

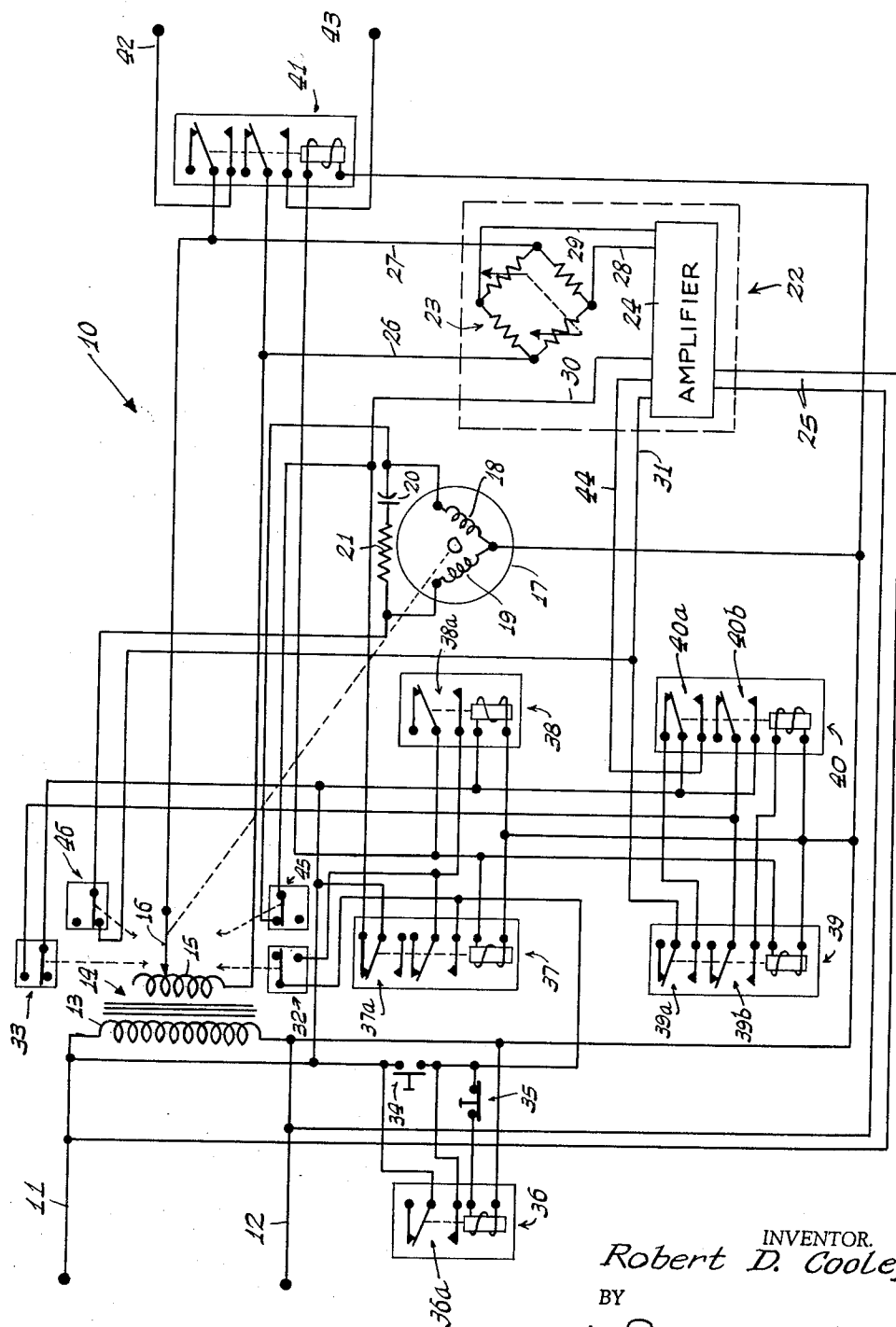
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VOLTAGE REGULATOR

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3,044,008

VOLTAGE REGULATOR

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The present invention relates to an electrical regulator for automatically maintaining an output voltage within small limits of a selected value.

