Title: COMMUNICATION INTERFACE APPARATUS FOR AN ELECTRICAL DISTRIBUTION PANEL, AND SYSTEM AND ELECTRICAL DISTRIBUTION PANEL INCLUDING THE SAME

Abstract: A system includes a number of electrical switching apparatus having separable contacts, an operating mechanism structured to open and close the separable contacts, a trip mechanism cooperating with the operating mechanism to trip open the separable contacts, a test circuit structured to test the trip mechanism and determine a failure to protect condition thereof, and a communication circuit structured to communicate the failure to protect condition. The system also includes an electrical distribution panel having a housing housing the number of electrical switching apparatus, and a communication interface structured to receive the failure to protect condition from the communication circuit and annunciate the failure to protect condition.
before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))
This application is a continuation-in-part of application Serial No. 12/206,194, filed September 8, 2008, and entitled "Electrical Switching Apparatus Including A Trip Coil Open Circuit Test Circuit And System Including The Same".

BACKGROUND

Field

The disclosed concept pertains generally to electrical switching apparatus, such as circuit interrupters, and, more particularly, to electrical distribution panels including such electrical switching apparatus. The disclosed concept also pertains to systems including an electrical distribution panel. The disclosed concept further pertains to communication interfaces for electrical distribution panels.

Background Information

Electrical switching apparatus include, for example, circuit switching devices; circuit interrupters, such as circuit breakers; network protectors; contactors; motor starters; motor controllers; and other load controllers.

Ground fault circuit interrupters (GFCIs) include ground fault circuit breakers (GFCBs), ground fault switches, ground fault receptacles, and other ground fault contactors, motor starters, motor controllers and other load controllers.

Arc fault circuit interrupters (AFCIs) include arc fault circuit breakers (AFCBs), arc fault switches, arc fault receptacles, and other arc fault contactors, motor starters, motor controllers and other load controllers.

Some electronic AFCBs and GFCBs include manually-initiated self-test circuitry to determine if the circuit breaker is able to perform its arc fault and/or ground fault detection function(s).

When the trip coil of known circuit breakers fails to an open circuit condition, such circuit breakers are unable to provide trip protection, and are unable to provide a warning of this condition to the user.

Electrical distribution panels, such as load centers, house the electrical connections between the incoming power lines of an electric power distribution system and the numerous branch circuits in an installation, such as a residence or light
commercial or industrial facility. Typically, the load center will have a main circuit breaker as well as separate circuit breakers for each of the branch circuits.

There is room for improvement in electrical distribution panels including electrical switching apparatus.

There is also room for improvement in systems including an electrical distribution panel.

There is further room for improvement in communications with electrical distribution panels.

**SUMMARY**

These needs and others are met by embodiments of the disclosed concept, which provide a communication interface in, at, on or near an electrical distribution panel, which houses a number of electrical switching apparatus. The communication interface can receive signals from the electrical switching apparatus that correspond to a number of failure to protect conditions. In turn, the communication interface can provide, for example, an alert that annunciates the number of failure to protect conditions. For example, the communication interface operatively associated with the electrical distribution panel can generate a local annunciation (e.g., without limitation, visible and/or audible) signal, and/or can generate a remote annunciation (e.g., without limitation, alert) signal (e.g., without limitation, using a power line carrier signal; a wireless communication signal).

In accordance with one aspect of the disclosed concept, a system comprises: a number of electrical switching apparatus comprising: separable contacts, an operating mechanism structured to open and close the separable contacts, a trip mechanism cooperating with the operating mechanism to trip open the separable contacts, a test circuit structured to test the trip mechanism and determine a failure to protect condition thereof, and a communication circuit structured to communicate the failure to protect condition; and an electrical distribution panel comprising: a housing housing the number of electrical switching apparatus, and a communication interface structured to receive the failure to protect condition from the communication circuit and annunciates the failure to protect condition.

