Dec. 25, 1934. W. K. FLEMING 1,985,634

REGULATING SYSTEM

Filed April 4, 1928 2 Sheets-Sheet I

FIG. 1

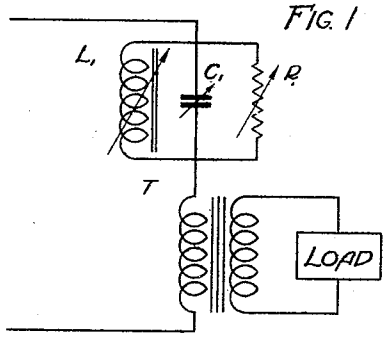
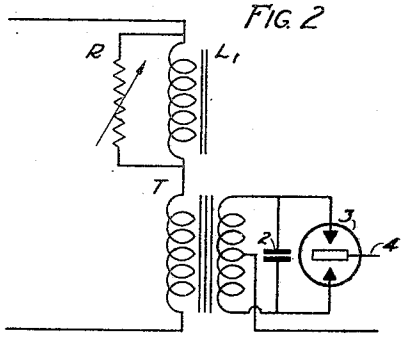


FIG. 2



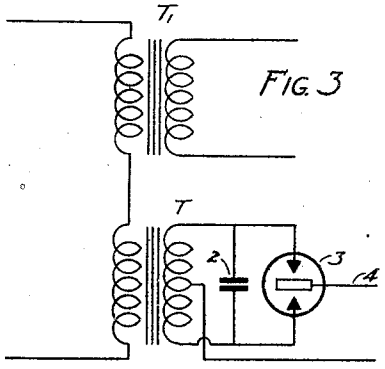


FIG. 3

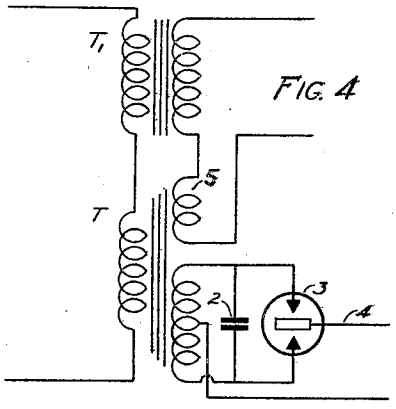


FIG. 4

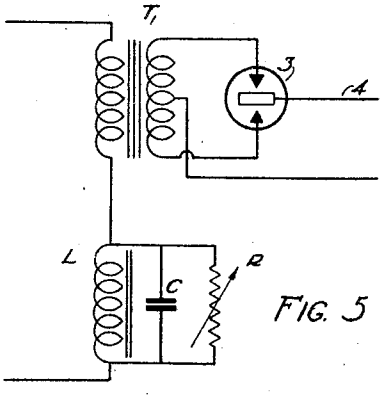


FIG. 5

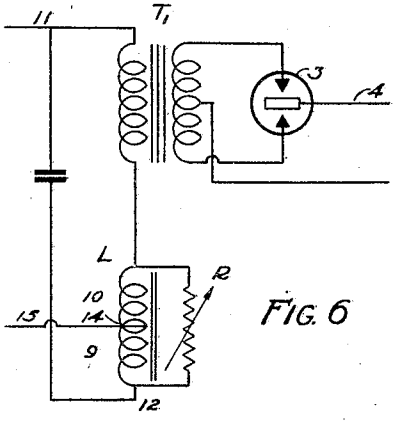


FIG. 6

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REGULATING SYSTEM

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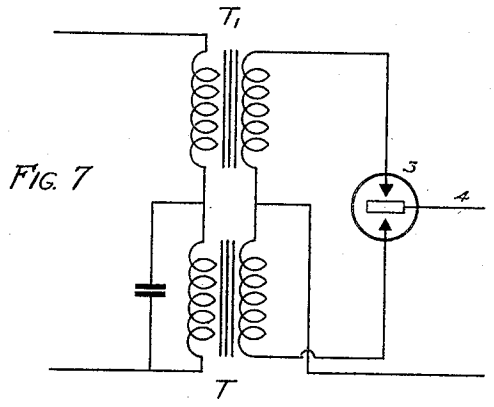