The regulator, as hereinafter described, in addition to performing as a regulator, also prevents the output voltage from being immediately and instantaneously appearing at the output terminals when the regulator is initially started or upon resumption of power after a power failure. In particular installations, for example in the controlling of the voltage to filaments of vacuum tubes, the preventing of an instantaneous output voltage from appearing on the tubes appreciably lengthens the tube life by minimizing the surge strain on the filaments.

An object of the present invention is to provide an automatic voltage regulator which upon starting, gradually increases its output voltage from a minimum or zero value to the approximately regulated value before automatic regulation of the output voltage commences.

Another object of the present invention is to provide an automatic voltage regulator as above set forth in which, in case of power failure and then resumption, the output voltage starts at a minimum or zero value and gradually builds up to its regulated value.

A further object of the present invention is to provide an automatic voltage regulator for achieving the above objects which is simple in design, relatively economical to fabricate, easy to operate and reliable even over extended periods of use.

In achieving the above objects, there is provided a voltage regulator including a motorized adjustable transformer having its input connectible to a source of electrical energy (such as 120 volts A.C.) and its output serving as the output of the regulator. A sensing circuit senses the deviation of the output voltage from its selected value and produces a signal that directs (through an amplifier) the movement of the motor to vary the transforming ratio of the adjustable transformer to change the output voltage and hence maintain it within prescribed limits of its desired value.

In order to achieve the prevention of instantaneous voltage rise from a minimum value to the selected value from appearing at the output of the regulator, there is provided a control means which serves to direct the energization of the motor to cause the output voltage to be gradually increased from a minimum value to the preselected range. Additionally there is provided in the control circuit, relays which prevent connection between the output terminals and the output of the adjustable transformer until the minimum value is reached to thereby prevent the output voltage from being connected to the output of the adjustable transformer during starting at other than the minimum value. This control means includes a plurality of relays and a pair of switches positioned to operate at selected positions (and hence output voltages) of the adjustable transformer, as will be hereinafter more specifically explained, in order to enable the motor to be energized without any voltage appearing at the output of the regulator and to enable the output voltage to increase from a minimum value to the regulated value. After the output voltage reaches the regulated value, the control circuit is rendered inoperative to control the adjustable transformer until there occurs either a manual cessation of the regulator or until a power failure, at which time the control circuit upon

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being manually energized gradually increases the output voltage from a minimum value to the selected value.

Other features and advantages will hereinafter appear. In the drawing:

The sole figure is an electrical schematic diagram of the automatic voltage regulator of the present invention.

Referring to the drawing, the regulator is generally indicated by the reference numeral 10 and includes a pair of input leads 11 and 12 connected to the primary side 13 of an adjustable transformer 14 having a secondary winding 15 on which a movable brush 16 is operable. The brush 16 is connected to be driven by an output shaft of a motor 17 (the shaft not being shown and the connection being mechanical as illustrated by the dotted line connection between the brush and motor).

The motor is reversible and has a pair of fields 18 and 19 electrically interconnected through a phase shifting mechanism consisting of a condenser 20 and a resistor 21.

In-phase energization of the winding 18 with out-of-phase energization of winding 19 causes the motor to rotate and move the brush 16 to decrease the output value of the voltage from the secondary winding 15, while in-phase energization of the winding 19 and out-of-phase energization of the winding 18 cause a reverse movement of the motor and hence brush 16 to increase the output voltage of the transformer 14.

The automatic regulating circuit of the regulator is indicated by the reference numeral 22 and includes a sensing means having a bridge 23 and an amplifier 24, the latter being energized from the input by a pair of leads 25, though it may be energized from the output of the regulator if desired. The bridge 23 is preferably of the non-linear type which is in balance at a selected voltage and the output voltage of the transformer 14 through a pair of leads 26, 27 is compared therewith, so that a deviation therebetween produces a signal which varies in polarity and magnitude with the signal being fed to the amplifier through the leads 28, 29. The amplifier in turn controls the in-phase energization of either the winding 18 or 19 through the leads 30 and 31.