As another aspect of the disclosed concept, an electrical distribution panel comprises: a number of electrical switching apparatus comprising: separable
contacts, an operating mechanism structured to open and close the separable contacts, a trip mechanism cooperating with the operating mechanism to trip open the separable contacts, a test circuit structured to test the trip mechanism and determine a failure to protect condition thereof, and a communication circuit structured to communicate the failure to protect condition; a housing housing the number of electrical switching apparatus; and a communication interface structured to receive the failure to protect condition from the communication circuit and annunciate the failure to protect condition.

The housing may be an enclosure comprising a knockout opening; and the communication interface may be mounted within the knockout opening in order to provide access to both inside and outside of the enclosure.

The communication interface may be further structured to annunciate the failure to protect condition by identifying one of the number of electrical switching apparatus or the cause of the failure to protect condition.

As another aspect of the disclosed concept, a communication interface apparatus is for an electrical distribution panel comprising a housing housing a number of electrical switching apparatus, each of the number of electrical switching apparatus being structured to determine a failure to protect condition thereof and to communicate the failure to protect condition. The communication interface apparatus comprises: a receiver structured to receive the failure to protect condition from a number of the number of electrical switching apparatus; and a processor apparatus structured to input the received failure to protect condition from the receiver and responsively annunciate the failure to protect condition.

The receiver may be structured to communicate inside of the housing; and the processor apparatus may comprise a transmitter structured to communicate the failure to protect condition remote from the housing.

The housing of the electrical distribution panel may include an opening; and the receiver may be structured to mount within the opening.

**BRIEF DESCRIPTION OF THE DRAWINGS**

A full understanding of the disclosed concept can be gained from the following description of the preferred embodiments when read in conjunction with the accompanying drawings in which:
Figure 1 is a block diagram of a circuit breaker in accordance with embodiments of the disclosed concept.

Figure 2 is a block diagram of a circuit breaker in accordance with another embodiment of the disclosed concept.

Figure 3 is a block diagram in schematic form of a circuit breaker in accordance with another embodiment of the disclosed concept.

Figure 4 is a block diagram of a system including a circuit breaker and an electrical distribution panel in accordance with another embodiment of the disclosed concept.

Figure 5 is a block diagram of an electrical distribution panel including a plurality of electrical switching apparatus and a communication interface apparatus in accordance with other embodiments of the disclosed concept.

Figure 6 is a block diagram in schematic form of a load center including a plurality of circuit breakers and a communication interface apparatus in accordance with other embodiments of the disclosed concept.

**DESCRIPTION OF THE PREFERRED EMBODIMENTS**

As employed herein, the term "number" shall mean one or an integer greater than one (*i.e.*, a plurality).

As employed herein, the term "processor" shall mean a programmable analog and/or digital device that can store, retrieve, and process data; a computer; a workstation; a personal computer; a microprocessor; a microcontroller; a microcomputer; a central processing unit; a mainframe computer; a mini-computer; a server; a networked processor; or any suitable processing device or apparatus.

As employed herein, the term "electrical distribution panel" shall mean a load center, a panelboard, or any other suitable indoor or outdoor panel for distributing electrical power to a number of electrical loads.

As employed herein, the term "bi-directional LED" shall mean a light emitting diode, which is electrically connected, or which can be electrically connected, in series with a resistor, and which can be illuminated by current flowing in either direction through the resistor and through the bi-directional LED.

As employed herein, the term "wireless" shall expressly include, but not be limited by, radio frequency (RF), light or visible light or infrared light,
ultrasound, wireless area networks, such as, but not limited to, IEEE 802.11 and all its variants (e.g., without limitation, 802.11a; 802.11b; 802.11g), IEEE 802.15 and all its variants (e.g., without limitation, 802.15.1; 802.15.3, 802.15.4), IEEE 802.16 and all its variants, other wireless communication standards (e.g., without limitation, ZigBee™ Alliance standard), HyperLan, DECT, PWT, pager, PCS, Wi-Fi, Bluetooth™, and cellular.

The disclosed concept is described in association with an arc fault circuit breaker, although the disclosed concept is applicable to a wide range of electrical switching apparatus, such as, for example and without limitation, GFCIs and AFCI/GFCIs.

