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(54) **PROTECTION DEVICE WITH LOCKOUT TEST**

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(57) **ABSTRACT**

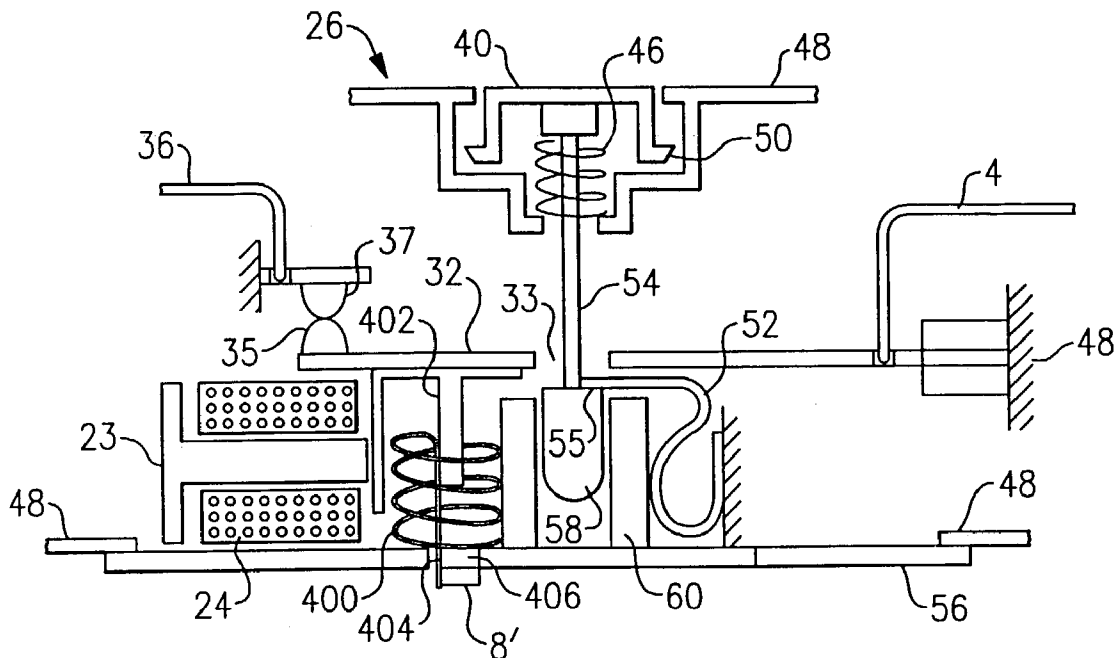
A protective device includes a test button for enabling a test signal for testing an operating condition of at least one of the device components, such as the sensor, detector, switch, solenoid and trip mechanism. The test button also enables a current through a resistor body which is affixed to a stationary part of the device. The resistor body keeps a lockout spring under tension. Failure of the test signal to operate the trip mechanism within a predetermined time interval causes the resistor body conducting said current to reach a predetermined temperature, wherein the resistor body ceases to hold a lockout spring, thereby permitting the lockout spring to move to a position which causes the set of interrupting contacts to remain permanently in a disconnected position.

(21) Appl. No.: **10/263,028**

(22) Filed: **Oct. 2, 2002**

Related U.S. Application Data

(60) Provisional application No. 60/326,531, filed on Oct. 2, 2001.



