April 25, 1950 F. H. JOHN ET AL 2,505,620

REGULATING TRANSFORMER SYSTEM

Filed Jan. 28, 1947

FIG. 1

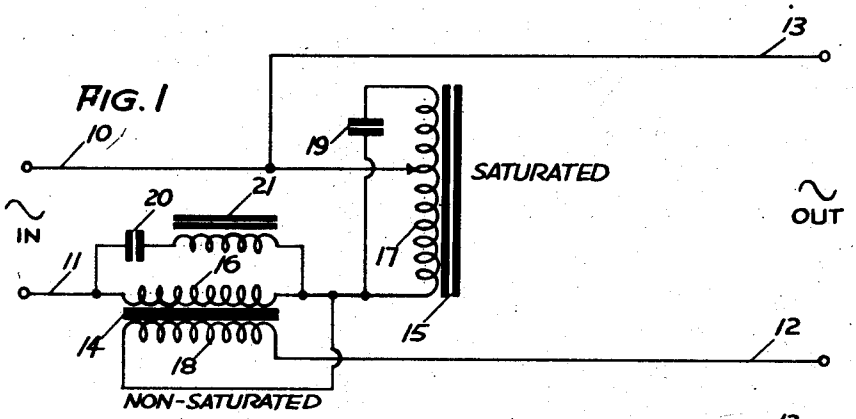


FIG. 2

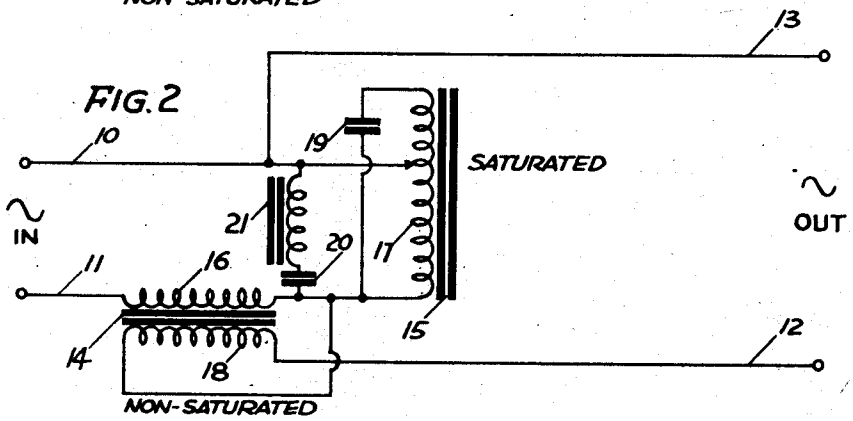
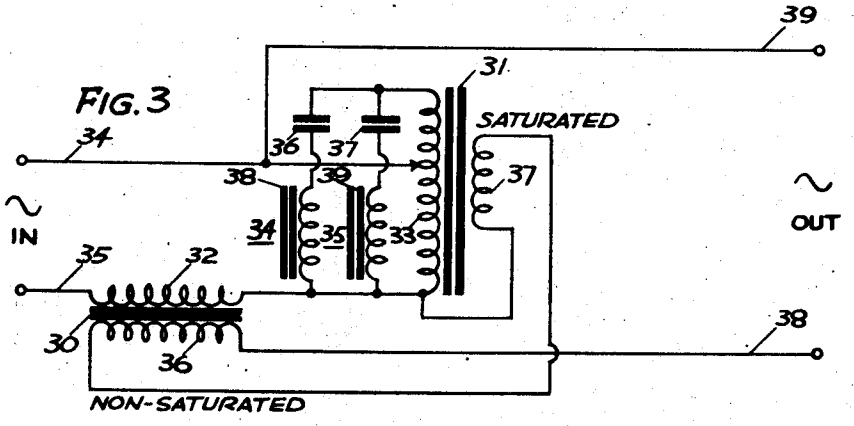


FIG. 3



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REGULATING TRANSFORMER SYSTEM

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4 Claims. (Cl. 323—61)

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This invention relates to alternating current regulating systems of the magnetic or inductive type.

It is an important object of this invention to provide an improved form of alternating current voltage regulating system having a regulated output voltage of substantially sinusoidal waveform.

