June 27, 1967 B. H. PINCKAERS 3,328,606

SCR BIDIRECTIONAL SWITCH APPARATUS HAVING VARIABLE IMPEDANCE INPUT CONTROL CIRCUIT

Filed Nov. 2, 1964

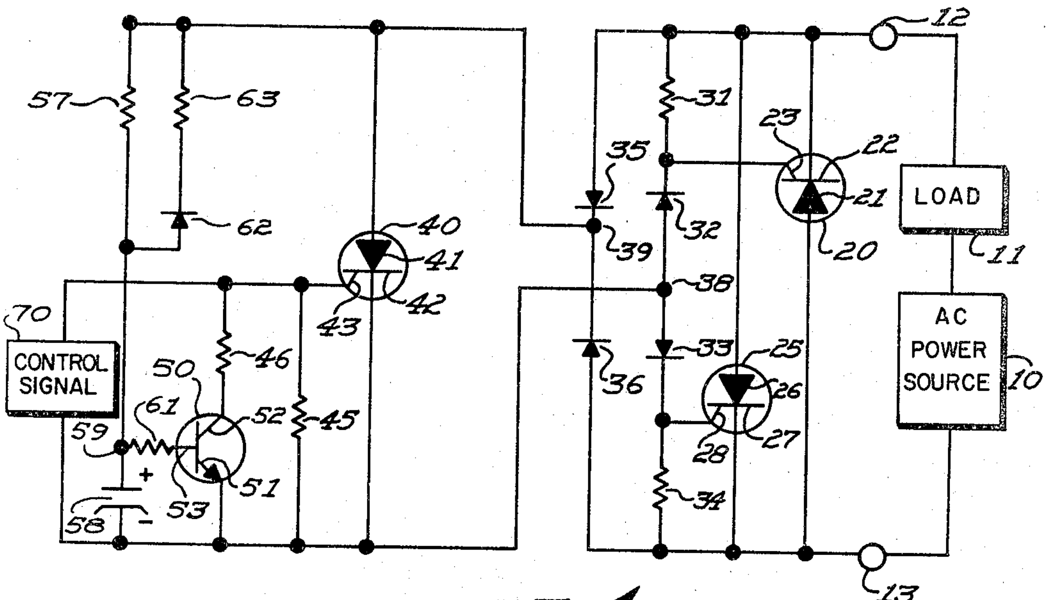

FIG. 1

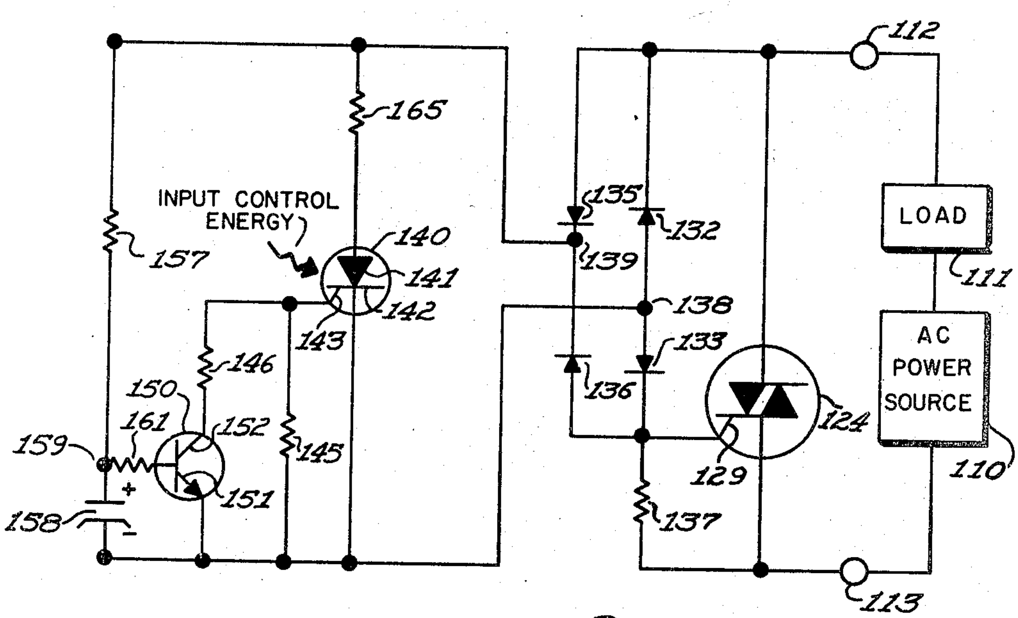

FIG. 2

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United States Patent Office 3,328,606
Patented June 27, 1967