FIG. 7

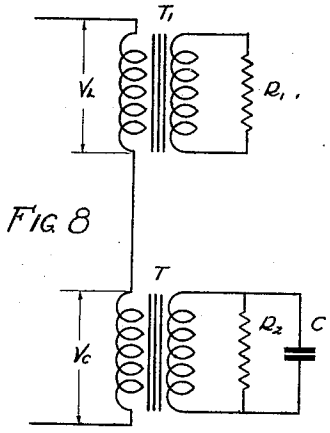


FIG. 8

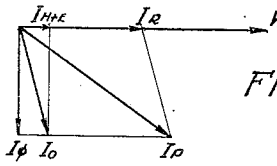


FIG. 9

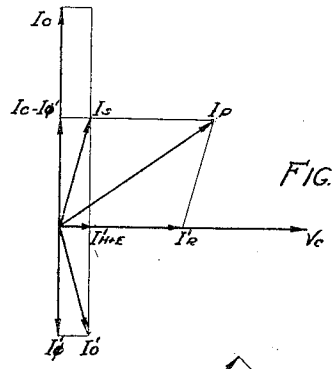


FIG. 10

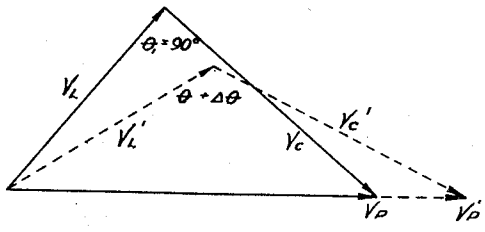


FIG. 12

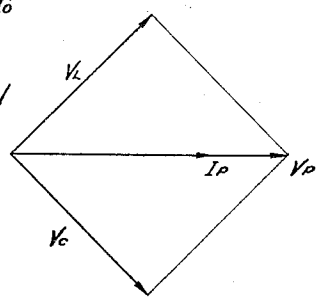


FIG. 11

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UNITED STATES PATENT OFFICE

1,985,634

REGULATING SYSTEM

Wilfred K. Fleming, Cambridge, Mass., assignor to Raytheon Manufacturing Company, Newton, Mass., a corporation of Delaware

Application April 4, 1928, Serial No. 267,402

12 Claims. (Cl. 171—119)

My invention relates to an electrical regulating system and more specifically to a power transformation system whereby variations of input voltage over a wide range of limits do not affect the voltage output in any substantial degree.

The recent developments of radio receiving systems have resulted in a demand for means for supplying the filament and plate circuits of vacuum tubes from the ordinary house current mains. As is well known, the thermionic tubes used in such sets require that the power delivered to them be of substantially constant and invariable voltage. Under the present methods of distribution of alternating current for domestic purposes, it is practically impossible for the voltage of the house circuit to be constant throughout the day or to be equal to the voltage of the circuit in another house. The load variations through the day result in line variations. The position of the particular house circuit with respect to the supply transformer, as well as the position of the supply transformer with respect to the high tension mains, results in a voltage variation which not only occurs through the day in one particular spot, but which also occurs among a number of spots at one particular time.

The ordinary means for translating the alternating current of the mains into substantially direct current for use in a radio receiving set, comprises a transformer, a rectifier in secondary circuit, and means for filtering out and smoothing out the ripples in the rectified current. It will readily be seen that as the line voltage varies, the final rectified voltage will vary and unless compensating means at the radio receiving set are used, the tubes will be operated more or less haphazardly. Such haphazard tube operation is very bad on the life of the tube. If the filaments of the tubes are operated in such a manner, they will be burned out or stripped of their coating depending upon whether the filament is overloaded or underloaded. If the plate circuit varies too much, a great plate voltage overload will strip the filament or paralyze the tube.

My invention aims at overcoming the variations in secondary voltage, irrespective of how the primary line voltage may vary within reasonably wide limits. Although I have described my invention with reference to a vacuum tube supply system, it is to be clearly understood that my invention is independent of this and may be used wherever a constant voltage which is to be obtained from a variable voltage is required. Although the variations may be fast, it will readily be understood that the variations might just as well be over a period of days or even weeks and in fact, the supply voltage need not necessarily vary at all and can very well be different from what is ordinarily taken as the average.

In the broader aspects of the invention, the voltage supply is divided up into two vector quantities. The magnitude of one of these vector quantities is kept substantially constant and this quantity is the one that is actually used. The other vector quantity is allowed to vary although its magnitude, too, may be kept constant. In either case, this second vector quantity, whether variable or constant, may be used or discarded. The angle between the two vectors is allowed to vary. In this way, the supply voltage which, of course, represents the resultant vector is broken up into the above two vectors. The variable resultant has as its counterpart in the components, the variable phase angle and perhaps one variable vector, the other remaining substantially constant.

