Dec. 9, 1969 D. L. NEILL 3,483,432

HYBRID ELECTROMECHANICAL-SEMICONDUCTOR CIRCUIT BREAKER

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FIG. 1

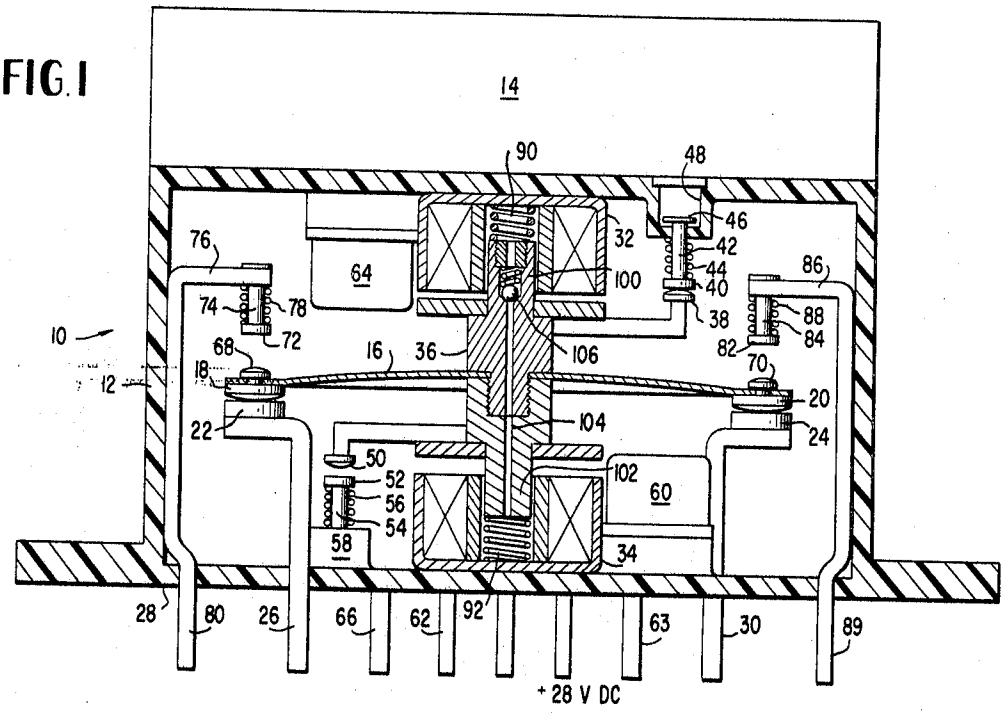
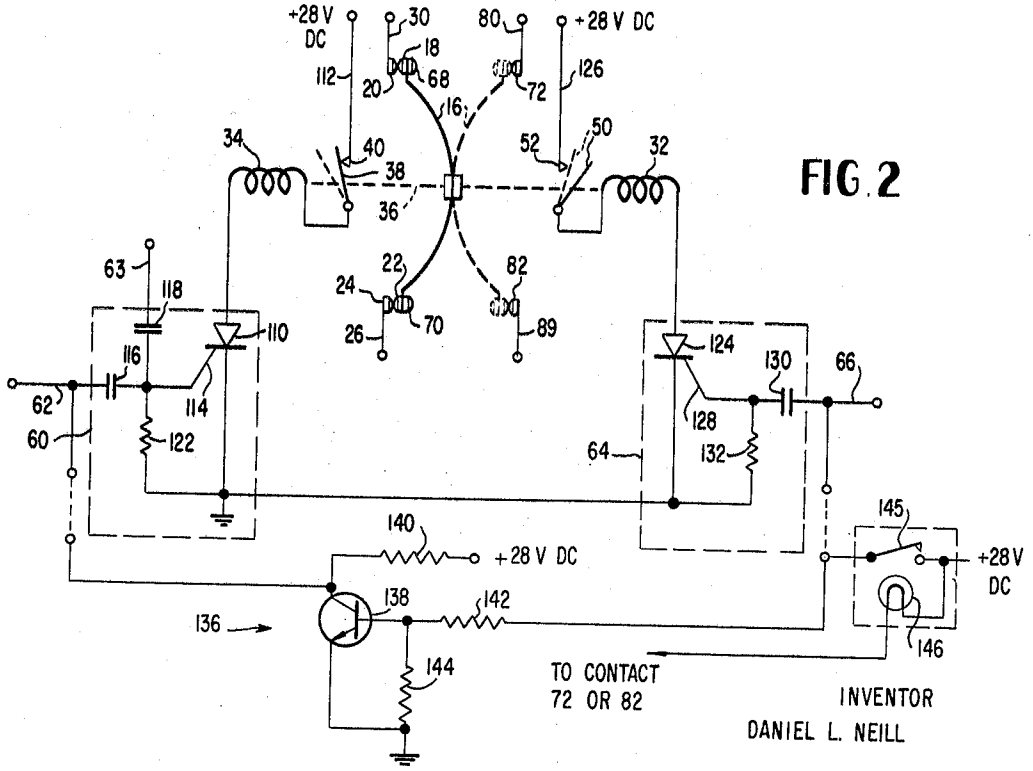



