

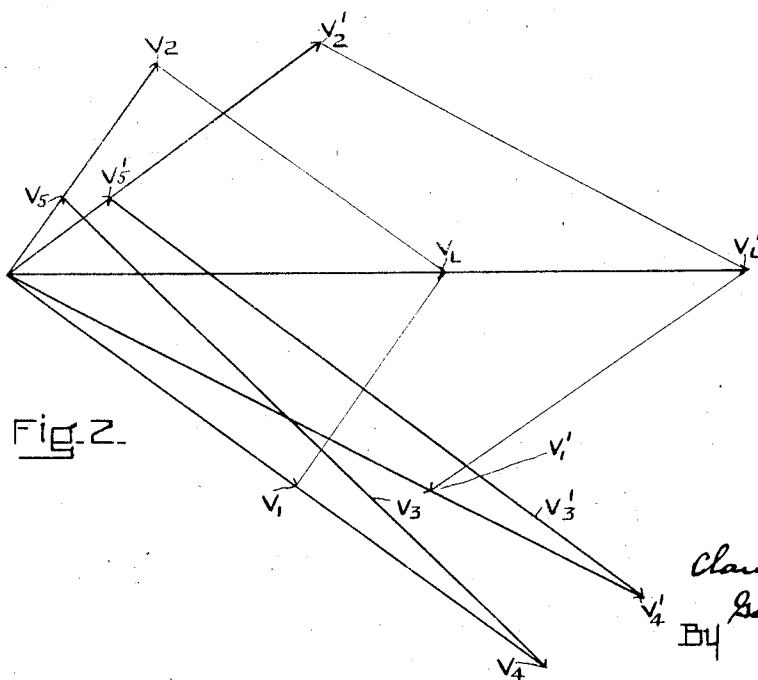
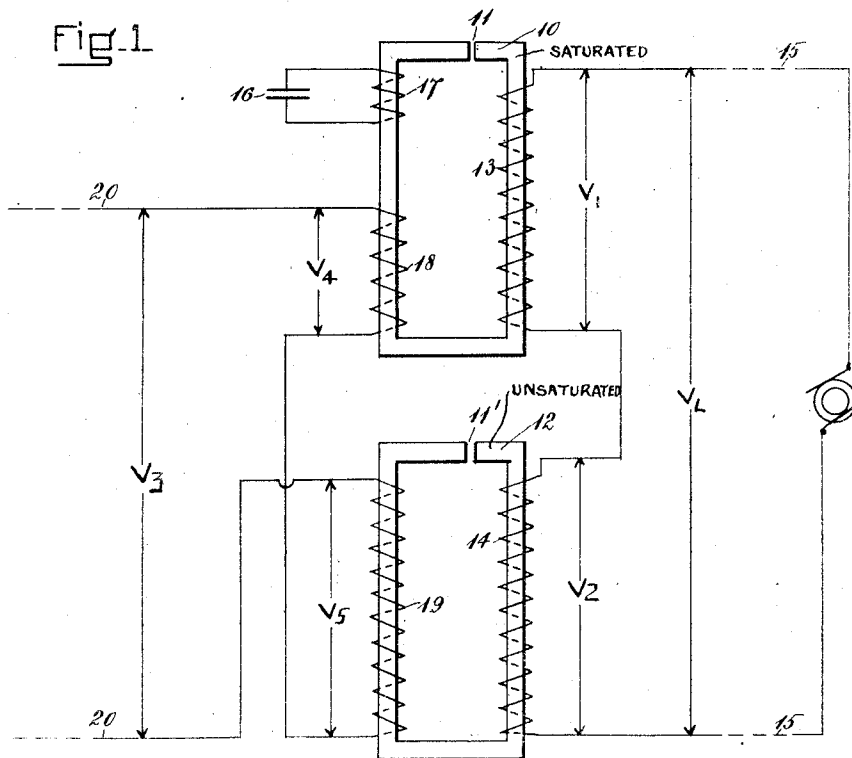
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VOLTAGE REGULATION SYSTEM

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## VOLTAGE REGULATION SYSTEM

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7 Claims. (Cl. 171-119)

The object of the present invention is to provide a system whereby a practically constant voltage may be obtained from a source of alternating current, such as a commercial power distribution system, which is subject to voltage fluctuations due to load variations and other causes.

the system is to be used in connection with radio receiving sets.

