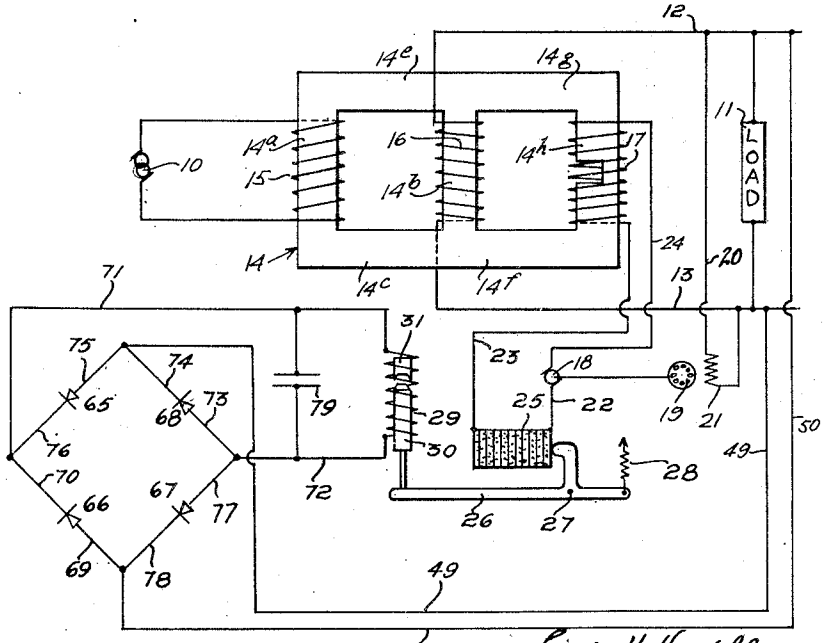
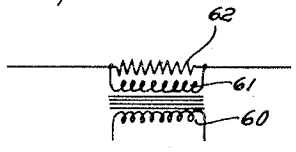


Fig. 3.



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SYSTEM AND APPARATUS FOR REGULATION

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This invention relates to electric regulation and more particularly to an apparatus and system for the regulation of alternating current circuits.

One of the objects of this invention is to provide a thoroughly dependable and simple apparatus and system for regulating a function of the alternating current energy in a work or translation circuit. Another object is to provide a system and apparatus of the above-mentioned character that will be capable of inexpensive embodiment in practical form, that will be sensitive and accurate in action and that will be well adapted to meet certain peculiar conditions of 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 a system and apparatus for achieving regulation for constancy of voltage in an alternating current supply or work circuit;

Figure 2 is a diagrammatic representation of a modified form of system and apparatus, and

Figure 3 is a similar but fragmentary diagrammatic representation of the systems of Figures 1 and 2, but showing the changes effected to make those systems regulate for constancy of alternating current, as distinguished from constancy of alternating potential.

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

Referring now to Figure 1 of the drawing, there is shown at 10 a source of alternating current such as an alternator intended to supply alternating current energy to a load diagrammatically indicated at 11, the latter being connected to the work circuit 12—13. The latter circuit is connected to the source 10 through a transformer generally indicated at 14, the latter having a primary winding 15 connected to the source 10 and a secondary winding 16 connected to the work circuit 12—13.

Windings 15 and 16 are related to a magnetic core having a vertical leg 14^a about which extends winding 15 and a vertical leg 14^b about which extends winding 16, these vertical legs 14^a and 14^b being connected by horizontal legs 14^c and 14^e, thus to form a complete magnetic circuit for the flux produced by the primary winding 15.

Associated with this magnetic circuit and preferably with the core leg 14^b is what may be termed a magnetic shunt formed preferably by extending horizontal core legs 14^c and 14^e as at 14^f and 14^g, respectively, the latters extensions being joined by a vertical leg 14^h. The core may be made of any suitable magnetic material, such as laminated sheet iron or silicon steel.

Disregarding, for the moment, the magnetic shunt 14^g—14^h—14^f, windings 15 and 16 may have any desired or suitable ratio of transformation to suit the potential of the source 10 and the potential across the work circuit 12—13 from which the load 11 is supplied with energy, and these windings with their magnetic circuits may have any suitable or desired power or load characteristics.

Surrounding the leg 14^h of the magnetic shunt is a winding 17 energized by a direct current obtained from any suitable source; illustratively, we have shown a generator 18 as a source of direct current energy for this winding 17, the generator 18 being driven by any suitable motor 19 conveniently supplied with energy from the work circuit 12—13, being connected to the latter by conductors 20 and 21.