FIG. 2




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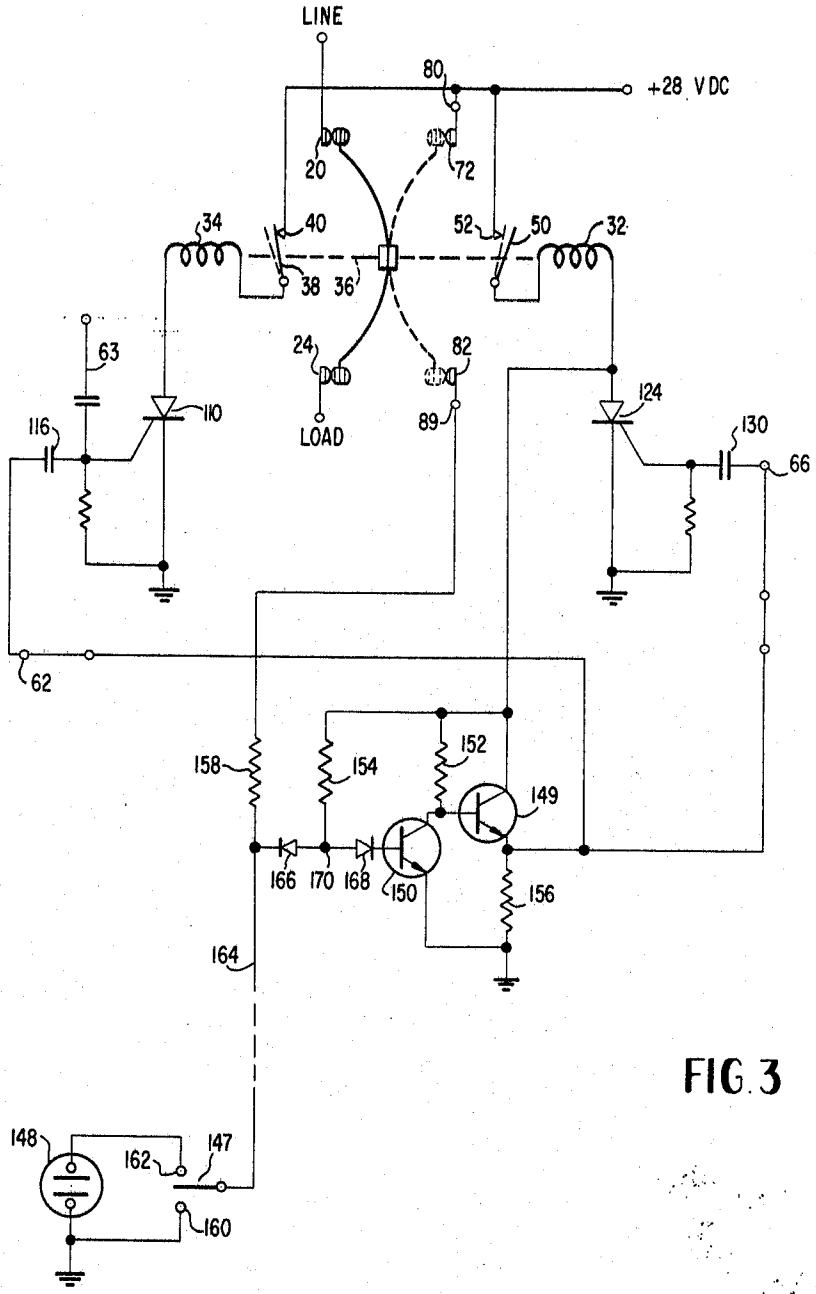