It is another object of this invention to provide a system of voltage regulation for alternating current, the system employing a number of transformers, inductances and condensers to obtain a regulated output voltage of substantially sinusoidal waveform which is relatively devoid of harmonics whereby the relationship between peak, average, and R. M. S. output voltages is almost exactly the same as a sine wave and wherein simultaneous voltage regulation to close limits of the peak, average, and R. M. S. values of output voltage is obtained.

Further objects and advantages of this invention will be apparent upon reference to the following specification and drawing in which:

Fig. 1 is a schematic diagram of one form of the invention;

Fig. 2 is a schematic diagram of another form of the invention; and

Fig. 3 is a schematic diagram of yet another form of the invention.

One of the magnetic or transformer types of alternating current voltage regulating system over which this invention is an improvement is generally shown and described by the U. S. patent to Fleming 1,985,634, issued December 25, 1934. The system shown therein may be generally stated to comprise two impedances connected in series, one of the impedances consisting of a highly saturated magnetic core inductance designed to be operated near the bend of its saturation curve. The winding of the saturated core inductance is resonated to the fundamental frequency of the line voltage by a parallel connected condenser or impedance of opposite sign and, since its inductance is substantially saturated, the impedance of the resonant circuit thus obtained in series with the line and the other impedance is extremely variable for slight line voltage changes. Each of the impedances has secondary windings inductively related thereto and the connections of the elements in the system are such, as set forth in the prior patent, to produce a regulated voltage output for considerable variations of voltage input. The waveform of the regulated voltage output from such a system is not sinusoidal, it being rich in third and fifth harmonics of the fundamental as well as numerous other odd harmonics to a lesser extent.

It has been discovered by this invention that the presence of the odd harmonic waveforms in the regulated voltage output from such a system is due to an inherent function of the saturated

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inductance operating near the bend of its saturation curve which, in order to produce a sinusoidal voltage output, requires an input containing certain odd harmonic currents in amounts according to the exact point on the saturation curve that the inductance is operating. The supply of such harmonic currents from the fundamental line frequency to the saturated inductance is ordinarily blocked by the non-saturated impedance in series therewith. This invention therefore provides a means for supplying certain harmonic currents of the fundamental line frequency to the winding of the saturated inductance so that the resultant voltage output will be substantially sinusoidal and devoid of harmonics.

The system shown by Fig. 1 of the drawing provides one means of supplying harmonic currents of the fundamental line frequency to the primary of a saturated transformer used in such system. Terminals 10 and 11 are connected to the alternating current line of a known fundamental frequency such as, for example, sixty cycles per second. The regulated voltage output of the system appears at the terminals 12 and 13. A non-saturated transformer 14 and a saturated autotransformer 15 are provided with their primaries 16 and 17 connected in series with the line voltage at terminals 10 and 11 and their secondaries 18 and 17 connected in series opposition with the output terminals 12 and 13. Connected across the winding of the saturated autotransformer 15 is a condenser 19 adapted to resonate the tuned circuit comprised of primary 17 and condenser 19 to the line frequency. Thus far, the voltage regulating or stabilizing system is conventional. In order to supply certain harmonic currents of the line frequency to the saturated primary 17, in accordance with the teachings of this invention, to provide a substantially sinusoidal waveform for the output voltage, a series tuned resonant circuit comprising the condenser 20 and inductance 21 is connected across the primary 16 of transformer 14 in series with the saturated primary 17. With the series tuned circuit adapted to resonate at a selected harmonic, for example the third harmonic of the line frequency, it will be apparent that such harmonic current is bypassed around the non-saturated impedance of winding 16 or, in other words, is generated from the fundamental line frequency to be supplied to the saturated primary 17 so that its output voltage will be substantially sinusoidal and devoid of the third harmonic. It should be understood that the selection of a particular harmonic frequency or combination of harmonic frequencies for the series tuned circuit or circuits is a matter of choice as determined by the desired quality of sinusoidal waveform for the output voltage and the number of harmonics to be eliminated in the output voltage. Also it should be

noted that although a saturated core autotransformer of one-to-one ratio has been described, the system of the invention is not limited to the use of such ratio or autotransformer. For example, conventional insulated transformers of either step-up or step-down ratios may be used and such is done in the system of Fig. 3 to be later described.

