VOLTAGE REGULATOR

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FIG. 1

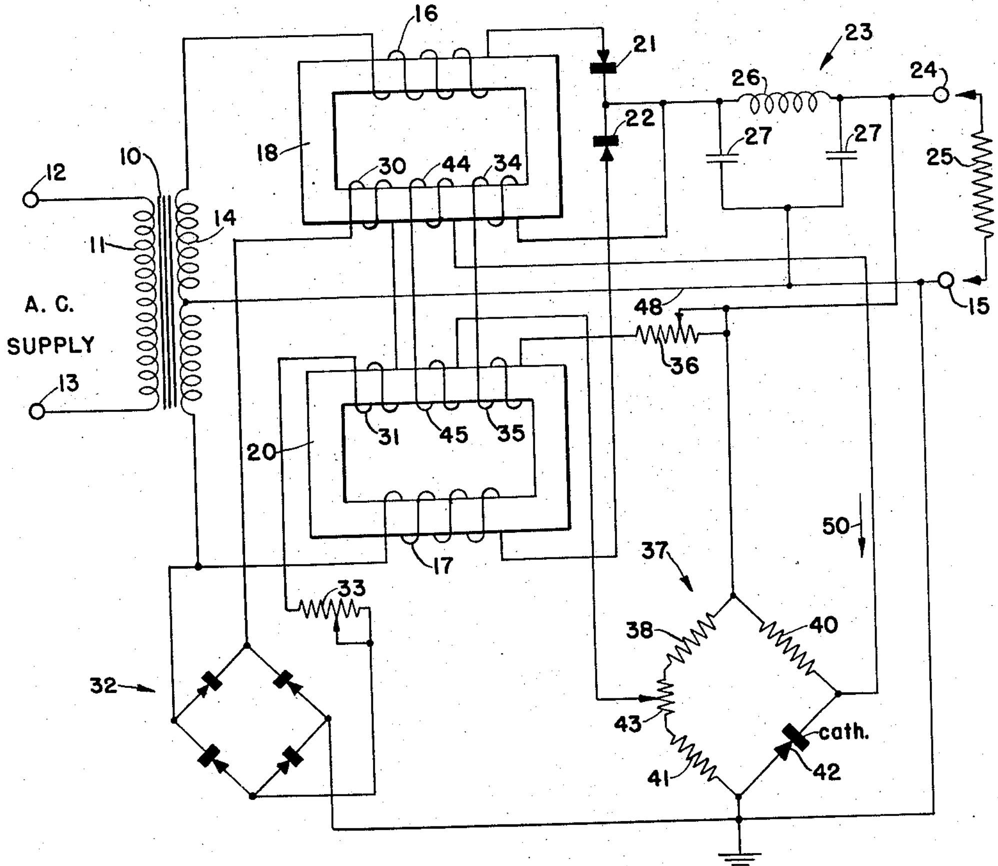
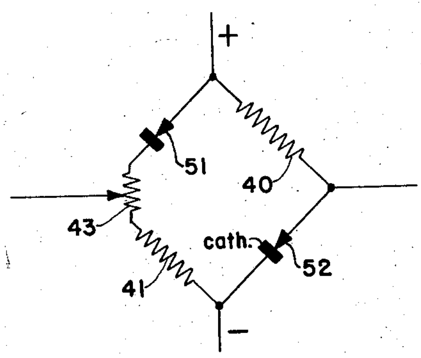


FIG. 2



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1

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VOLTAGE REGULATOR

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This invention relates to voltage regulators for alternating current supply lines which are rectified to produce a regulated direct current voltage. It has particular reference to voltage regulators which do not employ electron discharge devices. The invention has further reference to voltage regulators which employ two saturable reactors which work in combination to produce a constant direct current voltage across a load when the alternating current supply varies over a wide range of voltage values and when the connected load varies over a wide range of resistance values.