In using my invention on a battery eliminator, for vacuum tube circuits, I have found by experiment that the line voltage may vary between 100 and 135 volts with a negligible variation in the tube supply circuits. When it is considered that the voltage supplied to the battery eliminator is multiplied to obtain some of the higher plate circuit voltages, it may readily be appreciated how little is the actual change in the substantially constant vector quantity.

The means for accomplishing this comprises in general a transformer, the primary of which is in series with a reactance which is either predominantly capacitative or inductive. If the reactance is capacitative, then there is also an inductance as a choke or transformer used in connection therewith. This choke or transformer has a large capacity used with it so that the combination is capacitative. The substantial constancy of voltage may be obtained either at the terminals of the inductive or capacitative part of the system. In any event, the inductance which may be either a choke or a transformer, which is part of the capacitative portion of the system, is operated preferably at the upper bend of the magnetization curve. This is done in order to take advantage of the very large variation of inductance with small variation of impressed voltage.

The capacity may be assumed to be constant for all practical purposes. The result is, therefore, that in the capacitative portion of the system a small change in voltage across the terminals of

that portion of the system will result in a current change which will result in a great change of the value of inductance and hence the effective reactance of the capacitative portion of the system is materially changed, thus resulting in a phase displacement between current and voltage.

Of course it is to be understood that the choke might be used in the inductive portion of the system and the transformer be part of the capacitative portion of the system.

By actual measurement the voltage across each portion of the system has been measured and since the actual numerical values do not differ very much with the variation in line voltage, the only logical conclusion is that the phase angle is changed. The inductance of the capacitative portion of the system need not of necessity be operated at that portion of the curve and may actually be operated on any non-linear part of the magnetization curve, but best results are obtained by operating as stated. The inductive portion of the system may or may not be operated at the same portion of magnetization curve.

The circuits illustrated in the drawings are a few illustrations of how the invention may be carried out.

Referring to the drawings, Figure 1 shows the basic idea involved,

Figure 2 is a modification of Figure 1,

Figures 3 and 4 show further modifications in which the reactance is a transformer for supplying current at low voltage, as for the filaments of vacuum tubes,

Figure 5 is another form that the invention may take,

Figures 6 and 7 are further modifications,

Figure 8 is a diagrammatic showing of the circuit,

While Figures 9 and 10 are vector diagrams referring respectively to the top and bottom portions of Figure 8,

Figures 11 and 12 are vector diagrams of the final resultants obtained.

Referring to the drawings and more especially to Figure 1, it will be seen that transformer T has its primary in series with a complex reactance shown diagrammatically as resistance, capacity, and inductance. The secondary of transformer T feeds into what is diagrammatically shown as a load and which in practice usually consists of a filter or smoothing circuit, a voltage divider and the various tubes used in a radio receiving set. Transformer T is run at the upper bend of the magnetization curve for the reasons stated above. The reactance in series with the transformer primary, has a potential across it which is out of phase with the potential across the transformer primary. If the line voltage varies, it is found that the component voltages across the reactance and transformer primary do not vary much in magnitude, but do vary considerably in phase angle.

Figure 2 shows the reactance comprising inductance and resistance. The transformer T has condenser 2 across its secondary. Center tap 1 forms one side of the output line while 4 forms the other side of the output line, the output of the secondary being rectified by device 3 which may be of any type whatsoever. Condenser 2 is of a high value so that the entire transformer T is substantially a capacitative load in which the voltage lags while the current leads. Inasmuch as the reactance is inductive in character, the voltage across that will lead while the current lags. Thus, it can be seen that although the total voltage across the line may vary substantially, still the component voltages may vary very little, the variation being taken up by the difference in phase angle between the two reactive loads.

In Figure 3, the inductively reactive load is transformer T_1 which may in itself supply power as for filaments.

In Figure 4, the reactive transformer T_1 has connected in series with its secondary, coil 5 which is wound on the same core as transformer T. This results in having some of the voltage steadying characteristics of the T transformer circuit carried over into the T_1 transformer circuit. In this figure, T_1 may also supply current.

In Figure 5, transformer T_1 furnishes the steady supply of current. In series with this transformer is a complex capacitative reactance containing inductance, capacitance and variable resistance. In this circuit the core of L, inductance, is operated at the bend of the magnetization curve. T_1 may or may not be similarly operated and in any event is preferably of high inductance.

Figure 6 shows an arrangement in which transformer T_1 furnishes the constant current and has in series with its primary, a reactance comprising an inductance L and variable resistance R. This inductance L is composed of two portions—9 and 10, with midpoint contact 14 from where line 15 of the supply main is taken. 11 is the other supply line. A condenser is connected across from line wire 11 to the outer end of 9 shown as 12. In this arrangement the current from 11 through the condenser to 12, through 9 to 14, and then 15, leads the current from 11 through the primary of T_1, 10, to 14, and then 15. The leading current in 9 induces a similarly leading current in 10 with the result that the current going through L leads the current going through the primary of T_1. L will be operated at the upper bend of the magnetization curve as in the preceding case.