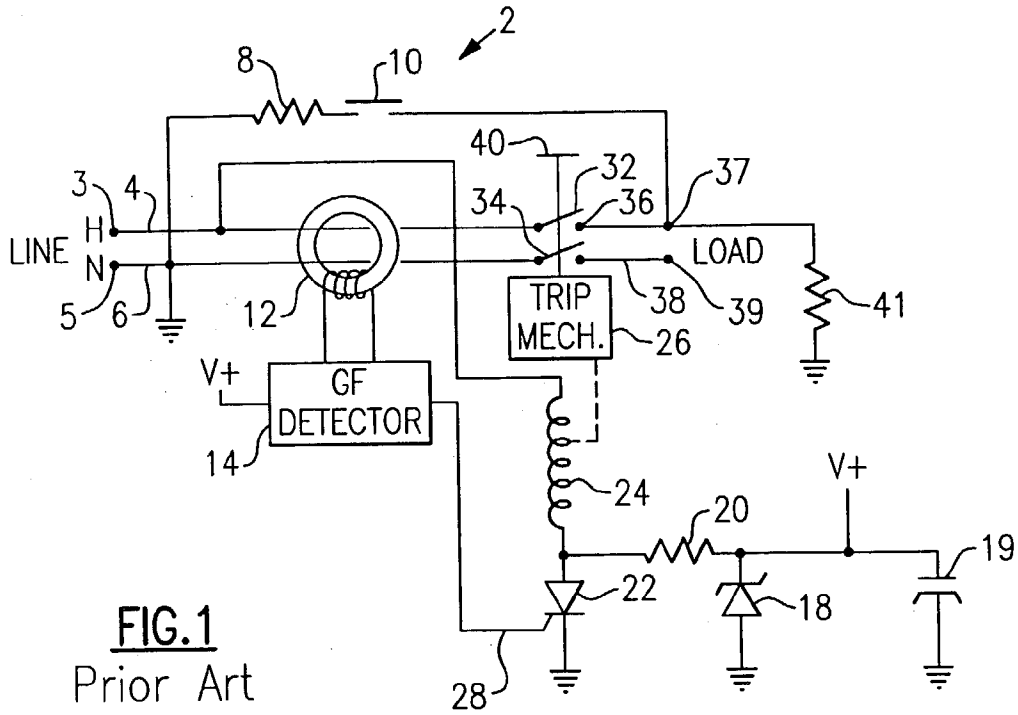


FIG.1
Prior Art

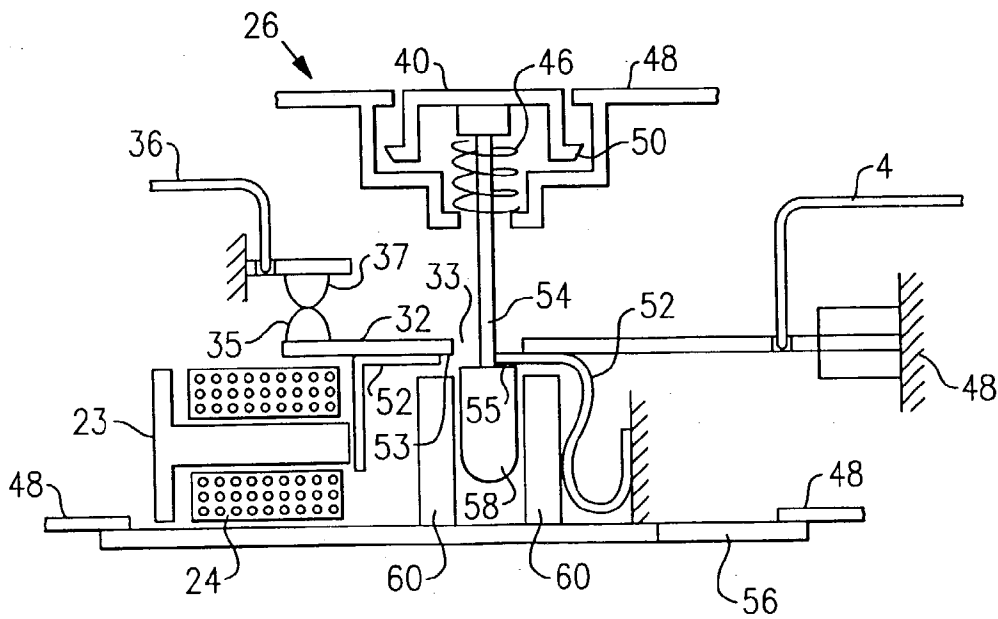


FIG.2
Prior Art

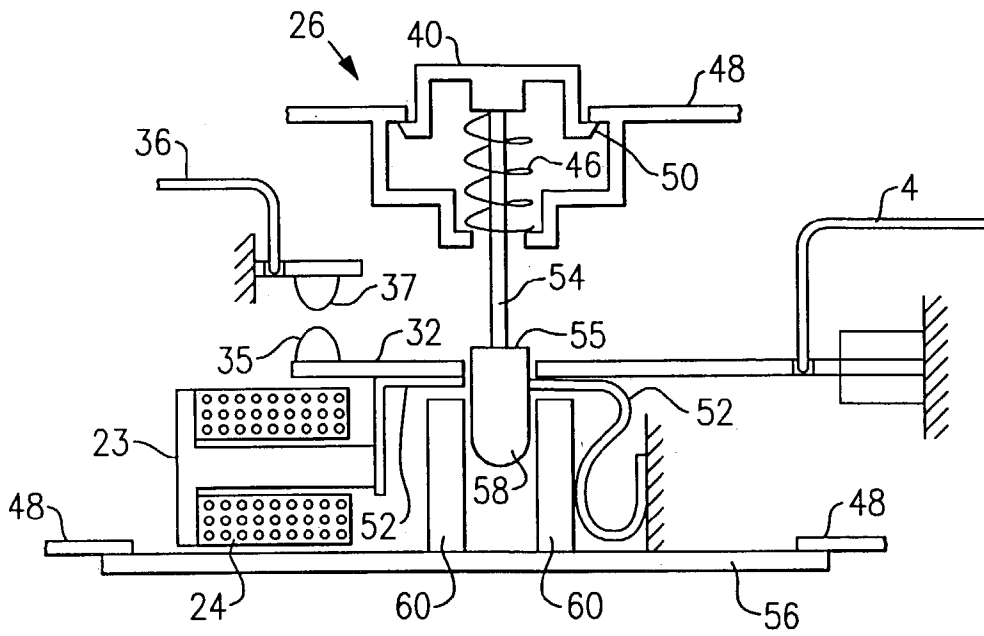


FIG. 3
Prior Art

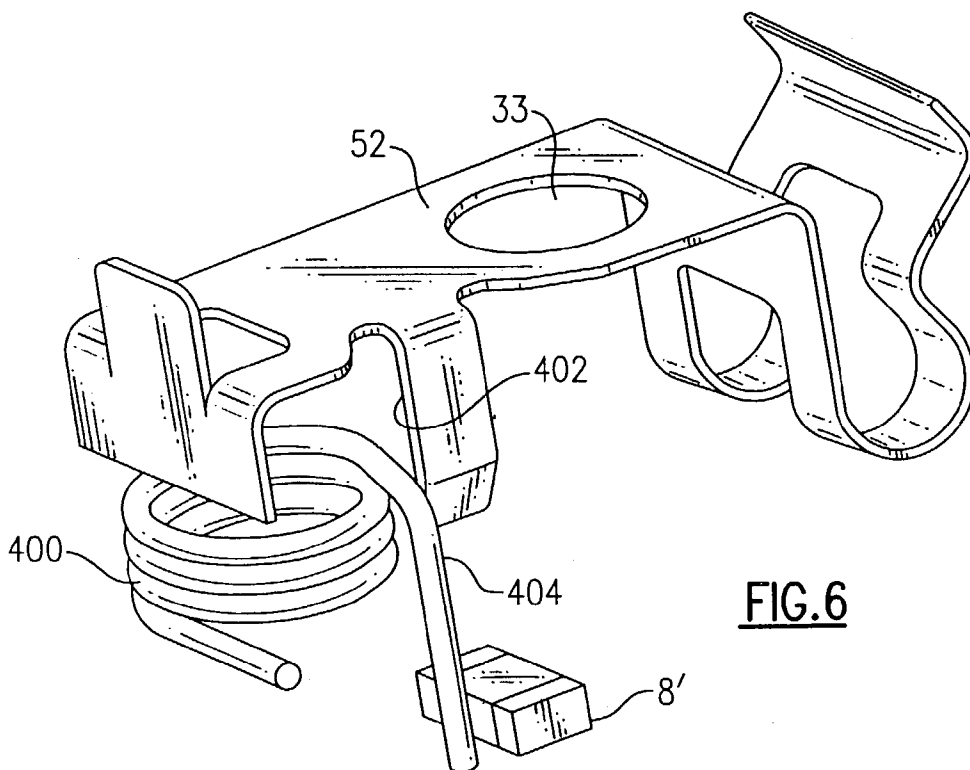


FIG. 6

