Oct. 21, 1969 F. G. LOGAN 3,474,327

ALTERNATING CURRENT LINE VOLTAGE REGULATOR (LVR)

Filed July 31, 1967 2 Sheets-Sheet 1

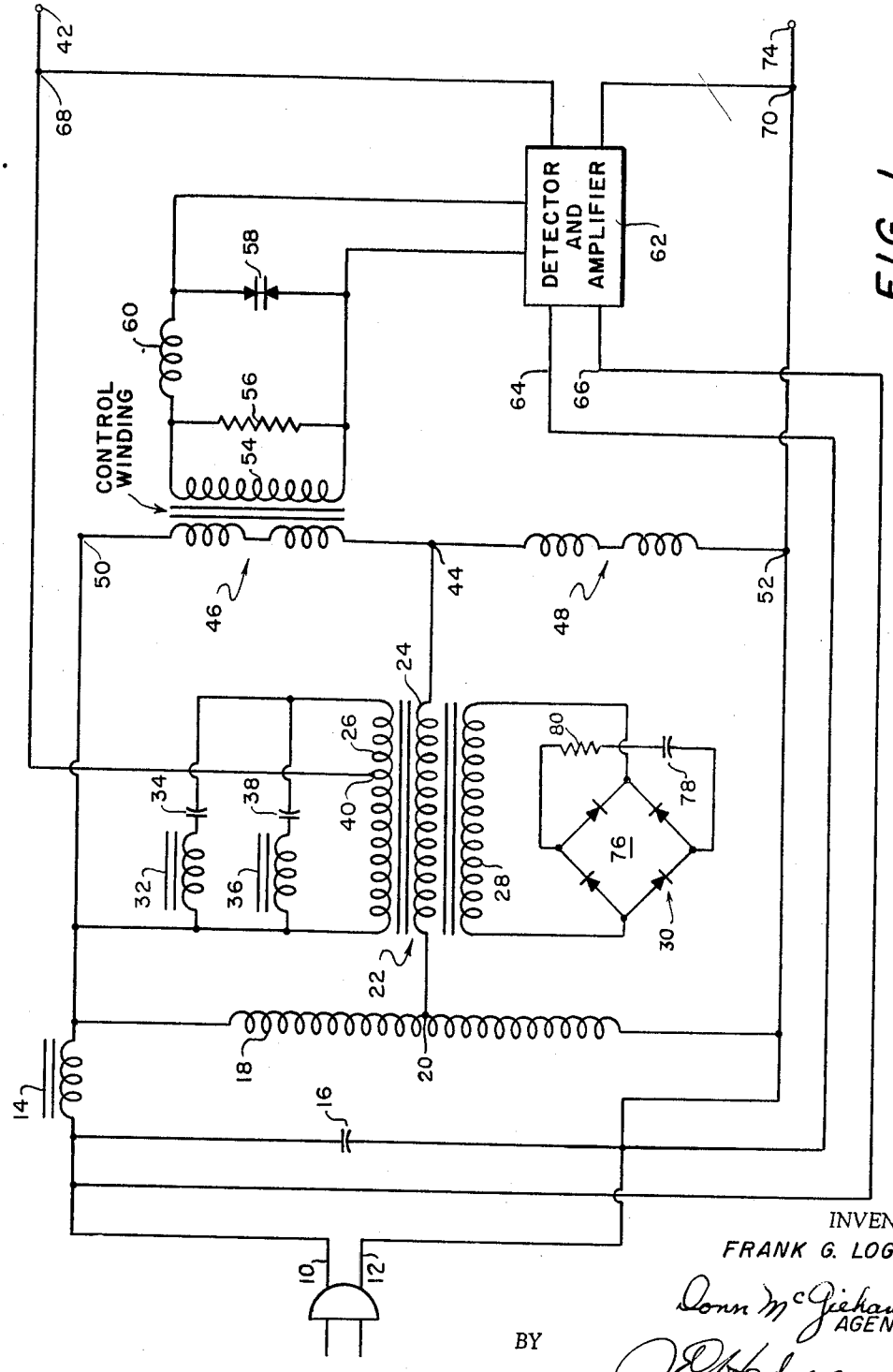


FIG. 1.