Many types of voltage regulators have been designed and used which employ electron discharge devices such an triodes and pentodes in amplifier circuits in order to produce a control current which can be applied to a saturable reactor and vary the impedance in a series or parallel circuit to regulate the output voltage. Other voltage regulators use a single transformer arrangement, the core of which is partially saturated, for voltage regulation without the use of amplifier circuits. These regulators have not produced good regulation, the output voltage varying over several percent when the input voltage is varied over a range of plus or minus 10 percent. The present invention employs two transformer cores, each of these cores being normally operated at a value of magnetic flux which partially saturates the core material. The value of the output voltage, above or below a desired value, is sensed by a Wheatstone bridge arrangement containing one or two dry plate rectifiers as the bridge arms. This sensing circuit together with a plurality of biasing and controlling coils on the two transformer cores produces a regulation at the load terminals which is a considerable improvement over similar prior art devices. The absence of electron discharge devices eliminates the failure due to broken filaments, short circuited elements within a vacuum container, and loss of vacuum.

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

Another object of the invention is to provide a voltage regulator which has long life and is not subject to the failures which are generally inherent in regulators containing electron discharge devices.

Another object of the invention is to provide a voltage regulator which is able to withstand excessive vibration and mechanical shock without changing its operating characteristics.

Another object of the invention is to simplify the construction and assembly of voltage regulators.

The invention comprises an alternating current supply for two half-wave saturable core reactors, each of which contains three control windings. One of these saturable reactors includes a main winding for transmitting the alternating current from one terminal of a supply line to the load circuit. The second of these saturable reactors includes a similar main winding for transmitting alternating current from the other terminal of the supply

2

line to the load circuit. Both the first and second reactors contain a control coil in series with a rectifier unit for compensating for supply voltage variations. Both reactors also contain a control coil which compensates for variations in load voltage. And in addition both reactors contain a control coil connected to a load sensing circuit for fine adjustment of the output voltage.

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 of the voltage regulator.

Fig. 2 is a schematic diagram of connections of an alternate form of the bridge sensing circuit.

Referring now to Fig. 1 a supply transformer **10** includes a primary winding **11** having terminals **12**, **13** which are to be connected to an alternating supply line which may vary considerably in voltage. A secondary winding **14** includes a tap at its mid-point which is connected to a negative terminal **15** of the load circuit. The end terminals of winding **14** are connected to two power windings **16** and **17** which are placed on two cores **18** and **20**. The other ends of windings **16** and **17** are connected in series with dry plate rectifier units **21** and **22**, the negative terminals of these rectifiers being connected together and to a filter circuit **23** which is designed to eliminate most of the pulsing components of the rectified power so that only direct current is available at terminals **24** and **15** which are to be connected to an external load **25**. Filter **23** may include a series inductor **26** and two capacitors **27**.

The line voltage variations are partly compensated by a coil **30** on core **18** and a similar coil **31** on core **20**. These two coils are in series and are connected to opposite junction points of a four element rectifier **32**, the other two junction points of which are connected across the lower half of winding **14**. It will be obvious that the voltage across this portion of secondary winding **14** is subject to all the voltage variations of the A. C. supply line. Connection might have been made across the entire winding **14** or across the supply terminals **12**, **13** but in order to reduce the inductive effect from other outside circuits one portion of this circuit is connected to ground. A variable resistor **33** is connected in series with windings **30** and **31** for manual adjustment.

In order to compensate for load voltage variations two windings **34** and **35** are connected in series with an adjustable resistor **36** and connected across the terminals of inductor **26**. Winding **34** is on core **18** while winding **35** is on core **20**, the current through these two windings being proportional to the resistive voltage drop of inductor **26**.

The output voltage on terminals **24**, **15** is sensed by a bridge arrangement **37** which in Fig. 1 is indicated by three main resistor arms **38**, **40**, and **41**. The fourth arm comprises a dry plate rectifier component **42**. The degree of unbalance of the bridge and the regulated output voltage may be adjusted by varying a small voltage divider **43**. The output terminals are connected to opposite junction points of the bridge while the other two junction points are connected to two control windings **44** and **45** in series. Winding **44** is on core **18** while winding **45** is on core **20**.

