May 31, 1932. H. K. KOUYOUMJIAN 1,860,543

ELECTRIC CONTROLLING APPARATUS

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Fig. 1.

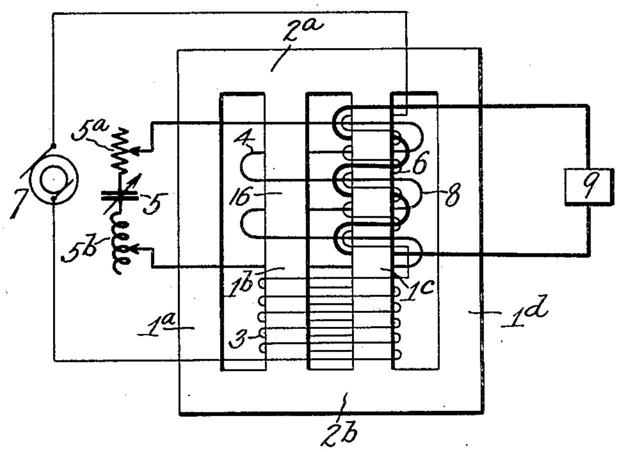
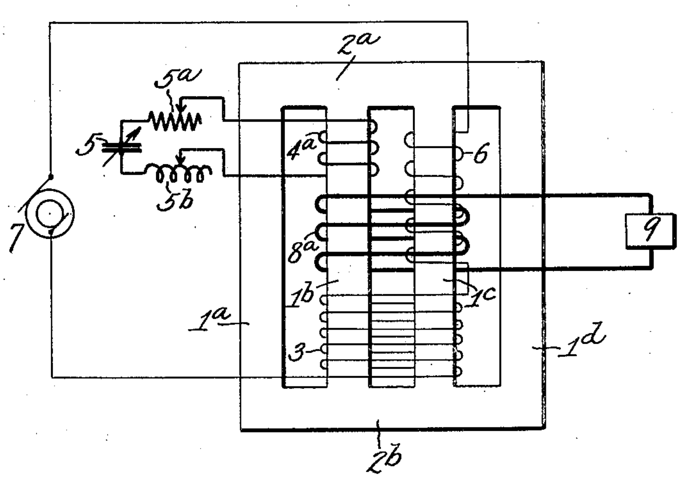


Fig. 2.



Inventor

Haroutiun K. Kouyoumjian

By his Attorney

Lawrence K. Sager

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Fig. 3.

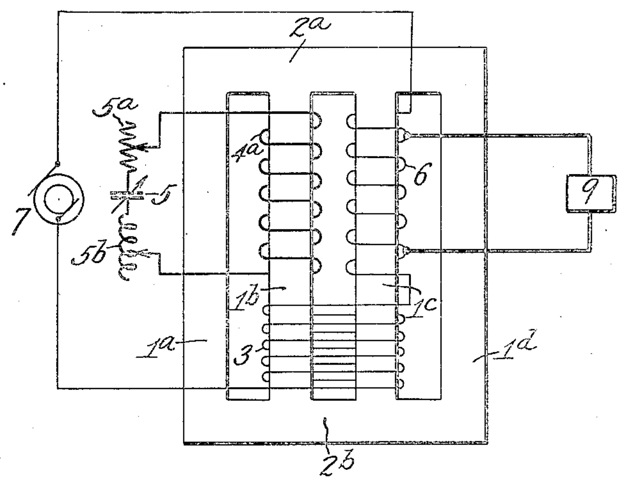
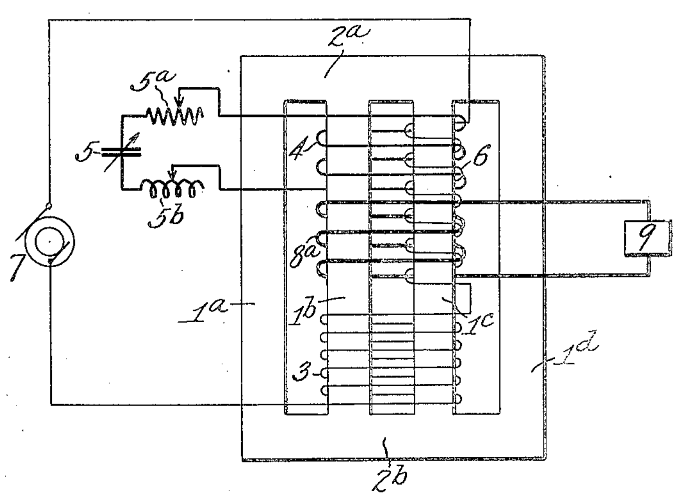


Fig. 4.