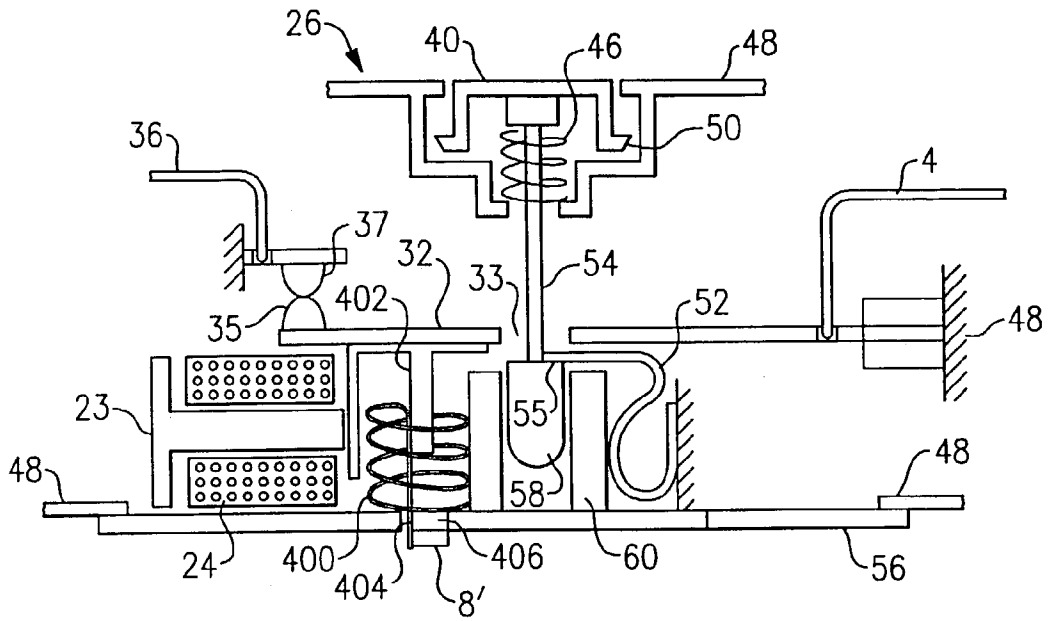


FIG. 4

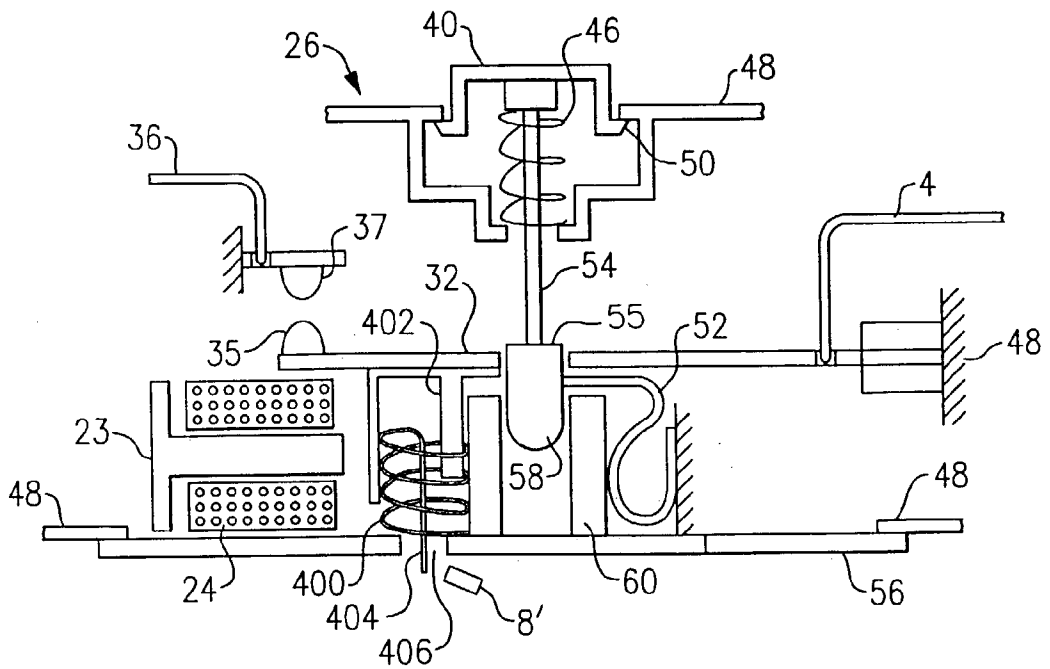
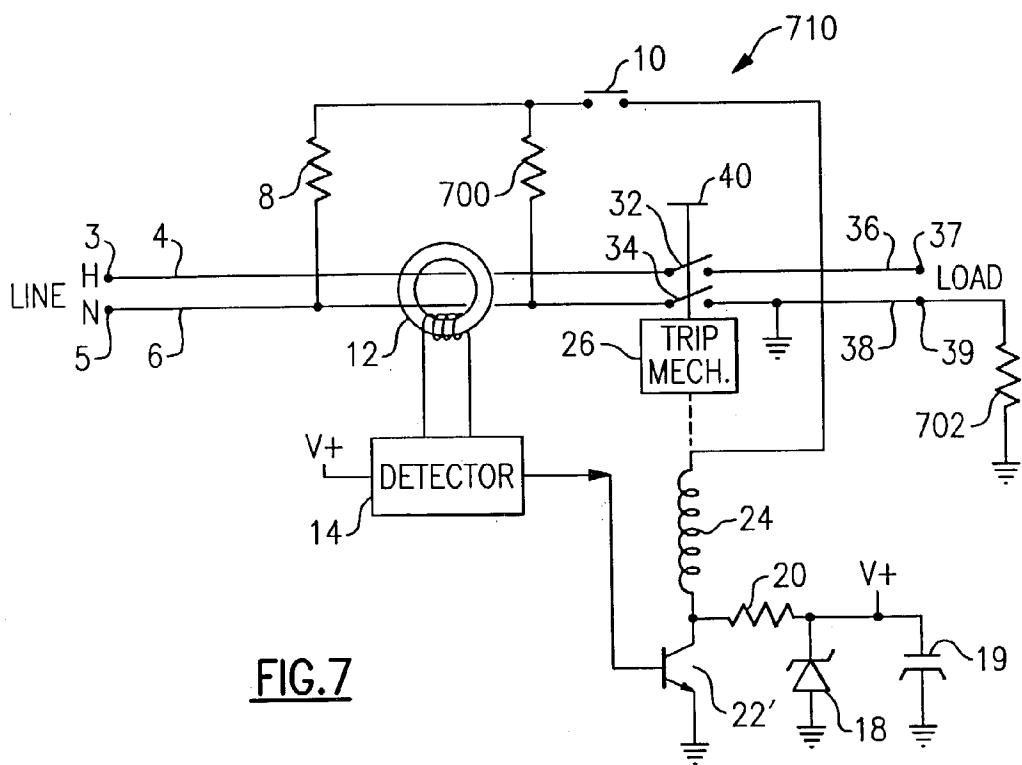
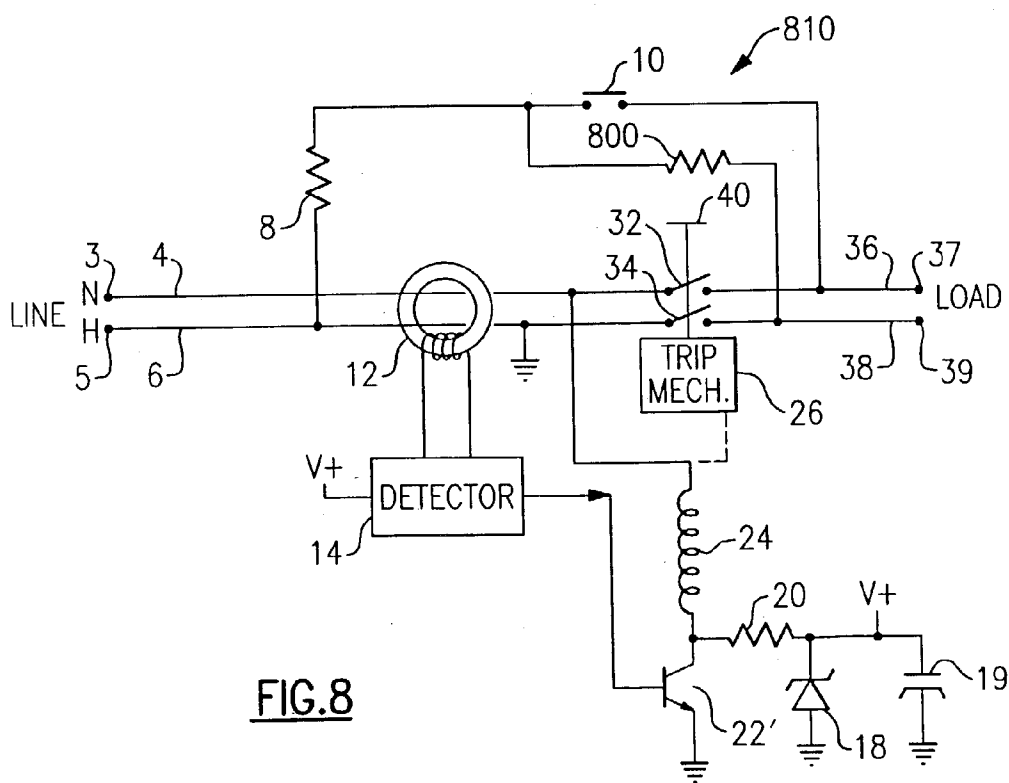
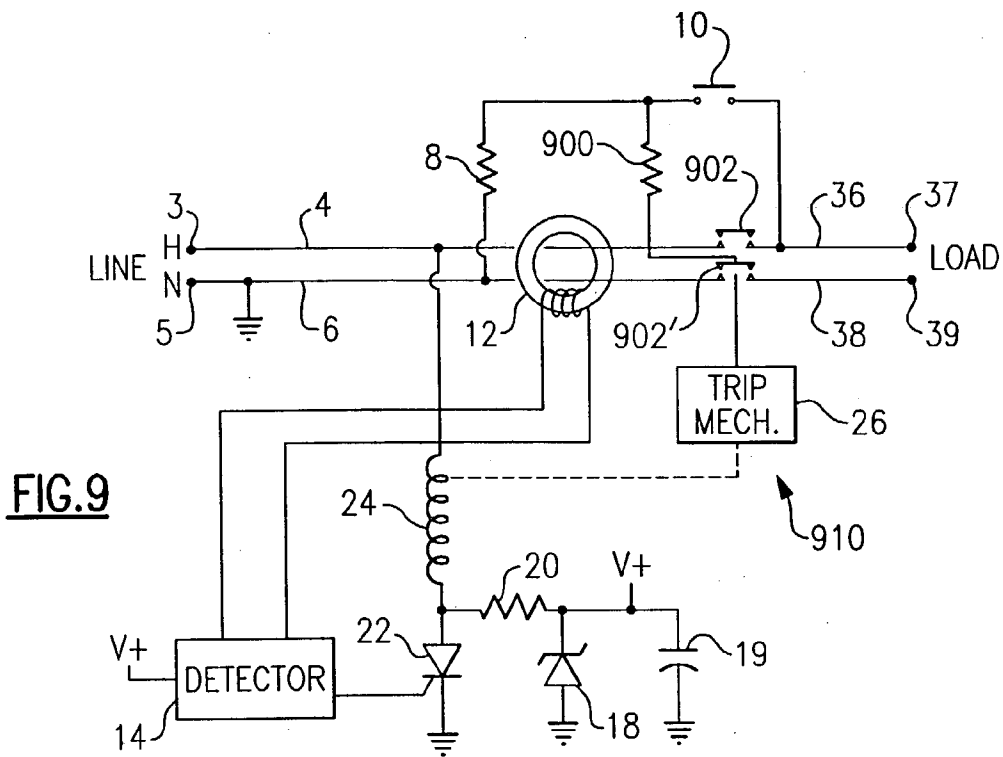
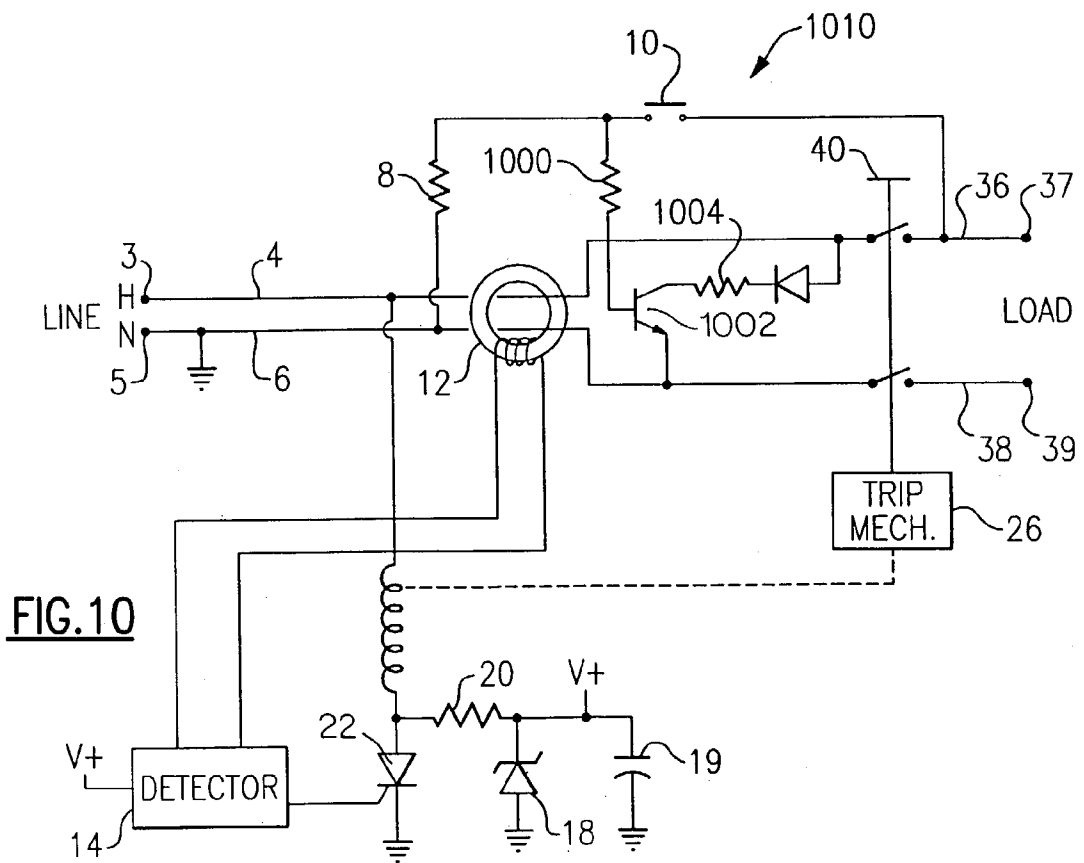