In Figure 7, there are two transformers—T_1 and T_2 with their primaries and secondaries in series. The outer end of the secondaries go to rectifier 3 and then to output line 4. The output line is taken from the inner connection of the two secondaries.

Across the primary of T is shunted a condenser. In this system, T is operated at the upper bend of the magnetization curve and as in the preceding case, the phase angle between currents through T_1 and through T vary to take up the variations in impressed primary voltage.

Referring to Figure 8, two transformers T and T_1 are shown. T has capacitance C across its secondary which operates in such a way that the entire transformer load becomes capacitative rather than inductive. R_1 and R_2 represent the loads. V_C and V_L each represent the capacitative and inductive load voltages in series across the line.

In the vector diagrams, Figures 9 and 10, Figure 9 represents the inductive portion of the system, namely T_1 and its circuits while Figure 10 represents the capacitative portion of the entire load—that is, transformer T and its circuits. I_P represents the line current. Along vector V_L may be laid off vectors I_R and I_{h+e}. I_R represents the load current while I_{h+e} represents the current losses due to hysteresis and eddy currents. At right angles to the current vector, is vector I_ϕ which represents the magnetizing component of the current at right angles to the primary volt-

age. The resultant Io of the two vectors I_{h+e} and I_ϕ represents the no load operating current The vector I_P, which is the resultant of I_R and Io, represents the current going through the primary of T_1. In case T_1 were a choke this current would, of course, be the current going through the choke. As can be seen, the angle between V_L and I_P represents the lagging current in T_1.

Referring to Figure 10, V_C, I'_R, and I'_{h+e} are laid off in similar manner. The resultant I'_O is obtained in the same manner as in Figure 9. At right angles to V_C and opposite in direction to I'_ϕ, is laid off I_C which is the capacitative leading current. Subtracting I'_ϕ from I_C and then combining I'_{h+e} with this difference vector, we obtain vector Is. Combining this vector with the load current I'_R, we finally obtain the resultant I_P which, as above, represents the current through the primary of the load—in this case—of transformer T. It should be noted that since T and T_1 have their primaries in series, I_P will be the same in both instances and, therefore, vectors I_P in Figures 9 and 10 are equal to each other. Figure 11 is a composite of both resultants of Figures 9 and 10. Taking vector V_P, which represents the voltage corresponding to the current I_P, and laying I_P along in the same direction, we may obtain components V_L and V_C from the original V_P. It should be noted that the supply line is assumed to have substantially unity power factor since I_P and V_P are in the same direction. In Figure 12, V_C has been transposed above V_P so as to close the triangle.

Assume that V_P varies. It is readily seen that this variation may be taken up in any one of three ways. The sides of the triangle V_L and V_C may both remain substantially constant while their angles with respect to each other and to the base V_P may change. This, of course, is only true within certain limits. In addition, the lengths of the two sides V_L and V_C, as well as their angles, may change to meet the changing length of V_P. A third way is for the angles to remain the same as V_P changes, while the lengths of V_L and V_C change. It is possible to have only one side of V_L and V_C change. It is also possible to have only one side of V_L or V_C change as well as the angles when base V_P changes. The dotted lines V'_L and V'_C show a variation of base V'_P. V_L remains substantially constant while θ varies as well as V_C. Thus it can be seen that though base V_P varies considerably, still V_L and V_C do not vary much, V_L swinging and describing an arc of a circle. In my system, we keep at least one of the sides, preferably V_L, constant and allow V_C and the corresponding angles to vary as V_P changes. I can, of course, keep both V_L and V_C constant and merely allow the angles to vary, but this method is not as desirable from a commercial point of view as only keeping one side constant.

In this way, it will be seen that I have devised a system whereby a substantially constant voltage may be obtained under conditions when a greater voltage which includes the first mentioned voltage, varies through a considerable range.

What is claimed is:

1. A system for obtaining substantially constant output voltage across a constant or varying load from a source of fluctuating input voltage, such system consisting of two transformers whose primaries are connected in series and whose secondaries are connected in series, and a condenser inductively connected to the primary of one of said transformers.

2. A system for obtaining substantially constant output voltage across a constant or varying load from a source of fluctuating input voltage, such system consisting of two transformers whose primaries are connected in series and whose secondaries are connected in series, and a condenser in parallel relation with the primary of one of said transformers.