INVENTOR
FRANK G. LOGAN

BY Donn McGiehan AGENT

J. E. Hodges ATTORNEY

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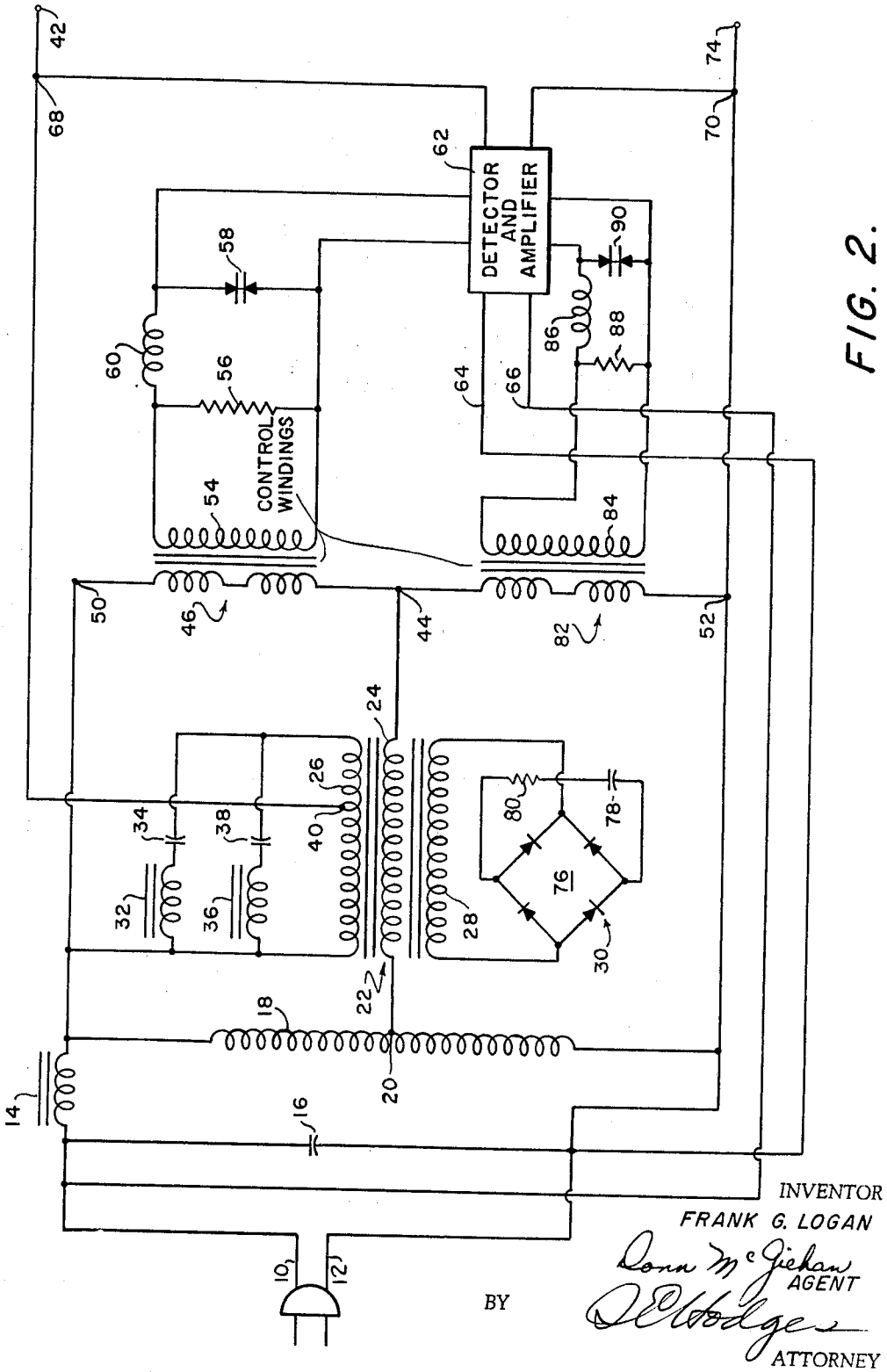


FIG. 2.