The operation of this circuit is as follows: Let it first be assumed that an average voltage of the A. C. supply is impressed upon terminals **12** and **13**. This produces an alternating current, generated by the upper half of winding **14**, which flows through winding **16**, rectifier **21**, inductor **26**, to terminal **24** and load **25**. The return circuit for this current is through terminal **15** and conductor **48** to the mid-point of winding **14**. A similar circuit may be traced from the bottom portion of winding 14 through winding 17, rectifier 22, inductor 26, terminal 24, load 25, terminal 15, and common conductor 48. A portion of the voltage generated by the lower half of winding 14 is rectified by bridge rectifier 32 and a direct current is sent through windings 30 and 31 on cores 18 and 20. The flux generated by windings 30, 31 opposes the flux generated by coils 16 and 17 but since windings 16 and 17 carry comparatively large currents, coils 30 and 31 act simply to reduce the flux a small amount.

Inductor 26 has a resistive component which produces a direct current potential drop across its terminals and this potential is employed to send direct current through windings 34 and 35 on cores 18 and 20 in a direction which aids the main flux generated by windings 16 and 17. It will be obvious that the current through windings 34 and 35 is proportional to the current taken by the load and therefore the aiding flux generated by these coils compensates the regulator in proportion to the current it delivers.

The bridge sensing circuit, as described above is connected across terminals 24 and 15 and the output of the bridge is connected to the main control windings 44 and 45. It is not necessary to balance the bridge in order to make the circuit produce a regulated voltage. The adjustable voltage divider 43 is provided for adjusting the sensing circuit to vary the output voltage at the load terminals and when this is done, over a wide range of values, the bridge 37 may be either balanced or unbalanced and the output current from the bridge may flow in either direction causing windings 44 and 45 to either aid or oppose the main flux values generated by the other windings.

Let it now be assumed that the supply voltage connected to terminals 12 and 13 is increased. This action sends more current through windings 16 and 17 and tends to increase the voltage across the load 25. However, the increase in voltage sends more current through rectifier 32 and the connected windings 30 and 31 and this additional current through these windings opposes the increase in flux produced by windings 16 and 17 and as a result the flux due to these two pairs of windings causes only a small increase in flux in cores 18 and 20. The increase in current through windings 16 and 17 produces an increased current through inductor 26 and a resultant increase in current through windings 34 and 35. This current, however, causes an increase in flux in cores 18 and 20. The change of current through windings 34 and 35 due to a change of voltage at the A. C. supply terminals is quite small, these two windings being intended for a compensating action when the impedance of the load is changed.

The output voltage is sensed by bridge 37 and when this voltage tends to rise, the bridge changes its degree of balance due to the fact that rectifier 42 comprises one of its arms. This rectifier is connected in a manner opposite to the usual connection of such circuit elements; that is, the terminal which is normally the cathode is connected to the positive side of the bridge and the normal anode is connected directly to the negative terminal. Because of this connection rectifier 42 generally presents a very high resistance to the flow of current but when the voltage across it exceeds the zener voltage the rectifier resistance becomes much lower and alters the bridge balance. As a result of this change the junction point between resistor 40 and rectifier 42 is lowered in potential and current then flows through coils 44 and 45 in a direction indicated by arrow 50. This current produces a flux in cores 18 and 20 which opposes the main flux generated by windings 16 and 17. When the circuit is operating within the calculated range of values cores 18 and 20 are at or close to the saturation point of the core material and a reduction of the flux in these cores causes less saturation and an increase in the reactance of the main windings. This increases the series impedance, creates a greater alternating voltage drop and lowers the output voltage to the desired value.

Now let it be assumed that the input voltage remains at a constant value while the output load is reduced, thereby increasing the current appreciably. Such an action would normally lower the output voltage since it would require a larger flow of current through reactor 26 and windings 16 and 17. The bridge circuit 37 will obviously detect this lowering in voltage and control the flux through cores 18 and 20 to raise the output voltage to the desired value but the load compensating circuit which is bridged across the terminals of reactor 26 aids considerably in this control action. An increase in current to the load also causes an increase in windings 34 and 35 and aids the flux generated by the main windings, thereby causing more saturation in the cores, a lowering of the reactance values of windings 16 and 17, and increasing the voltage at the output terminals to the desired value.

