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S. STEINITZ

2,453,470

ELECTRIC CONTROLLING APPARATUS

Filed Dec. 7, 1945

2 Sheets-Sheet 1

Fig. 1.

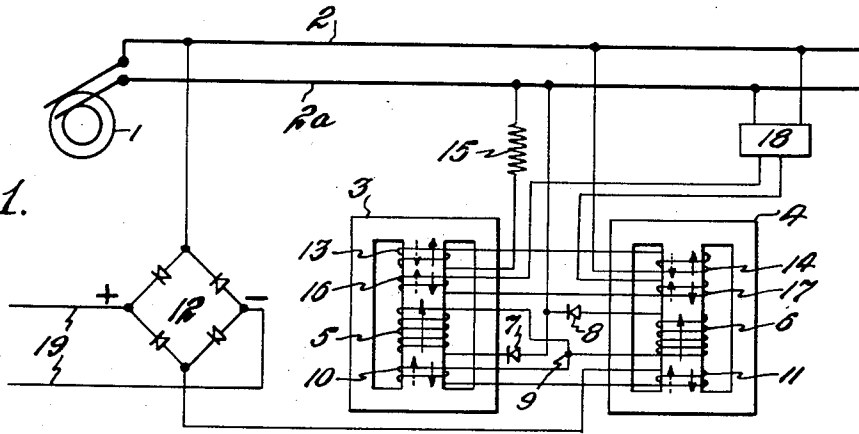


Fig. 2.

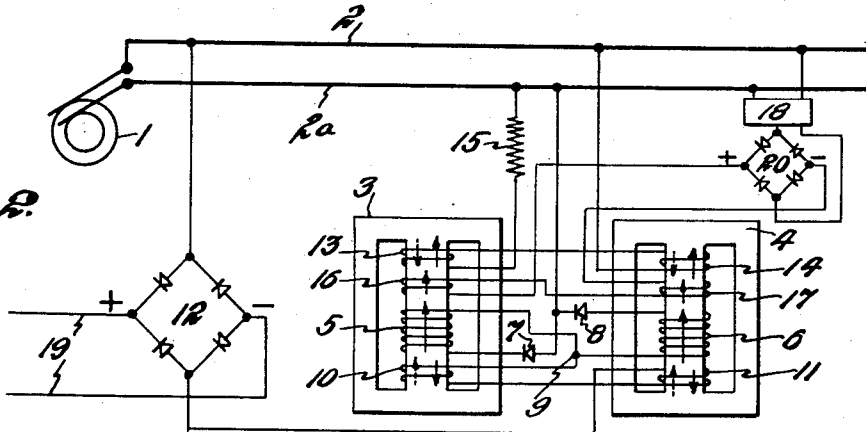
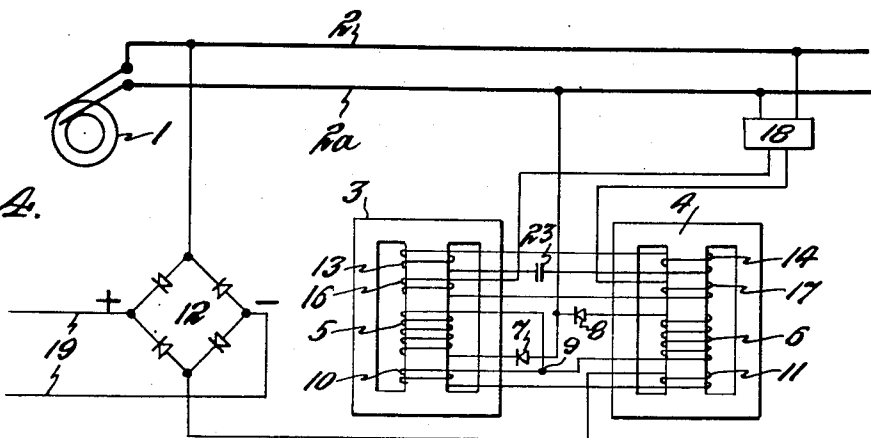


Fig. 4.



