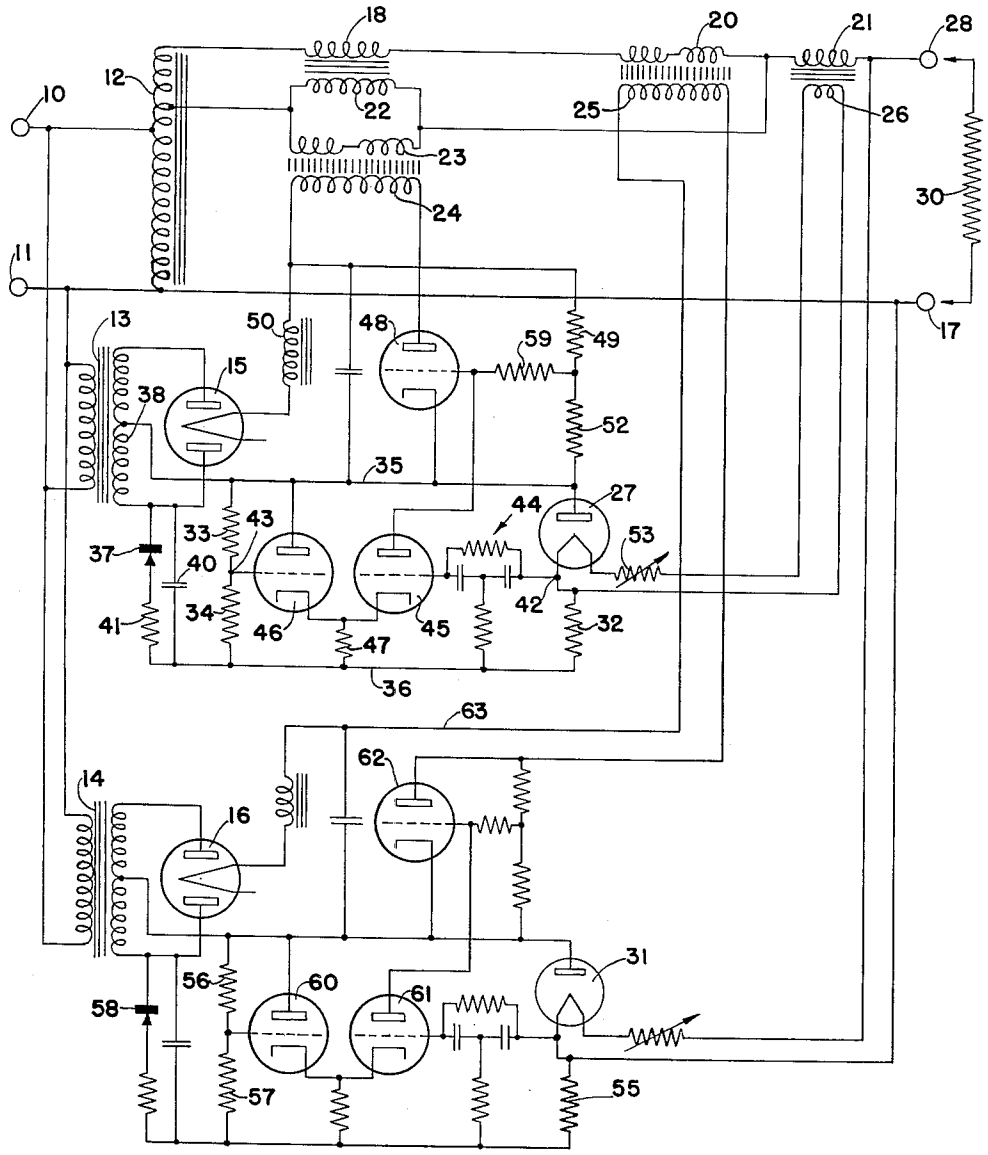
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VOLTAGE REGULATOR

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VOLTAGE REGULATOR

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This invention relates to voltage regulators and has particular reference to voltage regulators for alternating current supply lines which are responsive to changes of current as well as changes of voltage. The invention also relates to a circuit which counteracts the distortion of wave form which is normally present in voltage regulators of this type.