The adjustable transformer 14, motor 17 and the automatic regulating circuit are components well known in the art and though a specific embodiment of them has been disclosed it will be appreciated that other well known types of automatic regulators may be employed.

In the specific embodiment of the control circuit of the present invention for achieving the above set forth objects, there is provided a normally open switch 32 positioned to be operated by the brush 16 at its minimum or zero voltage position and a second normally open switch 33 positioned to be operated by the brush 16 when the brush is on the winding 15 to produce a voltage within the preselected automatic regulating range. Dotted lines are connected to the switches 32 and 33 and terminate adjacent the brush 16 at the position the brush must be to actuate the switches.

The control circuit further includes a normally open start button 34, a normally closed stop button 35 and relays 36 through 41 inclusive. Each of the relays has either one or two switches, one being present in relays 36 and 38 and two being present in the other relays, with the switches being shown in the deenergized position of the relays. The relays are electrically connected together and to the other elements and it is to be noted that the relay 41 is located between the output winding 15 of the transformer and output terminals 42 and 43 of the regulator so that unless the relay 41 is energized, no voltage appears at the output terminals.

With the elements as shown, the input energized and the start button 34 being pressed, the down coil 18 of the motor is initially in-phase energized to position the brush 16 at its minimum value prior to any voltage ap-

pearing in the output terminals, and when the minimum value of the output voltage from the transformer is reached, the output of the regulator is connected. Then the output voltage is gradually increased to the preselected value at which time the control circuit releases control of the transformer.

This is accomplished in the following manner: When the input leads 11 and 12 are energized, the relay 38 is energized closing its switch 38a and this relay is maintained energized whenever voltage appears at the input. In addition current flows through switch 37a, in-phase through the down coil 18 and out-of-phase through the up coil 19, to cause the brush to move to its minimum position (which is preferably slightly above zero voltage) and at this position, the switch 32 is closed. Upon the switch 32 being closed, the starting button 34 is manually closed and current flows to the relay 36 through the normally closed stop button 35 energizing the relay 36 and closing the switch 36a to provide a holding circuit for the relay 36 bypassing the starting button 34 which can then be released to return to its normally open position. In addition to energizing relay 36, relay 37 is also energized through the switch 32 and the switch 38a. Similarly relays 39 and 41 are energized through the switch 32 and the switch 38a. This causes opening of the switch 37a breaking the circuit to the down coil 18.

The up coil 19 is then in-phase energized through a switch 40a and 39a which causes the motor to begin advancing the brush 16 to increase the output voltage. It will also be apparent that energization of relay 41 connects the terminals 42 and 43 to the secondary of the transformer 14 so that the transformer voltage now appears at the output of the regulator.

The up coil 19 is maintained energized until the brush reaches a position on the winding 15 which produces a voltage within the range of the selected output voltage and at this position the switch 33 is closed. After the brush during this movement has moved away from the switch 32, the switch opens; however, a holding circuit for the relays 37, 39 and 41 is established through switch 36a, switch 37b, switch 38a.

Upon the switch 33 being closed by the brush 16, relay 40 is energized through switch 39b. This breaks the circuit to the up coil 19 by reason of changing the position of switch 40a and a circuit is established through this switch 40a and a lead 44 to the amplifier 24. The amplifier and sensing means now control the movement of the motor and hence serve to regulate the output voltage to maintain it within the desired range. A holding circuit for the relay 40 is established through the switch 40b and the switch 39b and hence the switch 33 need not be maintained closed by the brush 16. Thus as the regulator performs its normal function of regulating with the regulating circuit in control, all the relays are energized and both switches 32 and 33 are open.

