United States Patent

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[54] **AUTOMATIC VOLTAGE REGULATOR WITH FAST ACTING CIRCUIT**
6 Claims, 2 Drawing Figs.

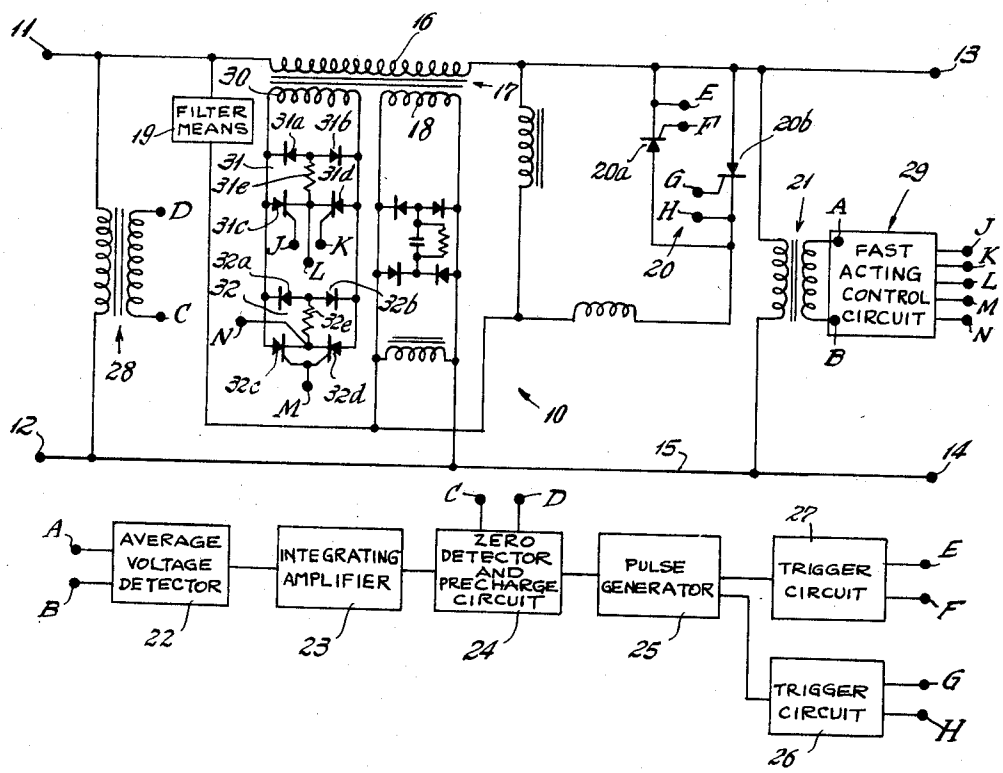
[52] **U.S. Cl.** **323/45,** 323/62
[51] **Int. Cl.** **G05f 1/30**
[50] **Field of Search** 323/9, 20, 24, 45, 47, 62

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ABSTRACT: An automatic voltage regulator of the type having a buck-boost transformer which is rendered exceedingly fast acting to prevent excessive changes in the value of the output voltage caused by a sudden exterior change of condition. The regulator includes a fast acting circuit that immediately responds to a sudden change of the output voltage and acts to nullify the delayed reaction of the buck-boost transformer to adjust to the sudden change until the detector circuit for the transformer has responded to the changed condition and caused the value of output voltage to again be at its selected value under the control of the transformer.