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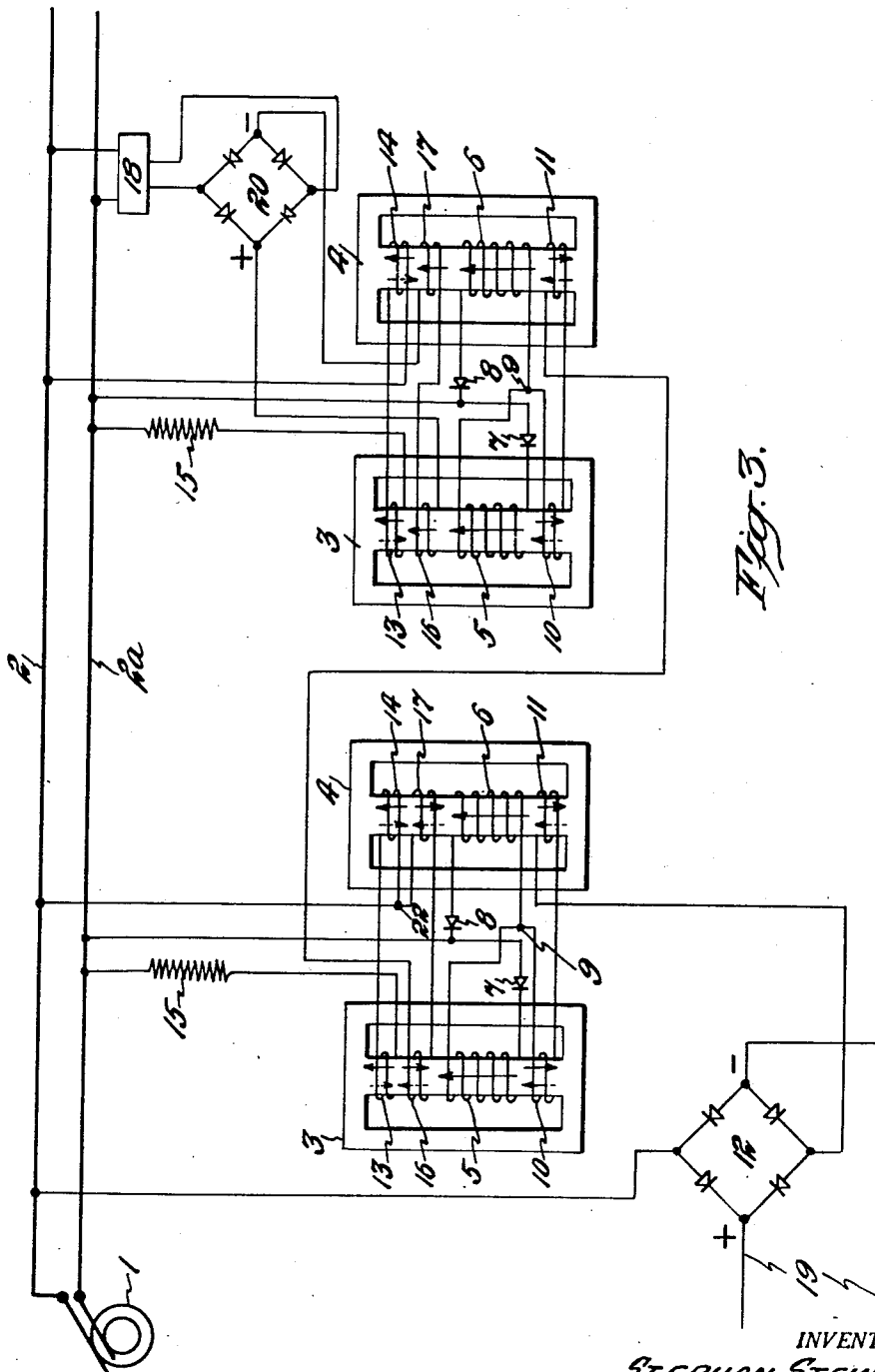
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2 Sheets-Sheet 2



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ELECTRIC CONTROLLING APPARATUS

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11 Claims. (Cl. 323—89)

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The controlling apparatus of this invention particularly relates to means for amplifying comparatively small changes in voltage or current in order to supply the amplified changes for use in control purposes such as for the regulation of a dynamo-electric machine or for recording or indicating the amplified changes and in general for various other purposes where it is desired to amplify comparatively small changes to pronounced changes.

