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VOLTAGE REGULATOR

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FIG. 1

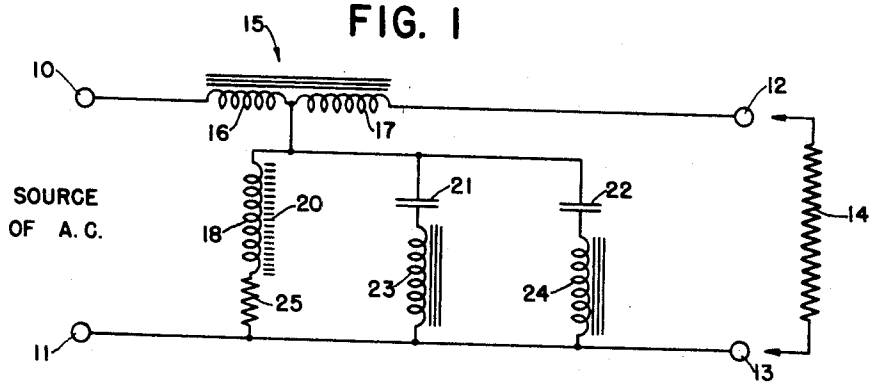


FIG. 2

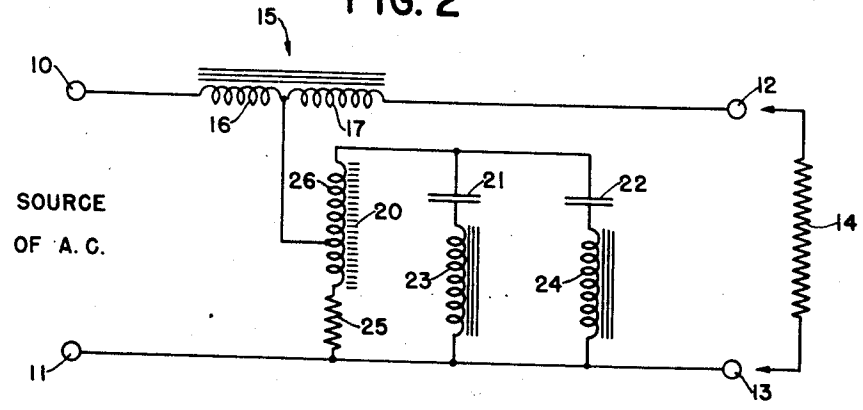
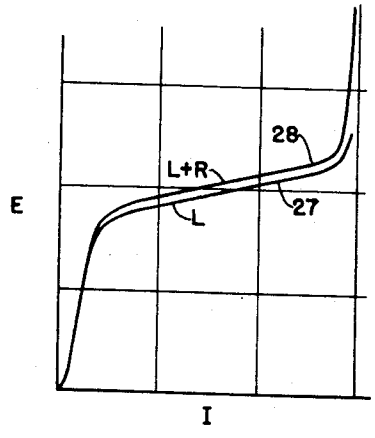


FIG. 3



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VOLTAGE REGULATOR

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3 Claims. (Cl. 323—77)

This invention relates to a voltage regulator which employs resonance as one of the features of regulation. It has particular reference to the use of a resistor in the resonant circuit in order to deliver a wave form at the output terminals which contains few harmonics.

Many forms of voltage regulators have been designed and built employing a saturated core reactor in a resonant circuit as a means for voltage regulation. Such regulators have no moving parts, are self contained and last for a long time without servicing. The main objection of this type of regulator is the output wave form which is generally distorted and contains many harmonic components. The present invention eliminates the majority of these components and produces an output wave which is susbtantially undistorted. The elimination of the harmonics is accomplished by the simple addition of a resistor in series with the saturable reactor. This addition can be made at only a slight increase in cost yet the results are substantially different from prior art regulators of this general type.

The voltage regulator here shown may be generally described as comprising two impedances connected in series, one of these impedances including 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 capacitor 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 voltage changes.

One of the objects of this invention is to provide an improved voltage regulator which avoids one or more of the disadvantages and limitations of prior art regulators.

Another object of the invention is to improve the wave form of a voltage regulator.

Another object of the invention is to provide a voltage regulator which is relatively cheap and which provides good regulation within a wide range of applied voltage and load variation.

The invention comprises a series load compensating transformer in conjunction with a saturable reactor connected in a resonant circuit. The resonant circuit contains a resistor, the saturable reactor, and one or more capacitors which provide the resonant characteristic.

For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following description taken in connection with the accompanying drawings.

Fig. 1 is a schematic diagram of connections showing one form of the circuit.

Fig. 2 is a schematic diagram of connections showing an alternate circuit.

Fig. 3 is a graph showing the variation of peak exciting current I with applied voltage E for the saturable reactor alone (curve 27). A similar curve is shown (curve 28) when the resistor 25 is added.