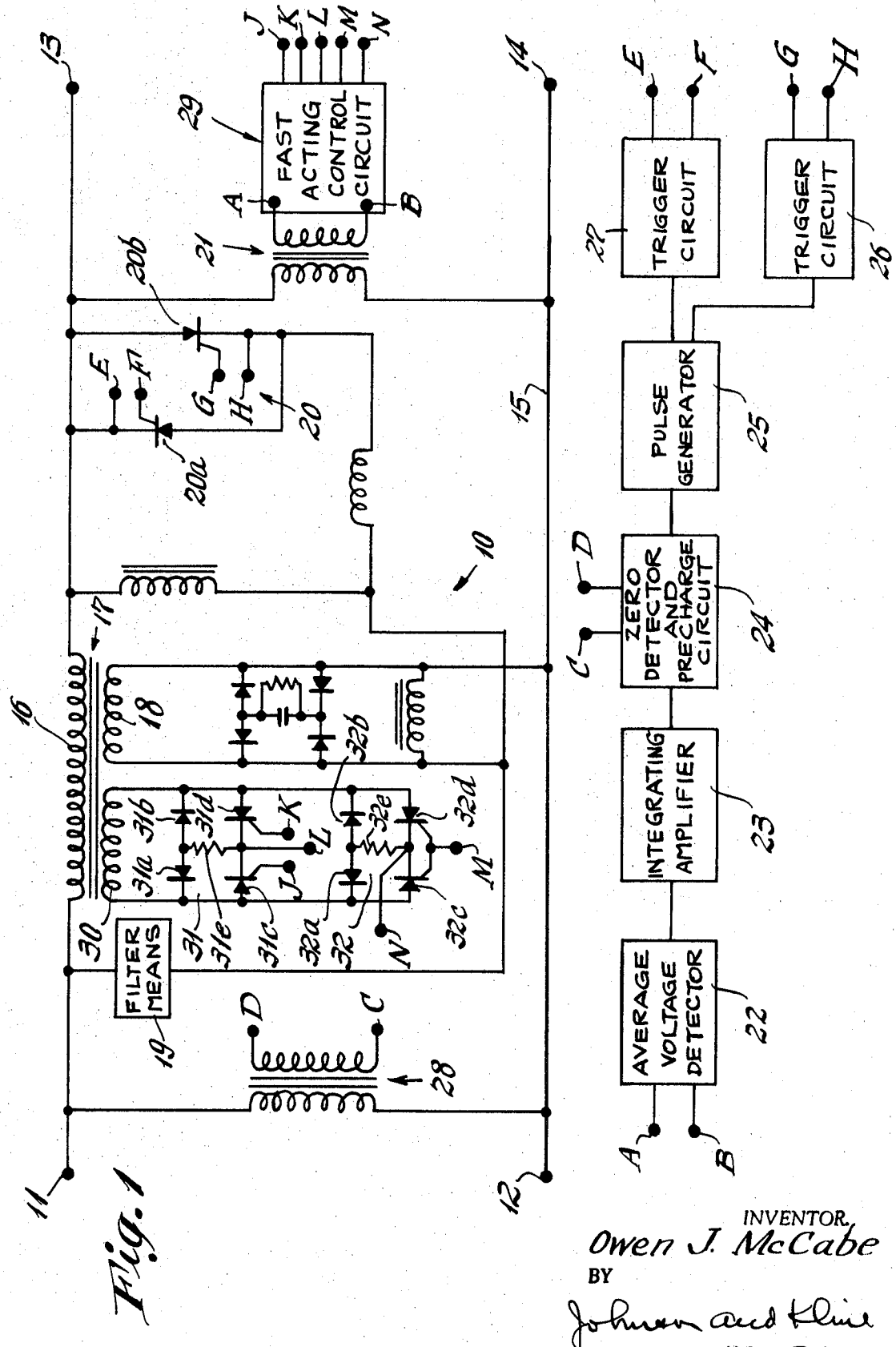


Fig. 1

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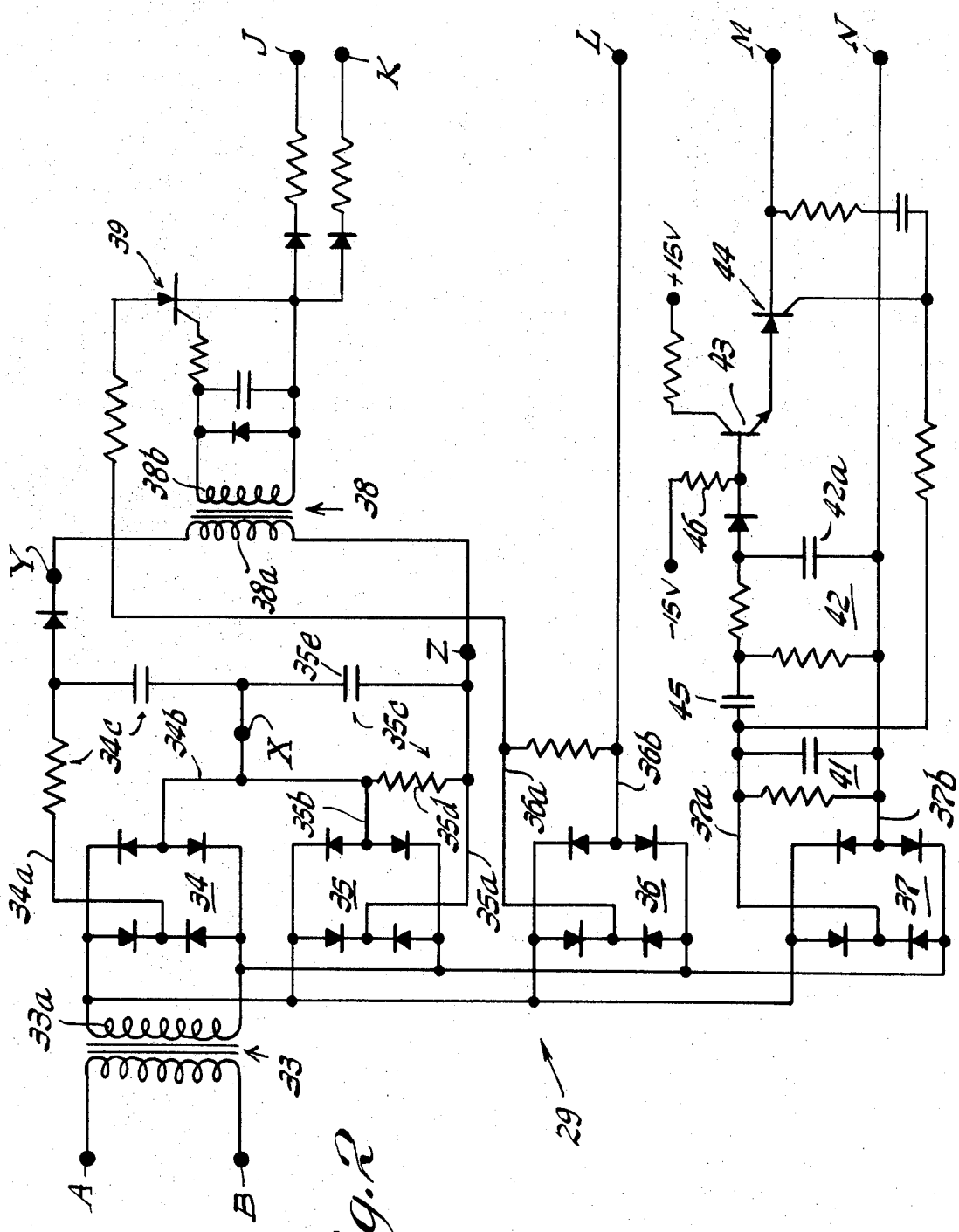


Fig. 2

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AUTOMATIC VOLTAGE REGULATOR WITH FAST ACTING CIRCUIT

The present invention, while incorporable in many types of automatic voltage regulators, is herein disclosed as used in a regulator of the type disclosed in my copending U.S. Pat. application Ser. No. 799,629 assigned to the assignee of the present invention. Such a regulator has a pair of input terminals at which an AC voltage is applied and a pair of output terminals at which a selected value of output voltage appears. Positioned between an input and output terminal is a secondary winding of a buck-boost transformer which regulates the input voltage in accordance with a voltage applied to its primary winding. This latter corrective voltage is controlled by adjusting the conductance of semiconductor means through the use of a detector circuit that senses the value of the corrective voltage that is needed to maintain the value of output voltage.

The ability of the detector circuit to respond to a change in the output voltage to maintain it constant is relatively rapid, on the order of 3 or 4 cycles of 400 cycles/sec. AC and hence is satisfactory for most operating conditions. However, in some situations, such as when a heavy load is suddenly connected or disconnected, the output voltage may be altered drastically for a few cycles before the detection circuit responds to control it. The detector circuit causes the large deviation by continuing to call for the same corrective voltage for the few cycles after the sudden change that was necessary before the change. The deviation of the output voltage is normally quite large and even though it exists for only a short time, it may be sufficient to render the regulator unusable and unsatisfactory in many situations.