The main object of the invention is to provide amplifying means for markedly increasing the changes where the change at the source is comparatively small; and to accomplish this by simple and dependable means without moving parts. Another object is to reduce the care and attention required to a minimum by the avoidance of variable contacts and other movable parts. Another object is to provide amplifying apparatus which will be rapid in its response to changes and at the same time secure stability of control.

Further objects and advantages will be understood from the following description and accompanying drawings illustrating preferred embodiments of the invention.

In the U. S. Patent of F. G. Logan granted October 21, 1941, No. 2,259,647 there is disclosed apparatus embodying reactor control particularly for obtaining a wide range of voltage control applied to a load circuit. The present invention embodies certain features thereof but in addition provides auxiliary controls for securing greater amplification of comparatively small changes at the source and for securing a more rapid response to changes at the source.

Fig. 1 is a diagram showing one embodiment of the present invention wherein the variable source supplying the amplifying means is alternating; Fig. 2 is a diagram similar to Fig. 1 except the variable source is direct current; Fig. 3 is a diagram showing the cascading of two amplifying means wherein one is supplied by a variable direct current and the other is supplied by an amplified variable alternating current; and Fig. 4 is a diagram showing a modification of Fig. 1.

Referring to Fig. 1, an alternating source of current 1 is indicated supplying current to the mains 2, 2a and it is assumed that the variable voltage of the lines is desired to be amplified for the purpose of regulating the generator in any way desired or for any other controlling or indicating purpose. Two reactors having cores 3 and 4 are indicated, although in some cases these may be combined to a single core but the explanation of the mode of operation is simpler and more

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easily understood when two separate cores are used. A main winding 5 is shown enveloping the middle leg of the core 3 and a similar main winding 6 is shown enveloping the middle leg of the core 4. These windings are supplied respectively with pulsating direct currents. This result is obtained by connecting one of the lines 2a of the source of energy to the winding 5 through the half-wave rectifier 7 and by similarly connecting the line 2a to the winding 6 through the half-wave rectifier 8. These rectifiers are reversed with reference to each other in relation to their connections to the line 2a with the result that half-wave direct currents are supplied in one direction to the winding 5 and half-wave direct currents are supplied in the opposite direction to the winding 6. These half-wave pulsating currents are, of course, displaced from each other 180°. The remaining terminals of the windings 5 and 6 are connected together at the junction 9, from which a connection extends to another winding 10 on the middle leg of the core 3 and then the circuit continues through another winding 11 on the core 4 to a terminal of the full wave rectifier 12, from the opposite terminal of which connection is made to the line 2. The current supplied through the windings 10 and 11 to the rectifier 12 is alternating. It may be assumed that the magneto-motive force of the half-wave direct current in the winding 5 is in an upward direction with reference to the middle leg of the core 3, as indicated by the arrow on the winding 5, and that the magnetomotive force of the winding 6 is in an upward direction with reference to the middle leg of the core 4, as indicated by the arrow on the winding 6. The winding 10 is connected in relation to the winding 5 such that when winding 5 is inactive, the magnetomotive force of winding 10 is in the upward direction, as indicated by the dotted arrow on winding 10; and when winding 5 is active this magnetomotive force is downward as indicated by the full line arrow on winding 10. The magnetomotive force of winding 11 is similarly related to that of winding 6 as indicated by the dotted and full line arrows on winding 11.