If it is desired to stop the regulator manually, the button 35 is pressed opening the holding circuit to the relay 36, opening switch 36a, which breaks the holding circuit for the relays 37 39 and 41. Relay 39 being deenergized, opens switch 39b deenergizing the relay 40. Upon relay 37 being deenergized switch 37a closes, energizing the down field 18 and the brush is moved to its minimum output position.

It will be appreciated that only an instantaneous opening of the switch 35 is required to break the holding circuit for relay 36 and thus break the other circuits. Also when relay 41 is deenergized when the button 35 is depressed, the output voltage from the secondary 15, as it decreases, does not appear at the output terminals of the regulator. If voltage still remains at the input terminal the output voltage of the transformer automatically decreases to its minimum value to be ready to be gradually increased again.

In the event of a power failure during automatic regula-

tion, the output voltage is immediately decreased to zero and operation of the start button 34 is required to bring the output voltage from its minimum value to the preselected value. The relay 38 becomes deenergized by the power failure and opens switch 38b which opens the holding circuits for relays 37, 39 and 41 and relay 36 also becomes deenergized. Even though the relay 38 is again energized when power resumes, the down coil 18 of the motor will be energized through the switch 37a until the switch 32 closes and the start button 34 is closed to cause the other relays to be energized in the above disclosed manner and the output voltage to increase from its minimum value to its preselected value.

In order to cause cessation of energization of the motor at its minimum position and to prevent travel of the brush beyond both limits of travel, two normally closed switches 45 and 46 are provided. The switch 45 is electrically connected in the line to the down coil 18 while the switch 46 is connected in the line to the up coil 19. These switches are positioned to be actuated by the brush when the brush reaches the positions at which the dotted lines connected to each switch terminate. Thus as the brush travels downwardly to decrease the transformer output voltage, it first closes switch 32 and then, while maintaining closed this switch, opens switch 45. Accordingly when the switch 45 opens the motor is deenergized and the control circuit is ready to gradually increase the output voltage after operation of the starting button 34 by energizing the up coil 19.

The switch 46 is positioned beyond the switch 33 in the upward path of travel of the brush 16 and in the event, through malfunctioning of one of the components, the up coil drives the brush into engagement therewith, it deenergizes the up coil. The motor is capable of rotating even with one coil open as happens when either of the switches 45 or 46 is open and of moving the brush 16.

While there has been shown six relays, it will be appreciated that a lesser number having more switches may be utilized in place of it, for example relays 37, 39 and 41, since they are either energized or deenergized together, may be combined into one relay if desired. It is also contemplated to have an indicator light for indicating when there is no output voltage and this may be advantageously, for example, connected from one input line to the other through the unused (upper) contact of switch 36a.

It will accordingly be appreciated that there has been disclosed a specific embodiment of an automatic voltage regulator which prevents instantaneous increase of voltage from a minimum value to the preselected voltage range from appearing at the output of the regulator, either resulting from intentionally starting the regulator or from resumption of power after a power failure. This is accomplished by a control circuit having interacting relays which disconnect the output terminals of the regulator from the adjustable transformer output until the transformer output reaches a minimum value. Then the output terminals are connected and the output voltage is gradually increased to the desired value at which time the control circuit shifts control of the adjustable transformer to a typical automatic voltage regulator sensing circuit and amplifier.

Variations and modifications may be made within the scope of the claims and portions of the improvements may be used without others.

I claim:

1. A voltage regulator comprising an input connectible to a source of electrical energy, an output, an adjustable voltage means connected between the input and output for adjusting the output voltage, regulating means for sensing the deviation of the output voltage from a preselected value and operable to direct the voltage means to maintain the output voltage within a selected range of the value, and a control circuit for causing the output voltage to attain its preselected range only after it has

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been increased gradually from a minimum value, said circuit including means connected to the voltage means for normally energizing said voltage means to reduce the voltage therefrom, means for rendering said reducing energizing means inoperative when the regulating means controls the voltage means, and means for causing said rendering means to become ineffective upon a disruption of power from said source whereby upon a resumption of power the energizing means causes the voltage means to be energized to reduce its output voltage, said control circuit being connected to said input for obtaining electrical energy therefrom and including means connected between the input and output for opening the output whenever said reducing energizing means controls the voltage means.