FIG. 3

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# HYBRID ELECTROMECHANICAL-SEMICONDUCTOR CIRCUIT BREAKER

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U.S. Cl. 317—58 15 Claims

## ABSTRACT OF THE DISCLOSURE

A circuit breaker including two solenoids having a common core plunger movable between a trip position and a set position in accordance with the energization of the solenoids, a bistable snap action switch actuated by the plunger between a stable trip position and a stable set position, and a pneumatic dashpot for retarding movement of the switch to one of the positions.

This invention relates generally to remotely controlled circuit breakers and more particularly to an improved hybrid electromechanical-semiconductor circuit breaker.

Broadly the invention is an improved remotely controlled circuit breaker incorporating a solenoid-actuated bistable snap blade for load switching and solid state circuits for trip and reset control. The snap blade is actuated by a plunger which serves as a common movable core for trip and reset solenoids mounted on opposite sides of the snap blade. In the normal set or closed position of the circuit breaker, the load is energized through the snap blade and a pair of contacts mounted on opposite ends thereof. When a trip signal from a load sensing circuit is applied to the trip control circuit, the trip solenoid is energized to actuate the snap blade to its trip position in which the load is interrupted at both contacts. A reset signal must then be applied to the reset control circuit to energize the reset solenoid to reset or reclose the circuit breaker, i.e. return the snap blade to its normal position so that the load is energized.

In the set or closed position of the circuit breaker, closed control contacts connect a control voltage supply and the trip solenoid to a normally non-conducting silicon controlled rectifier. When a trip signal is applied to the gate of the SCR, the SCR fires and the trip solenoid is energized to actuate the snap blade to the trip or open position. In the trip position, the control contacts of the trip solenoid are opened and another set of control contacts are closed to connect the reset solenoid and control voltage supply to another non-conducting SCR. When a reset signal is applied to the gate of the second SCR, the reset solenoid is energized to actuate the snap blade to its normal position to close the load circuit, open the reset control contacts, and close the trip control contacts. The trip control may also be energized manually to open the load circuit at any time. Auxiliary contacts on the snap blade permit an appropriate trip indicator to be energized when the snap blade is in its trip or open position.

Once the SCR in the trip solenoid circuit is fired, no additional trip signal is required to maintain the circuit breaker in the tripped condition. The same is true when the SCR in the reset solenoid circuit is fired to reset the circuit breaker. The incorporation of the snap blade in such a hybrid circuit breaker eliminates the necessity for standby power once the circuit breaker is placed in either its trip or set position.

The bistable snap blade is a monometal, rather than a bimetal, and is preferably dish-shaped even though other forms of snap blades may be used. The plunger and auxiliary contacts are spring mounted. The plunger, which acts as the snap blade actuator and as the movable core for the trip and reset solenoids, includes an integral pneumatic dashpot which retards the closing or resetting movement of the plunger to damp out vibration and eliminate contact chatter without inhibiting the quick tripping or opening action of the breaker.