Another winding 13 is shown on the middle leg of the core 3 which is connected in series with a similar winding 14 on the middle leg of the core 4, the circuit through these windings being completed by connection of the winding 14 to the line 2 and by connection of the winding 13 to the line 2a through an impedance device 15. This device is of a character to properly adjust the phase of the current in its circuit and tends to maintain the

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current of the windings 13 and 14 substantially constant even though the voltage on the main windings 5 and 6 may change. The winding 13 is connected in this circuit so that its magnetomotive force during the half-wave periods when the winding 5 is active is in the same direction as that of the winding 5, as indicated by the full line arrow on winding 13. It follows that during the half periods when the winding 5 is inactive, the magnetomotive force of the winding 13 will be in the opposite direction, as indicated by the dotted arrow on the winding 13. The winding 14 is connected in its circuit so that during the half periods when the winding 6 is active, the magnetomotive force of the winding 14 will be in the same direction as that of the winding 6, as indicated by the full line arrow on the winding 14. During the half periods when the winding 6 is inactive, the magnetomotive force of the winding 14 will, of course, be in the opposite direction, as indicated by the dotted arrow on the winding 14.

Another winding 16 is applied to the middle leg of the core 3 and is connected in series with a similar winding 17 on the middle leg of the core 4. These windings are the main control windings of the reactor and are the windings which are subjected to and receive the small variations of voltage or current which are to be amplified by the responsive action of the controlling apparatus. The controlling source in this instance is alternating and may be supplied from any device but must have the same frequency as that of the circuits already described and the phase of its current should preferably be in phase with that of the currents in the windings already described. The closer to this phase relationship, the better the results obtained where the change to be amplified is voltage or current change, although appreciable departures therefrom may still give desirable results. These control windings 16 and 17 are shown for simplicity as supplied from a device 18 which indicates in a general way any means for coupling this circuit to the lines 2 and 2a, as by transformers, an amplifying inductor, or any other coupling means. The winding 16 is connected so that its magnetomotive force is opposite to that of the winding 5 during the half-wave periods when the winding 5 is active, as indicated by the full line arrow on the winding 16. When the winding 5 is inactive, the magnetomotive force of the winding 16 will be in the opposite direction, as indicated by the dotted arrow on the winding 16. The winding 17 is connected so that its magnetomotive force is opposite to that of the winding 6 during the half periods when the winding 6 is active, as indicated by the full line arrow on the winding 17. When the winding 16 is inactive, the magnetomotive force of the winding 17 will be in the opposite direction, as indicated by the dotted arrow on the winding 17.

The output circuit of the amplifying apparatus is shown connected to and supplying current to the rectifier 12 from which direct current lines 19 may be used for any purpose where direct current control is desired, but it will be understood that the alternating output of the amplifying apparatus may be used as such in cases where so desired, in which case the rectifier 12 would be omitted.

In operation, the core 3 and its windings are effectively operative during every other half-wave period of the alternating supply, whereas the core 4 and its windings are operative for effective controlling action during the intervening

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half-waves of the alternating current source. The action of each reactor is similar to that of the other and the action of the reactor having the core 3 will first be explained. The main winding 5 has a large number of turns and receives current from the alternating source during half-wave periods in one direction and magnetizes the middle leg of the core in one direction as indicated by the arrow on the winding 5 by half-wave impulses. The energy received by this winding from the source and delivered to the rectifier 12 is widely varied in response to the action of the controlling windings. The winding 13 is subjected to an approximately constant alternating current and during the half-waves when the winding 5 is active, the magnetomotive force of the winding 13 is in the same direction as that of winding 5 and is provided with a sufficient number of turns to considerably reduce or offset the magnetizing current of winding 5. It thereby increases the impedance of winding 5 and the available range of control of the current of winding 5. The controlling winding 16 receives alternating current from the variable source and the phase of its current in relation to the pulsating current of winding 5 results in decreasing the impedance and increasing the current in winding 5. Thus any increase in the voltage of the source will be amplified in the increase of current in the winding 5. Similarly any decrease in the voltage of the source will be amplified in the decrease of current in the winding 5.

This amplified response of the main winding 5 is further increased by the fact that the winding 10 is in series therewith. This winding, like winding 11, is subjected to an amplified alternating current and has comparatively few turns. It acts similarly to the main control winding 16 giving a compound amplifying effect in the same way.