The disclosed concept is also described in association with determining an open circuit condition of a trip coil, although the disclosed concept is applicable to a wide range of "failure to protect conditions" of electrical switching apparatus including, for example and without limitation, a condition that a circuit interrupter has lost the ability to protect its power circuit and needs servicing; an open condition of a ground fault or high frequency current sensor or current transformer; and/or a broken or out of tolerance component which causes a transfer function to be outside of programmed limits.

Referring to Figure 1, an electrical switching apparatus, such as a circuit breaker 2, includes separable contacts 4, an operating mechanism 6 structured to open and close the separable contacts 4, and a trip circuit 8 including a trip coil 10 and a fault detector 12. The fault detector 12 energizes the trip coil 10 to cause the operating mechanism 6 to open the separable contacts 4. A test circuit 14 is structured to test the trip coil 10 and determine an open circuit condition thereof. An annunciation circuit 16 is structured to annunciate the open circuit condition of the trip coil 10.

Example 1

Figure 2 shows an arc fault / ground fault circuit breaker 20 including the separable contacts 4, the operating mechanism 6 and the trip coil 10 of Figure 1, along with an AFCI/GFCI control/sense circuit 22, an open coil sense and indication circuit 24, a self test circuit 26 and a communications circuit 28. It will be appreciated that these circuits 22, 24, 26, 28 can be combined and/or can be
implemented by any suitable number of analog, digital and/or processor-based
circuits. The example circuits 22,24,26,28 cooperatively detect and communicate
circuit breaker failure states through output 29 (e.g., transmitter) to a receiver 30
(shown in phantom line drawing) in, at, on or near an electrical distribution panel 32
(shown in phantom line drawing). One or both of the open coil sense and indication
circuit 24 and the self test circuit 26 detect a failure of the trip coil 10. One or both of
the open coil sense and indication circuit 24 and the communications circuit 28.

d provide a corresponding annunciation of this failure condition.

Example 2

In this example, the trip coil 10 includes a voltage. One or both of the
open coil sense and indication circuit 24 and the self test circuit 26 can be a test
circuit structured to sense the voltage of the trip coil 10, determine if that voltage is
greater than a predetermined value, and responsively determine an open circuit
condition of the trip coil 10.

The circuit 24, as shown, includes the series combination of a resistor
34 and a bi-directional light emitting diode (LED) 36 (i.e., the LED is illuminated by
current flowing in either direction through the resistor 34). As will be described,
during the open circuit condition of the trip coil 10, a predetermined current flows
through that series combination. In the absence of that open circuit condition, the
voltage of the trip coil 10 is insufficient to illuminate the bi-directional LED 36.

The detection of the open trip coil 10 of the circuit breaker 20 is
possible since the operating power for the AFCI/GFCI control/sense circuit 22 is
normally obtained through the trip coil 10. Nominal operating current (e.g., without
limitation, about 12 mA, which is insufficient to energize the trip coil 10) for the
circuit 22 normally flows between the load side of the separable contacts 4 and a
neutral conductor 38, and through the circuit 22 and the trip coil 10.

When the trip coil 10 is open, for example and without limitation,
about 12 mA of current would otherwise flow through it. Here, an alternate path for
this current is provided by the series combination of the resistor 34 and the bi-
directional LED 36 when the trip coil 10 is open. Hence, the AFCI/GFCI
control/sense circuit 22, which provides the AFCI/GFCI fault detection function, is
normally powered through the trip coil 10 in the absence of its open circuit fault
condition, and is alternatively powered through the circuit 24, which provides a test function, during the trip coil open circuit fault condition. The series combination of the resistor 34 and the bi-directional LED 36 is advantageously electrically connected in parallel with the trip coil 10, and illuminates the bi-directional LED 36 and powers the circuit 22 during the trip coil open circuit fault condition.

Example 3

For example and without limitation, the resistance of the trip coil 10 is normally about 20 ohms and with the nominal current through the AFCI/GFCI control/sense circuit 22 of about 12 mA, the voltage across the trip coil 10 is, thus, normally about 0.2 V. The example resistance of resistor 34 is about 5 kΩ (with a 3 W power rating to make this circuit highly reliable) and the voltage thereacross is, thus, about 50 V when the trip coil 10 is open. If the trip coil 10 is open, then the current through resistor 34 provides the power to operate the circuit 22 and, also, lights the LED 36 to visually indicate the trip coil failure. Hence, the open coil status sensor provided by the circuit 24 can preferably be sized to provide an alternate path in order to keep the electronics of the AFCI/GFCI control/sense circuit 22 operational and/or to illuminate the LED 36 for failure indication.