The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention, as illustrated in the accompanying drawings.

In the drawings:

FIGURE 1 is a cross-section view showing the structure of an improved hybrid electromechanical-semiconductor circuit breaker;

FIGURE 2 is a schematic diagram of the improved circuit breaker; and

FIGURE 3 is a schematic diagram showing a modified trip and reset control circuit for the improved circuit breaker.

In FIGURE 1, a preferred embodiment of the improved hybrid electromechanical-semiconductor switch **10** is shown enclosed in a housing **12**. A semiconductor load current sensing circuit **14** which produces a trip signal upon the occurrence of an overload is the subject of another patent application.

In the illustrated embodiment, switch **10** includes a bistable monometal snap blade **16** which is a dish-type blade in the preferred embodiment, but may be a slotted spring-type, for example. In FIGURE 1, the switch is shown in its set or closed position in which the movable switch load contacts **18** and **20** are in engagement with the fixed load contacts **22** and **24**, respectively. Fixed load contact **22** is mounted on a pin **26** which passes through the base **28** of housing **12**, and fixed load contact **24** is fixed to a pin **30** which also passes through base **28**. In use, pins **26** and **30** are connected in series with the load to be protected.

A reset solenoid **32** is mounted at the top of housing **12**, and a trip solenoid **34** is mounted on the base **28**. A magnetic core plunger **36** acts as a movable armature for the two solenoids and also passes through and is secured to, snap blade **16**. In the set condition illustrated, plunger **36** is in its upper position, and snap blade **16** is also in its upper flexed position. A control contact **38** mechanically fixed to plunger **36**, but electrically isolated therefrom, is in engagement with a control contact **40** which is mounted on a piston **42**. Piston **42** is spring biased downwardly by means of a spring **44**. The enlarged upper portion **46** of plunger **42** extends into a small cylinder **48** formed in housing **12**. Cylinder **48**, piston **42** and spring **44** act as a dashpot to damp out vibrations of contact **40** when it is forceably engaged by contact **38**, upon resetting of the breaker.

In like manner, another control contact **50** is also fixed to plunger **36**. Contact **50** is disposed opposite a corresponding control contact **52** fixed to a plunger **54** which is spring-mounted by a spring **56**. Plunger **54** cooperates with a cylinder **58** to form a dashpot in the manner described in connection with contact **40**.

Control contact **40** is connected through a solid state trip control circuit **60** and trip solenoid **34** to pins **62** and **63**. The internal trip signal from the trip control system **14** appears on pin **62** for monitoring. Pin **63** is connected to an external remote trip control which may be manually actuated, from the cockpit of an airplane, for example. In like manner, the control contact **52** is electrically connected through a solid state reset control circuit **64** and reset solenoid **32** to pin **66**.

Mounted on snap blade **16** opposite contacts **18** and **20** are contacts **68** and **70**, respectively. Opposite con-

tact **68** is an auxiliary contact **72** mounted on a member **74** which is spring-mounted on an arm **76** by a spring **78**. Arm **76** is fixed to housing **12** and extends through base **28** as a pin **80**. In like manner, another auxiliary contact **82** is mounted opposite contact **70** and is fixed to a member **84** which is spring-mounted on an arm **86** by means of a spring **88**. Arm **86** is fixed to housing **12** and extends through base **28** as another pin **89**. When the switch is in its set or closed position, as illustrated, auxiliary contacts **68**, **72** and **70**, **82** are open. However, when plunger **36** is moved downwardly to cause snap blade **16** to flex so that contacts **68** and **70** move upwardly to place the switch in its open or trip position, these auxiliary contacts are then closed. Pins **80** and **89** may be connected to any appropriate trip indicator means.