INVENTOR
FRANK G. LOGAN
Donn McGiehan
AGENT
BY
ATTORNEY

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ALTERNATING CURRENT LINE VOLTAGE REGULATOR (LVR)

Frank G. Logan, Bowie, Md., assignor to the United States of America as represented by the Secretary of the Navy

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Int. Cl. H02p 13/12, 21/08
U.S. Cl. 323—45 8 Claims

ABSTRACT OF THE DISCLOSURE

An alternating current line voltage regulator utilizing two reactors in series across the line, detector and amplifier circuitry sensing the load voltage variations to automatically adjust the control winding voltages of one or both said reactors whereby the midpoint connection between said reactors is electrically moved toward one or the other of the line connections thereby regulating the voltage seen by the load.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

Background of the invention

The present invention relates to line voltage regulators and more particularly to the type which are connected to a source of voltage which varies more than can be tolerated and which will deliver to the load, a voltage regulated to within desired limits, and utilizes simple, small, and lightweight, reliable components of proven design.

The voltage regulators in general use have the serious disadvantage of necessitating a voltage departure from the normal of a considerable degree before acting to check the same and usually cause an over-correction before arriving at a stable condition. Thus the voltage cannot be maintained constant, or approximately constant, but deviates therefrom more and more according to the amount of compensation required. Furthermore, such regulators not only require delicate and finely adjusted moving parts necessitating more or less frequent attention and repairs or adjustments, but are expensive and not always dependable. Prior art line voltage regulators were also generally characterized by large exciting currents which were necessarily supplied by the power source and many of them produce a high voltage "spike" across the load when subjected to abrupt input line voltage or load changes.

Summary

The instant invention solves the aforementioned problems and disadvantages of the prior art by the use of novel circuitry including a spike clipping circuit, a detector and amplifier circuit across the load and sampling the voltage applied to the load which, when amplified, provides control winding voltages to one or more saturable reactors or magnetic amplifiers. At least two reactances are required to be connected in series across the main line, one of which may be a saturable reactor having control windings and the other being a linear reactor, or, alternatively both may be saturable reactors and both having control windings. The common connection point between the two reactors can therefore be seen to be "floating," that is, if one of the saturable reactors is a magnetic amplifier which is caused to be more conductive (having less impedance) the floating point will be moved closer to the potential of one side of the circuit from the source of power or lines, to which the magnetic amplifier is connected. Conversely, where the control windings are excited to cause a magnetic amplifier to become less conductive, that is, having higher impedance, the "floating" point will be moved electrically further away from the potential of the line to which that magnetic amplifier is connected.

As can be seen, only one of the reactors need be controllable, however, it is obvious that two magnetic amplifiers in series may be used and the control windings excited in opposite directions to produce the effect of electrically moving the "floating" point, as with the single magnetic amplifier. The double magnetic amplifier arrangement may be desirable in some particular applications for better control. The aforementioned "floating" point is connected to one end of the primary winding of an isolation transformer to isolate the load so that line polarity problems are not involved. The other end of the isolation transformer is connected to a center tap on the winding of an auto-transformer which is connected across the main power source.

The secondary winding of the isolation transformer is connected in such a manner that one side attaches to the circuit from the power sources, or line, and the other side attaches to the load. In shunt across this secondary are connected a plurality of series LC filter networks to eliminate harmonic outputs. A tertiary winding is provided on this isolation transformer across which the spike clipping circuit is connected.

Accordingly, it is the primary object of this invention to provide a line voltage regulator which is simple, small, and lightweight and employs reliable, low maintenance components.

Another object of this invention is to provide a line voltage regulator which will immediately sense line voltage variations and which will automatically and immediately correct such variations.

Still another object of this invention is to provide a line voltage regulator using one or more trouble free magnetic amplifiers, or saturable reactors.

Still another object of this invention is to provide a line voltage regulator which will attenuate high voltage spikes across the load when subjected to abrupt input line voltage or load changes.

Other objects and features of the invention will become apparent to those skilled in the art as the disclosure is made in the following detailed description of the preferred embodiments of the invention as illustrated in the accompanying sheets of drawings:

Brief description of the drawings

FIG. 1 is a schematic and block diagram of the overall line voltage regulator; and

FIG. 2 is a schematic and block diagram of a line voltage regulator of the second embodiment utilizing two magnetic amplifiers in series across the line.

