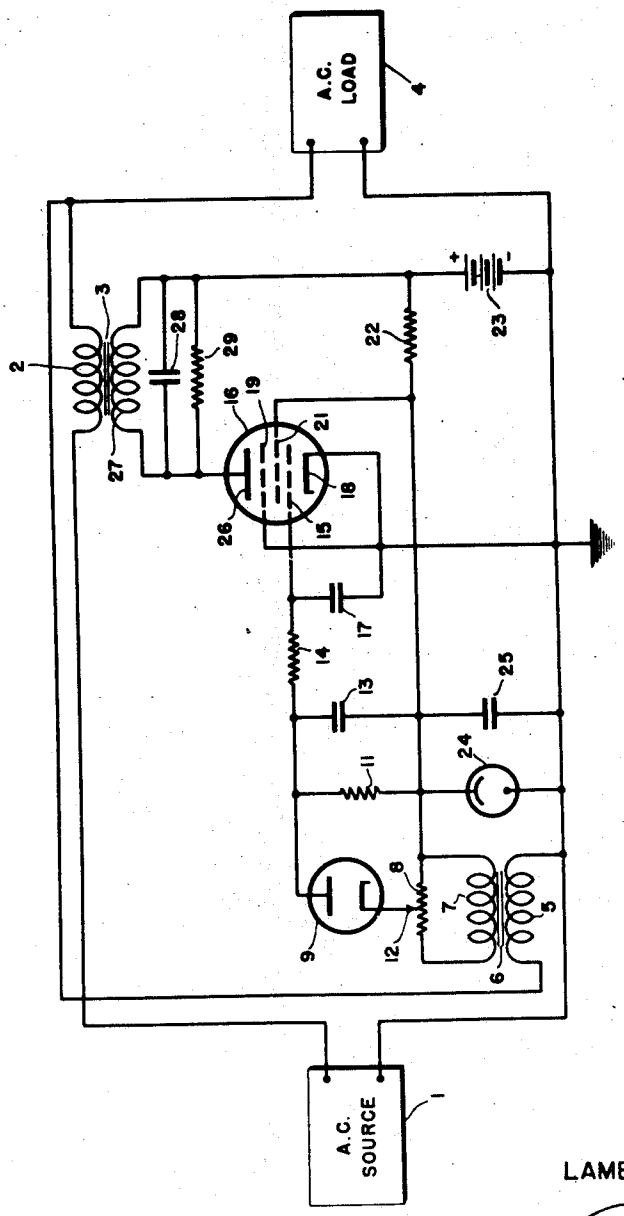
June 8, 1948. L. L. JOHNSON 2,443,006

VOLTAGE REGULATOR

Filed May 24, 1944



INVENTOR

LAMBERT L. JOHNSON

BY

ATTORNEY

Patented June 8, 1948 2,443,006

UNITED STATES PATENT OFFICE

2,443,006

VOLTAGE REGULATOR

Lambert L. Johnson, Fort Wayne, Ind., assignor, by mesne assignments, to Farnsworth Research Corporation, a corporation of Indiana

Application May 24, 1944, Serial No. 537,154

3 Claims. (Cl. 323—38)

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This invention relates to voltage regulators and particularly to electronic regulators capable of maintaining the voltage of an alternating current supply substantially constant.

According to conventional practice, numerous forms of electronic voltage regulators have been used to maintain the voltage of an alternating current supply system substantially constant. Generally this type of regulator employs a regulating or rheostat tube, connected in series with the supply circuit. Such a tube, in turn, is controlled by another tube, connected in parallel with the supply circuit. The second tube responds to voltage fluctuations in the supply circuit and appropriately alters the impedance of the rheostat tube to counteract tendencies for the voltage of the supply system to deviate from a predetermined normal value.