A set reaction spring **90** is mounted in the bore of reset solenoid **32** and biases plunger **36** downwardly. In like manner, a trip reaction spring **92** is mounted in the bore of trip solenoid **34** and biases the plunger **36** upwardly. However, the force produced by set reaction spring **90** exceeds the force of the trip reaction spring **92** by a considerable amount (about 24 ounces minimum) to produce adequate contact forces for a 50 ampere rating, for example. Since the auxiliary contacts do not require such high forces, trip reaction spring **92** can have a much lower spring constant than set reaction spring **90**. Auxiliary contact springs **78** and **88** compensate for the lighter trip reaction spring **92**. The mass-spring system formed by the components of the switch is susceptible to vibration in the plane normal to the axis of plunger **36**. In order to eliminate this vibration, the reset solenoid **32** and the trip solenoid **34** are designed to cooperate with plunger **36** to form a unidirectional dashpot. The upper portion **100** of plunger **36** is reduced in diameter so that there is a slight clearance between portion **100** and the inner surface of the bore of reset solenoid **32**. In like manner, the lower portion **102** of plunger **36** is reduced in diameter so that a small gap is formed between it and the inner surface of the bore of trip solenoid **34**. An axial bore **104** extends the length of plunger **36**. A spring -biased check ball valve **106** mounted in the plunger adjacent the upper end of bore **104** provides the unidirectional damping feature. Check valve **106** permits rapid downward movement of plunger **36** to trip the breaker but tends to delay or inhibit upward motion of plunger **36** upon closing or setting of the switch contacts. This dashpot effect prevents contact chatter or vibration which otherwise might occur because of the characteristic susceptibility of the plunger mass-spring system to vibrate, and uncontrolled sympathetic vibration is positively inhibited.

FIGURE 2 is a schematic diagram of the electrical circuit of the improved hybrid electromechanical-semiconductor switch, the structure of which is illustrated in FIGURE 1. Where appropriate, the same reference numerals have been used in FIGURES 1 and 2 to identify the corresponding parts.

A silicon controlled rectifier **110** is connected in series with trip solenoid **34**, control contacts **38** and **40**, and a lead **112** which is connected to a +28 v. DC control voltage supply in this example. The gate **114** of SCR **110** is connected through a capacitor **116** to the trip signal input pin **62**. Gate **114** is also connected through another capacitor **118** which extends to the remote trip signal input pin **63**. A resistor **122** is connected between gate **114** and ground. In like manner, an SCR **124** is connected in series with reset solenoid **32**, control contacts **50**, **52** and a lead **126** which is also connected to the DC control voltage. The gate **128** of SCR **124** is connected through a capacitor **130** to the reset pin **66**. A resistor **132** is connected between the gate and ground.

In operation, when snap blade **16** is in its set or closed position illustrated by the full lines in FIGURE 2, a load connected between pins **30** and **26** is energized through contacts **22** and **18**, switch blade **16**, and contacts **20** and **24**. In this position, control contacts **38** and **40** are closed, but control contacts **50** and **52** are open. Consequently, SCR **110** is forward biased by the +28 v. DC applied to lead **112**. However, SCR **110** is held non-conducting by gate **114** in this switch position when rated load current is flowing. However, upon the occurrence of an overload current, a positive trip signal derived from sensing system **14** is applied to pin **62** through capacitor **116** which applies a firing pulse to gate **114**. Consequently, SCR **110** becomes immediately conducting to complete a current path through trip solenoid **34**. Solenoid **34** is thereby energized to attract plunger **36** downwardly against the force of trip reaction spring **92**. (See FIGURE 1.) Once snap blade **16** passes over center, it snaps into the dotted line position shown in FIGURE 2 and requires no standby electrical power to maintain it in that position. The difference in spring constants between springs **90** and **92** aids in the mechanical action of the snap blade in keeping the blade in its trip position.