Prior art voltage regulators employing saturable reactors for the control of constant voltage or constant current have always produced a distorted wave form at the output terminals. This condition is due to the fact that a saturable reactor operates when its core is partly saturated and hence produces a wave with a pronounced third harmonic. The present invention partly rectifies this disadvantage by applying a distorted wave in series with the output terminals, this wave containing a third harmonic which is 180 degrees out of phase with the harmonic produced by the series connected saturable reactor. This circuit corrects the wave form and at the same time helps the regulation by controlling the current to the load circuit in response to a sensing device which varies in accordance with the current flowing in the load.

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 arrangements.

Another object of the invention is to regulate an alternating current supply and produce constant voltage with minimum wave form distortion.

Another object of the invention is to provide a voltage regulator which is controlled by both the voltage across the load and the current through it.

Another object of the invention is to provide a voltage regulator with a greater range than the usual type of alternating current regulator circuit.

One feature of the invention includes a voltage sensing circuit which is responsive to the voltage across the load and which controls a saturable reactor connected to a current transformer in series with the alternating current supply.

Another feature of the invention includes a sensing device which is responsive to the current flowing in the load circuit and produces a change in reactance which is connected in series with the alternating current supply. The combination of these two features produces an output voltage which is constant in voltage and is undistorted in wave form.

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

The drawing is a schematic diagram of connections of the voltage regulator.

Referring now to the drawing the voltage regulator includes a pair of input terminals **10**, **11**, which are to be connected to an alternating current supply system which may vary considerably in voltage. The terminals are connected to an autotransformer **12** which provides an

increase in voltage and permits a voltage tap for use by the current regulating system. Also connected to the supply terminals **10**, **11**, are two transformers **13** and **14** which are coupled to rectifier tubes **15** and **16** to provide high voltage direct current for the use of two amplifying circuits which will be described later.

Input terminal **11** is connected directly to output terminal **17**. The high voltage terminal of the autotransformer **12** is connected in series with three windings **18**, **20**, and **21**; the first of these **18** is the secondary winding of a transformer whose primary winding **22** is connected in parallel with a saturable reactor winding **23**. The reactance of winding **23** is controlled by the direct current in winding **24** which is connected to the output circuit of an amplifying system. Winding **20** is a reactor on a saturable core, the reactance of which is controlled by the direct current in winding **25** which is derived from a second amplifying system.

Winding **21** is the primary winding of a transformer whose secondary winding **26** is connected to the filament of a sensing diode **27** which is part of the input circuit of the first amplifying system. One side of winding **21** is connected to output terminal **28**, a load circuit **30** being connected across terminals **28** and **17**. Also connected across the output terminals is the filament of a second diode **31** which comprises the input circuit of the second amplifier system.

The two amplifier systems have identical circuits hence only one will be described. Diode **27** is connected as one arm of a bridge circuit, the other four arms being **32**, **33**, and **34**. Direct current power is supplied to conductors **35** and **36** which form opposite junction connections for the bridge system. The direct current for this bridge is supplied by rectifier **37** and the lower part of winding **38** which forms a part of transformer **13**. This direct current supply is filtered by a capacitor **40** and a resistor **41**.

The degree of unbalance of this bridge circuit is determined by a sensing circuit which is connected to points **42** and **43**, point **42** being connected in series with an anti-hunt circuit **44** and the control electrode of an amplifier tube **45**. Point **43** is connected directly to the control electrode of an amplifying tube **46**. Amplifier tube **46** has its anode connected directly to conductor **35** with its cathode connected in series with a resistor **47** to conductor **36**. Amplifier tube **45** has a similar cathode connection with its anode connected to the control electrode of an output amplifier tube **48**. The anode current for tube **45** is derived from the filament circuit of rectifier tube **15** in series with an inductor **50** and a resistor **51**. A voltage divider composed of resistors **49** and **52** is connected between the positive supply line and the cathode of tube **48**. The control electrode of tube **48** is connected to the junction point of these resistors in series with another resistor **59**. The anode of tube **48** is connected in series with winding **24** to the positive supply line and the filament of rectifier tube **15**.