3,328,606

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Filed Nov. 2, 1964, Ser. No. 408,277
6 Claims. (Cl. 307—88.5)

This invention is concerned with control circuits, and more particularly with an electronic switch having a differential.

An embodiment of this invention has a pair of parallel-inverse or back-to-back connected controlled rectifiers connected across a serial combination of a load and A.C. power source. This configuration is well known in the art and it is therefore the method of gating on the controlled rectifiers which is of primary importance to the understanding of this invention. It is proposed to use a third controlled rectifier connected by a bridge rectifying circuit to the source of power and to the gate electrodes of the controlled rectifier. The third controlled rectifier may be of a very low power type, and thus comparatively inexpensive. The gate electrode of the third controlled rectifier is connected to a differential establishing circuit comprising a parallel combination including one branch having resistance means and another branch having a serial combination of a resistance means and a transistor output circuit. A capacitor is connected through a resistor to the control electrode of the transistor such that when the third controlled rectifier is off the transistor is on to establish a first value of resistance for the serial combination. A control signal of a predetermined magnitude is applied to turn on the third controlled rectifier at which time the capacitor will discharge to turn off the transistor and vary the impedance of the parallel circuit. Therefore a different magnitude of control signal is necessary to turn off the controlled rectifier and a differential has been established by varying the impedance of the input circuit connected to the control electrode of the third controlled rectifier. The control signal may be a voltage or current input to the parallel branch or, if the third controlled rectifier is light sensitive, the control signal may be light energy.

It is an object of this invention to provide an electronic switch having an automatic differential.

It is another object of this invention to provide an electronic bidirectional switch in which the electronic contacts of the switch are controlled by a controlled rectification device, and where the input circuit for the controlled rectification device is a variable impedance circuit for establishing a differential for the switch.

It is another object of this invention to provide a differential circuit for a control circuit in which a controlled rectifying device having a variable impedance in its control circuit is connected by bridge rectification means to an A.C. control circuit.

It is yet another object of this invention to provide a differential establishing circuit for a pair of electronic bidirectional contacts, said differential circuit comprising a controlled rectifier having a variable impedance in its control circuit where the variation of impedance is accomplished by switching one resistor in and out of circuit with other resistances.

It is a still further object of this invention to provide a differential establishing circuit having a pair of electronic bidirectional contacts, where the differential is achieved by varying the impedance of the control circuit having a low power controlled rectifier, and where the variation is accomplished by varying the bias to a parent control device in the control circuit. These and other objects of this

invention will become apparent upon consideration of the following claims, specification and drawings, of which:

FIGURE 1 is a schematic representation of one embodiment of this invention using a pair of parallel inverse connected controlled rectifiers and a third controlled rectifier requiring a direct gate input control signal, and

FIGURE 2 is another embodiment of this invention using a bidirectional controlled rectifier having a single gate input electrode, and using a third controlled rectifier sensitive to light energy.

An embodiment of FIGURE 1 discloses a pair of terminals **12** and **13** across which are serially connected a load **11** and a source of A.C. power **10**. There is also disclosed a pair of controlled rectifiers **20** and **25**. Controlled rectifier **20** has an anode **21**, a cathode **22** and a gate **23**. Controlled rectifier **25** has an anode **26**, a cathode **27** and a gate **28**. Cathode **22** and anode **26** are connected to terminal **12**, while anode **21** and cathode **27** are connected to terminal **13**, to thus connect controlled rectifiers **20** and **25** in parallel-inverse relation across the terminals **12** and **13**. Also connected across terminals **12** and **13** is a serial branch comprising, in sequence, a resistor **31**, a diode **32**, a diode **33** and a resistor **34**. Another serial branch connected between terminals **12** and **13** comprises a diode **35** and a diode **36**. Diodes **32**, **33**, **35** and **36** are poled so as to form a full wave bridge rectification circuit.