3. A system for obtaining substantially constant output voltage across a varying load from a source of fluctuating input voltage, such system consisting of two transformers whose primaries are connected in series and whose cores are excited at different flux densities, the secondaries of said transformers being connected in series with each other and with a load circuit, and a condenser inductively connected to the primary of the transformer with the higher flux density.

4. A system for obtaining substantially constant output voltage across a varying load from a source of fluctuating input voltage, such system consisting of two transformers whose primaries are connected in series and whose cores are excited at different flux densities, the secondaries of said transformers being connected in series with each other and with a load circuit, and a condenser in parallel relation with the primary of the transformer with the higher flux density.

5. A voltage regulation system comprising two transformers, means connecting the primaries of said transformers in series with each other and with a source of alternating current, an iron core for each of said transformers, one of said cores being magnetically saturated and the other core being magnetically unsaturated, means for automatically shifting the phase of the primary voltage of each of said transformers with respect and in response to a fluctuating line voltage, secondary circuits for said transformers, respectively, and means connecting said secondary circuits in series with each other and with a load circuit, said secondary circuits being so connected and related that their resultant voltage is substantially constant from no load to full load for wide fluctuations in line voltage.

6. A voltage regulator comprising, in combination, two windings connected in series with each other and with a source of alternating current, the inductance of one of said windings varying inversely yith the voltage across the terminals thereof, and that of the other of said windings being substantially constant with respect to variations in the voltage across its terminals, means for automatically shifting the phase of the voltage across each of said windings with respect and in response to a fluctuating line voltage, and secondary windings inductively associated with the first mentioned windings, respectively, and connected in series with each other and with a load circuit, said secondary windings being so connected and related that their resultant voltage is substantially constant from no load to full load for wide fluctuations in line voltage.

7. A voltage regulator comprising, in combination, two transformers having their primaries connected in series with each other and with a source of alternating current, and their secondaries connected in series with each other and with a load circuit, and means for automatically shifting the phase of the primary voltage of each of said transformers with respect and in response to a fluctuating line voltage, whereby the resultant

voltage of said secondaries is substantially constant from no load to full load for wide fluctuations in line voltage.

8. A voltage regulator comprising, in combination, two transformers having their primaries connected in series with each other and with a source of alternating current, the vector sum of the primary voltages being variable, and their secondaries connected in series with each other and with a load circuit, and means for rendering the resultant of the secondary voltages substantially constant from no load to full load for wide fluctuations in line voltage.

9. A voltage regulation system comprising, in combination, two transformers, means connecting the primaries of said transformers in series with each other and with a source of alternating current, an iron core for each of said transformers, one of said cores being magnetically saturated and the other core being magnetically unsaturated, a condenser inductively related to the transformer, the core of which is magnetically saturated for automatically shifting the phase of the primary voltages of each of said transformers with respect and in response to a fluctuating line voltage, secondary circuits for said transformers, respectively, and means connecting said secondary circuits in series with each other and with a load circuit, said secondary circuits being so connected and related that their resultant voltage is substantially constant from no load to full load for wide fluctuations in line voltage.

10. A voltage regulator comprising, in combination, two windings connected in series with each other and with a source of alternating current, the inductance of one of said windings varying inversely with the voltage across the terminals thereof, and that of the other of said windings being substantially constant with respect to variations in the voltage across its terminals, a condenser operatively associated with the winding, the inductance of which varies inversely with the voltage across the terminals thereof for automatically shifting the phase of the voltage of each of said windings with respect and in response to a fluctuating line voltage, and secondary windings inductively associated with the first mentioned windings, respectively, and connected in series with each other and with a load circuit, said secondary windings being so connected and related that their resultant voltage is substantially constant from no load to full load for wide fluctuations in line voltage.

11. A voltage regulating system comprising an impedance network consisting of two impedances in series with each other and with a source of alternating current, one of said impedances comprising an inductance and a capacity in parallel, said inductance having a magnetic core and being designed to operate near its saturation point, windings inductively related to said impedance network, said impedances being so proportioned with respect to each other and said windings being so connected that a voltage which is substantially constant from no load to full load for wide fluctuations in line voltage is produced between two spaced points in said windings.

12. In an electrical energy regulating device consisting of an electrical circuit for coupling a utilizing circuit to a source, an impedance and a saturated iron core choke coil in series therewith, an impedance of opposite sign to said first mentioned impedance in parallel with said choke coil and means for coupling the utilizing circuit across said choke coil.

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