Description of the preferred embodiment

Referring now to the drawings there is shown in FIG. 1 an electrical schematic diagram of a line voltage regulator according to this invention. Terminals **10** and **12** are connected to an alternating current source, the voltage of which varies more than can be tolerated by a particular load, which voltage it is desired to regulate. Across the line, which is connected to terminals **10** and **12**, there is connected a capacitor **16** and in series between terminal **10** and an auto-transformer **18** there is connected a choke **14**. The bottom end (as viewed in the drawing) of the auto-transformer **18** is directly connected to the other side of the line which is connected to connection **12**, hence the auto-transformer is connected across the line from the source of power. A tap **20** is provided on the

auto-transformer to which is connected the primary winding 24 of the isolation transformer 22, which in the preferred embodiment has three windings.

In the preferred embodiment a spike clipping circuit 30 is connected across the tertiary winding 28 of the isolation transformer 22 and consists of a rectifier bridge 76 containing four semi-conductor diodes. The output of the bridge is connected across a capacitor 78 of high capacitance charged through a resistor 80 forming a series RC circuit which may have a time constant of approximately one-quarter second. The other end of the primary winding 24 is connected to terminal 44 which forms the common connection between serially connected reactors 46 and 48, one or both of which may be saturable reactors having control windings, such as magnetic amplifiers. The secondary winding 26 is connected at one end to the junction between auto-transformer 18 and choke 14 and in parallel with two series inductance-capacitance circuits, or harmonic filters comprising inductances 32, 36 and capacitance 34, 38. A tap on the secondary winding 26 of the isolation transformer 22 is provided which connects directly to the load terminal 42.

In the preferred embodiment described here, one magnetic amplifier 46 and a linear reactor 48 are used. The reactors are connected in series directly across the line at terminals 50 and 52. The control winding 54 of the magnetic amplifier 46 is paralleled with a resistance 56 and a pair of back-to-back diodes 58. The upper ends (as viewed in FIG. 1) of the resistance 56 and the back-to-back diodes 58 are separated by a choke 60.

Across the control winding 54 of the magnetic amplifier 46 and the paralleling circuitry of resistance 56 and back-to-back diodes 58, there is connected a typical well known detector and amplifier circuit 62 such as described in Patent No. 3,319,153 (shown here in block form). The detector and amplifier 62 derives its operating voltage from the main line through conductors 64 and 66. The input to the sensing circuit of the detector and amplifier is attached directly across the load at terminal 68 and 70.

Referring now to FIG. 2 wherein like reference numerals refer to the same components referred to in FIG. 1, a substantially similar line voltage regulator circuit is shown with the exception that the linear reactor 48 is replaced with a saturable reactor 82 of the same configuration as the saturable reactor 46. The saturable reactor 82 further comprises a control winding 84 which is connected to the output of the detector and amplifier circuit 62 (shown in block form). Connected in series in one of the lines between the detector and amplifier and the control winding 84 is a choke 86. Connected in shunt across the control winding 84 there is a resistor 88 and on the other side of choke 86 toward the detector and amplifier there is connected in shunt across the leads to the control winding a pair of semiconductor diodes 90 connected back-to-back. This circuit is a duplicate of that discussed for the preferred embodiment.

Description of the operation

The line voltage regulator of this invention is connected to a source of alternating current at terminals 10 and 12 which varies in voltage more than can be tolerated by a load which is connected between terminals 42 and 74. Because the use of this line voltage regulator may present an undesirable reactive load to the alternating current source and induce harmonics into the line source, a power-factor correction network consisting of a choke 14, connected in series to the line terminating in terminal 10; and a capacitor 16, connected across the line between terminals 10 and 12, may be included. An auto-transformer 18 is connected between two AC lines and is provided with a tap 20 for obtaining a portion of the line voltage existing between terminals 10 and 12. One side of the primary of the isolation transformer 22 is connected to this tap and the other side is connected to the midpoint of two reactors 46 and 48 which are connected in series across the AC lines at terminals 50 and 52. By controlling the reactance of one or both of the saturable reactors connected across the AC lines, which is accomplished by changing the voltage in control windings 54 in the preferred embodiment or both 54 and 84 in the second embodiment, the midpoint 44 is caused to be electrically moved towards one or the other of the AC lines thus causing the voltage in the primary 24 of isolation transformer 22 to vary as desired.