There is also disclosed a controlled rectifier **40** having an anode **41**, a cathode **42** and a gate **43**. Anode **41** is connected to a terminal **39** between diodes **35** and **36**. Cathode **42** is connected to a terminal **38** between diodes **32** and **33**. Thus the controlled rectifier **40** is connected to the unidirectional output of the bridge rectifier comprising the diodes **32**, **33**, **35** and **36**. A resistor **45** is connected between gate **43** and cathode **42**. A transistor **50** is shown having an emitter **51**, a collector **52** and a base **53**. A resistor **46** is connected between gate **43** and collector **52**. Emitter **51** is connected to cathode **42**. A resistor **57** and a capacitor **58** are connected between anode **41** and cathode **42**. Base **53** is connected by a resistor **61** to a terminal **59** between resistor **57** and capacitor **58**. A serial combination of a diode **62** and a resistor **63** is connected across resistor **57**. A source of control signal **70** is connected between gate **43** and cathode **42**.

To best understand the operation of FIGURE 1 it should first be assumed that the control signal **70** is less then a predetermined magnitude at which it is desired to turn on the switch. This will means that controlled rectifier **40** is off and therefore that controlled rectifiers **20** and **25** are off. The bidirectional or AC power supply **10** will then be presenting power to the input of the full wave bridge rectification circuit comprising diodes **32**, **33**, **35** and **36**. Across the unidirectional output terminals **38** and **39** of the bridge will appear a pulsating unidirectional voltage representing the full wave rectification. This pulsating voltage appears from anode **41** to cathode **42** of controlled rectifier **40**, however, controlled rectifier **40** will not turn on due to the absence of a sufficient current in gate **43**. The pulsating voltage will also be felt across the branch comprising resistor **57** and capacitor **58**. Capacitor **58** will therefore charge to a value of voltage of the polarity shown.

The voltage stored in capacitor **58** will forward bias the base **53** to emitter **51** junction of transistor **50**. A current will therefore flow from the positive plate of capacitor **58**, through resistor **61**, from base **53** to emitter **51**, and back to the negative plate of capacitor **58**. It should be noted that resistor **57** is chosen such that the charge on capacitor **58** never goes below a predetermined value despite the fact that the charging voltage is a pulsating voltage.

The base to emitter current flow in transistor **50** will, by proper design, effectively connect resistor **46** in parallel with resistor **45**. This results in an impedance in the input gate circuit of controlled rectifier **40** which is lower than the impedance of resistor **45** alone. The effect of this lower impedance is to require a higher input magnitude from the control signal **70** to gate on controlled rectifier **40**.

Now assume that the magnitude of control signal **70** reaches a predetermined magnitude at which there is sufficient current into gate **43** to turn on controlled rectifier **40**, which is forward biased by the pulsating voltage. One effect of the turn on of controlled rectifier **40** is the gating on of either controlled rectifier **20** or **25**. If terminal **12** is positive with respect to terminal **13** there will be a current flow from terminal **12** through diode **35**, through terminal **39**, from anode **41** to cathode **42** of controlled rectifier **40**, through terminal **38**, through diode **33**, and through resistor **34** to terminal **13**. The current flow through resistor **34** will cause a gate current to flow into gate **28** to turn on controlled rectifier **25**. If terminal **13** is positive with respect to terminal **12** there will be a current flow from terminal **13** through diode **36**, through terminal **39**, from anode **41** to cathode **42** of controlled rectifier **40**, through terminal **38**, through diode **32** and through resistor **31** to terminal **12**. This current through resistor **31** will result in a current flow into gate **23** to turn on controlled rectifier **20**. It should be noted that when the gate currents are present at gates **23** or **28**, the respective controlled rectifier **20** or **25** is forward biased so that it will turn on in the presence of gate current.