Inventor
Haroutiun K. Kouyoumjian
By his Attorney
Lawrence K. Sager

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Fig. 5.

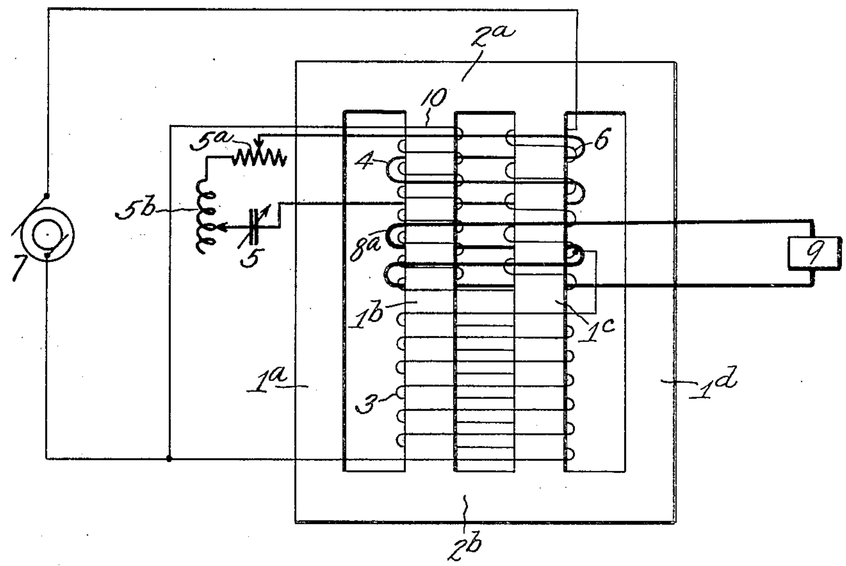
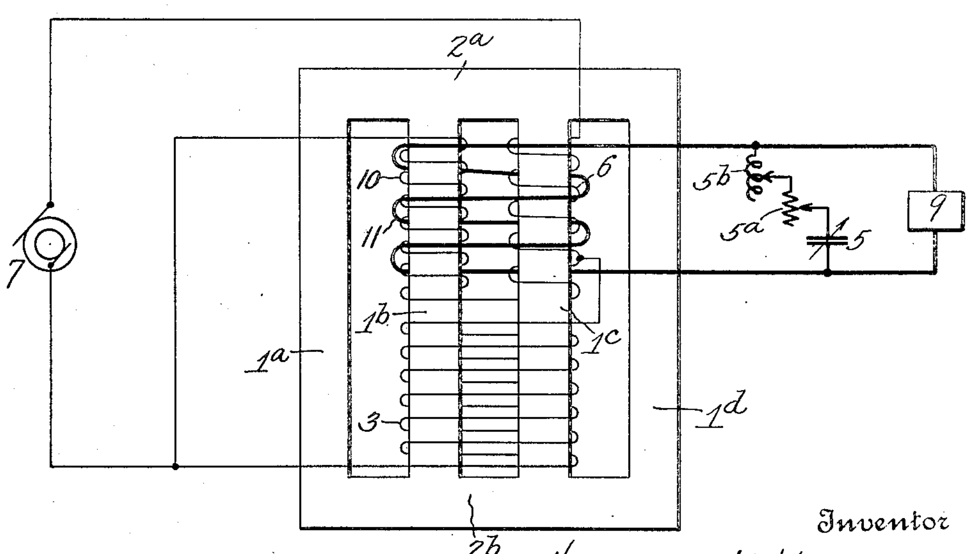


Fig. 6.



Inventor

Haroutiun K. Kouyoumjian

By his Attorney

Lawrence K. Sager.