A somewhat modified form of regulating system having means for applying certain fundamental currents of the line frequency to the saturated primary winding is shown in Fig. 2 of the drawing. Elements of the system which are the same as in the system of Fig. 1 will be given identical reference numerals and will not be further described. It will be noted that in this form of the invention the series tuned resonant circuit comprised of condenser 20 and inductance 21, tuned to a harmonic of the fundamental line frequency, is connected in parallel to the saturated primary winding 17 instead of in parallel to the non-saturated primary 16 as shown by Fig. 1. In both systems the results are the same, the series tuned circuit functioning to generate a selected harmonic current of the fundamental line frequency and apply it across the terminals of saturated primary 17 so as to obtain substantially sinusoidal waveforms for the regulated voltage output.

The system of Fig. 3 is somewhat different. A non-saturated transformer 30 and a saturated transformer 31 are provided with their primaries 32 and 33 connected in series with the line input terminals 34 and 35 and their secondaries 36 and 37 connected in series opposition to the output terminals 38 and 39. Connected across the saturated primary 33 is a pair of series tuned circuits 34 and 35, respectively, including condensers 36 and 37 and inductances 38 and 39, respectively. One of the series tuned circuits 34 or 35 may be designed to resonate at the third harmonic of the fundamental line frequency and the other may be resonated at the fifth harmonic. It should be mentioned that in such an arrangement neither of the inductances 38 and 39 offers a substantial impedance to the fundamental line frequency so that the condensers 36 and 37 may simultaneously function to resonate the saturated primary 33 to the fundamental line frequency, thus eliminating the condenser 19 shown in the systems of Figs. 1 and 2. It should be apparent that the waveform of the voltage output from the system of Fig. 3 will be substantially more sinusoidal than that obtained from the systems of Figs. 1 and 2 since it is substantially more devoid of harmonic content, both the third and fifth harmonics being substantially eliminated. Obviously additional series tuned circuits for other odd harmonic frequencies, such as the seventh, ninth etc., may be used alone or together where a specifically desired quality of sinusoidal waveform for the output voltage is desired.

It is not intended that this invention be limited to the specific systems described since it is apparent that equivalent means for generating certain odd harmonic currents of the line frequency and applying them to the saturated core magnetic winding in such regulating systems will occur to those skilled in the art.

What is claimed is:

1. A voltage regulating system comprising 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, means by-passing the other of said impedances to apply one or more selected odd harmonic currents of the fundamental line frequency to said inductance, and windings inductively related to said impedances, said windings being connected in series opposition whereby a regulated voltage having a waveform substantially devoid of the selected harmonics is obtained between two spaced points on said windings.

2. A voltage regulating system comprising two transformers, means connecting the primaries of said transformers in series with each other and 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 to resonate the primary of the saturated core transformer to the fundamental line frequency, and means connected across the primary of the unsaturated core transformer to apply one or more selected odd harmonic currents of the fundamental frequency to the primary of the saturated core transformer, the secondaries of said transformers being connected in series opposition whereby a resultant regulated voltage having a waveform substantially devoid of the selected harmonics is obtained across said secondaries.

3. A voltage regulating system comprising 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, means comprising one or more series resonant circuits tuned to one or more selected odd harmonic frequencies of said fundamental frequency and connected in parallel with one of said impedances, and windings coupled to said impedances and connected in series opposition with respect to each other whereby a regulated voltage having a waveform substantially devoid of the selected harmonics is obtained between two spaced points on said windings.

4. A voltage regulating system comprising two transformers, means connecting the primaries of said transformers in series with each other and 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 mangetically unsaturated, means to resonate the primary of the saturated core transformer to the fundamental line frequency, means comprising one or more series resonant circuits tuned to one or more selected odd harmonics of said fundamental frequency and connected in parallel with the primary of the unsaturated core transformer, and means connecting the secondaries of said transformers in series opposition whereby a resultant regulated voltage having a waveform substantially devoid of the selected harmonics is obtained across said secondaries.

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548,526	Great Britain	Oct. 12, 1942

Certificate of Correction

Patent No. 2,505,620 April 25, 1950

FRANK H. JOHN ET AL

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 4, line 38, for the word "one" read *the other*;

and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 18th day of July, A. D. 1950.

[SEAL]

JOE E. DANIELS,
Assistant Commissioner of Patents.

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