It is accordingly an object of the present invention to provide an automatic voltage regulator which maintains an output voltage substantially constant even with sudden changes in exterior conditions.

Another object of the present invention is an automatic voltage regulator that has a normal regulating circuit and in addition a fast acting regulating circuit which is effective to nullify or inhibit the normal regulating circuit from altering the input voltage for the few cycles after a sudden change required for the regulating circuit to adjust to the new condition.

A further object of the present invention is to achieve the above objects with an automatic voltage regulator which has a fast acting circuit that is relatively economical to fabricate, easily incorporated into the presently existing regulator but yet which is reliable and durable in use.

In carrying out the present invention the specific embodiment of the automatic voltage regulator herein described includes the structure essentially disclosed in my above-noted application. It accordingly has a transformer which has a secondary winding connected in series between an input and output terminal. A corrective voltage introduced into the primary of the transformer will be added to the value of the input voltage to produce the selected value of output voltage. The quantity of corrective voltage is adjusted by controlling the phase conduction of semiconductor means through a detector circuit that is connected to sense the value of the output voltage.

The transformer, according to the present invention, has a fast acting circuit which includes an additional primary winding and paths which connect the ends of the winding so that whenever a path is made conductive, the additional primary winding is effectively short circuited. Normally the paths are open or nonconductive but are made conductive whenever the output voltage deviates from a predetermined range of values about its selected value. Such a severe deviation will occur when a heavy load connected to the output terminals is suddenly switched on or off and which could normally produce a drastic decrease or increase, respectively, in the value of the output voltage for a few cycles before the detector circuit effects a correction by changing the value of the corrective voltage. Irrespective of whether the sudden change of condition would effect an increase or a decrease in the output voltage, the present invention provides for short circuiting the additional primary winding to nullify or inhibit the corrective voltage being applied by the primary winding and prevent it from appearing in the output voltage. Under the condition where a heavy load is switched off, the short circuited additional primary winding will absorb the ampere-turns in the transformer that are being added by the primary winding before it responds to the change. Hence, the boosting corrective voltage is prevented from appearing in the secondary winding and subsequently in the output voltage. On the the other hand, where a heavy load is suddenly connected the transformer primary winding is adding little or no voltage and hence the output voltage will be much less than the selected value for a few cycles. The short circuiting of the additional primary winding causes the effective impedance of the secondary winding to be substantially reduced as the short circuited additional primary winding is reflected therein and thus the secondary winding will only be a slight impedance to the input voltage so that the value of the output voltage will essentially by the value of the input voltage.

The fast acting circuit senses the value of the output voltage for each half-cycle thereof and is caused to become effective only if the value of the output voltage exceeds a predetermined range from the selected value. In one embodiment with the output voltage selected at 115 volts, the circuit becomes effective when the value of the output voltage is greater than 121 volts and less than 190 volts. Thus, the fast acting circuit is normally not rendered operative for substantially all of the duration of use of the regulator. Moreover, when the regulator was controlling 400 CPS AC power, the fast acting circuit only becomes cooperative for about 3—4 cycles before the normal control circuit responds to cause the output voltage value to deviate less than that required to effect operation of the fast acting circuit.

Other features and advantages will hereinafter appear.

In the drawing

FIG. 1 is a block and schematic diagram of the automatic voltage regulator of the present invention.

FIG. 2 is an electrical schematic diagram of the control portion of the fast acting circuit.

Referring to the drawing, the regulator is generally indicated by the reference numeral **10** and includes a pair of input terminals **11** and **12** and a pair of output terminals **13** and **14**. A lead **15** connects the terminals **12** and **14** together in common while the terminals **11** and **13** are connected in series through a secondary winding **16** of a transformer **17**. The transformer **17** further includes a primary winding **18** which has one end connected to a filter means **19** and to semiconductor means **20** while its other end is connected to the common lead **15**. A transformer **21** is connected across the output terminals **13** and **14** and provides at the points A and B a value of voltage related to the value of the output voltage.