Another effect of the turn on of controlled rectifier **40** is the creation of a discharge path for capacitor **58**. The discharge current will flow from the positive plate of capacitor **58**, through terminal **59**, through diode **62** and resistor **63**, from anode **41** to cathode **42** of controlled rectifier **40**, and back to the negative plate of capacitor **58**. Note that a portion of the current will also discharge through resistor **57** but the resistor **63** is chosen to allow a faster discharge of the capacitor **58**. Note also that the branch comprising diode **62** and resistor **63** is not a mandatory part of this circuit if resistor **57** is chosen of a value which would allow the proper discharge of capacitor **58**.

When capacitor **58** has substantially discharged, base **53** will no longer be forward biased with respect to emitter **51**, thus transistor **50** will be off or non-conductive. Thus the discharge of capacitor **58** has the effect of turning off transistor **50** to remove resistor **46** from the circuit. This will increase the value of the gate input circuit impedance to that of resistor **45**. The effect of this increased impedance is that a greater part of the control signal flows into gate **43**, which means that the control signal itself can be decreased before controlled rectifier **40** no longer fires. The overall effect of the change of impedance is to create a differential for the switch. Variation of the gate circuit input impedance, accomplished by turning off transistor **50**, will in turn vary the input current necessary to turn on controlled rectifier **40**.

When the input control signal **70** has dropped below the gate-on level determined by resistor **45**, controlled rectifier **40** will no longer turn on and the pulsating voltage across terminals **38** and **39** will again charge capacitor **58**, as previously described, to again turn on transistor **50** to return the circuit to its original standby condition .

It is thus apparent that the embodiment of FIGURE 1 is an electronic switch having an automatic differential. The controlled rectifiers **20** and **25** represent the contacts of the switch, and the automatic differential is achieved by using the turn on and turn off of transistor **50** to vary the impedance of the gate input circuit.

The embodiment of FIGURE 2 discloses a pair of terminals **112** and **113**. A serial combination of a source of AC power **110** and a load **111** is connected between terminals **112** and **113**. Also connected between terminals **112** and **113** is a bidirectional controlled rectifier **124** having a gate electrode **129**. The bidirectional controlled rectifier is here shown as a Triac. A resistor **137** is connected between terminal **113** and gate **129**. A pair of oppositely poled diodes **132** and **133** are serially connected between terminal **112** and gate **129**. Another pair of oppositely poled diodes **135** and **136** are serially connected between terminal **112** and gate **129**. The four diodes **132**, **133**, **135** and **136** are all poled so as to embody a full wave bridge rectification network. There is also shown a light activated controlled rectifier **140** having an anode **141**, a cathode **142** and a gate **143**. A resistor **165** is connected between anode **141** and a terminal **139** between diodes **135** and **136**. Cathode **142** is connected to a terminal **138** between diodes **132** and **133**. Thus light activated controlled rectifier **140** is connected across the unidirectional output of the bridge rectification network comprising diodes **132**, **133**, **135** and **136**. A serial combination of resistor **157** and a capacitor **158** is connected between terminals **139** and **138**. A resistor **145** is connected between gate **143** and cathode **142**. A transistor **150** is disclosed having an emitter **151**, a collector **152** and a base **153**. A resistor **146** is connected between collector **152** and gate **143**. Emitter **151** is connected to cathode **142**. A serial combination of a resistor **157** and a capacitor **158** is connected between terminals **136** and **139**. Base **153** is connected by a resistor **161** to a terminal **159** between resistor **157** and capacitor **158**.

The operation of FIGURE 2 can best be understood by first assuming that there is no input light energy to turn on light activated rectifier **140**, and that therefore there is no gate-on current to bidirectional controlled rectifier **124**. The bidirectional or A.C. power supply **110** will cause an alternating voltage to appear between terminals **112** and **113**. This voltage will appear across the full wave bridge rectification circuit, comprising diodes **132**, **133**, **135** and **136**. As a result there will be a unidirectional pulsating voltage across terminals **138** and **139**. This unidirectional pulsating voltage will appear across light activated rectifier **140**. However, light activated rectifier **140** is biased by resistor **145** so as not to turn on as a result of the presence of the pulsating voltage.