In the accompanying drawing:—

Figure 1 is a diagram of a voltage regulator embodying my invention; and

Fig. 2 is a vector diagram employed for more fully explaining the principle thereof.

In the drawing, 10 is a transformer core whose length is great compared to its width so as to provide a relatively long magnetic circuit of comparatively high reluctance, and 11 represents a relatively short air gap which is employed in cases where it is desirable to eliminate the upper harmonics in the voltage delivered to the load circuit. 12 is a second transformer core having substantially the characteristics of the core 10 and provided with an air gap 11' which preferably is somewhat larger than the air gap 11.

The primaries 13, 14 are connected in series with the line 15, 15 and in order to shift the phase of the voltage  $V_1$  across the primary 13 on the core 10, and the phase of the voltage  $V_2$  across the primary 14 on the core 12 with respect and in response to the fluctuating line voltage  $V_L$ , a condenser 16 connected in series with the secondary 17 may be employed. By means of said condenser the phases of the voltages  $V_1$  and  $V_2$  are automatically shifted with respect and in response to the line voltage  $V_L$  because, by virtue of the capacitance of said condenser, the voltage  $V_1$  always lags behind the line voltage while the voltage  $V_2$  always leads the line voltage, as shown by the diagram in Fig. 2. This relation is true for all fluctuations of line voltage and for all variations of load from no load to full load. The ratio of the turns in the secondary 17 to those of the primary 13 is greater than unity and may be as high as 10 to 1. By this arrangement the condenser 16 which reacts through the magnetic field to shift the phase of the voltage  $V_1$  may be very much smaller than if it were connected directly across the primary 13, the effect of such condenser depending upon the square of the ratio of transformation, for example, if such ratio is 10 to 1, a condenser of one microfarad connected across the secondary will have the same effect as a condenser of 100 microfarads connected across the primary. Wound on the cores 10 and 12 are secondaries 18, 19, respectively, which as shown, in the present instance, are connected in opposition and in series with the load circuit 20, 20.

As above stated, the secondaries 18 and 19 are so connected and related to the other ele-

With this object in view, my invention comprises essentially two transformers having their primaries connected in series with an alternating current source and their secondaries connected in series with each other and with a load circuit, such connection being in opposition or in conjunction, depending on the relative direction of the windings of said transformers, as hereinafter more fully explained. The transformers are so designed that the primary inductance of one remains substantially constant with respect to voltage changes across its terminals, and the inductance of the other varies rapidly and inversely with voltage changes across its terminals. Means are provided for automatically shifting the phase of each of the primary voltages with respect to a fluctuating line voltage and in response to changes in such line voltage. For this purpose, a condenser may be employed and is connected across the terminals of the primary having the variable inductance, or preferably across the terminals of a winding inductively associated with said primary, so that the voltage across the terminals of said primary will lag behind the line voltage, while the voltage across the primary having the substantially constant inductance leads the line voltage.

The transformer windings are so related and arranged that the vector sum of the primary voltages varies with fluctuations of line voltage and the resultant of their secondary voltages is substantially constant from no load to full load. The voltages across said primaries vary with the line voltage, but their phase difference varies inversely with the line voltage because of the changes in the inductance of the variable inductance primary. It is desirable though not necessary that the magnetic circuits of the transformers belong compared to those of the usual transformer,—in other words, I prefer to employ a transformer core whose length is great compared to its width, the ratio of the length to the width being, for example, as large as 6 to 1 in contradistinction to the usual transformer in which such ratio is ordinarily about 3 to 1. Preferably each transformer core is provided with an air gap to eliminate upper harmonics where a simple harmonic voltage is desired, e. g., when