Patented May 31, 1932 1,860,543

UNITED STATES PATENT OFFICE

HAROUTIUN K. KOUYOUMJIAN, OF PROVIDENCE, RHODE ISLAND, ASSIGNOR TO WARD LEONARD ELECTRIC COMPANY, A CORPORATION OF NEW YORK

ELECTRIC CONTROLLING APPARATUS

Application filed September 8, 1930. Serial No. 480,286.

This invention relates to alternating current voltage regulators and transformers wherein the output voltage is maintained constant or approximately constant, regardless of variations of voltage in the supply line; and more particularly to such regulators or transformers supplying a variable load.

The present invention is an improvement over the inventions disclosed in my prior pending applications Serial Number 306,259, filed September 15, 1928, Serial Number 344,333, filed March 5, 1929, and Serial Number 404,537, filed November 4, 1929. In the latter application, I disclosed improved means for maintaining the output voltage constant regardless of variations in the load, as well as in the supply voltage. The present invention relates particularly to such type of apparatus, but also includes additional controlling means and improved method of control for maintaining the output voltage constant under variable load, even when the frequency of the supply circuit varies, as well as the voltage of the supply circuit.

Thus, the main object of the present invention is to provide improved controlling apparatus for maintaining the output voltage constant, or in such a way as may be desired, regardless of changes in frequency of the alternating current source, under varying load conditions, and also under variable voltage of the supply line. A further object is to obtain these results by a simple and inexpensive form of construction, and which will also be durable and dependable. Other objects and advantages of this invention will be understood by those skilled in the art from the following description and accompanying drawings.

Fig. 1 is a diagram showing one preferred embodiment of the invention; and Figs. 2 to 6 are similar diagrams illustrating modifications.

Referring to Fig. 1, the laminated iron, or steel, core is shown as having four legs 1*a*, 1*b*, 1*c* and 1*d*. The legs are joined together at their upper and lower ends by cross-pieces 2*a* and 2*b*. Ordinarily, the cross-sections of the different parts of the core will be about the same, although in some cases, for particular purposes, the cross-sections of the different parts may be modified relatively to each other. It will also be understood that instead of the core being made of the form indicated in the drawings, it may have various other conformations such, for example, as those disclosed in my said prior applications. The inner legs of the core carry a number of windings indicated diagrammatically, but it will be understood that the number of turns of the different windings will be made such as the particular conditions require, and that the location of the windings may be modified from that indicated, and that some of the windings instead of being superimposed with reference to each other, may be located side by side, or may be more or less distributed or sandwiched with each other to meet particular requirements.

The main, or primary, exciting winding 3 is shown as enveloping the end portions of the two inner legs. Another winding 4 is, in Fig. 1, shown enveloping the other end portions of the two inner legs and forms a closed circuit on itself for the passage of alternating current through the condenser 5, indicated as adjustable. Also, in series with this winding 4 is an adjustable resistance 5*a*, and an adjustable choke, or inductive, device 5*b*. This circuit, according to the present invention, is tuned, or made resonant, over a range of frequencies delivered by the source of supply, so that when the frequency varies, the inductive effect thereof upon the circuit of the winding 4 will not be materially affected by such change in frequency. For example, in the usual commercial installation of a 60 cycle system, the frequency varies from about 58 to 62 cycles. In such a case, the devices 5, 5*a* and 5*b* will be adjusted so that change of frequency over this range shall have no material effect on this circuit, and for that purpose the circuit must have sufficient resistance, either in the winding itself, or in an auxiliary device such as 5*a*, to secure a broad band tuning over the limits required, the adjustable capacitive and inductive devices 5 and 5*b* being used to secure proper resonance by the use of either one of these devices, or both, when necessary. In the example referred to, the circuit will be tuned so that at 60 cycles, the circuit will be operative at the mid-point of the band and so that change of the frequency to 58 or to 62, or to any intermediate point, will not materially affect the current induced in this circuit. Another exciting winding 6 is located on the leg 1*c*, and is so wound and connected as to act in opposition to the main exciting winding 3. This opposing, or bucking, winding is shown connected in series with the main exciting winding to the alternating current source of supply 7. The secondary, or output, winding 8 is shown in Fig. 1 as enveloping a portion of the leg 1*c* and supplies a translating device 9 in the consumption circuit. This device may be any form of translating device. In some cases, the main exciting winding 3 and the bucking winding 6 may be connected in parallel with each other across the supply line, but ordinarily the series connection has important advantages.