The bidirectional pulsating voltage will also appear across the branch comprising resistor **157** and capacitor **158**. Capacitor **158** will charge to a voltage having the polarities shown. As described in the above discussion of the operation of FIGURE 1, the voltage across capacitor **58** will result in a turn on of transistor **150** by providing a current flow from the positive plate of capacitor **158**, through resistor **161**, from base **153** to emitter **151** of transistor **150** and back to the negative plate of capacitor **158**. This will result in an effective turn on of transistor **150** to thus connect resistor **146** in parallel with resistor **145**. This presents a lower impedance to the gate **143** of controlled rectifier **140** than would resistor **145** standing alone. The result of this lower impedance is to bias light activated rectifier **140** such that a greater amount of light energy must be present to turn on light activated rectifier **140**. When the light energy present is sufficient to turn on light activated rectifier **140**, it will turn on due to the forward bias caused by the pulsating voltage between terminals **138** and **139**.

One effect of the turn on of light activated rectifier **140** is to provide a gate-on current for bidirectional controlled rectifier **124**. When terminal **112** is positive with respect to terminal **113** the gate current will flow from terminal **112** through diode **135** and terminal **139**, through resistor **165**. from anode **141** to cathode **142** of light activated rectifier **140**, through terminal **138** and diode **133**, and through resistor **137** to terminal **113**. The current through resistor **137** will cause a voltage drop of a polarity to cause a positive gate current flow into gate **129** of bidirectional controlled rectifier **124**. Since terminal 112 is positive with respect to terminal 113, bidirectional controlled rectifier 124 will turn on to allow a curent flow from terminal 112 through bidirectional control rectifier 124, to terminal 113. Thus load 111 is directly connected across A.C. power supply 110.

When terminal 113 is positive with respect to terminal 112 a current will flow from terminal 113 through resistor 137 through diode 136 and terminal 139, through resistor 165, from anode 141 to cathode 142 of light activated rectifier 140, through terminal 138 and diode 132 to terminal 112. This current flow through resistor 137 will result in a voltage drop across resistor 137 such as to provide a negative current flow into gate 129. Since terminal 113 is positive with respect to terminal 112, bidirectional controlled rectifier 124 will turn on to allow a current flow from terminal 113 through bidirectional controlled rectifier 124 to terminal 112. Thus on the second half cycle of A.C. voltage load 111 is again directly connected across A.C. power supply 110.

Another effect of the turn on of light activated rectifier 140 is to present a discharge path for capacitor 158. The discharge current will flow from the positive plate of capacitor 158 through resistor 157 and resistor 165, from anode 141 to cathode 142 of light activated rectifier 140 and back to the negative path of capacitor 158. The discharge of capacitor 158 will remove the forward base-to-emitter bias on transistor 150 to effectively turn off transistor 150 and remove resistor 146 from the circuit. The input gate impedance of light activated rectifier 140 is then increased to the value of resistor 145. The effect of this increase in gate input impedance is to lower the amount of light energy necessary to turn on light activated rectifier 140. Thus again a differential has been established by turning off an electronic switch to vary the gate input impedance of the control circuit. When the magnitude of light energy present has dropped below the amount necessary to turn on light activated rectifier 140, when biased by resistor 145 alone, the light activated rectifier 140 will no longer turn on, there will no longer be a gate current to turn on bidirectional controlled rectifier 124, capacitor 158 will charge to its previous value to again switch on transistor 150 to place resistor 146 in parallel with resistor 145, and the circuit will again be in the original standby condition.

Thus it can be seen that the embodiment of FIGURE 2 also represents an electronic switch. The contacts of the switch are represented by bidirectional controlled rectifier 124, here schematically shown as a Triac, and the differential for the switch is automatically effected by using transistor 150 to vary the gate input impedance of light activated rectifier 140.