As is well known in the art, however, devices of this character employing conventional electronic devices, depend for their successful operation upon the impression of voltages thereon of substantial magnitudes, usually of the order of several hundred volts. There are some types of loads which, for successful operation, require no deviation from a predetermined value of the voltage impressed thereon and these loads frequently are such that the impressed voltage is relatively low, as for example, of the order of six volts. One load of this character is the heater elements of the electronic devices used in a vacuum tube voltmeter. Where the voltage to be measured by such an instrument is of a relatively low order of magnitude a slight fluctuation in the voltage of the alternating current supply for the cathode heater elements effects a change in the emission from the cathodes sufficient to introduce relatively large inaccuracies in the voltmeter indications. Inasmuch as a heater voltage is considerably lower than that required for the successful operation of electronic voltage regulators known to the prior art, such devices are not adequate.

It is an object of the present invention, therefore, to provide a novel voltage regulator for an alternating current supply which is instantaneously responsive to extremely small voltage fluctuations and, furthermore, is capable of maintaining the voltage at a substantially constant value.

In accordance with this invention, there is connected to a source of alternating current supply for a load circuit a coil having an iron core. The impedance of this coil is determined by the magnitude of the constant magnetization of the core.

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The regulator also includes a means responsive to voltage fluctuations of the alternating current supply to vary the magnitude of the constant core magnetization. In this manner, as the voltage of the alternating current source tends to increase, the constant core magnetization is varied in a sense, whereby to effect a compensating change in the impedance of the coil.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description, taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

The single figure of the accompanying drawing is a schematic circuit diagram of one form of voltage regulator embodying the instant invention.

Referring now to the drawing, there is shown diagrammatically an alternating current source 1. This source may be a commercial power system or any other convenient source of alternating current such as an electronic oscillator. The source may have substantially any desired frequency, such, for example, as in a commercial power system, 60 cycles per second. One terminal of the source 1 may be grounded, as shown. The other terminal is connected through a coil 2, which is provided with an iron core 3, to one terminal of an alternating current load 4. The other terminal of the load may be connected to ground.

There also is connected across the terminals of the load 4, the primary winding 5 of a voltage step-up transformer 6. The secondary winding 7 of the transformer is shunted by the resistance element of a potentiometer 8.

A rectifier tube 9, which in the event that half wave rectification is desired may be a diode, is connected in series with a load resistor 11 across a selected portion of the potentiometer 8. The alternating current voltage impressed upon the rectifier tube may be varied by means of an adjustable contact 12 provided with the potentiometer. A filter condenser 13 is connected in parallel with the load resistor 11.

The anode of the rectifier tube 9 is connected through a resistor 14 to the control grid 15 of a direct current amplifier tube 16. A by-pass condenser 17 is connected between the control grid and the grounded cathode 18 of the amplifier tube. The suppressor grid 19 of this tube also is connected to the cathode. The screen grid 21 of the amplifier tube is connected through a resistor 22 to the positive terminal of a source of direct

current energy such as a battery 23. The negative terminal of the battery is connected to ground.

One terminal of the secondary winding 7 of the transformer 6 is connected through the resistor 22 to the positive terminal of the battery 23. Also, a voltage regulating tube 24 is connected between this terminal of the transformer secondary winding 7 and ground. The regulator tube is shunted by a by-pass condenser 25.

The anode 26 of the amplifier tube 16 is connected through a coil 27 to the positive terminal of the battery 23. The coil 27 is wound upon the iron core 3 and provides a substantially constant magnetization of the core. If desired, the coil 27 may be shunted by a condenser 28 and/or a resistor 29.

Referring now to the operation of the described voltage regulating apparatus, the detailed description will be prefaced by a brief consideration of the behavior of iron cored reactors where the core magnetization is influenced by both alternating current and direct current components. It is well known that the impedance of a coil such as the coil 2 is a function of the total of the ohmic non-inductive resistance and the inductive reactance thereof. The non-inductive resistance remains substantially constant. The inductive reactance of the coil depends upon the point on the magnetization curve of the iron core 3 about which the alternating current component varies. This point is determined by the constant magnetization of the core by the direct current component. The higher up on the magnetization curve that this point is located, the lower is the inductive reactance of the coil 2, and, consequently, the lower is the impedance of this coil. In order to effect operation at a higher point on the magnetization curve it is necessary to increase the direct current magnetizing component. The present invention takes advantage of this characteristic of an iron core reactor.