When the blade snaps to its tripped position, trip control contacts **38** and **40** open to interrupt the current through SCR **110** and return the SCR to its non-conducting state. Simultaneously control contacts **52** and **50** are closed to forward bias SCR **124** by virtue of its connection through reset solenoid **32**, to lead **126** which is connected to +28 v. DC control voltage. If it is desired to reset or reclose the circuit breaker **10**, a positive reset voltage is applied to pin **66** and converted to a pulse by means of capacitor **130**. The output of capacitor **130** is applied to gate **128** and fires SCR **124** so that current flows through reset solenoid **32**, thereby energizing the solenoid and attracting plunger **36** upwardly so that snap blade **16** is returned to its initial set or load energizing position. Again, no standby electrical power is required to maintain the bistable snap blade **16** in this stable set position. The reset signal applied to pin **66** must be at least 1.0 volt DC in order to fire SCR **124**.

Capacitor **130** serves two functions. It converts a voltage level to a pulse to fire SCR **124**, thereby eliminating the necessity for standby power consumption. In addition, capacitor **130** prevents recycle closing of the circuit breaker after overload tripping. The breaker cannot be reset until the reset signal is removed and then reapplied. When the reset signal is removed capacitor **63** discharges through resistor **132**. The input impedances of the trip and reset control circuits **60** and **64** are kept low to insure compatibility of the electromechanical and solid state components and also to reduce noise and transient susceptibility of the trip and reset triggering circuits.

Also illustrated in FIGURE 2 is a modification of the trip and reset control circuits **60** and **64**. An additional circuit **136** may be connected between the reset signal pin **66** and the trip signal pin **62**. Circuit **136** includes an NPN transistor **138** having its collector connected through a load resistor **140** to the +28 v. D.C. control voltage and also to the trip input lead **62**. The base of transistor **138** is connected through a voltage divider **142**, **144** to reset pin **66**. The emitter of transistor **138** is connected to ground. Located remotely from the circuit breaker are a switch **145** and a trip indicator lamp **146**. Lamp **146** is connected to one of the auxiliary contacts **72** or **82** and is energized by +28 v. when the circuit breaker is tripped.

In the operation of this modification, a continuous reset signal of approximately 1 milliwatt is applied to pin **66** from remote switch **145** to maintain the circuit breaker in set or closed position. The cessation of such a signal would then permit the breaker to open or trip. No power would be consumed during the time the load circuit was open. The primary benefit of this modification is the reduction of necessary control wires to the circuit breaker from two wires to one wire. However, one additional wire is required to bring the trip indication from the auxiliary contacts to indicator **146**.

More specifically, if the breaker illustrated in FIGURE

2 is assumed to be in its trip position illustrated by the dotted lines, an application of a positive reset signal to pin **66** will fire SCR **124** and energize the reset solenoid **32** to reset the breaker. The reset signal is continuously applied so that transistor **138** is conducting, and its collector voltage applied to pin **62** is substantially at ground, and well below the minimum trip signal level. When the reset signal is removed, transistor **138** is cut off and its collector rises to the control voltage of +28 volts D.C. The resulting positive-going voltage is coupled through capacitor **116** to the gate **114** of SCR **110** and fires the SCR to energize the trip solenoid **34** and trip the breaker. When the breaker is closed, any overload current will actuate the overload sensing system **14** to produce the trip signal which is applied to pin **62** to trip the breaker as previously described.

Still another modification of the trip and reset control circuit is shown in FIGURE 3. This arrangement requires only one wire between the circuit breaker and a remote single pole, double throw actuator switch **147** and a remote indicator **148** to provide both control and indication functions. The same reference numerals are used for identical parts of FIGURES 2 and 3.