The controlling effect of the windings 16 and 10 may be analyzed further from another viewpoint. When the main winding 5 is inactive, the magnetomotive forces of windings 16 and 10 are in the same direction as the magnetomotive force of the winding 5 when it becomes active in the next half wave. Thus during the inactive periods of the winding 5, the windings 16 and 10 serve to pre-condition the core by raising its magnetization in the same direction as that due to winding 5 in the next half wave. This, of course, reduces the impedance of winding 5. It follows that any increase in current in the windings 16 and 10 permits an amplified increase of current in winding 5 and any decrease reduces the current in winding 5 to an amplified degree, the core being worked on the steep portion of its magnetization curve. Although the magnetomotive forces of the windings 16 and 10 are in opposition to that of winding 5 when the latter winding is active, they do not then have any serious counteracting effect because their ampere-turns are small in relation to those of the winding 5.

The action of the reactor having the core 4 is similar to that of the reactor already described. The amplifying effect may be varied by the relative proportioning of the turns of the various windings and the proportions of the core according to the conditions and results desired.

Fig. 2 is similar to Fig. 1, the corresponding parts being designated by the same reference characters; but in Fig. 2 the controlling windings 16 and 17 are supplied with direct current instead of alternating current. The variable controlling direct current supplying the wind-

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ings 16 and 17 in Fig. 2 may be from any direct current source but is indicated as being derived from the alternating current source of Fig. 2 through a rectifier 20. In this case the winding 16 is connected so that the magnetomotive force of its direct current is additive to that of the main winding 5 when the main winding 5 is active; and similarly the winding 17 is connected so that its magnetomotive force is additive to that of the winding 6 when this winding is active, as indicated by the full line arrows on the windings 16 and 17. The amplifying action in the disclosure of Fig. 2 is similar to that already described with reference to Fig. 1, except that the windings 16 and 17 in Fig. 2 continue their excitation in the directions indicated during the periods when the main windings 5 and 6 are active and inactive. The effect of the windings 16 and 17 is cumulative with the windings 5 and 6 respectively during their active periods, thereby reducing the reactance of the windings 5 and 6 upon increase of current in the control windings 16 and 17 resulting in an increased current in the windings 5 and 6. A decrease of current in these control windings has a reverse effect. Also when the windings 5 and 6 are inactive, the magnetomotive forces of windings 16 and 17 are in the same direction respectively as the magnetomotive forces of the windings 5 and 6 will be when they become active. Consequently the current in the windings 16 and 17 serve to variably condition the cores during the inactive periods of the windings 5 and 6 in a direction to reduce the reactance of the windings 5 and 6. Thus with direct current excitation of windings 16 and 17 the action is cumulative during both the active and inactive periods of the windings 5 and 6 in the production of amplified changes of current in the windings 5 and 6.

Fig. 3 embodies the controlling apparatus of Figs. 1 and 2 cascaded to further increase the amplification where such greatly increased amplification may be desired. The right-hand portion of Fig. 3 is the same as Fig. 2, the variable controlling current being direct current. The output of the apparatus controlled by this direct current is alternating and this output current is supplied to the controlling windings 16 and 17 of the left-hand portion of the apparatus. This is accomplished by a connection from the winding 11 of the right-hand core 4 through the winding 18 of the left-hand core 3, then through the winding 17 of the left-hand core 4 and then by a connection 22 back to the supply line. Thus it is apparent that the amplified current of the right-hand portion of the apparatus is delivered to the controlling windings of the left-hand portion of the apparatus and thereby is further amplified in its output circuit to the rectifier 12 and the controlled circuit 19.

Fig. 4 is the same as Fig. 1 except instead of connecting the windings 13 and 14 to the supply lines through an impedance device 15, the windings 13 and 14 are connected in series with each other in a local circuit through a capacitor or condenser 23. The currents induced in the windings 13 and 14 through this local condenser circuit have substantially the same effect as when these windings are supplied with current from the source. The windings 13 and 14 of Fig. 2 could similarly be connected in a local circuit containing a capacitor.