The bridge circuit shown in Fig. 2 is an alternate arrangement and illustrates the manner in which two rectifier components 51 and 52 may be used instead of one. These rectifiers are shown in their normal connection with their cathodes connected to the negative part of the circuit. Such a connection produces a change of resistance as the voltage across the rectifiers is varied but the resistance variation is not as large as when the rectifier is connected in the reverse direction.

From the above description it will be obvious that a voltage regulator, sensitive to both the input voltage and the output load, may be constructed without the usual electronic components.

While there have been described and illustrated specific embodiments of the voltage regulator, it will be obvious that many changes and modifications may be made in the connection of the windings and the disposition of the cores without departing from the field of the invention which should be limited only by the scope of the appended claims.

I claim:

1. A voltage regulator for an alternating current supply circuit comprising, a first magnetic core having a main winding coupled to one side of an alternating current supply, a second magnetic core having a main winding coupled to the other side of the alternating current supply, said main windings connected in series with rectifiers to one terminal of a direct current load, a first control winding on both of said cores which is coupled through a rectifier to the alternating current supply, a second control winding on both of said cores which is coupled to the terminals of a series impedance in the direct current load circuit, and a third control winding on both of said cores which is coupled through a bridge sensing circuit to the direct current load terminals.

2. A voltage regulator for an alternating current supply circuit comprising, a first magnetic core having a main winding coupled to one side of an alternating current supply, a second magnetic core having a main winding coupled to the other side of the alternating current supply, said main windings connected in series with rectifiers to one terminal of a direct current load, a connection between a center voltage tap coupled to the supply circuit and a second terminal of the direct current load, a first control winding on both of said cores which is coupled through a rectifier to the alternating current supply, a second control winding on both of said cores which is coupled to the terminals of a series impedance in the direct current load circuit, and a third control winding on both of said cores which is coupled through a bridge sensing circuit to the direct current load terminals.

3. A voltage regulator in accordance with claim 2 wherein the bridge sensing circuit includes a four-armed bridge and contains a non-linear resistance element as one of the arms thereof, said third control windings con-

nected to opposite junction points of said bridge and adapted to generate a magnetic flux which opposes the magnetic flux generated by the main windings.

4. A voltage regulator in accordance with claim 2 wherein said series impedance comprises an inductor which is part of a filter circuit for eliminating undesired alternating components from the direct current load.

5. A voltage regulator for an alternating current supply circuit which maintains a rectified direct current voltage within a restricted range of values comprising, a first magnetic core having a main winding coupled to one side of an alternating current supply, a second magnetic core having a main winding coupled to the other side of the alternating current supply, said main windings connected in series with rectifiers to one terminal of a direct current load for generating a main unidirectional magnetic flux in both of said cores, a first control winding on both of said cores which is coupled through a rectifier to the alternating current supply for generating a unidirectional magnetic flux which opposes said main flux, a second control winding on both of said cores which is coupled to the terminals of a series impedance in the direct current load circuit, and a third control winding on both of said cores which is coupled through a bridge sensing circuit to the direct current load terminals.

6. A voltage regulator for an alternating current supply circuit which maintains a rectified direct current voltage within a restricted range of values comprising, a

first magnetic core having a main winding coupled to one side of an alternating current supply, a second magnetic core having a main winding coupled to the other side of the alternating current supply, said main windings connected in series with rectifiers to one terminal of a direct current load for generating a main unidirectional magnetic flux in both of said cores, a first control winding on both of said cores which is coupled through a rectifier to the alternating current supply, a second control winding on both of said cores which is coupled to the terminals of a series impedance in the direct current load circuit, said second control windings for generating a magnetic control flux in said cores which aids said main flux, and a third control winding on both of said cores which is coupled through a bridge sensing circuit to the direct current terminals.

7. A voltage regulator as set forth in claim 6 wherein said third control windings generate a flux in said cores which increases the total flux whenever the output voltage is lowered by an increase in load current.

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