FIG. 5





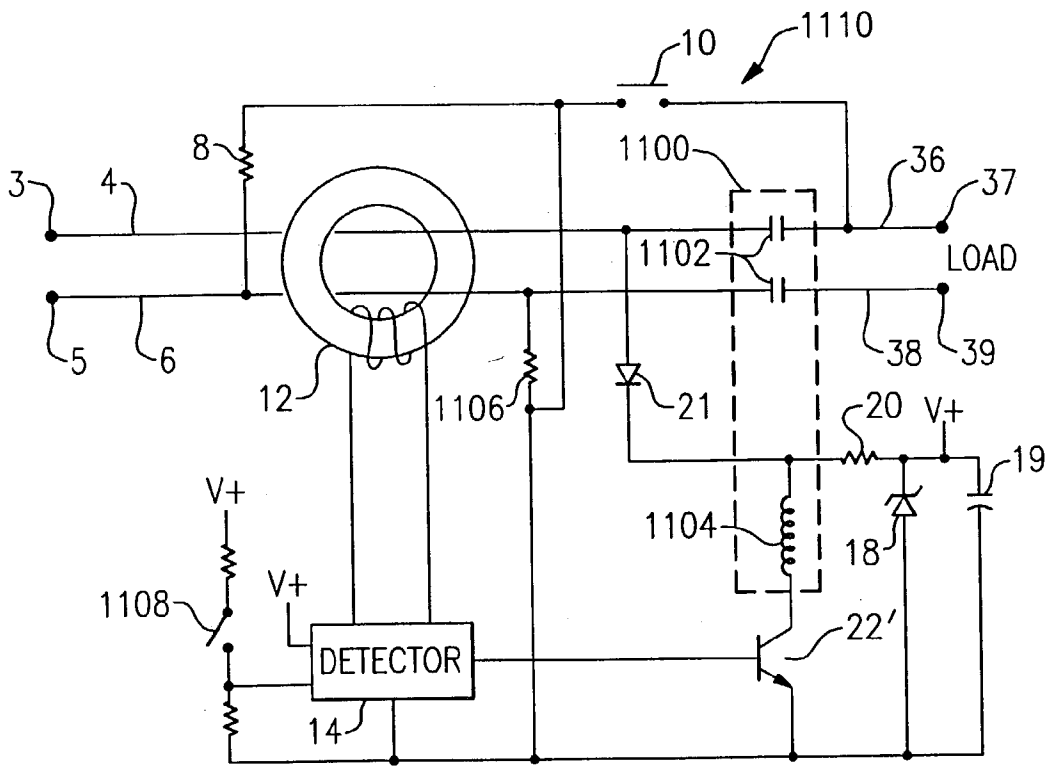


FIG.11

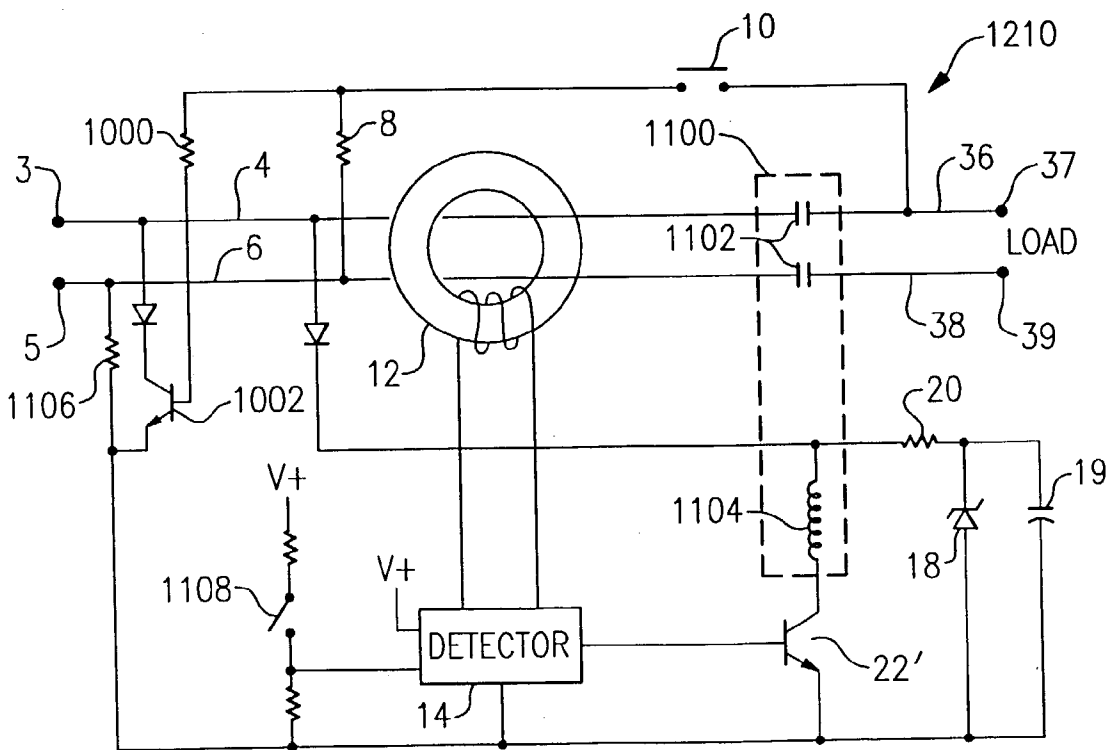


FIG.12

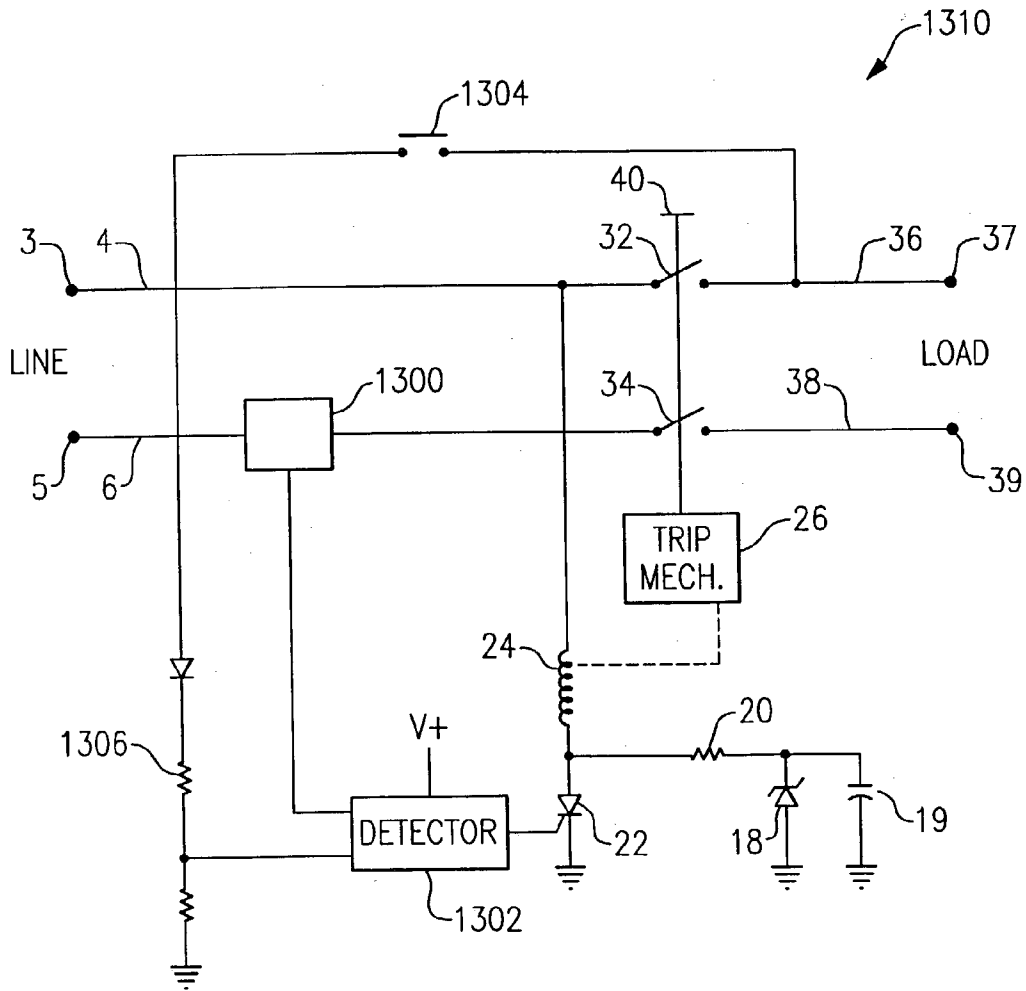


FIG.13

PROTECTION DEVICE WITH LOCKOUT TEST

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from U.S. Provisional Application Ser. No. 60/326,531 filed Oct. 02, 2001 and entitled SECONDARY TRIPPING MECHANISM, and from co-pending U.S. application Ser. No. 09/827,007 filed Apr. 05, 2001 and entitled LOCKOUT MECHANISM FOR USE WITH GROUND AND ARC FAULT CIRCUIT INTERRUPTERS, both of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] This invention relates generally to the field of devices for protecting electrical circuits in the event of faults, and more particularly to a device that protects from arc faults and ground faults, which is provided with a manual test feature that permanently denies power to the protected circuit should the test fail.