It will be obvious that the general principles herein disclosed may be embodied in many other forms other than that specifically illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. Control appartus comprising:
first and second terminals;
a source of bidirectional energy and a load serially connected between said terminals;
first and second controlled current carrying devices each having input, output and control electrodes;
means connecting said first and second devices input and output electrodes to said terminals so that said first and second devices are connected in parallel-inverse relation;
voltage bridge rectification means having bidirectional input terminals and unidirectional output terminals;
a portion of said bridge means connecting said first and second devices control electrodes, respectively, to said first and second terminals;
means connecting said input terminals to said first and second terminals;
a third controlled current carrying device having input, output and control electrodes;
means connecting said third device input electrode to one of said output terminals;
means connecting said third device output electrode to another of said output terminals;
means including energy storage means connected across said output terminals;
first impedance means connected between said third device control electrode and output electrode;
second impedance means connected across said first impedance means including switching means having a control electrode connected to said energy storage means, for varying the input impedance to said third device control electrode by switching said second impedance means out of circuit with said first impedance means;
and a source of control signal connected across said first impedance means.

2. A differential circuit for a control circuit comprising:
bridge rectification means having bidirectional input terminals and unidirectional output terminals;
means connecting a source of bidirectional energy across said input terminals;
a controlled rectifier having input, output and gate electrodes;
means connecting said input electrode to one of said output terminals;
means connecting said output electrode to another of said output terminals;
a source of control energy adapted to turn on said controlled rectifier;
means including energy storage means connected across said output terminals so that said energy storage means charges when said controlled rectifier is off and discharges when said controlled rectifier is on;
impedance means connected between said gate electrode and said output electrode for determining the turn-on level of said controlled rectifier; said impedance means including switch means having a control electrode;
means connecting said control electrode to said energy storage means so that when said energy storage discharges, said switch means will switch to vary the impedance of said impedance means to determine a turn-off level for said controlled rectifier different than said turn-on level;
and means connecting said controlled rectifier output electrode to said control circuit.

3. The differential circuit of claim 2 in which said controlled rectifier is a light activated controlled rectifier, and said source of control energy is a source of light energy.

4. The differential circuit of claim 2 in which said source of control energy is a source of unidirectional energy connected across said impedance means.

5. In an electronic switch in which a bidirectional controlled rectification means having a control circuit is connected across a load circuit including a source of bidirectional energy and a load, control means for said rectification means comprising:
bridge rectification means having bidirectional input terminals and unidirectional output terminals;
means connecting said bidirectional input terminals accross said load circuit;
a light activated controlled rectifier having an output circuit and a gate circuit;
means connecting said output circuit, across said unidirectional output terminals;:
means connecting said output circuit to said rectification means control circuit so that a current flow through said controlled rectifier will turn on said rectification means;
means including a capacitor connected across said unidirectional output terminals;

variable impedance means connected in circuit across said gate circuit for establishing a first turn-on level for said controlled rectifier, said variable impedance means including switch means having a control electrode;

means connecting said control electrode to said capacitor for establishing second turn-on level by varying the impedance of said variable impedance means;

and a source of light energy adapted to turn on said controlled rectifier.

6. In an electronic switch in which a bidirectional controlled rectification means having a control circuit is connected across a load circuit including a source of bidirectional energy and a load, control means for said rectification means comprising:

bridge rectification means having bidirectional input terminals and unidirectional output terminals;

means connecting said bidirectional input terminals across said load circuit;

a controlled rectifier having an output circuit and a gate circuit, said controlled rectifier being activated by a unidirectional current input to said gate circuit;

means connecting said output circuit across said unidirectional output terminals;

means connecting said output circuit to said rectification means control circuit so that a current flow through said controlled rectifier will turn on said rectification means;

means including a capacitor connected across said unidirectional output terminals;

variable impedance means connected in circuit across said gate circuit for establishing a first turn-on level for said controlled rectifier, said variable impedance means including switch means having a control electrode;

means connecting said control electrode to said capacitor for establishing second turn-on level by varying the impedance of said variable impedance means;

and a source of unidirectional current connected across said gate circuit adapted to turn on said controlled rectifier.

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