ments of the system that their resultant voltage which, in the present instance, is the vector difference of their voltages  $V_4$  and  $V_5$  is always substantially constant, irrespective of variations in the line voltage and irrespective of variations in load from no load to full load, and the direction of each of said secondary windings is so related to that of its primary that in the present instance each secondary voltage is substantially in phase with its primary voltage, as indicated in Fig. 2. This means, of course, that the primary winding of each transformer is wound in the opposite sense to its own secondary, and as shown in Fig. 2, the secondaries are connected reversely, or "in opposition" so that their resultant voltage is equal to the vector difference of their voltages; but the same ultimate result would obviously be obtained if the primary of each transformer were wound in the same sense as its own secondary, so that each secondary voltage would be substantially  $180^\circ$  out of phase with its primary voltage, and the secondaries connected, as before, in opposition. Also, the same ultimate result would be obtained if the primary of one transformer, say 10, were wound in the opposite sense to its own secondary, and the primary and secondary of the other transformer 12 were both wound in the same sense, and the secondaries connected directly, instead of reversely as shown in Fig. 2, that is to say, the lower (outside) terminal of secondary 18 connected to the upper (inside) terminal of secondary 19. This is so, because in such case the secondary voltage  $V_4$  of the first transformer will be substantially in phase with its primary voltage  $V_1$  and the secondary voltage  $V_5$  of the second transformer substantially  $180^\circ$  out of phase with its own primary voltage  $V_2$ . When I use the expression "the secondaries being so connected and related that their resultant voltage is substantially constant" in the appended claims, I desire to be understood as defining the foregoing and other obvious equivalent arrangements, and any and all other permutations of direction or sense of the transformer windings with the modes of connecting the secondaries in series.

The vector sum of the primary voltages  $V_1$  and  $V_2$  is equal at all times to the line voltage  $V_L$ . The resultant or, in the present instance, the vector difference of the voltages  $V_4$  and  $V_5$  is the load voltage  $V_3$ . As the line voltage increases, for example, to the value  $V_L'$ , the primary voltages will increase to the values  $V_1'$  and  $V_2'$ , respectively, and the secondary voltages will increase to the values  $V_4'$  and  $V_5'$ , respectively. The resultant, or, in the present instance, the vector difference of the voltages  $V_4'$  and  $V_5'$  is  $V_3'$  which is always substantially equal to  $V_3$ , for wide variations in  $V_L$ .

It is desirable to use high magnetizations in the core 10, and preferably to work on the flat portion of the B—H curve which represents magnetic saturation, e. g. to use flux densities of the order 13,000–16,000, because at such flux densities the permeability of transformer iron changes rapidly with the flux density and hence the inductance of the primary winding, which is proportional to permeability, also changes rapidly with the flux density, and I prefer, as above stated, to use a core having its length great compared to its width so as to increase the reluctance of the magnetic circuit, for, by so doing, I may obtain the same results with a lower degree of magnetization as would be effected if the core

had less reluctance and a higher degree of magnetization were used.

I have found in practice that by means of my invention substantially constant voltage may be obtained across the terminals of the load circuit when the line voltage is subjected to so large a variation as 35%, for example, when it varies between 90 and 130. Where a simple harmonic electromotive force in the output circuit is necessary or is more desirable than an absolutely constant voltage, as for instance, where the system is to be employed for supplying the several voltages for radio receiving sets employing alternating current tubes, I provide core 10 with a gap such as 11, to eliminate the upper harmonics and thereby prevent the radio set from giving off an audible hum, and in such case, I have found that the load voltage remains constant within about 2%.

If the air gap 11 is too long, the inductance of the primary 13 will not vary sufficiently with variations in the voltage  $V_1$  to accomplish my object, because such inductance is an inverse function of the sum of the length of the air gap and the ratio of the length of the iron circuit to the permeability thereof. I have found, however, that if said gap 11 be made relatively short, the inductance of the primary 13 will vary with sufficient rapidity with changes in the voltage  $V_1$  to effect the desired result.

Inasmuch as the inductance of the primary 14 should remain substantially constant irrespective of variations in the voltage  $V_2$ , the air gap 11' is made somewhat longer than the gap 11 so that the length thereof is much greater than the ratio of the length of the iron circuit to the permeability thereof, and therefore such ratio has but little effect in determining the value of the inductance. Furthermore, the flux densities employed in this core are more nearly normal, 10,000 to 13,000 lines, i. e., said core is unsaturated.

Without limiting myself thereto, I append a list of the constants of a voltage regulation system constructed in accordance with my invention to deliver 110 volts and current not exceeding .6 ampere with a variation in line voltage of from 90 to 130 volts:

Primary 13 270 turns of No. 19 wire.  
Primary 14 400 turns of No. 19 wire.  
Secondary 17 2800 turns of No. 27 wire.  
Secondary 18 510 turns of No. 24 wire.  
Secondary 19 160 turns of No. 24 wire.  
Condenser 16, 1 m. f.  
Cross section of core 10, 1 square inch.  
Length of air gap 11, .020 inch.  
Cross section of core 12, 1 square inch.  
Length of air gap 11', .040 inch.