BACKGROUND OF THE INVENTION

[0003] The electrical distribution system is defined to include the circuit breaker, branch circuit conductors, wiring devices, cord sets or extension cords, and electrical conductors within an appliance. A protective device is incorporated in an electrical distribution system for protecting a portion of the system from electrical faults. Ground fault circuit interrupters, also called GFCIs, are one type of protective device that has become quite widely used. They provide a very useful function of disconnecting an electrical power source from the protected portion of the system when a ground fault is detected. Among the more common types of ground faults sensed by known GFCIs are those caused when a person accidentally makes contact with a hot electrical lead and ground. In the absence of a GFCI, life threatening amounts of current could flow through the body of the person.

[0004] Arc fault circuit interrupters, also called AFCIs, are another type of protective device but that has been in use more recently. AFCIs disconnect an electrical power source from a load when an arc fault is detected. Among the more common type of arc faults sensed by known AFCIs are those caused by damaged insulation such as from an overdriven staple. This type of arc fault occurs across two conductors in the electrical distribution system such as between the line and neutral conductors or line and ground conductors. The current through this type of fault is not limited by the impedance of the appliance, otherwise known as a load coupled to the electrical distribution system, but rather by the available current from the source voltage established by the impedance of the conductors and terminals between the source of line voltage and the position of the fault, thus effectively across the line, and has been known as a "parallel arc fault." Another type of arc fault sensed by known AFCIs are those caused by a break in the line or neutral conductors of the electrical distribution system, or at a loose terminal at a wiring device within the system. The current through this type of fault is limited by the impedance of the load. Since the fault is in series with the load, this type of fault has also been known as a "series arc fault." In the absence of an AFCI, the sputtering currents associated with an arc fault, whether of the parallel, series or some other type, could heat nearby combustibles and result in fire.

[0005] Protective devices are typically provided with line terminals for coupling to the supply voltage of the electrical distribution system, and load terminals coupled to the protected portion of the system and a circuit interrupter for disconnection of the load terminals from the line terminals. The protective device is provided with a sensor for sensing the fault, a detector for establishing if the sensed signal represents a true hazardous fault, as opposed to electrical noise, and a switch responsive to the detector sensor, wherein the circuit interrupter comprising the contacts of a relay or trip mechanism are operated by a solenoid responsive to the switch to disconnect the load terminals from the line terminals. The disconnection is also known as tripping. A power supply may be required to furnish power to the sensor, detector, switch or solenoid.

[0006] Protective devices are commonly equipped with a test button which the owner of the protective device is instructed to operate periodically to determine the operating condition of the sensor, the detector, the switch, trip mechanism or relay, or power supply, any of which can fail and which may cause the circuit interrupter to not operate to remove power from the load side of the protective device to interrupt the fault. Since the protective device comprises electronic and mechanical components, failure modes comprise normal aging of electronic components, corrosion of mechanical parts, poor connections, mechanical wear, mechanical or overload abuse of the protective device in the field, electrical disturbances such as from lightning, or the like. Once the test has been manually initiated by operating the test button, the outcome of the test has often been indicated mechanically such as by a popping out of a button, visually through a lamp display or pivoting flag that comes into view, or audibly through an annunciator. As an alternative to a manual test, a self-test feature can be added to the protective device for automatic testing such as is described in U.S. Pat. No. 6,421,214 and U.S. application Ser. No. 09/827,007 filed Apr. 05, 2001 and entitled LOCKOUT MECHANISM FOR USE WITH GROUND AND ARC FAULT CIRCUIT INTERRUPTERS, both of which are incorporated herein by reference. Once the test has been automatically initiated through the self-test feature, the outcome of the test can be indicated by any of the previously described methods or by the permanent disconnection of the load terminals from the line terminals of the protective device, also known as "lock-out."

[0007] Protective devices have been located in an electrical distribution system in a variety of conventional device housings such as but not limited to circuit breakers typically installed inside a panel at the service entrance having an interrupting contact that disconnects the load in response to sustained overcurrent, receptacle outlets or snap switches typically installed inside a wall box, portable housings typically installed in plugs or connectors or as protective modules within appliances. Constructional requirements for the different device housings differ. Some differences arise from the pertinent UL (Underwriters Laboratories) safety standards, for example, UL standard 943 for GFCIs and UL standard 1699 for AFCIs. Unlike circuit breaker and receptacle devices, portable devices are susceptible to a poor connection between the receptacle and neutral plug blade. Therefore, only portable devices must continue to afford provide protection or interrupt load side power due to neutral supply conductor failure. This requirement for the portable protective device has often been accomplished

using a relay with normally open contacts serving as the circuit interrupter, such as disclosed in U.S. Pat. No. 4,574,324, whereas receptacle devices commonly use a circuit breaker and mouse-trap mechanism such as is disclosed in U.S. Pat. No. 4,939,615. Other differences arise from the nature of the housing itself, wherein protective devices that are housed in a circuit breaker and that require a power supply most conveniently derive power for the supply power from the load side of the circuit interrupter.

[0008] The prior art discloses methods for denying power to the load when there is protective failure. U. S. Pat. Nos. 6,040,967 and 6,282,070 deny power to the load side of the device when there is a loss of protective function. The device's test button is manually operated which causes the interrupting contacts to open via a mechanical linkage. Next, the reset button is manually operated which initiates a test signal. Failure to detect the test signal prevents the interrupting contacts of the device from being connected.

[0009] U.S. Pat. No. 6,262,871 is another example of a self-testing device but that opens a redundant set of mechanical contacts permanently upon detection of failure.

[0010] U.S. Pat. No. 6,324,043 denies power through use of a fusible link that opens when there is a loss of protection.

[0011] International Patent No. 01/97243 discloses the use of a redundant solenoid that operates in the event of device failure.

[0012] Prior art protective devices that afford self-test comprise complicated circuitry that is both expensive and subject to failure. Prior art protective devices that have required manual manipulation of test and reset buttons comprise complicated mechanical linkages. This type of manual lock-out device also requires the power supply for powering the protective circuitry to derive power from the line terminals of the protective device which is not convenient for the protective device housed in a circuit breaker enclosure that derive power typically from the load side terminals of the protective device. Manual lock-out devices have not been suitable for protective devices housed in a portable enclosure. Portable protective devices typically use a relay with normally open contacts comprising the interrupting contacts, a relay not being compatible with prior art manual lock-out devices.

SUMMARY OF THE INVENTION

[0013] Briefly stated, a protective device includes a test button for enabling a test signal for testing an operating condition of at least one of the device components, such as the sensor, detector, switch, solenoid and trip mechanism. The test button also enables a current through a resistor body which is affixed to a stationary part of the device. The resistor body keeps a lockout spring under tension. Failure of the test signal to operate the trip mechanism within a predetermined time interval causes the resistor body conducting the current to reach a predetermined temperature, wherein the resistor body ceases to hold a lockout spring, thereby permitting the lockout spring to move to a position which causes the set of interrupting contacts to remain permanently in a disconnected position.

[0014] The present invention denies power to the protected side of the device when there is a loss of protective function. Manual operation of the device's test button

enables an electrical test signal for testing the device. At the same time, a current is initiated through a resistor body in an embodiment, or fusible component in an alternate embodiment. If the test signal does not cause the interrupting contacts to disconnect within the expected time interval, the ongoing current through the resistor body causes solder connections to melt and the resistor body to physically dislodge to a second position under bias from a spring, the motion of resistor and spring resulting in the interrupting contacts of the protective device remaining permanently in the disconnected position. In an alternate embodiment, a fusible resistor burns open and ceases to conduct electrical current, resulting in the interrupting contacts of the protective device remaining permanently in the disconnected position.

[0015] According to an embodiment of the invention, a protective device for interrupting power upon detection of an electrical fault in an electrical distribution system includes a plurality of line terminals connectable to a source of voltage; a plurality of load terminals connectable to a load; interrupting means that connects or disconnects the plurality of line terminals from the plurality of load terminals; a sensor for sensing the electrical fault; a detector coupled to the sensor for detecting the electrical fault; a switch coupled to the detector responsive to the detected electrical fault; a solenoid coupled to the switch; a trip mechanism coupled to the solenoid which moves the interrupting means to a disconnected position upon occurrence and detection of the electrical fault; a lockout spring; a resistor body which holds the lockout spring in a first position under tension; a test button for enabling a test signal for testing an operating condition of at least one of the sensor, detector, switch, solenoid and trip mechanism, wherein the test button also enables a first current through the resistor body; and wherein failure of the test signal to operate the trip mechanism within a predetermined time interval causes the resistor body conducting the first current to reach a predetermined temperature, wherein the resistor body ceases to hold the lockout spring in the first position, thereby permitting the lockout spring to move to a second position, wherein the lockout spring being in the second position causes the interrupting means to remain permanently in the disconnected position.