Example 4

The self test circuit 26 of the circuit breaker 20 can monitor a wide range of other trip functions in addition to the open trip coil fault condition. See, for example, Examples 9 and 10, below. For example, in addition to the function provided by the circuit 24, the self test circuit 26 can monitor the open trip coil fault condition by sensing the voltage across the trip coil 10 (e.g., a voltage greater than a predetermined value indicates a failure) in order to indicate the open trip coil fault condition. Preferably, if a failure is detected by the self test circuit 26, then the communications circuit 28 annunciates the failure.

Example 5

The communications circuit 28 can provide an annunciation function by using, for example and without limitation, a magnetic loop driver and an antenna coil driven by the magnetic loop driver, or an infrared light emitting diode. For example, the magnetic loop driver and the antenna coil, or the infrared light emitting diode, can output a magnetic loop, or a wireless signal (e.g., an infrared light emitting
diode signal; radio frequency), respectively, including the trip coil open circuit fault condition to the receiver 30, which is in, at, on or near the electrical distribution panel 32. The receiver 30, in turn, annunciates the fault condition.

**Example 6**

For example and without limitation, an about 50 kHz to about 200 kHz magnetic loop can be employed.

For example, a suitable magnetic loop or magnetically coupled signal can be provided by a low frequency antenna driver IC ATA5278 marketed by Atmel Corporation of San Jose, California. The antenna driver device generates a magnetic low frequency field in conjunction with an antenna coil to transmit data to the example receiver 30. The carrier range can be between about 100 kHz and 150 kHz and modulation can have baud rates between about 1 kbaud and 4 kbaud.

**Example 7**

For example and without limitation, an output 29, such as an infrared light emitting diode (IRLED) can have a suitable periodic pulsed current driven by the communications circuit 28. The IRLED can direct infrared light, for example, into the inside of the electrical distribution panel 32.

**Example 8**

The self test circuit 26 can monitor the voltage across the trip coil 10. The open coil sense and indication circuit 24 is a parallel, failure indication circuit including a series circuit having the power resistor 34 and the inverse-parallel LED 36. The circuit 24 is in parallel with the trip coil 10.

It is believed that UL943 (ground fault standard) will soon require products to fail safe (i.e., trip or produce an indication of failure) when certain components are faulted.

The example circuit 24 produces a suitable fail safe function (e.g., an indication of failure of an open-circuited trip coil). If the trip coil 10 fails open (or fails short, which quickly turns into a fail open), then the power supply current, needed for arc fault and/or ground fault circuit interrupter circuit operation, will take the alternate path through the parallel circuit 24, thereby illuminating the LED 36.

The circuit 22 can include, for example and without limitation, one or more of a ground fault detector, a parallel arc fault detector, and a series arc fault
detector. Preferably, the self test circuit 26 is structured to test at least one of the ground fault detector, the parallel arc fault detector, and the series arc fault detector. For example, the arc fault detector is structured to energize the trip coil 10 in response to detection of an arc fault condition.

**Example 9**

The self test circuit 26 can include a microprocessor (μP) to determine if a number of trip functions of the circuit 22 are not working, including the AFCI/GFCI trip function. Thus, the μP is structured to determine operability of the number of trip functions, including that of the trip coil 10.

For example and without limitation, the impedance of the trip coil 10 is about 20 Ω, such that during normal operation when the circuit 22 uses about 12 mA of power supply current, the voltage of the trip coil 10 is only about 0.24 V, which is too small to activate the LED 36.