The cross-section of leg 1*b* and the ampere turns of the windings enveloping this leg are such that, under normal conditions, this part of the core is worked near, or just below, the knee of the saturation curve, although in some cases, for particular requirements, this core may be normally worked at a different part of the saturation curve. The cross-section of the leg 1*c* and the net ampere turns of the windings enveloping this leg, are such that this part of the core is normally worked on the so-called straight part of the saturation curve below the knee of the curve. For particular purposes, the normal condition of this portion of the core may be such as to be normally worked at a higher or lower portion of the straight part of the saturation curve, according to the results desired.

The operation in a general way may be understood by assuming the supply voltage and output voltage to be at normal amounts, and by assuming that the load remains fixed. Under these conditions, the ratio of the output voltage to the supply voltage will depend upon the relative number of turns in the different windings. The winding 4, by reason of having the condenser 5 of proper capacity in its circuit, carries an induced leading current and therefore acts cumulatively in the excitation of the core with the main exciting winding 3.

Now assume that the supply voltage falls to an abnormally low amount. There are two main factors which tend to offset the drop in voltage of the output circuit which would ordinarily occur. One factor is that although the main exciting winding 3 would carry less current and tend to cause a decrease in the excitation of the leg 1*c*, yet the bucking winding 6 would likewise carry less current and cause the bucking effect to be correspondingly reduced. The other factor is that the cumulatively acting winding 4 becomes more effective upon decrease of the supply voltage by reason of its leading current being increased. This is due to the fact that the leg 1*b* being at, or near, saturation under normal conditions of supply voltage, the winding 4 has less inductance and carries less current than when the leg 1*b* is somewhat below saturation. Thus the greater induced current in the cumulatively acting winding 4 upon decrease of supply voltage, together with the action due to the bucking coil 6, offsets the tendency toward reduced resultant excitation of the leg 1*c*, within the secondary, or output, coil 8, with the result that the output circuit is subjected to substantially the same flux change as before the decrease in the supply voltage, resulting in the output voltage being maintained constant or approximately constant. Similarly, when the supply voltage increases above the normal amount, the bucking winding 6 does, of course, have an increased bucking effect tending to hold the magnetization of the leg 1*c* down and, by reason of the leg 1*b* being carried to saturation, or near saturation, by the increased effect of the main winding 3, the inductance in the cumulatively acting winding 4 becomes less, causing less current to be induced in this winding, resulting in a reduction in the cummulative excitation. Thus the leg 1*c* carrying the output winding 8 is caused to have substantially the same magnetization as before the increase of voltage, resulting in the output voltage remaining constant or approximatey constant. In fact, if desired, the output voltage could be caused to decrease upon increase in supply voltage and vice versa, by proper relation of the turns in the different windings and capacity of the condenser 5.

An important advantage of this type is that the efficiency of the regulator and transformer remains approximately constant under wide variations in the supply voltage, because upon increase in supply voltage, the current taken from the line correspondingly decreases and vice versa.

For the purpose of maintaining the voltage of the output circuit constant or approximately constant under extreme changes of load, the leg 1*b* should be normally worked just below saturation. Assuming the load to be increased, there of course results an increased current in the main exciting winding 3 and in the bucking winding, and if it were not for the winding 4, the voltage of the output circuit would drop with increased load. The increase in the primary winding 3, however, causes an increased inductance in the winding 4, owing to the leg 1*b* being below saturation. The resultant increase in current in the cumulatively acting winding 4 tends to counteract the drop in voltage of the output circuit, which would otherwise occur. In fact, by causing the cumulatively acting winding 4 to be particularly responsive to an increase in primary current, its effect may be caused to over-compensate for the drop in voltage in the output circuit and actually cause a rise in voltage in the output circuit upon increase of load. When the load decreases, the reverse action takes place, so that the output voltage may be maintained constant or approximately constant under variable load, or controlled as desired. It will be understood that the leg 1*b* should normally be below saturation for obtaining the best results in maintaining the ouput voltage approximately constant under variable load. whereas for the purpose of maintaining the output voltage constant or approximately constant over extreme variations of supply voltage, the leg 1*b* should be at, or near, saturation, under normal conditions. Thus, the proportion of the parts and the relationship of the windings should be made such as to suit the particular conditions required. For example, if it is be desired to maintain the output voltage constant over extreme variations of supply voltage and over extreme variations in load, a compromise excitation of the leg 1*b* under normal conditions should be selected; but if the load remains approximately constant and it is particularly desired to offset extreme variations in the supply voltage, then the normal excitation of the leg 1*b* should be at, or near, saturation; but if the supply voltage does not vary greatly, and it is particularly desired to maintain a constant or approximately constant output voltage with increase in load, then the leg 1*b* should normally be excited below saturation.