[0016] According to an embodiment of the invention, a protective device for interrupting power upon detection of an electrical fault in an electrical distribution system includes a plurality of line terminals connectable to a source of voltage; a plurality of load terminals connectable to a load; a sensor for sensing the electrical fault; a detector coupled to the sensor for detecting the electrical fault; a switch coupled to the detector responsive to the detected fault; a relay, coupled to the switch, including a solenoid and a plurality of interrupting contacts wherein the relay disconnects the line terminals from the load terminals upon occurrence of the electrical fault, thereby moving the interrupting contacts to a disconnected position; a fusing element; a test button for enabling a test signal for testing an operating condition of at least one of the sensor, detector, switch, solenoid and trip mechanism and for providing a first current through the fusing element; wherein failure of the test signal to disconnect the interrupting contacts within a predetermined time interval causes the fusing element conducting the first current to reach a predetermined temperature,

wherein the fusing element causes an open circuit, and wherein the interrupting contacts remain permanently in the disconnected position.

[0017] According to an embodiment of the invention, a protective device for interrupting power upon detection of an electrical fault in an electrical distribution system includes a plurality of line terminals connectable to a source of voltage; a plurality of load terminals connectable to a load; a set of bus bars that connect or disconnect the plurality of line terminals from the plurality of load terminals, the set of bus bars including a hot bus bar and a neutral bus bar, wherein the hot bus bar connects a hot line terminal to a hot load terminal, and the neutral bus bar connects a neutral line terminal to a neutral load terminal; a resistor body one-way moveable between a first and second position, wherein when the resistor body is in the second position, the set of bus bars is permanently disconnected from the plurality of line terminals and the plurality of load terminals; a test button for enabling a test signal for testing an operating condition of the device to determine if the device is in good operating condition or bad operating condition, and for providing a current through the resistor body; the resistor body being connected on one end to the test button and on another end to the neutral bus bar; and wherein when the source of voltage is miswired to the load terminals and the test button is pressed, the resistor body does not move to the second position when the protective device is in the good operating condition.

[0018] According to an embodiment of the invention, a method for locking out a reset mechanism of an electrical protective device includes the steps of (a) providing a spring driven lockout for the reset mechanism; (b) providing a resistor body which holds the lockout in a first position, wherein the first position permits resetting the electrical protective device; (c) pressing a test button to check an operating condition of the electrical protective device; (d) sending a current through the resistor body in response to pressing the test button; and (e) moving the lockout to a second position in response to the resistor body reaching a predetermined temperature as a result of the current being sent through the resistor body for a longer period of time than a normal trip time of the electrical protective device, wherein the second position permanently prevents resetting of the electrical protective device.

[0019] According to an embodiment of the invention, a method for locking out a reset mechanism of an electrical protective device includes the steps of (a) providing a tripping mechanism which includes a normally open relay; (b) providing a fusing element which permits power to said relay so that said relay remains closed; (c) pressing a test button to check an operating condition of said electrical protective device; (d) sending a current through said fusing element in response to pressing said test button; and (e) blowing said fusing element in response to said fusing element reaching a predetermined temperature as a result of said current being sent through said fusing element for a longer period of time than a normal trip time of said electrical protective device, wherein said blowing of said fusing element creates an open circuit to said relay, thereby permanently preventing resetting of said electrical protective device.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0020] FIG. 1 shows a circuit diagram for a ground fault circuit interrupter (GFCI) according to the prior art;
- [0021] FIG. 2 shows a partial sectional view of a prior art mechanical implementation of the schematic of FIG. 1;
- [0022] FIG. 3 shows the mechanical implementation of FIG. 2 in the tripped state;
- [0023] FIG. 4 shows a partial sectional view of a mechanical implementation of an embodiment of the invention;
- [0024] FIG. 5 shows a partial sectional view of the mechanical implementation of FIG. 4 is shown in the lock-out position;
- [0025] FIG. 6 shows a three-dimensional view of some of the components of the embodiment of FIG. 4;
- [0026] FIG. 7 shows a protective device according to an embodiment of the invention;
- [0027] FIG. 8 shows a protective device according to an embodiment of the invention;
- [0028] FIG. 9 shows a protective device according to an embodiment of the invention;
- [0029] FIG. 10 shows a protective device according to an embodiment of the invention;
- [0030] FIG. 11 shows a protective device according to an embodiment of the invention;
- [0031] FIG. 12 shows a protective device according to an embodiment of the invention; and
- [0032] FIG. 13 shows a protective device according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0033] Referring to FIG. 1, a prior art GFCI 2 includes line terminals 3 and 5 for coupling to a power source of the electrical distribution system and load terminals 37 and 39 appropriate to the installed location, whether a circuit breaker, receptacle, plug, module, or the like. A ground fault represented by resistor 41 produces an additional current in conductor 4 that is not present in conductor 6. Sensor 12 senses the difference current between conductors 4 and 6 which is then detected by a ground fault detector 14. Detector 14 issues a trip command to an SCR 22 which in turn activates a solenoid 24, which activates a trip mechanism 26 releasing contact armatures 34 and 32, thereby disconnecting power to the load by breaking the circuit from a line hot 4 to a load hot 36 and from a line neutral 6 to a load neutral 38. A contact 10 along with a resistor 8 form a test circuit which introduces a simulated ground fault. When contact 10 is depressed, the additional current on conductor 4 is sensed by sensor 12 as a difference current causing the device to trip. Current flows through resistor 8 for the interval between depression of the contact 10 and the release of contact armatures 34 and 32, which is nominally 25 milliseconds. The device is reset by pressing a reset button 40 which mechanically resets trip mechanism 26. A resistor 20, a Zener 18, and a capacitor 19 form a power supply for GFCI 2.

[0034] Referring to FIG. 2, the mechanical layout for the circuit diagram of FIG. 1 is shown in which like elements are like numbered. Trip mechanism 26 is shown in the set state, meaning that contacts 37 and 35 are closed. Contacts 35 and 37 are held closed by action of a trapped make-force spring 46 acting on an escapement 55 on a reset stem 54 to lift a reset latch spring 52 and by interference, an armature 32. Reset latch spring 52 includes a hole 53 and armature 32 includes a hole 33, which holes 33 and 53 permit entry of a tip 58 of reset stem 54. Reset stem 54 is held in place by a block 60. Armature 32 and a printed circuit board (PCB) 56 are mechanically referenced to a housing 48 so that the force in spring 46 is concentrated into armature 32.

[0035] Referring to FIG. 3, the mechanism of FIG. 2 is shown in the tripped state. The tripped state occurs when SCR 22 activates a magnetic field in solenoid 24, which in turn pulls in plunger 23 to displace reset latch spring 52. Displacing reset latch spring 52 allows a flat portion 55 to clear the latch spring 53 interference, which then releases the interference between latch spring 52 and armature 32. Armature 32 has a memory which returns armature 32 to a resting position against solenoid 24, opening contacts 35 and 37 and disconnecting power to the load. The principles shown in FIGS. 1-3 are adaptable to any number of mechanical configurations including U.S. Pat. No. 5,510,760 which is incorporated herein by reference.

[0036] Referring to FIG. 4, a partial sectional view of a mechanical implementation of an embodiment of the invention is shown. A resistor 8', shown schematically in FIG. 1 as resistor 8, is designed to withstand self-heating that results from each depression of contact 10, which causes current to flow through resistor 8' for the expected trip time of the GFCI. For example, resistor 8' for a 6 mA GFCI coupled to a 120 VAC supply is required by UL to be 15 KOHms, which dissipates nominally 0.96 Watts during each trip time interval. In particular, resistor 8' must survive several thousand trip time intervals accomplished by depressing contact 10 and reset button 40 alternately. During normal operation of GFCI 2, resistor 8' is physically positioned to restrain lockout spring 400. Resistor 8' is preferably mounted and soldered so that the body of resistor 8' impedes movement of lockout spring 400.

[0037] Referring to FIG. 5, a partial sectional view of the mechanical implementation of FIG. 4 is shown in the lock-out position. The GFCI 2 has failed in some manner such that the trip time in response to depressing contact 10 is greater than the expected interval including failure of GFCI 2 to trip altogether. Examples of failure modes include a defective sensor 12, and for a sensor 12 comprising a transformer, open or shorted turns. The detector 14, typically composed of electronic components, may have poor solder connections or components that have reached end of life. The SCR 22 may short circuit either due to reaching end of life or due to a voltage surge from a lightning storm, thereby causing continuous current through solenoid 24 which burns open through over activation, or, alternatively, SCR 22 may open circuit. The mechanical components associated with trip mechanism 26 may become immobilized from wear or corrosion. The power supply, if provided, may fail to deliver power in accordance with the design such that sensor 12, detector 14, SCR 22, or solenoid 24 are non-operative.