In FIGURE 3, when load contacts **20** and **24** are open, a switch transistor **150** obtains power from the +28 v. D.C. control bus through collector resistor **152**, winding **32**, and closed contacts **50, 52**. The transistor is biased on by a resistor **154**, thereby effectively shorting to ground the base of another transistor **149**. Consequently, transistor **149** is off. The reset terminal **66** and trip terminal **62** are connected in common to the emitter of transistor **149**, the emitter being connected through a resistor **156** to ground. With transistor **149** turned off, terminals **62** and **66** are esesntially at ground potential. The +28 v. D.C. control bus potential is applied through terminal **80**, the auxiliary contacts **72** and **82**, terminal **89** and a resistor **158** to a single remote control wire **164**. Indicator **148** and switch **147** require only ground connections at the remote location, thus eliminating the need for additional protective means for wire **164** which may be shorted to ground without endangering any power bus connections.

In the operation of this modification, switch **147** is in the center position with both contacts **160** and **162** open when the load contacts **20, 24** are open as illustrated by the dotted line position of blade **16**. Control contacts **50, 52** are closed and contacts **38, 40** are open. To close the load contacts, ground is placed on wire **164** by throwing switch **144** so as to close contact **160**. This shorts the base of transistor **150** to ground turning it off. Diode **168** insures that junction **170** will be at a voltage lower than necessary to forward bias transistor **150** into conduction. Transistor **149** now is forward biased and becomes conducting to raise the potential at terminals **66** and **62** to approximately 10 volts. This voltage transition is coupled to the gate of SCR **124** through capacitor **130** to fire SCR **124**, thereby energizing reset solenoid **32** to reset the breaker. SCR **110** is not affected as control contacts **38, 40** remain open until reset actually occurs. Switch **147** is then thrown to close contact **162** and prepare a circuit to indicator **148**. If a trip signal should occur at terminal **63**, SCR **110** will fire, thereby energizing trip solenoid **34** and causing the load contacts to open as the auxiliary contacts **72, 82** are closed through blade **16**. This tripped condition will be indicated by the circuit from the +28 volts D.C. control bus through the contacts **72** and **82**, resistor **158**, wire **164** and contact **162** of switch **147**. Diode **166** prevents transistor **149** from shorting indicator **146**. The breaker may be reset by throwing switch **47** to contact **160** which repeats the process previously described.

If the breaker had not tripped with switch **147** closed to contact **162**, the breaker could have been manually opened by throwing switch **144** to contact **160**, to turn off transistor **150** and turn on transistor **149**, thereby producing a positive pulse at terminals **62** and **66**. In this case, the pulse fires SCR **110** to open the breaker since control contacts **38, 40** were closed and contacts **50, 52** were open.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

**1.** A circuit breaker comprising:
- (a) a housing,
- (b) a first solenoid mounted on said housing,
- (c) a second solenoid mounted on said housing,
- (d) a common core plunger for said solenoids and movable between a trip position and a set position in accordance with the energization of said solenoids,
- (e) a bistable snap action switch means coupled to and actuated by said plunger, one stable position of said switch corresponding to the trip position and the other to the set position, and
- (f) a pneumatic dashpot at one end of said plunger for retarding movement of said switch means to one of the stable positions.

**2.** A circuit breaker as defined in claim **1** wherein said pneumatic dashpot comprises:
- (a) a cylinder formed in one of said solenoids, and
- (b) a piston formed on one end of said plunger and disposed within said cylinder.

**3.** A circuit breaker as defined in claim **2** wherein said dashpot retards the movement of said switch means in only one direction and said plunger has an axial bore extending the length thereof, and further comprising a check valve mounted in said bore to permit fluid flow therethrough in only one direction.

**4.** A circuit breaker as defined in claim **3** further comprising:
- (a) first spring means biasing said plunger towards its set position, and
- (b) second spring means biasing said plunger toward its trip position, said first spring means exerting a substantially stronger bias force than the other.

**5.** A circuit breaker as defined in claim **1** further comprising:
- (a) a pair of load contacts mounted on said switch means,
- (b) first and second control contacts mounted on said switch means, and
- (c) third and fourth control contacts spring mounted relative to said housing, and each adapted to be engaged by a different one of said first and second control contacts, said first and third control contacts being in engagement in the set position and said second and fourth control contacts being in engagement in the trip position.