The energization of direct current winding 17 from the direct current source 18 is variable under the control of a compressible carbon pile 25, the latter with winding 17 being in a circuit across the source 18 that extends from source 18, conductor 22, carbon pile 25, conductor 23, winding 17, and thence by way of conductor 24 back to the other terminal of generator 18.

The resistance of carbon pile 25 is controlled by means of a bell crank lever 26 pivoted at 27 and having one of its arms in engagement with the free or unanchored end of carbon pile 25, a spring 28 acting upon the lever 26 to swing the latter in a direction to compress the carbon pile and thus reduce its resistance; opposing the action of spring 28 is a solenoid winding 29 acting upon a core 30 connected to the lever 26.

Coil 29 and the magnetic circuit to which it is related are constructed and designed, as is diagrammatically indicated in Figure 1, so that the winding 29, when energized by a certain value of uni-directional current, holds the core 30 in whatever position it has been moved within its range of movement; conveniently, to achieve

this purpose, core 30 may be tapered at its upper end and may coact with a fixed core piece 31 provided with a correspondingly tapered recess with which the upper tapered end of core 30 coacts. Moreover, to achieve this holding action most efficiently, winding 29 should be energized by uni-directional current that is relatively free from pulsations of low frequency. Nevertheless, coil 29 is energized by a function of the alternating current energy supplied to the load 11 or work circuit 12—13 but, in accordance with certain features of our invention, in a manner to prevent the relatively low frequency, such as the 60- or 25-cycle frequency usually employed in commercial power circuits, from having a detrimental effect upon the action of the solenoid. Moreover, as will be described in detail hereinafter, the achievement of a state of equilibrium between the pull of the solenoid 29—30 and the pull of spring 28 bears a definite relation to the energization of winding 17 of the transformer core, and hence to the degree of saturation by winding 17 of the above-mentioned magnetic shunt.

Coil 29 is energized by uni-directional current derived by rectification of alternating current derived from the alternating current source 10, and such rectification, together with other features of action and control to be hereinafter more clearly described, is achieved preferably by way of a rectifier 32 preferably taking the form of a three-element thermionic type of vacuum tube. Device 32 has a suitable cathode, illustratively in the form of a filament 33, a plate anode 34 and, in accordance with certain other features of our invention, it also has a control grid or control element 35 for controlling the uni-directionally conductive electronic conduction path extending from the filament cathode 33 to the plate anode 34.

Connected across work circuit 12—13, by conductors 36 and 37, is one winding 38 of a transformer whose other winding 39 is connected in circuit with the above-mentioned uni-directional electronic conduction path of the device 32 and also with winding 29. More specifically, this circuit will be seen to extend from one terminal of transformer winding 39, conductor 40, coil 29, conductor 41, cathode 33 of device 32, plate anode 34, and by way of conductor 42 back to the other terminal of winding 39 of the transformer. Windings 38 and 39 are related to a suitable magnetic circuit diagrammatically indicated at 43.

Winding 39 thus supplies a suitable voltage in the plate circuit of device 32 for achieving adequate uni-directional energization of winding 29 that controls the carbon pile 25 and the energization of winding 17 on the shunt of transformer 14, the ratio of transformation of transformer 38—39 being suited to this plate circuit voltage and to the voltage of the work circuit 12—13.

Cathode 33 derives its heating current from a suitable low voltage winding 44 suitably related to the magnetic circuit 43 of transformer 38—39 and connected to filament cathode 33 by conductors 45 and 46.

Bearing in mind that, in the arrangement of Figure 1, the alternating potential across conductors 12—13 is to be maintained constant, it is to be noted that winding 38 of transformer 38—39—44 is connected across the work circuit 12—13 and its voltage will vary as the voltage of circuit 12—13 varies; like variations correspondingly takes place in the secondary windings 39 and 44 of this transformer and may, if desired, be made to take a material part in the regulation of the voltage across the work circuit 12—13. Thus, an increase in the voltage across the work circuit increases the voltage of winding 39 and thus, by increasing the voltage in the plate circuit of device 32, causes a corresponding increase in the uni-directional current energizing control winding 29. The same increase in voltage across the work circuit 12—13 causes an increase in the voltage of transformer winding 44, thus increasing the heating of filament cathode 33, and thus increasing the conductivity of the electronic conduction path in which the transformer winding 39 and control winding 29 are included with consequent increase in uni-directional energizing current in winding 29. These effects will thus be seen to act cumulatively upon the control winding 29 and we prefer to use these cumulative effects or either of them though, in view of certain other features of our invention, we desire it to be understood that our invention is not to be limited to either or both of these effects.