Operation of the semiconductor means to provide a voltage in the winding **18** which is normally added to the value of the input voltage to maintain the selected value of output voltage is achieved by the use of a control circuit that includes an average voltage detector **22**, an integrating amplifier **23**, a zero detector and precharge circuit **24**, a pulse generator **25** and a pair of trigger circuits **26** and **27**. The outputs of the trigger circuits E and F and G and H are connected between the gate and anode of semiconductors (specifically controlled rectifiers) **20***a* and **20***b* to control their conduction. Additionally, a transformer **28** is connected across the input terminals **11** and **12** to provide a voltage at the points C and D that is in phase with the input voltage and applied to the zero detector and precharge circuit **24**.

The regulator, as above-described, functions to add a corrective voltage to the input voltage which has a value related to the degree of conduction of the semiconductor means for each half-cycle. For a fuller description of the structure and operation of the above automatic voltage regulator reference is made to my above-noted pending patent application.

It has been found that through the regulator performs extremely satisfactory during normal operating conditions that a sudden change in an external condition could cause the output voltage to drastically deviate from the selected value for a few cycles of AC input. This is caused by the control circuit response time requiring a few cycles before it can alter the voltage in the winding **18** to the value necessary to maintain the selected value of output voltage. One such condition occurs when a heavy load is connected across the output terminals **13** and **14** there is a large boosting corrective voltage and suddenly the load is disconnected. For the few cycles which the control circuit requires to substantially reduce its boosting corrective voltage, the boosting voltage will be added to the input voltage and cause the output voltage to be substantially increased as for example 50 percent of the selected value. Moreover, if a load is suddenly connected, the output voltage would decrease for a few cycles until the boosting voltage in the transformer winding **18** was increased to the necessary value to maintain the output voltage at the desired value.

In accordance with the present invention, there is provided a fast acting control circuit generally indicated by the reference numeral **29** which prevents the drastic change in the output voltage for the few cycles that the normal control circuit requires to respond. The fast acting circuit includes an additional primary winding **30** on the transformer **17** and a pair of short circuiting paths **31** and **32**. The path **31** includes oppositely disposed diodes **31***a* and **31***b* together with oppositely disposed controlled rectifiers **31***c* and **31***d*. A resistor **31***e* is connected between the diodes and rectifiers. The path **31** provides a short circuit path through the resistor **31***e* for the winding **30** when either controlled rectifier properly phased, is rendered conducting.

Similarly, the short circuit path **32** has a pair of diodes **32***a* and **32***b* and oppositely disposed controlled rectifiers **32***c* and **32***d* together with a resistor **32***e*. Again the winding **30** will be short circuited upon conduction through either the semiconductor **32***c* or **32***d* with the short circuit current being directed through the resistor **32***e*. The resistors **31***e* and **32***e* are basically selected to decrease the inductive impedance of the paths rather than to limit the current flowing in the path.

The portion of the fast acting circuit **29** shown in FIG. **2** has outputs J, K and L connected to the similarly lettered terminals of the controlled rectifiers **31***c* and **31***d* in the path **31** and outputs M and N connected to the similarly lettered terminals of the controlled rectifiers **32***c* and **32***d* in the path **32**. Normally the controlled rectifiers in the two paths are nonconducting and only become conducting upon the application of a gating pulse or voltage applied to the terminals of the controlled rectifiers to be rendered conducting.

Referring now to FIG. **2** which is a schematic diagram of the fast acting control circuit except for the components shown in FIG. **1**, there is provided a transformer **33** connected to the terminals A and B of the regulator so that there is applied to the transformer **33** a value of voltage related to the value of the output voltage. The secondary winding **33***a* of the transformer is connected in parallel to rectifying bridges **34**, **35**, **36** and **37**. The bridge **34** has a positive lead **34***a* and a negative lead **34***b* between which are connected a resistance capacitance network **34***c* or filter which has a relatively long response time. The positive lead **35***a* of the bridge **35** and its negative lead **35***b* also have connected therebetween a filter network **35***c* consisting of a resistor **35***d* and condenser **35***e*. The negative leads are common to a junction X.

The transformer **38** has its primary winding **38***a* connected between the positive leads **34***a* and **35***a* and its secondary winding **38***b* connected between the gate and cathode of a controlled rectifier **39**. The bridge **36** has its positive lead **36***a* connected to the anode of the controlled rectifier **39** and its negative lead **36***b* connected to the terminal L. The terminals J and K are connected through a resistor and diode, as shown, to the cathode of the controlled rectifier **39**.