Before describing in detail the operation of the voltage regulator, a brief consideration will be given to the voltages impressed upon the input circuit of the amplifier tube 16. The cathode 18 of this tube is maintained, by a direct connection, at ground potential. The positive terminal of the rectifier load resistor 11 is maintained at a fixed positive potential with respect to ground by means of the regulator tube 24. The negative terminal of the load resistor is coupled to the control grid 15 of the amplifier tube. Under normal operating conditions, the potentiometer contact 12 is adjusted suitably to effect the development in the load resistor 11 of a voltage substantially equal to the voltage across the regulator tube. Inasmuch as the voltage across the load resistor is of opposite polarity to the voltage across the regulator tube, it is seen that the control grid 15 of the amplifier tube is maintained substantially at the same potential as the cathode 18. Under these conditions the space current flow between the cathode 18 and the anode 26 of the amplifier tube is of normal magnitude.

The voltage developed in the load resistor 11 is proportional to the voltage impressed upon the load circuit 4. The proportionality is determined by the step-up ratio of the transformer 6 and the adjustment of the contact 12 of the potentiometer 8. Preferably in a device of this character, the voltage across the regulator tube 24, and the substantially equal and opposite voltage developed in the load resistor 11, is of the order of

thirty times greater than the voltage impressed up on the load circuit 4.

The normal value of space current conducted through the tube 16 also flows through the magnetizing winding 27. This winding furnishes the direct current constant magnetizing component for the iron core 3. So long as the voltage of the alternating current supply to the load 4 remains at the desired value, the direct current through the magnetizing coil 27, remains constant. Consequently, the inductive reactance and the impedance of the coil 2 also remain constant.

Assume now that the voltage of the alternating current supply to the load 4 increases by a very slight amount such as, for example, a fraction of a volt. As a result, the voltage induced in the secondary winding 7 of the transformer 6 is increased proportionately. By reason of the step-up ratio between the secondary winding 5 and the primary winding 7, the increase of the secondary winding voltage may be of the order of several volts. Consequently, when the selected portion of this voltage is rectified in the tube 9, there is developed in the load resistor 11 a negative voltage increased in magnitude by several volts over the normal value thereof. By reason of the fact that the positive terminal of the resistor 11 connected to the transformer winding 7 is maintained at a predetermined value with respect to ground by the regulator tube 24, and the fact that the cathode 18 of the amplifier tube 16 is maintained permanently at ground potential, the increased voltage developed in the load resistor 11 effects the impression upon the control grid 15 of the amplifier tube of a negative voltage increased in magnitude by several volts.

The conduction of space current in the tube and in the magnetizing winding 17 is decreased correspondingly. As a result of the decrease in the magnitude of the current flowing in the magnetizing winding 27, the constant value of the magnetization of the core 3 is decreased. In other words, the operating point on the magnetization curve is lowered. There is effected in this manner a corresponding increase in the inductive reactance, and consequently, the impedance of the coil 2. Since this coil is in series with the connection between the alternating current source 1 and the load 4, there is effected a voltage drop in the coil of an increased magnitude over that which previously existed. The magnitude of the increase in the voltage drop through the coil 2 may be made, by suitable design and adjustment of the voltage regulating apparatus, equal to the slight increase of the voltage impressed upon the load 4 which, as described, also is responsible for the change made in the functioning of the voltage regulating apparatus.

It is obvious without further detailed description that a slight decrease from normal of the voltage impressed upon the load 4 will effect an increase in the constant magnetization of the core 3, whereby a compensating decrease of the inductive reactance and the impedance of the coil 2 is effected.