In accordance with these other features of our invention, we cause variations in voltage across the work circuit 12—13 to affect the control element or grid 35 of the thermionic device 32 and the action of the latter we place under the control of a contact-making voltmeter generally indicated at 47. Voltmeter 47 has its actuating coil 48 connected across work circuit 12—13 by conductors 49 and 50 so as to be responsive to any changes in voltage in the work circuit. Under the control of coil 48 of voltmeter 47 is a movable contact 51 coacting with a fixed contact 52. The parts of the voltmeter 47 are so constructed that contact 51 separates from contact 52 when the intended voltage across the circuit 12—13 is departed from in a downward direction and is brought into contact with fixed contact 52 if the intended voltage begins to be exceeded.

The closure of contacts 51—52 is made effective to apply a positive potential to control grid 35, thus to cause the latter to greatly increase the conductivity of the electronic conduction path in device 32 and correspondingly to cause the uni-directional current in control coil 29 to increase. This positive potential, thus applied to grid 35, may be obtained in any suitable manner, and conveniently we arrange grid 35 and contacts 51—52 in a circuit that leads to conductor 40 which joins the positive terminal of transformer winding 39 with the positive terminal of winding 29. More specifically, the closure of contacts 51—52 effects the closure of a circuit extending from grid 35, conductor 53, a resistance 54, conductor 55, movable contact 51, fixed contact 52, and by way of conductor 56 to the positive conductor 40.

When contacts 51—52 are open, grid 35 is, in effect, connected to the filament cathode 33 by conductor 53, a resistance 57, and conductors 58 and 46. A suitable condenser 59 is shunted between the grid 35 and the cathode 33.

Resistances 54 and 57 and the capacity of condenser 59 are proportioned so that the rise in voltage on grid 35, when contacts 51—52 close, is at the desired rate to give a correspondingly desired rate of rise of uni-directional current in the plate circuit of the tube 32 and in which plate circuit is included the regulating coil 29.

Accordingly, when an increase, above intended

value, in the voltage across conductors 12—13 takes place, not only is the voltage of transformer winding 39 and the filament-heating current supplied by transformer winding 44 correspondingly increased with results and effects already above-mentioned, but also the voltmeter 47 effects a closure of contacts 51—52 to cause a suitable rate of increase in positive potential to be effective upon control grid 35. Raising the positive potential applied to control grid 35 effects a corresponding raising or increase of the conductivity of the electronic conduction path in the device 32 and causes a greater flow of uni-directional current in the plate circuit and hence through the regulating coil 29. This latter action may be utilized alone or it may and preferably does have contributed thereto the action of the increase in voltage of the plate anode 34 and the action of the increased heating of filament cathode 33 added thereto to cause an increase in the uni-directional current energizing regulating winding 29.

This rapidly increased energization of regulating winding 29 disturbs the equilibrium theretofore existing between its pull and the pull of spring 28, and lever 26 is moved in clockwise direction about its pivot 27 to diminish the pressure on carbon pile 25, increase its resistance and thus relatively rapidly diminish the direct current energization of winding 17 on the transformer shunt. Up to that time, the current through winding 17 on the shunt 14^g—14^h—14^f has been sufficient to almost saturate this magnetic shunt, thus so greatly diminishing the permeability of this magnetic shunt to the flux produced by primary winding 15 of the transformer 14 that practically all of the flux produced by winding 15 passes through the core leg 14^b about which extends winding 16. At normal or intended voltage across work circuit 12—13, the energization of control winding 29 is such that its pull on core 30 is in equilibrium with the pull of spring 28.