**6.** A circuit breaker as defined in claim **5** further comprising:
- (a) a solid state trip control circuit mounted on said housing and electrically connected to said first solenoid, and
- (b) a solid state reset control circuit mounted on said housing and electrically connected to said second solenoid.

**7.** A circuit breaker as defined in claim **6** further comprising:
- (a) first conductor means connecting in series said first and third control contacts, said first solenoid, and said trip control circuit,
- (b) second conductor means connecting in series said second and fourth control contacts, said second solenoid and said reset control circuit, and
- (c) input means for applying control signals to said trip and control circuits to complete current paths through said first and second solenoids, respectively, to actuate said switch means to its trip and reset bistable positions, respectively.

8. A circuit breaker as defined in claim 7 wherein each of said control circuits comprises:
(a) a solid state controlled rectifier having its anode-cathode circuit connected in series with its associated solenoid, and
(b) means connecting the gate of each rectifier to said input means.

9. A circuit breaker as defined in claim 8 wherein said switch means further comprises:
(a) a conductive bistable blade,
(b) first and second auxiliary contacts mounted on opposite ends of said blade, and
(c) third and fourth auxiliary contacts spring mounted on said housing and adapted to be engaged by said first and second auxiliary contacts, respectively, when said switch means is in the trip position.

10. A circuit breaker as defined in claim 9 wherein said input means conprises:
(a) a trip terminal connected to said trip control circuit,
(b) a rest terminal connected to said reset control circuit, and
(c) a normally conducting transistor connected between said trip and reset terminals for applying a control signal to said trip control circuit when said transistor is cut off.

11. A circuit breaker as defined in claim 10 further comprising means connecting said transistor to a first source of control power whereby said control signal is shunted away from said trip terminal when said transistor is conducting.

12. A circuit breaker as defined in claim 11 further comprising:
(a) a remote actuator switch,
(b) means connecting one side of said actuator switch to a second source of control power, and
(c) means connecting the other side of said switch to the base of said transistor and to said reset terminal.

13. A circuit breaker as defined in claim 12 further comprising a remote trip indicator connected between said other side of said switch and one of said auxiliary contacts, whereby said trip indicator is energized from said second source of control power when said circuit breaker is in the trip position.

14. A circuit breaker as defined in claim 9 further comprising:
(a) a trip terminal connected to said trip control circuit,
(b) a reset terminal connected to said reset control circuit,
(c) a trip indicator and a single pole, double throw actuator switch located remotely from said switch means, said actuator switch having a movable element and two fixed contacts,
(d) a single wire having its remote end connected to said movable element and its local end to one of said auxiliary contacts,



(e) means for connecting another of said auxiliary contacts to a source of voltage, and
(f) means connecting said trip indicator across said two fixed contacts of said switch actuator.

15. A circuit breaker as defined in claim 14 further comprising:
(a) means connecting one of said fixed contacts to ground,
(b) a first transistor connected between said second conductor means and ground,
(c) means connecting the base of said first transistor to the local end of said single wire so that said first transistor is conducting when said circuit breaker is in the trip position,
(d) a second transistor coupled between said second conductor means and ground,
(e) a resistor connected between ground and the emitter of said second transistor,
(f) means connecting the base of said second transistor to the collector of said first transistor so that said second transistor is non-conducting when said circuit breaker is in the trip position, and
(g) means connecting said trip and reset terminals to the junction of said resistor and the emitter of said second transistor, so that the engagement of said movable element with the grounded fixed contact renders said first transistor non-conducting to render said second transistor conducting, thereby applying a control signal to said reset control circuit to place said circuit breaker in the set position, and so that the subsequent engagement of said movable element with the other fixed contact of said actuator switch causes said indicator to be energized from said voltage source when the circuit breaker is subsequently returned to its trip position.


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