It has been found in many cases that satisfactory operation of the voltage regulating apparatus may be secured without shunting the magnetizing winding 27. In other cases, somewhat improved results have been obtained by shunting this winding either by a condenser such as 28 or by a resistor such as 29 or by both, as illustrated. Similarly, satisfactory results have been

obtained by effecting only a half wave rectification of the alternating voltage impressed upon the load. It, however, is considered to be within the scope of this invention to effect a full wave rectification of the voltage, if desired. The substitution of a double diode for the single diode 9 shown and the necessary circuit modifications are deemed to be within the skill of those versed in the art, and consequently, require no specific illustration thereof. Obviously, it also is within the scope of this invention to connect the coil 2 in parallel with the load 4. In such a case the sense of the magnetization changes in the core 3 to compensate for voltage fluctuations will be opposite to those described.

The present invention is not considered to be limited for use with alternating current supply circuits of any particular voltage or frequency, or load requirements. Therefore, the following table of circuit constants is given by way of example only. To supply approximately 1 ampere of alternating current to a load at 6.3 volts the coil 2 may consist of approximately 40 turns, the iron core 3 may be approximately 1 square inch in cross section and the coil 27 may include approximately 3400 turns. The normal direct current conducted through the coil 27 may be approximately 9 milliamperes.

A. C. source—6.3 volts, 60 cycles/sec.
Transformer 6—Step-up ratio 30:1
Potentiometer 8—50,000 ohms
Rectifier tube 9—½ of 6H6
Resistor 11—250,000 ohms
Condenser 13—0.25 microfarad
Resistor 14—270,000 ohms
Amplifier tube 16—6AC7
Condenser 17—1 microfarad
Resistor 22—10,000 ohms
Battery 23—300 volts
Tube 24—VR150
Condenser 25—15 microfarads
Condenser 28—0.01 microfarad
Resistor 29—100,000 ohms

While there has been described what, at present, is considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In an alternating current supply system including a source of alternating current and a load circuit connected thereto, a voltage regulator comprising, an iron core reactor having a first winding connected in series between said source and said load circuit, a rectifier coupled across said load circuit to rectify said alternating current and thereby develop a negative unidirectional control voltage, a direct current amplifier having an input circuit including a control grid responsive to said control voltage, and an output circuit for said amplifier including a source of direct current energy and a second winding on said iron core reactor.

2. In an alternating current supply system including a source of alternating current and a load circuit connected thereto, a voltage regulator comprising, an iron core reactor having a first winding connected in series between said source and said load circuit, a transformer having a primary winding connected across said load circuit, a rectifier connected to said load circuit to rectify said alternating current and thereby to develop a negative unidirectional control voltage, a secondary winding on said transformer connected effectively in series with said rectifier, a direct current vacuum tube amplifier having an input circuit including a control grid responsive to said control voltage, and an output circuit for said amplifier including a source of direct current energy and a second winding on said iron core reactor.

3. In an alternating current supply system including a source of alternating current and a load circuit connected thereto, a voltage regulator comprising, an iron core reactor having a first winding connected in series between said source and said load circuit, a voltage step-up transformer having a primary winding connected across said load circuit, a rectifier including a load impedance, a secondary winding on said transformer connected effectively in series with said rectifier and said load impedance, a direct current vacuum tube amplifier having an input circuit including a control grid and a cathode, said cathode being maintained substantially at ground potential, means including a voltage regulating tube for maintaining the positive terminal of said load impedance at a predetermined positive potential with respect to ground, means including a potentiometer connected to said rectifier for effecting the development in said load impedance of a voltage substantially equal to said predetermined positive potential, means for connecting the negative terminal of said load impedance to said control grid, and an output circuit for said amplifier including a source of direct current energy and a second winding on said iron core reactor.

LAMBERT L. JOHNSON.

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