The regulation obtained by means of my invention is independent of load from no-load to full load of the particular rating. The efficiency of my improved regulator is relatively high, a 60-watt system having an efficiency of 60% at 130 volts input, and 80% at 90 volts input. Inasmuch as the usual 60-watt transformer has an efficiency of 85%, the energy loss to get the desired result is not prohibitive.

Radio receiving sets of the type known as "electrical", that is, those which require no batteries and are connected directly to a light socket, are provided with means whereby the proper voltages are delivered to the lamp filaments, plates, grids, etc., and in such case, the load circuit of my system will simply be connected to the termi-

nals of such sets which heretofore are connected to the lighting circuit.

It will, however, be a merely obvious extension of the system shown and described herein to provide each of the cores 10, 12 with a plurality of sets of secondaries 18, 19 designed to deliver constant potential of the proper values for the various elements of the radio receiving set, for example, one pair of secondaries which will deliver five volts for tube filaments, another pair for 1.5 volts for other tube filaments, another pair which will deliver 600 volts to the plates of rectifier tubes, etc.

Having thus described an illustrative embodiment of my invention, without however limiting the same thereto, what I claim and desire to secure by Letters Patent is:—

1. A voltage regulation system comprising in combination two transformers each having an iron core provided with an air gap, one of said cores being magnetically saturated, and the other core being magnetically unsaturated, means connecting the primaries of said transformers in series with each other and with a source of alternating current; 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; secondaries for said transformers, respectively, and means connecting said secondaries in series with each other and with a load circuit, said secondaries being so connected and related that their resultant voltage is substantially constant from no load to full load for wide fluctuations in line voltage.

2. A voltage regulator comprising in combination two windings connected in series with each other and with a source of alternating current, an iron core for each of said windings, one of said cores being magnetically saturated and having a relatively short air gap, and the other core being magnetically unsaturated; 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 the resultant voltage is substantially constant from no load to full load for wide fluctuations in line voltage.

3. A voltage regulator comprising in combination two windings connected in series with each other and with a source of alternating current, an iron core for each of said windings, one of said cores being magnetically saturated and having a relatively short air gap, and the other core being magnetically unsaturated and having a relatively long air gap, 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.

4. A system for obtaining substantially constant output voltage across a varying load from a source of fluctuating input voltage, such system comprising two transformers whose primaries are connected in series and whose cores are excited at different flux densities, the transformer whose core has the higher flux density being a step-up transformer and the transformer whose core has the lower flux density being a step-down transformer, means connecting the secondaries of said transformers in series with each other and with a load circuit, and a condenser inductively connected to the primary of the transformer, the core of which has the higher flux density.

5. A system for obtaining substantially constant output voltage across a varying load from a source of fluctuating input voltage, such system comprising two transformers whose primaries are connected in series and whose cores are excited at different flux densities, the transformer whose core has the higher flux density being a step-up transformer and the transformer whose core has the lower flux density being a step-down transformer, means connecting the secondaries of said transformers in series with each other and with a load circuit, a winding inductively related to the primary of the transformer having the higher flux density, said winding having a greater number of turns than the primary with which it is related, and a condenser connected to the terminals of said winding.

6. A system for obtaining substantially constant output voltage across a varying load from a source of fluctuating input voltage, such system comprising two transformers whose primaries are connected in series and whose cores are excited at different flux densities, the ratio of the secondary voltage of the transformer whose core has the higher flux density to the secondary voltage of the transformer whose core has the lower flux density being greater than unity, means connecting the secondaries of said transformers 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.

7. A system for obtaining substantially constant output voltage across a varying load from a source of fluctuating input voltage, such system comprising two transformers whose primaries are connected in series and whose cores are excited at different flux densities, the ratio of the secondary voltage of the transformer whose core has the higher flux density to the secondary voltage of the transformer whose core has the lower flux density being substantially five to one, means connecting the secondaries of said transformers 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.

CLAUDE F. CAIRNS.