A positive gating pulse will appear at the terminals J and K for effecting conduction of the controlled rectifiers **31***c* and **31***d* whenever the output voltage exceeds a selected value. This is achieved by the resistor capacitor network **34***c* producing at the point Y a positive value of unidirectional voltage which is related to the value of output voltage and moreover is of relatively substantially constant value by reason of the network **34***c* having a high time constant which may be on the order of 10 cycles or so. Thus, even if a sudden change in the value of the output voltage occurs, the value of the voltage at the point Y will only slowly respond to the change. On the other hand, the value of positive voltage at the point Z is also unidirectional and by reason of the values of the resistor **35***d* and condenser **35***e* is caused to have a very short time constant, less than one-half a cycle so that the voltage at the point Z will immediately reflect the change when the value of the output voltage changes.

With a sudden decrease in the value of output voltage, it will be understood that the voltage at the point Z will decrease in value faster than the point Y and hence producing a potential difference therebetween which will appear in the secondary winding **38***b* to produce a gate signal which effects conduction of the controlled rectifier **39** and creates a gating pulse at the terminals J and K. The gating pulse is produced each half cycle and applied to both controlled rectifiers **31***c* and **31***d* so that one will be rendered conducting for each half cycle.

In order to prevent a substantial instantaneous rise in output voltage from its normal valve, the bridge **37** has a positive lead **37***a* and a negative lead **37***b* which have resistor capacitor networks **41** and **42** therebetween for filtering. The circuit **41** is a fast time filter perhaps on the order of a one-half a millisecond while the condenser **42***a* basically performs high frequency filtering and hence is also quickly responsive. Accordingly, at the base of a transistor **43** there will be applied a voltage that is related to the value of the output voltage with this voltage varying in value almost simultaneously with changes in the output voltage. The collector of the transistor **43** is connected to a positive unidirectional voltage source, as shown, and its emitter is connected to the anode of a controlled rectifier **44** with the cathode thereof being connected to the terminal M. The transistor **43** essentially functions as an AC amplifier by reason of the condenser **45** permitting only voltage changes to flow to the base thereof. However, there tends to be a slight DC leakage and to overcome this leakage and provide a bias voltage on the base which normally tends to prevent conduction of the transistor, a resistor **46** is connected between the base and a negative source of unidirectional voltage.

During normal operation, a gating pulse does not appear at the terminals M by reason of the bias voltage on the base of transistor **43** being such as to prevent conduction thereof. However, upon a sudden rise in the value of the output voltage, the lead **37***a* will increase positively which will, through the condenser **45**, applying a positive voltage on the base which overcomes the negative bias and effects conduction of the transistor **43**. Additionally, a voltage is applied to the gate of the controlled rectifier **44** obtained from the lead **37***a*. Thus, the increase in the voltage in the lead **37***a* causes the anode of the controlled rectifier to have a positive voltage applied thereto by the transistor **43** conducting and the gate a positive signal which causes it to become conducting, and hence a positive gating signal will appear at the terminal M.

In the circuit for preventing a sudden increase in value of the output voltage, the determination of the value of the output voltage will effect a conducting pulse is set both by the bias voltage on the transistor **43** and the gate signal on the control rectifier **44** and is preferably about 5—10 percent greater than the selected value of the output voltage. In the previously described portion of the circuit having bridges **34** and **35**, the value of the output voltage which will produce a signal on the terminals J and K is basically set by the resistors in the gate circuit of the controlled rectifier **39** and is preferably about 5—10 percent less than the selected value of output voltage. It will be understood that in both circuits there is a continuous monitoring of the value of the output voltage and that both circuits are capable of responding within the

half-cycle in which the output voltage deviates from the range determined by the two circuits. Moreover, the circuits will continue functioning to provide gating pulses whenever the output voltage value is without the range.