But, due to the above-assumed increase in voltage across circuit 12—13, this equilibrium has been disturbed and the direct current energization of winding 17 diminished; the magnetic saturation theretofore caused by winding 17 is correspondingly relatively rapidly diminished and thus the permeability of the magnetic shunt to flux produced by transformer primary 15 is relatively rapidly increased. Hence, some of the flux produced by primary windings 15 and theretofore passing through core leg 14^b is now permitted to pass through the shunt circuit 14^g—14^h—14^f, thus diminishing the flux linkage with transformer secondary 16 and thus diminishing the potential produced in the second winding 16. Thus, the voltage across the circuit 12—13 is quickly brought back to normal, and should it be over-reached in a diminishing direction, voltmeter 47 releases movable contact 51 and the latter action causes the removal of the theretofore applied positive potential from the control grid 35. The conductivity of the vacuum tube 32 is thus at once greatly diminished and there results also a diminution in the energizing current flowing through regulating winding 29; this action is accompanied by decreases in the plate voltage supplied by transformer secondary 39 and by diminished heating of cathode 33, due to the diminishing voltage produced in transformer secondary 44. Spring 28 then becomes effective to start increasing the pressure on carbon pile 25 and this action in turn results in increasing the excitation of the winding 17 on the transformer shunt so as to increase the degree of saturation of the transformer shunt circuit and thus to diminish the amount of flux shunted away from secondary winding 16. The flux linkage with the latter winding is thus increased and the otherwise diminishing voltage across conductors 12—13 is quickly brought back to normal. The rate at which this cycle of operations is repeated may depend upon various factors and due to the inherent relatively high rapidity of operation of the circuits controlling the energization of regulating coil 29, the cyclic repetition of the above-described sequence of operations is relatively high with the result that a high degree of constancy of potential across the circuit 12—13 may be dependably achieved and maintained.

Should it be desired to maintain constancy of current in the circuit 12—13, as distinguished from constancy of potential, we may make the instrument 47 of Figure 1 responsive to changes from an intended value of current supplied to the load 11, and accordingly we may interpose between the voltmeter 47 a step-up transformer (see Figure 3) whose high voltage winding 60 is connected by conductors 49—50 to the winding 48 of the voltmeter 47 and whose relatively low voltage winding 61 is connected across a low resistance shunt 62 inserted in one of the main line conductors, such as the conductor 13, winding 61 being thus responsive to the potential drop across the resistance 62 which, of course, varies with changes in current therethrough.

Turning now to Figure 2 of the drawing, we have there illustrated a possible modified form or embodiment of certain of the features of the arrangement of Figure 1 and, more particularly, we have shown in Figure 2 an arrangement for supplying the controlling coil 29 with uni-directional current derived from the alternating current. Interposed between the work circuit 12—13 and the controlling coil 29 is a number of rectifiers, illustratively four; these rectifiers are indicated in the drawing at 65, 66, 67 and 68. They may be of any suitable construction, for example, they may be of the thermionic type of valve having a heated cathode and a plate anode. As appears from Figure 2, these rectifiers are arranged so as to insure full-wave rectification of the alternating potential and hence current to which the regulating coil 29 is to be responsive.

The circuit arrangement will be clear, it is believed, when the action of the system and arrangement of Figure 2 are considered in detail. Assuming one half-wave of the potential effective across the work circuit 12—13 to be momentarily effective, a current, proportional to the potential and corresponding to this half-wave, may be considered as flowing from main line conductor 12, conductor 50, conductor 69, valve or rectifier 66, conductor 70, conductor 71, regulating winding 29, conductor 72, conductor 73, valve 68, conductor 74, and thence by way of conductor 49 to the other main line conductor 13. During this half-wave the flow of current through coil 29 in reversed direction is prevented by valve 67 and 65. The next succeeding half-wave of the alternating potential effective across conductors 12—13 is now reversed and sends a current through coil 29 in the same direction that the current flowed therethrough during the preceding half-wave, but

this time from main line conductor 13, conductor 49, conductor 75, valve 65, conductor 76, conductor 71, regulating coil 29, conductor 72, conductor 77, valve 67, conductor 78, and by way of conductor 50 to the other main line conductor 12. During this action current flow through coil 29 in opposite direction is prevented by the action of valves 68 and 66.

This action of the valves, arranged as above described and as shown in Figure 2, is repeated for each cycle of the alternating potential across conductors 12—13, the coil 29 being thus always energized by current flowing therethrough in the same direction and, moreover, by a current, the magnitude or intensity of which, is proportional to the potential effective across the work circuit 12—13. If desired, a condenser 79 may be shunted across coil 29 to smooth out the successive half-waves of current corresponding to these successive rectified half-cycles and thus the current through winding 29 is made to be a substantially steady uni-directional current proportional to the effective value of the alternating potential across the circuit to be regulated for constancy of potential.