The operation of this circuit is as follows: Variations in load current passing through winding **21** are transformed to a lower voltage in winding **26** which is connected directly to the filament of tube **27** in series with an adjustable resistor **53**. These current variations change the temperature of the filament causing it to emit a variable number of electrons, thereby changing the resistance between point **42** and conductor **36**. These variations of resistance are applied to amplifier tube **45** and the amplified voltage variations are applied to the control electrode of tube **48** resulting in a current through winding **24** which is controlled by the current in winding **21**. It should be noted that the current in winding **21** is alternating while the current in winding **24** is direct current and serves only to control the reactance value of winding **23**.

The distortion introduced by winding 20 is due to the partly saturated core which is maintained in its saturated condition by the normal current through winding 25. An increase in current flow in winding 25 increases the saturation value and reduces the reactance so that a peak is added to both halves of the wave. The net result of this distortion is the creation of a third harmonic component.

The distortion introduced by winding 23 is due to the partly saturated core which holds windings 23 and 24. An increase in current in winding 23 increases the saturation value of the core and reduces the reactance value of winding 23, causing it to take more than the normal value of current, thereby reducing the current through winding 22. The net result of this distortion is the creation of a third harmonic component having a negative maximum current value which is 180° out of phase with the negative maximum current value of the third harmonic component introduced by winding 20. This distorted wave is applied in series with the supply line by the unsaturated transformer 22—18 and causes the third harmonic components to cancel each other.

The amount of third harmonic applied to winding 18 is in direct proportion to the current passing through this winding. This variation is controlled by current transformer 21—26, diode 27, and the amplifying system as described above.

The voltage compensating circuit which includes diode 31 and amplifier tubes 60, 61, and 62 has been described before in patents such as No. 2,682,635 issued June 29, 1954 to William H. Henrich. The output voltage is sensed by diode 31 which is part of a four-arm bridge, the other three arms being resistors 55, 56, and 57. This bridge is supplied with a direct current potential derived from rectifier 58 and the bridge unbalance is sensed by tubes 60 and 61. The unbalance voltage is amplified by amplifier tube 62 and applied to winding 25 which is also connected to the positive terminal of rectifier tube 16. Variations of current in winding 25 cause variations in the saturation value of the core material and resultant variations of reactance of winding 20.

When the voltage across the load 30 increases the filament temperature in diode 31 also increases, causing the resistance of diode 31 to decrease, thereby raising the potential on the control electrode of amplifier tube 61. This action lowers the voltage of the anode and the control electrode in amplifier tube 62, thereby lowering the anode current through the tube and through winding 25 and causing an increase in the reactance value of winding 20. This increase causes an increase of the potential drop across the winding and compensates for the voltage rise across the load.

From the above description it will be evident that the invention provides a constant alternating current voltage at a pair of load terminals which covers a wide range of voltage values and which delivers a wave which is devoid of harmonic distortion.

While there has been described and illustrated a specific embodiment of the voltage regulator, it will be obvious that the amplifier circuits could be modified and changed 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 system comprising, a coupling circuit which transfers alternating current power from a pair of input terminals to a pair of output terminals connected to a load, a first sensing system which is coupled to the output terminals and applies an amplified direct current control signal to a first saturable reactor connected to said coupling circuit for altering the transmitted voltage, and a second sensing system coupled in series arrangement with the coupling circuit and arranged to produce a signal which is proportional to the current taken by the load, said second sensing system arranged to apply a direct current control signal to a second saturable reactor which is connected in parallel arrangement with a first winding of a transformer, a second winding of which is in series connection between the input and output terminals.