2. A voltage regulator comprising an input connectible to a source of electrical energy, an output, an adjustable voltage means connected between the input and output for adjusting the output voltage, regulating means for sensing the deviation of the output voltage from a preselected value and operable to direct the voltage means to maintain the output voltage within a selected range of the value, and a control circuit for causing the output voltage to attain its preselected range only after it has been increased gradually from a minimum value, said circuit including means connected to the voltage means for normally energizing said voltage means to reduce the voltage therefrom, means for rendering said reducing energizing means inoperative when the regulating means controls the voltage means, means for causing said rendering means to become ineffective upon a disruption of power from said source whereby upon a resumption of power the energizing means causes the voltage means to be energized to reduce its output voltage, and means operated by the voltage means for ceasing energization of the voltage means at a predetermined minimum value of voltage therefrom, said control circuit being connected to said input for obtaining electrical energy therefrom and including means connected between the input and output for opening the output whenever said reducing energizing means controls the voltage means.

3. A voltage regulator comprising an input connectible to a source of electrical energy, an output, an adjustable voltage means connected between the input and output for adjusting the output voltage, regulating means for sensing the deviation of the output voltage from a preselected value and operable to direct the voltage means to maintain the output voltage within a selected range of the value, and a control circuit for causing the output voltage to attain its preselected range only after it has been increased gradually from a minimum value, said circuit including means connected to the voltage means for normally energizing said voltage means to reduce the voltage therefrom, means for rendering said reducing energizing means inoperative when the regulating means controls the voltage means, means for causing said rendering means to become ineffective upon a disruption of power from said source whereby upon a resumption of power the energizing means causes the voltage means to be energized to reduce its output voltage, means operated by the voltage means for ceasing energization of the voltage means at a predetermined minimum value of voltage therefrom, and means for energizing the voltage means to increase the voltage therefrom after the cessation means has stopped energization of the voltage means, said control circuit being connected to said input for obtaining electrical energy therefrom and including means connected between the input and output for opening the output whenever said reducing energizing means controls the voltage means.

4. A voltage regulator comprising an input connectible to a source of electrical energy, an output, an adjustable voltage means connected between the input and output for adjusting the output voltage, regulating means for

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sensing the deviation of the output voltage from a preselected value and operable to direct the voltage means to maintain the output voltage within a selected range of the value, and a control circuit for causing the output voltage to attain its preselected range only after it has been increased gradually from a minimum value, said circuit including means connected to the voltage means for normally energizing said voltage means to reduce the voltage therefrom, means for rendering said reducing energizing means inoperative when the regulating means controls the voltage means, means for causing said rendering means to become ineffective upon a disruption of power from said source whereby upon a resumption of power the energizing means causes the voltage means to be energized to reduce its output voltage, means operated by the voltage means for ceasing energization of the voltage means at a predetermined minimum value of voltage therefrom, means for energizing the voltage means to increase the voltage therefrom after the cessation means has stopped energization of the voltage means, means operated by the voltage means for ceasing energization of the voltage means by the increasing voltage means after the voltage from the output has reached the preselected range, and means operable after the cessation of the increasing voltage energizing means, for transferring control of the voltage means to the regulating means, said control circuit being connected to said input for obtaining electrical energy therefrom and including means connected between the input and output for opening the output whenever said reducing energizing means controls the voltage means.