Variation of the primary voltage in the isolation transformer 22 causes a variation of voltage in the secondary 26. In the preferred embodiment, using saturable reactor 46 and a linear reactor 48, two series LC networks consisting of chokes 32, 36, capacitors 34, 38 respectively are utilized in shunt across the secondary 26 of the isolation transformer to attenuate the harmonics present.

A tertiary winding 28 provided on the isolation transformer 22, is shunted with a spike clipping circuit. When a spike occurs on the line, or the load is changed abruptly, and particularly when a large increment of load is dropped, voltage in the primary 24 of the isolation transformer 22 tends to rise sharply. The bridge rectifier connected across the tertiary winding 28 when connected to a suitable load, which in this case consists of a series RC network consisting of capacitor 78 and resistor 80, will burden the isolation transformer 22 such that the voltage in the secondary 26 will not rise as a result of the spike occurring in the primary or the load changing abruptly. To provide constant load voltage a detector and amplifier circuit are connected accross the load at terminals 68 and 70 to sense the load voltage variation. Within the detector and amplifier 62, the load voltage is compared with a reference voltage and any necessary corrections are amplified and directed to the control winding 54 in the case of the preferred embodiment or to both control windings 54 and 84 in the second embodiment which as previously mentioned will cause the saturable reactors to become more or less conductive.

To protect the detector and amplifier from any voltage induced into the control winding from the main windings of the saturable reactors, a resistor 56 is connected across the control windings to eliminate hash, a choke 60 is connected in series between one end of the control winding and the detector amplifier to reduce induced ripple current, and further, a pair of back-to-back diodes 58 are connected in shunt across the detector and amplifier to protect it against transients occurring in the control winding. This last described network is also provided for control winding 84 when two saturable reactors are connected in series across the line as in the case of the second embodiment.

It should be understood, of course, that the foregoing disclosure relates only to the preferred embodiments of the invention and that numerous modifications or alterations may be made therein without departing from the spirit and the scope of the invention.

What is claimed is:

1. A line voltage regulator for providing a constant voltage to a load comprising:

input terminal means connected to an AC power source;

a plurality of reactors at least one of which being variable connected in series across said power source;

power coupling means connected between said input terminal means and a common connection point between at least one of said plurality of serially connected reactors and the others of said reactors;

means for connecting said load between said power coupling means and one of said input terminal means;

a first control winding means inductively coupled to at least one of said reactors for varying the reactance thereof;

said power coupling means having an output regulated in response to the relative reactance variation occurring in said reactors; and

detector and amplifier circuitry means sensing voltage variations across said load and providing an output connected to said first control winding means;

said control winding means being responsive to said variations across said load for effecting a reactance change in said reactors.

2. The device of claim **1** wherein said power coupling means comprises:

a first transformer means connected across the input terminal means; and

a second transformer means connected between said first transformer means and said common connection point between said plurality of serially connected reactors.

3. The device of claim **2** wherein said second transformer means further includes:

a secondary winding connected between one side of said power source and said load;

at least one tuned filter circuit connected in shunt across said secondary winding for reducing harmonic output.

4. The device of claim **3** further including:

a tertiary winding on said second transformer means; and

a spike clipping circuit connected in shunt across said tertiary winding for burdening said transformer when a voltage spike occurs in the voltage output of said transformer due to abrupt load changes or line voltage spikes.

5. The device of claim **4** wherein the spike clipping circuit comprises:

a bridge rectifier; and

a series resistance capacitance circuit connected across the output of said bridge rectifier.

6. The device of claim **5** wherein said detector and amplifier circuitry is protected from induced currents in said control winding by a hash, ripple and transient filter circuit comprising:

a choke in series with said control winding;

a resistor paralleling said control winding; and

a pair of back-to-back diodes paralleling said control winding.

7. The device of claim **1** further comprising:

a secondary control winding inductively coupled to at least one of the said reactors other than the reactor having said first control winding, said reactor having said second control winding being on the opposite side of said common connection point from the reactor having said first control winding;

said second control winding being connected to the output of said detector and amplifier circuitry means.

8. A device as claimed in claim **7** in which said control windings are connected to react in opposition.

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JOHN F. COUCH, Primary Examiner

G. GOLDBERG, Assistant Examiner

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