2. A voltage regulator for an alternating current supply system comprising, a coupling circuit which transfers alternating current power from a pair of input terminals to a pair of output terminals connected to a load, a first sensing system which is coupled to the output terminals and applies an amplified direct current control signal to a first saturable reactor connected in series between the input terminals and the output terminals, and a second sensing system coupled in series with a coupling conductor which transmits a signal proportional to the current taken by the load, said second sensing system connected to apply a direct current control signal to a second saturable reactor which is connected in parallel with a first winding of a transformer, a second winding of which is in series connection between the input and output terminals.

3. A voltage regulator for an alternating current supply system comprising, a power transformer coupled to a pair of input terminals for receiving alternating current power from a supply which may vary in applied voltage, a coupling circuit between said transformer and a pair of output terminals connected to a load, a first sensing system connected to the output terminals and coupled to an amplifier which applies a direct current control signal to a first saturable reactor connected in series between said transformer and one of the output terminals, and a second sensing system coupled in series with a coupling conductor which transmits a signal proportional to the current taken by the load, said second sensing system connected to apply a direct current control signal to a second saturable reactor which is connected in parallel with a first winding of a transformer, a second winding of which is in series connection between the input and output terminals.

4. A voltage regulator for an alternating current supply system comprising, a power transformer coupled to a pair of input terminals for receiving alternating current power from a supply which may vary in applied voltage, a coupling circuit between said transformer and a pair of output terminals connected to a load, a first sensing system connected to the output terminals and coupled to an amplifier which applies a direct current control signal to a first saturable reactor connected in series between said transformer and one of the output terminals, and a second sensing system coupled in series with a coupling conductor which transmits a signal proportional to the current taken by the load, said second sensing system connected to apply a direct current control signal to a second saturable reactor which is connected in parallel with a first winding of a transformer, a second winding of which is in series connection between the input and output terminals, said sensing systems each including a filamentary diode with the filament of each diode connected to the circuit to be sensed.

5. A voltage regulator for an alternating current supply system comprising, a power transformer coupled to a pair of input terminals for receiving alternating current power from a supply which may vary in applied voltage, a coupling circuit between said transformer and a pair of output terminals connected to a load, a first sensing system connected to the output terminals and coupled to an amplifier which applies a direct current control signal to a first saturable reactor connected in series between said transformer and one of the output terminals, and a second sensing system coupled in series with a coupling conductor which transmits a signal proportional to the current taken by the load, said second sensing system connected to apply a direct current control signal to a second saturable reactor which is connected in parallel with a first winding of a transformer, a second winding of which is in series connection between the input and output terminals, said

first winding of the transformer also having one terminal connected to a portion of the transformer and the other terminal connected to a terminal of the first saturable reactor.

6. A voltage regulator for an alternating current supply system comprising, a power transformer coupled to a pair of input terminals for receiving alternating current power from a supply which may vary in applied voltage, a coupling circuit between said transformer and a pair of output terminals connected to a load, a first sensing system connected to the output terminals and coupled to an amplifier which applies a direct current control signal to a first saturable reactor connected in series between said transformer and one of the output terminals, and a second sensing system coupled in series with a coupling conductor which transmits a signal proportional to the current taken by the load, said second sensing system connected to apply a direct current control signal to a second saturable reactor which is connected in parallel with a first winding of a transformer, a second winding of which is in series connection between the input and output terminals, said sensing systems each including a filamentary diode which is one arm of a four arm Wheatstone bridge and having

the filament of each diode coupled to the circuit to be sensed for changes.

7. A voltage regulator for an alternating current supply system comprising, a power transformer coupled to a pair of input terminals for receiving alternating current power from a supply which may vary in applied voltage, a coupling circuit between said transformer and a pair of output terminals connected to a load, a first sensing system connected to the output terminals and coupled to an amplifier which applies a direct current control signal to a first saturable reactor connected in series between said transformer and one of the output terminals, a second sensing system coupled in series with a coupling conductor which transmits a signal proportional to the current taken by the load, said second sensing system connected to apply a direct current control signal to a second saturable reactor which is connected in parallel with a first winding of a transformer, a second winding of which is in series connection between the input and output terminals, and a power supply for said first winding of the transformer which is derived from the power transformer.

No references cited.