5. A voltage regulator comprising an input connectible to a source of electrical energy, an output, an adjustable voltage means connected between the input and output for adjusting the output voltage, regulating means for sensing the deviation of the output voltage from a preselected value and operable to direct the voltage means to maintain the output voltage within selected limits of the value and a control circuit for causing the output voltage to attain its preselected range only after it has been increased gradually from a minimum value, said circuit including means connected to the adjustable voltage means for normally energizing said adjustable voltage means to reduce the voltage therefrom, means for rendering said first means inoperative when the regulating means controls the adjustable voltage means, and a manually operable switch means for causing said rendering means to become ineffective and for shifting control of the voltage means to the reducing energizing means whereby the voltage means is energized to reduce the voltage therefrom, said control circuit being connected to said input for obtaining electrical energy therefrom and including means connected between the input and output for opening the output whenever said reducing energizing means controls the voltage means.

6. A voltage regulator comprising an input connectible to a source of electrical energy, an output, an adjustable voltage means connected between the input and output for adjusting the output voltage, regulating means for sensing the deviation of the output voltage from a preselected value and operable to direct the voltage means to maintain the output voltage within selected limits of the value and a control circuit for causing the output voltage to attain its preselected range only after it has been increased gradually from a minimum value, said circuit including means connected to the adjustable voltage means for normally energizing said adjustable voltage means to reduce the voltage therefrom, means for rendering said first means inoperative when the regulating means controls the adjustable voltage means, a manually operable switch means for causing said rendering means to become ineffective and for shifting control of the voltage means to the reducing energizing means whereby the voltage means is energized to reduce the voltage there-

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from, and switch means positioned between the voltage means and the output and normally being open, said means being closed when the regulating means controls the voltage means and being open by operation of the manually operable switch means, whereby the voltage means is disconnected from the output of the regulator when the reducing energizing means controls the voltage means.

7. A voltage regulator comprising an input connectible to a source of electrical energy, an output, an adjustable voltage means connected between the input and output for adjusting the output voltage, regulating means for sensing the deviation of the output voltage from a preselected value and operable to direct the voltage means to maintain the output voltage within a selected range of the value, and a control circuit for causing the output voltage to attain is preselected range only after it has been increased gradually from a minimum value, said circuit including means connected to the voltage means for normally energizing said voltage means to reduce the voltage therefrom, means for rendering said reducing energizing means inoperative when the regulating means controls the voltage means, means for causing said rendering means to become ineffective upon a disruption of power from said source whereby upon a resumption of power the energizing means causes the voltage means to be energized to reduce its output voltage, and switch means positioned between the voltage means and the output and normally being open and connected with the rendering means to be closed by the rendering means upon operation thereof.

8. A voltage regulator comprising an input connectible to a source of electrical energy, an output, an adjustable voltage means connected between the input and output for adjusting the output voltage, regulating means for sensing the deviation of the output voltage from a preselected value and operable to direct the voltage means to maintain the output voltage within selected limits of the value and a control circuit for causing the output voltage to attain its preselected range only after it has been increased gradually from a minimum value, said circuit including means connected to the voltage means for normally en-

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energizing said voltage means to reduce the voltage therefrom, means connected to the voltage means which upon energization controls said voltage means to increase the voltage therefrom, and means operable by the voltage means at a predetermined value for shifting control of the voltage means from the reducing energizing means to the increasing energizing means, said control circuit being connected to said input for obtaining electrical energy therefrom and including means connected between the input and output for opening the output whenever said reducing energizing means controls the voltage means.

9. A voltage regulator comprising an input connectible to a source of electrical energy, an output, an adjustable voltage means connected between the input and output for adjusting the output voltage, regulating means for sensing the deviation of the output voltage from a preselected value and operable to direct the voltage means to maintain the output voltage within selected limits of the value and a control circuit for causing the output voltage to attain its preselected range only after it has been increased gradually from a minimum value, said circuit including means connected to the voltage means for normally energizing said voltage means to reduce the voltage therefrom, means connected to the voltage means which upon energization controls said voltage means to increase the voltage therefrom, means operable by the voltage means at a predetermined value for shifting control of the voltage means from the reducing energizing means to the increasing energizing means, and normally open switch means positioned between the voltage means and the output of the regulator and interconnected with the increasing energizing means to be closed upon control of the voltage means by the increasing energizing means.

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