**Example 10**

Referring to Figure 3, a circuit interrupter (e.g., without limitation, such as ground fault circuit interrupter / arc fault circuit interrupter 102) includes separable contacts 104, a neutral conductor 106, and an operating mechanism 108 structured to open and close the separable contacts 104. A number of current sensors 110 are structured to sense at least current flowing through the separable contacts 104. Each of the current sensors 112,114 includes a primary winding 116 and a secondary winding 118. The primary winding 116 is electrically connected in series with the separable contacts 104. A trip mechanism 120 is structured to cooperate with the secondary windings 118 and the operating mechanism 108 to trip open the separable contacts 104. Preferably, the operating mechanism 108 includes or cooperates with a suitable reset mechanism 109, which is structured to cooperate with the operating mechanism 108 to close the separable contacts 104 after the operating mechanism 108 trips open the separable contacts 104. A test circuit 122 tests the current sensors 110 and the trip mechanism 120 and is structured to apply stimulus test signals 124,126 directly to the secondary windings 118 of the current sensors 112,114, and a test signal 135 to a summer 137 at the output of current sensor 132. This advantageously allows the stimulus test signals 124,126 to be several orders of magnitude (i.e., as reduced by the turns ratio of the current sensors 112,114) lower than that needed at
the primary winding 116. For example, injecting relatively high frequency current signals onto a power line can be in violation of FCC rules if this exceeds FCC limits, which are typically lower than the values used for arc fault detection.

For example, for ground fault detection, the current sensor 112 is a current transformer structured to sense a difference between the current flowing through the separable contacts 104 from the line terminal 128 to the load terminal 130 and a current flowing through the neutral conductor 106. Also, for series arc fault detection, the current sensor 114 is a current transformer structured to sense the current flowing through the separable contacts 104. For purposes of series arc fault detection, that current includes frequencies greater than about 100 kHz, and the current sensor 114 is structured to sense that current including those frequencies. The other current sensor 132 is a suitable shunt structured to sense the current flowing through the separable contacts 104 for purposes of parallel arc fault detection.

An analog ground fault sensing circuit 134 cooperates with the current sensor 112, an analog line current sensing circuit 136 and the summer 137 cooperate with the current sensor 132, and an analog series arc fault sensing circuit 138, which provides high frequency gain and filtering, cooperates with the current sensor 114. The analog ground fault sensing circuit 134 outputs a sensed signal 140 to a microcomputer (μC) 142 and, in particular, to channel 143 of analog-to-digital converter (ADC) 144 thereof. The analog line current sensing circuit 136 outputs a sensed signal 146 to channel 147 of the μC ADC 144. The analog series arc fault sensing circuit 138 outputs a sensed signal 148 to a peak detector circuit 150 and to an envelope detection circuit 152. The peak detector circuit 150 outputs a peak signal 154 to channel 155 of the μC ADC 144. The output 156 of the envelope detection circuit 152 is input by the negative input of a comparator 158, which uses a reference (PULSE COUNT THRESHOLD) 160 at its positive input. The output 162 of the comparator 158 is input by a counter 164 of the μC 142.

The μC 142 includes a microprocessor (μP) 166 having routines 168, 170 and 172 that respectively provide a ground fault detector cooperating with the analog ground fault sensing circuit 134, a parallel arc fault detector cooperating with the analog line current sensing circuit 136, and a series arc fault detector cooperating
with the analog series arc fault sensing circuit 138 through the peak detector circuit 150, the envelope detection circuit 152, the comparator 158 and the counter 164.

The test circuit 122 is structured to provide both of (i) a first test of the current sensor 112 and the analog ground fault sensing circuit 134 and (ii) a second test of the current sensor 114 and the analog series arc fault sensing circuit 138, and to cause the trip mechanism 120 to cooperate with the operating mechanism 6 to output a trip signal 174 and trip open the separable contacts 104 responsive to failure of at least one of the first test and the second test, and, otherwise, to maintain the separable contacts 104 closed responsive to passage of both of the first test and the second test.

The current sensor 112 and the analog ground fault sensing circuit 134 have a first transfer function. Also, the current sensor 114 and the analog series arc fault sensing circuit 138 have a second transfer function. The test circuit 122 is further structured to provide the test signal 124 to the current sensor 112 and the analog ground fault sensing circuit 134 to test the first transfer function without causing a ground fault to be detected by the ground fault detector routine 168. The test circuit 122 is also structured to provide the test signal 126 to the current sensor 114 and the analog series arc fault sensing circuit 138 to test the second transfer function (e.g., without limitation, resulting from high frequency resonance of the current sensor 114) without causing an arc fault to be detected by the series arc fault detector routine 172.