As long as the potential across the work circuit 12—13 is of the desired or intended value, the uni-directional current through coil 29 is sufficient to cause winding 29 to hold the movable parts associated with the carbon pile 25 in a definite position, a state of equilibrium being thus maintained. As soon, however, as the effective value of alternating potential across the work circuit 12—13 departs from the intended value, this state of equilibrium is disturbed and regulating coil 29 is at once effective to cause a change in the saturation of the magnetic shunt 14^g—14^b—14^f.

For example, should the voltage across the work circuit increase, the uni-directional energization of coil 29 correspondingly increases, the resistance of carbon pile is increased, thus diminishing the magneto-motive-force of winding 17 on the transformer 14, and thus permitting an increase in the amount of flux that this magnetic shunt by-passes away from the core leg 14^b. The decrease of the flux passing through core leg 14^b correspondingly diminishes the flux linkages with winding 16 and the voltage produced by the latter and effective across the circuit 12—13 is thus likewise diminished and with it the uni-directional current energizing winding 29. As soon as the intended value is again reached, winding 29 has its pull restored to normal and equilibrium between that pull and the pull of spring 28 is re-established and the new value of magnetic saturation of the transformer shunt circuit is thus maintained until another departure from the intended value of effective alternating potential across the work circuit takes place.

Should this effective potential diminish, a reversed action takes place, the correspondingly diminished energization of regulating winding 29 permitting spring 28 to disturb the theretofore existing equilibrium and to decrease the resistance of carbon pile 25, thus to increase the magnetic saturation of the transformer shunt and correspondingly to diminish the flux that the shunt by-passes around the core leg 14^b. Thus, more of the flux produced by primary winding 15 is forced through core leg 14^b and this action continues until the potential across work circuit 12—13 is again restored to normal, whence equilibrium is re-established between the coil 29 and spring 28 and related movable parts, and this new value of magnetic saturation caused by winding 17 maintained until another departure from the intended value of potential across the work circuit takes place.

With each re-establishment of the intended value of alternating potential, regulating coil 29, due to the character of the current energizing it, is enabled dependably to coact with the character of its magnetic circuit and to hold the core 30 and associated movable parts in whatever position they have been moved due to the preceding change or departure that initially caused movement thereof, and thus the intended or desired permeability of the magnetic shunt associated with the core or transformer 14 may be maintained. As will be clear from the foregoing, the saturation of the core shunt, caused by direct current winding 17 may vary throughout relatively wide limits and due to such features as those above-described, winding 29 may be depended upon to maintain the saturation at any one value within this relatively wide range.

If it is desired to employ the arrangement of Figure 2 for maintaining constancy of alternating current flow in the circuit 12—13, the rectifiers, instead of being connected by conductors 49 and 50 across the work circuit 12—13, are connected by conductors 49—50 (see now Figure 3) to the relatively high voltage winding 50 of a transformer, the primary winding 61 of which is shunted across a relatively low resistance 62 that carries the current flowing to the load and which is to be maintained constant. The transformer 50—61 is thus made to respond to changes in the potential drop across the resistance 62, this drop being, of course, directly proportional to the current flowing through the resistance 62. The ratio of transformation of the transformer 61—50 is appropriately suited to the characteristics of the rectifiers and to the resistance drop to be maintained constant across the resistance 62.

It will thus be seen that there has been provided in this invention a system and apparatus in which the several objects above set forth, together with many thoroughly practical advantages are successfully achieved. It will furthermore be seen that the system and apparatus are well adapted to meet the varying conditions of hard practical use.

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 and a work circuit and a transformer interposed therebetween, said transformer having electromagnetic means for affecting the ratio of transformation of said transformer, a compressible carbon pile for controlling said electromagnetic means, a winding for controlling the pressure on said carbon pile, an electronic conduction device for affecting the energization of said winding, a contactor for affecting the conductivity of said device, and means responsive to changes in a function of the output of said source for controlling said contactor.

2. In apparatus of the character described, in

combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having electromagnetic means for affecting the ratio of transformation of said transformer, a compressible carbon pile for controlling said electromagnetic means, a winding for controlling the pressure on said carbon pile, an electronic conduction device having a heated cathode and connected in circuit with said winding, and means for varying the heating of said heated cathode substantially in response to changes in a function of the output of said source.

3. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having electromagnetic means for affecting the ratio of transformation of said transformer, a compressible carbon pile for controlling said electromagnetic means, a winding for controlling the pressure on said carbon pile, and means including a unilaterally conductive device connecting said winding to be energized by uni-directional current from said alternating current source.

4. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having electromagnetic means for affecting the ratio of transformation of said transformer, a compressible carbon pile for controlling said electromagnetic means, a winding for controlling the pressure on said carbon pile, means including a uni-laterally conductive device connecting said winding to be energized by uni-directional current from said alternating current source, and means responsive to changes in a function of the output of said source for varying the conductivity of said device.

5. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having electromagnetic means for affecting the ratio of transformation of said transformer, a compressible carbon pile for controlling said electromagnetic means, a winding for controlling the pressure on said carbon pile, means including a uni-laterally conductive device connecting said winding to be energized by uni-directional current from said alternating current source, said device having a heated cathode, and means affecting the heating of said cathode in response to changes in a function of the output of said source.

6. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having electromagnetic means for affecting the ratio of transformation of said transformer, a compressible carbon pile for controlling said electromagnetic means, a winding for controlling the pressure on said carbon pile, means including a uni-laterally conductive device connecting said winding to be energized by uni-directional current from said alternating current source, said device having a control element to vary its conductivity, a contactor for affecting said control element, and means responsive to changes in a function of the output of said source for controlling said contactor.

7. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having a variable magnetic shunt associated with its magnetic circuit, means including a plurality of rectifying devices arranged substantially in the form of a bridge for controlling said shunt, and means connecting said first-mentioned means to be responsive to a function of the energy supplied by said generator, whereby said magnetic shunt is varied in response to changes in said function.

8. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having a variable magnetic shunt associated with its magnetic circuit, and means for controlling said variable shunt, said means including a coil and a plurality of rectifying devices arranged substantially in the form of a bridge, two diagonal points of which are connected to be responsive to changes in a function of the energy supplied to said work circuit and two other diagonal points of which are connected to said coil.

9. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having a variable magnetic shunt associated with its magnetic circuit, and means for controlling said variable shunt, said means including a variable resistance and means responsive to changes in a function of the energy supplied to said work circuit for controlling said variable resistance.

10. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having a variable magnetic shunt associated with its magnetic circuit, a carbon pile, means affected by said carbon pile for controlling said variable shunt, a coil for controlling the pressure on said carbon pile, and means including a rectifying device connecting said coil to be responsive to a function of the energy supplied to said work circuit.

11. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having a variable magnetic shunt associated with its magnetic circuit, a carbon pile, means controlled by said carbon pile for controlling said variable shunt, a coil for controlling the pressure on said carbon pile, and means including amplifying means connecting said coil to be responsive to a function of the alternating current energy supplied to said work circuit.

12. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween said transformer having a variable magnetic shunt associated with its magnetic circuit, a carbon pile for controlling said variable shunt, a coil for controlling the pressure on said carbon pile, a uni-laterally conductive device having an anode and a heated cathode connected in circuit with said source and with said coil to supply the latter with uni-directional current derived from said source, and means responsive to changes in a function of the energy supplied to said work circuit for varying the conductivity of said device.

13. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having a variable magnetic shunt associated with its mag-

netic circuit, a carbon pile for controlling said variable shunt, a coil for controlling the pressure on said carbon pile, means including a contactor for affecting the conductivity of said device, and means responsive to changes in a function of the energy supplied to said work circuit for controlling said contactor.

14. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having a magnetic shunt associated with its magnetic circuit, a winding about said shunt, a source of direct current for energizing said winding, a variable resistance for controlling the energization of said winding, and means including an electronic conduction device responsive to a function of the energy supplied to said work circuit for controlling said variable resistance.

15. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having a magnetic shunt associated with its magnetic circuit, a winding about said shunt, a source of direct current for energizing said winding, means for controlling the energization of said winding, a coil for controlling said means, and amplifying means responsive to changes in a function of the energy supplied to said work circuit for affecting said coil.

16. In apparatus of the character described, in combination, a source of alternating current and a work circuit and a transformer interposed therebetween, said transformer having a magnetic shunt associated with its magnetic circuit, a winding about said shunt, a source of direct current for energizing said winding, a compressible carbon pile for controlling the energization of said winding, a coil for affecting the pressure on said pile, and means including rectifying means connecting said coil to be responsive to a function of the energy supplied to said work circuit.

17. In apparatus of the character described, in combination, a source of alternating current, a work circuit supplied therefrom, reactance means for controlling a function of the energy supplied to said work circuit, said reactance means having related to it means for varying the effective flux of said reactance means per unit current energizing said reactance means, means for controlling said reactance-varying means and including an electronic conduction device having a control element, and circuit-making and breaking means responsive to changes in said function for affecting said control element.

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