[0038] When failure of GFCI 2 occurs, the current through resistor 8' flows for the time that contact 10 is manually

depressed, on the order of at least seconds, which is two orders of magnitude longer than if the trip mechanism 26 were to operate in response to depressing contact 10. Resistor 8', which is preferably coupled electrically to GFCI 2 through solder, heats from the current and melts the solder. Resistor 8', no longer restrained by the solder, or in an alternative embodiment by an adhesive, is physically dislodged by the bias of lockout spring 400. Force is then applied by an end 404 of lock-out spring 400 against a feature on the reset latch spring 52, for example, a tab 402. The force in lockout spring 400 is greater than the force in reset latch spring 52. As previously described, reset latch spring 52 is displaced allowing a flat portion 55 to clear the latch spring 53 interference, which then releases the interference between reset latch spring 52 and armature 32. Armature 32 has a memory which returns armature 32 to a resting position against solenoid 24, opening contacts 35 and 37 and disconnecting power to the load. Thus when the GFCI 2 is operational, the tripping mechanism 26 is able to operate, and the armatures 32 and 34 disconnect when plunger 23 applies force to reset latch spring 52. If GFCI 2 is not operative, lockout spring 400 applies force to reset latch spring 52, likewise causing armatures 32 and 34 to disconnect. When GFCI 2 is tripped under the influence of lockout spring 400, armatures 32 and 34 are permanently disconnected irrespective of depressing contact 10 or reset button 40 or any further movement in plunger 23. Thus resistor 8' is integral to the lock-out feature of the present invention.

[0039] Referring to FIG. 6, components of the embodiment of FIG. 4 are shown in a three-dimensional view including lockout spring 400, end 404, resistor 8', and latch spring 52. Spring 404 is preferably affixed to the same structure as resistor 8'.

[0040] Referring to FIG. 7, a protective device 710 shows a resistor 700 which is then used as the resistor body which constrains spring 400. There are other ground fault circuit interrupters whose trip thresholds are greater than 6 milliamperes intended for a variety of supply voltages or phase configurations, and intended for personnel protection or fire prevention. Alternate trip levels typically include 30 milliamperes in the U.S. or Europe, or 300 or 500 milliamperes in Europe, to which the invention as described applies. For devices where the current through resistor 8 may produce insufficient heat during the anticipated duration that contact 10 is manually depressed to melt the solder, resistor 8 can be supplemented by a resistor 700 in parallel with resistor 8 which connects to line 6 on the other side of sensor 12 from where resistor 8 connects to line 6. Currents through resistors 8 and 700 are enabled by depressing contact 10. Resistor 8 generates a simulated test signal comprising a difference current to test GFCI 2 as previously described. Resistor 700 is coupled so as to conduct common mode current but no difference current. Since the current through resistor 700 does not influence the amount of simulated test current required by UL, which is set by the value of resistor 8, the value of resistor 700 can be whatever value is convenient for producing sufficient heat in resistor 700 when contact 10 is manually depressed to release lockout spring 400 when GFCI 2 is not operational. FIG. 7 also shows how the lockout function is unaffected by whether the power supply for the GFCI comprising resistor 20, Zener 18, and capacitor 19 are coupled to the load side of armatures 32 and 34. Load side power derivation may be convenient for GFCIs or

protective devices housed in a circuit breaker. FIG. 7 also shows how SCR 22 can be replaced by a transistor 22', with either device comprising a switch for controlling solenoid 24.

[0041] Referring to FIG. 8, a protective device 810 which is an alternate embodiment to FIG. 7 shows a resistor 800 which serves the same function as resistor 700 in FIG. 7 but is coupled to the load side of the interrupting contacts, i.e., contact armatures 32, 34. This may be important for 6 milliamperes GFCI receptacles and portables where the hot and neutral supply conductors are inadvertently transposed by the installer, wherein the hot side of the supply voltage from the electrical distribution system is connected to line terminal 5. If the armatures 32 and 34 in FIG. 7 are disconnected in response to a fault current, a hazardous current may yet flow through resistors 8 and 700 through ground fault 702 when contact 10 is depressed. However, if armatures 32 and 34 in FIG. 8 are disconnected, current flows through resistor 8 but not through resistor 800, which is not a problem because the current flow through resistor 8 alone has already been determined to be non-hazardous.

[0042] Referring to FIG. 9, a protective device 910 which is an alternative embodiment to FIG. 8 is shown in which the trip mechanism comprises one or more bus bars as disclosed in U.S. Pat. No. 5,510,760, incorporated herein by reference, instead of contact armatures. Resistor 900 serves the same function as resistor 800 in FIG. 8 except that resistor 900 is coupled to moveable bus bar 902'. For receptacle housings it is possible for the installer to miswire a GFCI such that the supply voltage is connected to load terminals 37 and 39, which would cause resistor 800 (FIG. 8) to melt solder when contact 10 is depressed, even when device 810 is in good working condition, i.e., operational. The problem is alleviated in the embodiment of FIG. 9 whereby resistor 900 melts solder only when bus bar 902' remains connected when contact 10 is depressed, that is, when device 910 is non-operational. Miswiring thus does not cause a permanent lock-out of device 910.

[0043] Referring to FIG. 10, a protective device 1010 which is an alternate embodiment to FIG. 7 is shown, wherein contact 10 enables a current through resistor 8, as previously described, and a second current through a resistor 1000 in which the second current is preferably less than a tenth of the current through resistor 8. The second current depends on an interface circuit such as a transistor switch 1002. Transistor switch 1002 causes current to flow through a resistor 1004 of identical function to resistor 700 described in FIG. 7, i.e., resistor 1004 is normally in such a position as to leave spring 400 (FIG. 6) under tension, but when resistor 1004 heats up from the current through it sufficient to dislodge the solder affixing resistor 1004 to a fixed reference surface, the dislodgement of resistor 1004 releases spring 400.

[0044] FIG. 10 shows an alternative to FIG. 8 wherein a hazardous current does not occur when the hot and neutral supply conductors are inadvertently transposed as described in FIG. 8. In addition, FIG. 10 shows another remedy for the issue described in the FIG. 9 embodiment wherein resistor 1004 melts solder only if protective device 1010 is non-operational and not when protective device 1010 is miswired.

[0045] Referring to FIG. 11, a protective device such as GFCI 1110 according to an alternate embodiment is shown,

wherein the so called mouse trap mechanism, i.e., the tripping mechanism of the GFCI of FIGS. 1-5, is replaced by a relay 1100 having normally open contacts 1102 that connect or disconnect line terminals 3 and 5 from load terminals 37 and 39 respectively, and a solenoid 1104, which is designed to carry current when contacts 1102 of GFCI 1110 are connected, a construction that is common to, but not limited to, portable GFCI devices. Solenoid 1104 is designed to conduct current for the unlimited duration that GFCI 1110 is in use, wherein solenoid 1104 is not susceptible to burn out caused by over-activation as previously described with respect to solenoid 24. A fusible element 1106 is in series with the solenoid and is designed to carry the continuous current through solenoid 1104 when transistor 22' is closed. Contact 10 enables current through resistor 8 which produces a difference current as previously described, and a common mode current, which, if the device is non-operational, enables a lock-out feature. The common mode current, which is greater than the solenoid current, is conducted through fusible element 1106.

[0046] If GFCI 1110 is operational, the load side is disconnected from the line side, causing the device to trip and resistor 8 and common mode currents to stop flowing even if contact 10 continues to be manually depressed. Fusible resistor 1106 must survive several thousand cycles of common mode current exposures from alternately depressing contact 10 to trip GFCI 1110 and switch 1108 to electronically reset GFCI 1110. The duration of each common mode current exposure is the expected time that GFCI 1110 requires for tripping after contact 10 has been depressed. If GFCI 1110 fails in some manner such that the trip time in response to depressing contact 10 is greater than the expected interval including the failure of GFCI 1110 to trip altogether, fusible element 1106 burns to an open circuit, permanently eliminating current through solenoid 1104 and rendering interrupting contacts 1102 in a permanently disconnected position. Fusible element 1106 can include a resistor.

[0047] Referring to FIG. 12, elements of the circuit diagram of FIG. 11 are combined with elements of the circuit diagram of FIG. 8 in a protective device 1210, wherein components having like functions bear like numbers. The concept shown in FIG. 11 is thus combined with the embodiment of FIG. 8 to protect against the inadvertent transposing of the hot and neutral supply conductors to terminals 3 and 5 from the electrical distribution system. For protective devices not equipped with a resistor 8, the value of resistor 1000 can be chosen so that current passing therethrough is less than 0.5 mA, which limit has been identified to be the perception level for humans.