For simplicity of explanation the cores 3 and 4 in the foregoing description have been shown as separate cores but they may be combined into

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single cores of various forms such as disclosed in the above referred to F. G. Logan patent and in such cases the operation and functioning of the apparatus would be similar to that already described.

Although the variable alternating current control supplied to the windings 16 and 17 has been described as due to change of voltage at its source, this control may be accomplished by shifting of phase of the controlling current or by a combination of a variable voltage and shifting of phase according to the character of the variable controlling source. Although the core windings are shown displaced from each other for clearness of disclosure, they would preferably be superimposed or otherwise suitably arranged in practice.

It will be understood that various modifications of this invention may be made for adaptation to particular requirements and conditions without departing from the scope of the invention.

I claim:

1. Amplifying apparatus comprising an alternating current source, a reactor core, a main winding on said core supplied with current from said source and delivering current to a controlled circuit, a half-wave rectifier in the circuit of said main winding for causing said winding to be subjected to a current in one direction during half-wave periods, a second winding on said core subjected to an approximately constant alternating current and having its magnetomotive force additive to that of said main winding when said main winding is active for reducing the magnetizing current of the main winding, and a control winding on said core subjected to changes in current for increasing the current in the main winding upon increase of current in the control winding and for decreasing the current in the main winding upon decrease of current in the control winding.

2. Amplifying apparatus comprising an alternating current source, a reactor core, a main winding on said core supplied with current from said source and delivering current to a controlled circuit, a half-wave rectifier in the circuit of said main winding for causing said winding to be subjected to a current in one direction during half-wave periods, a second winding on said core subjected to an approximately constant alternating current and having its magnetomotive force additive to that of said main winding when said main winding is active for reducing the magnetizing current of the main winding, and a control winding on said core subjected to changes in direct current for increasing the current in the main winding upon increase of current in the control winding and for decreasing the current in the main winding upon decrease of current in the control winding.

3. Amplifying apparatus comprising an alternating current source, a reactor core, a main winding on said core supplied with current from said source and delivering current to a controlled circuit, a half-wave rectifier in the circuit of said main winding for causing said winding to be subjected to a current in one direction during half-wave periods, a second winding on said core subjected to an approximately constant current for reducing the magnetizing current of the main winding, and a control winding on said core subjected to changes in alternating current for increasing the current in the main winding upon increase of current in the control winding and

for decreasing the current in the main winding upon decrease of current in the control winding.

4. Amplifying apparatus comprising an alternating current source, a reactor core, a main winding on said core supplied with current from said source and delivering current to a controlled circuit, a half-wave rectifier in the circuit of said main winding for causing said winding to be subjected to a current in one direction during half-wave periods, a second winding on said core subjected to an approximately constant alternating current and having its magnetomotive force additive to that of said main winding when said main winding is active for reducing the magnetizing current of the main winding, and a control winding on said core subjected to changes in current for increasing the current in the main winding upon increase of current in the control winding and for decreasing the current in the main winding upon decrease of current in the control winding.

5. Amplifying apparatus comprising an alternating current source, a reactor core, a main winding on said core supplied with current from said source and delivering current to a controlled circuit, a half-wave rectifier in the circuit of said main winding for causing said winding to be subjected to a current in one direction during half-wave periods, a second winding on said core subjected to an approximately constant alternating current and having its magnetomotive force additive to that of said main winding when said main winding is active for reducing the magnetizing current of the main winding, and a control winding on said core subjected to changes in direct current for increasing the current in the main winding upon increase of current in the control winding and for decreasing the current in the main winding upon decrease of current in the control winding.

6. Amplifying apparatus comprising an alternating current source, a reactor core, a main winding on said core supplied with current from said source and delivering current to a controlled circuit, a half-wave rectifier in the circuit of said main winding for causing said winding to be subjected to a current in one direction during half-wave periods, a second winding on said core subjected to an approximately constant alternating current and having its magnetomotive force additive to that of said main winding when said main winding is active for reducing the magnetizing current of the main winding, and a control winding on said core subjected to changes in alternating current for increasing the current in the main winding upon increase of current in the control winding and for decreasing the current in the main winding upon decrease of current in the control winding.