Referring now to Fig. 1, the voltage regulator includes input terminals 10, 11, which are to be connected to a source of alternating current which may vary considerably in applied voltage. The circuit also includes output terminals 12 and 13 for connection to a load 14. In series connection between terminals 10 and 12 is a transformer 15 having two windings 16 and 17. These windings are connected in series as shown and winding 17 is connected so that the voltage across its terminals aids the voltage across winding 16, this being the usual connection for transformers of this type.

A parallel resonant circuit is connected between the center connection of transformer 15 and the conductor which joins terminals 11 and 13. This resonant circuit includes a winding 18 on a saturable core 20 and one or more capacitors 21, 22, which may be connected directly across the terminals of winding 18. In order to reduce the harmonic content of the output current it is common practice to connect a small inductor such as 23 and 24 in series with capacitors 21 and 22, the values of these inductors being chosen so that capacitor 21 and inductor 23 are resonant at the third harmonic of the applied frequency and capacitor 22 and inductor 24 are resonant at the fifth harmonic of the applied frequency.

It has been found that a substantial reduction of wave form distortion will occur if a resistor 25 is connected between one end of winding 18 and the common conductor which connects terminals 11 and 13. This resistor controls the resonant current by reducing it only slightly and its inclusion does not affect the voltage regulation. It does cause a substantial reduction of wave form harmonics. The action of this resistance is twofold. First, it serves to limit the large exciting current peaks of winding 18. Second, it increases the absolute value of the fundamental frequency voltage component in relation to the harmonic voltages.

Fig. 3 shows the variation of the exciting current in winding 18 when the resistor 25 is omitted (curve 27) and when resistor 25 is added (curve 28). The average value of the current in winding 18 is plotted against the voltage measured across both the winding 18 and resistor 25, these measurements being made when the reactor and resistor are not connected in parallel with other circuits.

It should be evident that the inductive reactance of winding 18 is constant for any given frequency or for any harmonics of that frequency. It follows then that the higher frequency components are affected less by the resistance than the fundamental. Hence, if winding 18 is designed to have the same voltage drop across its terminals, both with and without resistor 25, then the combination of the two contains a lower harmonic content.

The regulating action of this circuit depends upon core 20 being saturated. Obviously then, resistor 25 cannot be increased without limit. However, within reasonable limits the added resistor not only reduces harmonic content but also makes the effect of load changes less noticeable.

In one circuit tested in the laboratory where the voltage across winding 18 was 112 volts, resistor 25 was given a value of six and a quarter ohms. The value of resistor 25 is within the range of two to ten percent of the maximum load resistance.

The circuit shown in Fig. 2 is the same as that shown in Fig. 1 except that the connection from the mid-point of transformer 15 to the saturable reactor is made to a mid-point on winding 26, making it an autotransformer. With this connection the reactance of winding 26 may be appreciably increased, thereby reducing the values of capacitors 21 and 22.

The invention is not confined to a circuit having two

series resonant paths. These paths may be replaced by a single capacitor or several additional resonant circuits may be added, resonant to the seventh, ninth, etc. harmonics of the fundamental frequency. The selection of these circuits depends upon the specific quality of waveform desired.

Having thus fully described the invention, what is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A voltage regulator for supplying alternating current from a supply source to a load having a predetermined maximum value comprising, two impedances in series with each other and with two input terminals which are to be connected to a source of alternating current, one of said impedances comprising two parallel connected circuits, one of said circuits including a saturable reactor and a resistor in series, the other of said circuits including a capacitor and an inductor in series, said reactor having a magnetic core and being designed to operate near its magnetic saturation condition, said resistor having a value which lies within the range of two to ten percent of said maximum load resistance, the other of said impedances comprising a non-saturated inductor with its windings connected in series between an input and an output terminal.

2. A voltage regulator for supplying alternating current from a supply source to a load having a predetermined maximum value comprising, two impedances in series with each other and with two input terminals which are to be connected to a source of alternating current, one of said impedances comprising two parallel connected circuits, one of said circuits including a saturable reactor and a resistor in series, the other of said circuits including a capacitative reactance which is adapted

to form a resonant circuit with said saturable reactor at the fundamental frequency of the source, said reactor having a magnetic core and adapted to operate near its magnetic saturation condition, said resistor having a value which lies within the range of two to ten percent of said maximum load resistance, the other of said impedances comprising a non-saturated inductor with its windings connected in series between an input and an output terminal.

3. A voltage regulator for supplying alternating current from a supply source to a load having a predetermined maximum value comprising, two impedances in series with each other and with two input terminals which are to be connected to a source of alternating current, one of said impedances comprising two parallel connected circuits, one of said circuits including a saturable reactor and a resistor in series, the other of said circuits including a plurality of series resonant circuits adjusted to resonate at odd harmonics of the source frequency, said reactor having a magnetic core and adapted to operate near its magnetic saturation condition, said resistor having a value which lies within the range of two to ten percent of said maximum load resistance, the other of said impedances comprising a nonsaturated inductor with its windings connected in series between an input and an output terminal.

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