Referring to FIG. **1**, it will be understood that during the operation when a substantial boosting corrective voltage is being added to the input voltage by relatively heavy conduction through the winding **18** and a load is disconnected, as by a switch, the heavy boosting voltage in the winding **18** will continue for about three or four cycles of 400 cycle per second AC. This increase suddenly the value of the output voltage for each of these few cycles before the control circuit responds to decrease in the corrective voltage. However, for the half-cycle when the value of output voltage is such as to cause circuit **29** to produce a gate pulse at the terminal M the winding **30** becomes effectively short circuited and will absorb the boosting voltage added by the winding **18** thereby inhibiting its effect on the output voltage which will essentially become a value close to the value of the input voltage. As the short circuit current only flows for a few cycles, the fast acting circuit is capable of absorbing this power even though there may be substantial amperage, on the order of perhaps 50 to 150 amperes.

For the opposite condition where a load is suddenly switched on to be connected to the output terminals and the winding **18** is providing insufficient boosting corrective voltage, the terminals J and K will have gating pulses applied thereto which also short circuits the winding **30**. However, in this instance, the short circuiting of the winding **30** is reflected into the secondary wining **16** to cause it to have basically only a resistive impedance. Hence the output voltage will essentially be at the same value as the input voltage thereby preventing a substantial decrease in the value of output voltage.

The circuit which controls the prevention of an instantaneous rise in voltage, namely, the path **32** would function similarly when the regulator is initially switched on as this, in effect, would appear to be an instantaneous rise in voltage. However, the energizing of the regulator will not produce a value of voltage in the lead **37** to effect the gate pulse until the regulator has achieved essentially the selected value necessary to overcome the bias on the transistor **43** and thus the fast acting circuit is not rendered operative when the regulator is initially energized.

It will accordingly be understood that there has been disclosed an automatic voltage regulator which through the use of an adjustable corrective voltage is capable of regulating an input voltage to a related value of output voltage. The corrective voltage requires a short period to be adjusted to a different value when a sudden change occurs and during this period, it could drastically change the value of the output voltage. However, it is inhibited by the use of a fast acting circuit which nullifies for this short period the effect of the corrective voltage to change the output voltage. This is achieved by having an additional primary winding on the transformer which adds the corrective voltage to the input voltage and by a short circuit path therefor which enables either the absorption of adding corrective voltage if present or minimizes the impedance of the transformer if a reducing corrective voltage is present for the short period.

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

I claim:

1. In combination with an automatic AC voltage regulator having input terminals at which an AC voltage is applied and output terminals at which a selected value of AC voltage is maintained, regulating means connected between terminals and responsive to a control signal to regulate the input voltage to the selected value of output voltage, detector means for sensing the value of the output voltage and supplying the control signal to the regulating means and in which the regulator requires a period of a few cycles of AC voltage to respond to sudden exterior changes of conditions, the improvement comprising a fast acting circuit for inhibiting the regulating means from regulating the input voltage, and including means for sensing the value of the output voltage and providing a signal when the value of the output voltage departs from a preselected range of value and inhibiting means connected to the regulating means for inhibiting the regulating means from effecting the input voltage, and in which the regulating means includes a transformer having a secondary winding connected between an input and an output terminal and a primary winding connected to a source of adjustable AC and in which the inhibiting means includes another primary winding on the transformer.

2. The invention as defined in claim **1** in which the inhibiting means includes short circuit means connected across the other primary winding, said short circuit means being normally inoperative and being rendered operative by the signal from when sensing means.

3. The invention as defined in claim **2** in which the sensing means includes a first circuit for providing a signal when the output voltage is greater than the predetermined range and a second circuit for providing a signal then the output voltage is less than the predetermined range.

4. The invention as defined in claim **3** in which the short circuit means includes a first path connected to the first circuit and a second path connected to the second circuit, said paths being rendered conducting only when receiving a signal from their respective circuits.

5. The invention as defined in claim **4** in which the first path includes means for providing a rectified voltage related to the value of the output voltage that is filtered by a slow filter means, means for providing another rectified voltage related to the output voltage that is filtered by a fast filter means and means for comparing the two rectified voltages to produce the signal when the latter exceeds the former.

6. The invention as defined in claim **4** in which the second path includes a means for providing a rectified voltage related to the value of the output voltage that is filtered by a fast filter means, a source of unidirectional power and means comprising the rectified voltage with the source of power to produce a signal when the former exceeds the latter.