[0048] Referring to FIG. 13, an alternate embodiment is shown in which the preceding concepts are applied to a general protective device 1310 representative of the class of general protective devices including AFCIs that require a contact 10 but that are not necessarily equipped with a GFCI or a sensor capable of sensing difference current. Such devices are disclosed in U.S. Pat. No. 6,421,214 which is incorporated herein by reference. Components having like functions bear like numbers. Sensor 1300 is similar to sensor 12 but may be a current sensor or shunt for sensing load current through either conductor 6 or through conductor 4. A detector 1302 is similar to detector 14 (FIG. 1) but senses particular signatures in the load current as has been dem-

onstrated in other patent applications as a method of identifying arc faults. A contact **1304** is similar to contact **10** (FIG. 1), which initiates a test of protective device **1310** when depressed. The test signal can be controlled by detector **1302** to test sensor **1300**, detector **1302**, switch **22**, and trip mechanism **26**. A resistor **1306** is similar to resistor **700** (FIG. 7) which is affixed to a fixed reference surface. If armatures **32** and **34** fail to operate due to a malfunction of protective device **1310**, the longer duration of current through resistor **1306** causes sufficient self-heating of resistor **1306** to melt the solder affixing resistor **1306** to the fixed reference surface, wherein resistor **1306** is dislodged due to force exerted by lockout spring **400** (FIG. 4), wherein lockout spring **400** causes armatures **32** and **34** to be permanently disconnected.

[0049] While the present invention has been described with reference to a particular preferred embodiment and the accompanying drawings, it will be understood by those skilled in the art that the invention is not limited to the preferred embodiment and that various modifications and the like could be made thereto without departing from the scope of the invention as defined in the following claims.

What is claimed is:

1. A protective device for interrupting power upon detection of an electrical fault in an electrical distribution system, comprising:

- a plurality of line terminals connectable to a source of voltage;
- a plurality of load terminals connectable to a load;
- interrupting means that connects or disconnects said plurality of line terminals from said plurality of load terminals;
- a sensor for sensing said electrical fault;
- a detector coupled to said sensor for detecting said electrical fault;
- a switch coupled to said detector responsive to said detected electrical fault;
- a solenoid coupled to said switch;
- a trip mechanism coupled to said solenoid which moves said interrupting means to a disconnected position upon occurrence and detection of said electrical fault;
- a lockout spring;
- a resistor body which holds said lockout spring in a first position under tension;
- a test button for enabling a test signal for testing an operating condition of at least one of said sensor, detector, switch, solenoid and trip mechanism, wherein said test button also enables a first current through said resistor body; and

wherein failure of said test signal to operate said trip mechanism within a predetermined time interval causes said resistor body conducting said first current to reach a predetermined temperature, wherein said resistor body ceases to hold said lockout spring in said first position, thereby permitting said lockout spring to move to a second position, wherein said lockout spring

being in said second position causes said interrupting means to remain permanently in said disconnected position.

2. The device according to claim 1 wherein said electrical fault comprises an arc fault or a ground fault.

3. The device according to claim 1 wherein said trip mechanism further comprises a plunger passing through said solenoid and responsive to a magnetic field produced thereby by said solenoid; and

a latch spring biasing said plunger in an opposing direction to a bias from said lockout spring;

wherein said bias of said lockout spring in said second position exceeds said bias of the latch spring, whereby said interrupting means remains permanently in said disconnected position.

4. The device according to claim 1 wherein said trip mechanism further comprises:

a plunger passing through said solenoid and responsive to a magnetic field produced therein; and

a latch for holding said interrupting means in said connected position, said latch including a tab;

wherein said latch is movable under an applied force from said plunger to release said interrupting means to said disconnected position; and

wherein said lockout spring in said second position bears against said tab to cause said interrupting means to remain permanently in said disconnected position.

5. The device according to claim 1, further comprising a ground fault circuit interrupter, wherein said resistor body consists of a test resistor which simulates a ground fault current when said test button is depressed.

6. The device according to claim 5, wherein a resistance of said test resistor is about 15 K-Ohms.

7. The device according to claim 1, further comprising:

a ground fault circuit interrupter which includes a test resistor to simulate a ground fault current;

wherein depressing said test button enables electrical currents through both said test resistor and said resistor body.

8. The device according to claim 1, further comprising:

a ground fault circuit interrupter which includes a test resistor to conduct a simulated ground fault current;

an interface circuit coupled to said resistor body;

wherein depressing said test button enables said simulated ground fault current through said test resistor and a second current to said interface circuit, and

wherein said interface circuit enables said first current through said resistor body when said test button is depressed;

wherein said first current exceeds said simulated ground fault current, and said simulated ground fault current exceeds said second current.

9. The device according to claim 8 wherein said second current and said simulated ground fault current are derived from a load terminal and said first current is derived from a line terminal.

10. The device according to claim 1, further comprising one of a receptacle, switch, circuit breaker, module, and portable housing containing said device.

11. The device according to claim 1, further comprising:

an interface circuit coupled to said resistor body;

wherein depressing said test button enables a second electrical current to said interface circuit, and

wherein said interface circuit enables said first current through said resistor body, said first current exceeding said second current.

12. The device according to claim 1, further comprising a power supply, wherein said detector receives power from said power supply and said power supply is coupled to either the line terminals or the load terminals.

13. A protective device for interrupting power upon detection of an electrical fault in an electrical distribution system, comprising:

a plurality of line terminals connectable to a source of voltage;

a plurality of load terminals connectable to a load;

a sensor for sensing said electrical fault;

a detector coupled to said sensor for detecting said electrical fault;

a switch coupled to said detector responsive to said detected fault;

a relay, coupled to said switch, including a solenoid and a plurality of interrupting contacts wherein said relay disconnects said line terminals from said load terminals upon occurrence of said electrical fault, thereby moving said interrupting contacts to a disconnected position;

a fusing element;

a test button for enabling a test signal for testing an operating condition of at least one of said sensor, detector, switch, solenoid and trip mechanism and for providing a first current through said fusing element;

wherein failure of said test signal to disconnect said interrupting contacts within a predetermined time interval causes said fusing element conducting said first current to reach a predetermined temperature, wherein said fusing element causes an open circuit, and wherein said interrupting contacts remain permanently in said disconnected position.

14. The device according to claim 13 wherein said electrical fault comprises an arc fault or a ground fault.

15. The device according to claim 13, further comprising:

a ground fault circuit interrupter which includes a test resistor to simulate a ground fault current;

wherein depressing said test button enables electrical currents through both said test resistor and said fusing element.

16. The device according to claim 13, further comprising:

an interface circuit connected to said fusing element;

wherein depressing said test button enables a second electrical current to said interface circuit; and

wherein said interface circuit enables said first current through said fusible element, said first current exceeding said second current.

17. The device according to claim 16 wherein said second current is derived from one of said plurality of load terminals.

18. The device according to claim 17 wherein said second current is less than 0.5 milliamperes.

19. The device according to claim 13, further comprising:

a ground fault circuit interrupter which includes a test resistor to conduct a simulated ground fault current;

an interface circuit coupled to said fusing element,

wherein depressing said test button enables a simulated ground fault current through said test resistor and a second current to said interface circuit, and

wherein said interface circuit provides said first current through said fusing element; and

wherein said first current exceeds said second current and said simulated ground fault current exceeds said second current.

20. The device according to claim 13, further comprising one of a receptacle, switch, circuit breaker, module, and portable housing containing said device.

21. The device according to claim 13 wherein said fusing element is a resistor.

22. A protective device for interrupting power upon detection of an electrical fault in an electrical distribution system, comprising:

a plurality of line terminals connectable to a source of voltage;

a plurality of load terminals connectable to a load;

a set of bus bars that connect or disconnect said plurality of line terminals from said plurality of load terminals, said set of bus bars including a first bus bar and a second bus bar;

a resistor body one-way moveable between a first and second position, wherein when said resistor body is in said second position, said set of bus bars is permanently disconnected from said plurality of line terminals and said plurality of load terminals;

a test button for enabling a test signal for testing an operating condition of said device to determine if said device is in good operating condition or bad operating condition, and for providing a current through said resistor body;

said resistor body being connected on one end to said test button and on another end to one of said first and second bus bars; and

wherein when said source of voltage is miswired to said load terminals and said test button is pressed, said resistor body does not move to said second position when said protective device is in said good operating condition.

23. A method for locking out a reset mechanism of an electrical protective device, comprising the steps of:

providing a spring driven lockout for said reset mechanism;

providing a resistor body which holds said lockout in a first position, wherein said first position permits resetting said electrical protective device;

pressing a test button to check an operating condition of said electrical protective device;

sending a current through said resistor body in response to pressing said test button; and

moving said lockout to a second position in response to said resistor body reaching a predetermined temperature as a result of said current being sent through said resistor body for a longer period of time than a normal trip time of said electrical protective device, wherein said second position permanently prevents resetting of said electrical protective device.

24. A method for locking out a reset mechanism of an electrical protective device, comprising the steps of:

providing a tripping mechanism which includes a normally open relay;

providing a fusing element which permits power to said relay so that said relay remains closed;

pressing a test button to check an operating condition of said electrical protective device;

sending a current through said fusing element in response to pressing said test button; and

blowing said fusing element in response to said fusing element reaching a predetermined temperature as a result of said current being sent through said fusing element for a longer period of time than a normal trip time of said electrical protective device, wherein said blowing of said fusing element creates an open circuit to said relay, thereby permanently preventing resetting of said electrical protective device.

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