7. Amplifying apparatus comprising an alternating current source and reactive means, said means comprising two main windings supplied with current from said source and delivering current to a controlled circuit, half-wave rectifiers in the circuit of said main windings respectively for causing each of said windings to be subjected to a current in one direction during half-wave periods, the output circuit from said windings being connected to deliver alternating current to the controlled circuit, two windings subjected to said alternating current of the controlled circuit and respectively related to the main windings to cause their magnetomotive forces when the main windings are inactive to be in the same direction respectively as the magnetomotive forces of the

main windings when active, and two control windings subjected to changes in current and respectively related to the main windings for increasing the current in the main windings upon increase of current in the control windings and for decreasing the current in the main windings upon decrease of current in the control windings.

8. Amplifying apparatus comprising an alternating current source and reactive means, said means comprising two main windings supplied with current from said source and delivering current to a controlled circuit, half-wave rectifiers in the circuit of said main windings respectively for causing each of said windings to be subjected to a current in one direction during half-wave periods, the output circuit from said windings being connected to deliver alternating current to the controlled circuit, two windings subjected to said alternating current of the controlled circuit and respectively related to the main windings to cause their magnetomotive forces when the main windings are inactive to be in the same direction respectively as the magnetomotive forces of the main windings when active, and two control windings subjected to changes in direct current and respectively related to the main windings for increasing the current in the main windings upon increase of current in the control windings and for decreasing the current in the main windings upon decrease of current in the control windings.

9. Amplifying apparatus comprising an alternating current source and reactive means, said means comprising two main windings supplied with current from said source and delivering current to a controlled circuit, half-wave rectifiers in the circuit of said main windings respectively for causing each of said windings to be subjected to a current in one direction during half-wave periods, the output circuit from said windings being connected to deliver alternating current to the controlled circuit, two windings subjected to said alternating current of the controlled circuit and respectively related to the main windings to cause their magnetomotive forces when the main windings are inactive to be in the same direction respectively as the magnetomotive forces of the main windings when active, and two control windings subjected to changes in alternating current and respectively related to the main windings for increasing the current in the main windings upon increase of current in the control windings and for decreasing the current in the main windings upon decrease of current in the control windings.

10. Amplifying apparatus comprising an alternating current source and reactive means, said means comprising core legs of magnetic material, a plurality of main windings on said legs respectively supplied with current from said source and delivering current to a controlled circuit, half-wave rectifiers in the circuit of said main windings respectively for causing each of said windings to be subjected to a current in one direction during half-wave periods, the output circuit from said windings being connected to deliver alternating current to the controlled circuit, a plurality of windings subjected to said alternating current of the controlled circuit and respectively related to the main windings for biasing the magnetization of said legs during the half-wave periods when said main windings are respectively inactive and in the direction of the magnetomotive forces of said main windings when active, and a plurality of control windings subjected to changes in cur-

rent and respectively related to the main windings for increasing the current in the main windings upon increase of current in the control windings and for decreasing the current in the main windings upon decrease of current in the control windings.

11. Amplifying apparatus comprising an alternating current source and reactive means, said means comprising two main windings supplied with current from said source and delivering current to a controlled circuit, half-wave rectifiers in the circuit of said main windings respectively for causing each of said windings to be subjected to a current in one direction during half-wave periods, the output circuit from said windings being connected to deliver alternating current to the controlled circuit, two windings subjected to an approximately constant current and respectively related to said main windings for reducing the magnetizing current of said main windings, two windings subjected to said alternating current of the controlled circuit and respectively re-

lated to the main windings to cause their magnetomotive forces when the main windings are inactive to be in the same direction respectively as the magnetomotive forces of the main windings when active, and two control windings subjected to changes in current and respectively related to the main windings for increasing the current in the main windings upon increase of current in the control windings and for decreasing the current in the main windings upon decrease of current in the control windings.

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