Now, as regards change in frequency of the source, a change in frequency, regardless of other varying conditions, would cause the current induced in the winding 4 to be modified to some value other than that required for maintaining the output voltage constant, or at the particular value desired. However, by reason of the fact that the circuit of the winding 4 is tuned over a broad band, extending over the variations in frequency of the source, it results that no matter how other conditions may vary, the change in frequency will have no material effect upon the output voltage. Thus, by the present invention, my regulator, or transformer, is improved so that in addition to the other desirable results obtained thereby, it also renders the apparatus immune to frequency variation, even when the load is variable.

Although in Fig. 1, the cumulative winding 4 carrying a leading current is shown enveloping both legs 1*b* and 1*c*, it will ordinarily be desirable in practice to form this winding in two coils, one enveloping the leg 1*b* and the other enveloping the leg 1*c* and connect the coils in series with each other and with the broad band tuning device, or devices, the direction of turns, however, being such as to tend to magnetize the two legs in a common direction, that is, in the same direction as when a single winding envelops both legs, as indicated in Fig. 1.

In some cases, the cumulatively exciting winding 4 instead of enveloping both legs, may envelop only one leg, such as the leg 1*b*, as shown in Fig. 2, where the winding 4*a* in series with the broad band tuning device, or devices, serves as the cumulatively acting winding carrying the leading current. Although enveloping a single leg with this winding is less expensive, yet the refinement of control is not then as high, ordinarily, as that obtained when this winding envelops both legs, but it may, however, desirably serve to fulfill certain requirements. Likewise, the output winding 8 instead of enveloping only one leg as in Fig. 1, may envelop both legs as indicated by the coil 8*a* in Fig. 2. Ordinarily, however, the results obtained are not as desirable as when the output winding envelops only the leg carrying the bucking winding.

In some cases, instead of providing an additional secondary winding to comprise the output circuit, the output lines may be tapped directly into the bucking winding, in which case this winding serves as an auto-transformer winding for supplying the translating device, or devices. This is illustrated in Fig. 3 where the supply lines are indicated as connected to the bucking winding 6. Obviously, this winding may be tapped at any portion thereof to supply any desired voltage to the consumption circuit. It will also be understood that in any of the other forms indicated in the drawings, the bucking winding could serve to supply the translating devices. In some cases where this occurs, an additional output winding may be added to supply a higher or lower voltage to other translating devices; and obviously the output winding, or windings, may be provided with taps to supply different voltages as may be desired.

Fig. 4 indicates another relative arrangement of the windings wherein the cumulative winding 4 is shown enveloping both legs as in Fig. 1, but the output winding 8 of Fig. 1 is indicated as a winding 8*a* enveloping both legs. It would be advantageous in practice to cause this winding 8*a* to be made in two coils connected in series, as already explained with reference to the winding 4.

Fig. 5 indicates another embodiment of my invention which is similar to Fig. 4, except an additional cumulative winding 10 as indicated on the leg 1*b* which is in series with the bucking winding 6 across the source 7, the main exciting winding 3 being in series with a portion of the bucking winding 6. This cumulative winding is disclosed in my prior applications Serial Number 306,259, filed September 15, 1928, and Serial Number

344,333, filed March 5, 1929, and ordinarily is not necessary when the cumulatively exciting winding 4 is used, but in some cases may be advantageously added.

Fig. 6 is similar to Fig. 5, except that a common winding 11 serves both as the output winding and as the cumulatively exciting winding 4, the circuit of the winding 11 being adjusted to have a leading current and tuned broadly by use of the resistance 5b and the other device or devices, connected in series across the winding 11 and in shunt with the load 9. This form of construction is capable of being used when the voltage of the output circuit and that required of the tuned circuit are about the same.

The broad band tuning of the resonant circuit may be accomplished by the use of any suitable means, or devices, and it is also evident that the invention may be embodied in various forms of construction of core, as already referred to, and in various relationships and locations of the windings without departing from the scope thereof.

I claim:

1. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, and means for broadly tuning the circuit of said third winding.

2. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, and means for tuning the circuit of said third winding to be resonant over the range of frequency of the supply current.

3. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, means for broadly tuning the circuit of said third winding, and an output winding on said core subjected to resultant magnetic effects.

4. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, means for tuning the circuit of said third winding to be resonant over the range of frequency of the supply current, and an output winding on said core subjected to resultant magnetic effects.

5. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, and means in the circuit of said third winding for causing a leading current to be induced therein and for broadly tuning the circuit of said third winding.

6. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, and means in the circuit of said third winding for causing a leading current to be induced therein and for tuning the circuit of said third winding to be resonant over the range of frequency of the supply current.

7. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, means in the circuit of said third winding for causing a leading current to be induced therein and for tuning the circuit of said third winding to be resonant over the range of frequency of the supply current, and an output winding on said core subjected to resultant magnetic effects.

8. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, and means for broadly tuning the circuit of said third winding, said portion of the core enveloped by said second winding being below saturation.

9. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, means for tuning the circuit of said third winding to be resonant over the range of frequency of the supply current, and an output winding on said core subjected to resultant magnetic effects, said portion of the core enveloped by said second winding being below saturation.

10. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, and means for broadly tuning the circuit of said third winding, a

portion of the core enveloped by said third winding being normally near saturation.

11. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, and means for broadly tuning the circuit of said third winding, said portion of the core enveloped by said second winding being below saturation and a portion of said core enveloped by said third winding being normally near saturation.

12. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, and means in the circuit of said third winding for causing a leading current to be induced therein and for broadly tuning the circuit of said third winding, said portion of the core enveloped by said second winding being below saturation.

13. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, and means in the circuit of said third winding for causing a leading current to be induced therein and for tuning the circuit of said third winding to be resonant over the range of frequency of the supply current, said portion of the core enveloped by said second winding being below saturation and a portion of the core enveloped by said third winding being normally near saturation.

14. Alternating current controlling apparatus comprising a core, an alternating current exciting winding on said core, a second alternating current exciting winding on another portion of said core acting in opposition to said first-named winding, a third winding on said core, and means for broadly tuning the circuit of said third winding, said first-named winding being in series with at least a portion of said second-named winding.

15. Alternating current controlling apparatus comprising a core, a main alternating current exciting winding embracing a portion of said core, a second alternating current exciting winding embracing another portion of said core and acting in opposition to said first-named winding, a third winding embracing at least another portion of said core, means in the circuit of said third winding to cause a leading current to be induced therein and for tuning said circuit to be resonant over the range of frequency of the supply current, and an output winding subjected to the combined magnetic effects.

16. Alternating current controlling apparatus comprising a core, a main alternating current exciting winding embracing a portion of said core, a second alternating current exciting winding embracing another portion of said core and acting in opposition to said first-named winding, a third winding embracing at least another portion of said core, means in the circuit of said third winding to cause a leading current to be induced therein and for tuning said circuit to be resonant over the range of frequency of the supply current, and an output winding subjected to the combined magnetic effects, said first-named winding being in series with at least a portion of said second-named winding.

17. Alternating current controlling apparatus comprising a core, a main alternating current exciting winding embracing a portion of said core, a second alternating current exciting winding embracing another portion of said core and acting in opposition to said first-named winding, a third winding embracing at least another portion of said core, means in the circuit of said third winding to cause a leading current to be induced therein and for tuning said circuit to be resonant over the range of frequency of the supply current, and an output winding subjected to the combined magnetic effects, said first-named winding being in series with at least a portion of said second-named winding, said portion of the core enveloped by said second-named winding being below saturation.

HAROUTIUN K. KOUYOUMJIAN.