As a non-limiting example, the current sensor 114 may be structured to resonate at a certain frequency. The circuit 138 may be structured to convert the current output of the current sensor 114 to a voltage signal by a first op-amp circuit (not shown), which is then filtered by a second op-amp circuit (not shown). Hence, the combined circuit 114,138 could mis-operate in several ways: (1) the sensing coil (secondary winding 118) could be an open-circuit; (2) the coil center frequency or output at resonance could be out-of-tolerance; (3) the gain of the first op-amp circuit could be out-of-tolerance; and (4) the filter characteristics of the second op-amp circuit could be out-of-tolerance. This self-test is structured to stimulate the high frequency sensing coil at or near its resonant frequency, measure the total circuit response at the µP 166, and detect any of these failure modes, which could occur either individually or in combination.
Various tests can include: (1) ground fault current sensing: verify the operation of the analog ground fault sensing circuit 134, the corresponding transfer function of the current sensor 112 and the circuit 134, and the continuity (coil continuity) of the coil (secondary winding 118) of the current sensor 112; (2) parallel arc fault current sensing: verify the operation of the analog parallel arc fault line current sensing circuit 136 and the validity of the corresponding transfer function thereof; (3) series arc fault high frequency current sensing: verify the operation of the analog series arc fault sensing circuit 138, the corresponding transfer function of the current sensor 114 (e.g., without limitation, a current transformer structured to resonate in response to frequencies greater than about 100 kHz; about 1 MHz), the circuit 138, the peak detector 150 and the envelope detection circuit 152, and the continuity (coil continuity) of the coil (secondary winding 118) of the current sensor 114; and (4) voltage of the trip coil 10 as sensed through channel 141 of ADC 144.

By injecting the test signals 124,126 directly to the secondary windings 118 and below the corresponding fault detection levels of the routines 168,172, this permits the test circuit 122 to evaluate the transfer function gain of the first and second transfer functions, rather than causing a direct trip. This advantageously permits both of the first test and the second test to be conducted before causing the trip mechanism 120 to cooperate with the operating mechanism 108 to trip open the separable contacts 104. For example, fault detection usually involves detection of a fault condition, which persists for some period of time. In order to prevent tripping on the test signals 124,126, these signals could either fail to meet the fault condition criteria or persist for less than the specified trip time period, or both. Hence, this permits the evaluation of multiple functions.

The trip mechanism 120 includes the ground fault detector routine 168, the parallel arc fault detector routine 170 and the series arc fault detector routine 172. The test circuit 122 is structured to respond to test pushbutton 176 and provide all of (i) a first test of the current sensor 112 and the analog ground fault sensing circuit 134, (ii) a second test of the current sensor 132 and the analog line current sensing circuit 136, and (iii) a third test of the current sensor 114 and the high frequency gain and filtering circuit 138, to cause the trip mechanism 120 to cooperate with the operating mechanism 108 to trip open the separable contacts 104 responsive to
passage of all of this first test, second test and third test, and, otherwise, to maintain the separable contacts 104 closed responsive to failure of at least one of such first test, second test and third test. This sequentially evaluates plural different protective functions (i.e., in this example, ground fault, parallel arc fault and series arc fault) with the single test pushbutton 176, and requires all of these protective functions to be good before the self-test is completed with a positive indication (i.e., tripping the circuit interrupter 102).

Example 11

Referring to Figure 4, a system 200 includes an electrical switching apparatus, such as the example circuit breaker 202 (e.g., an arc fault / ground fault circuit breaker), including separable contacts 204, an operating mechanism 206 structured to open and close the separable contacts 204, a trip circuit 208 including a trip coil 210 and a fault detector 212, which energizes the trip coil 210 to cause the operating mechanism 206 to open the separable contacts 204, a test circuit 214 structured to test the trip coil 210 and determine an open circuit condition thereof, and a communication circuit 216 structured to communicate the open circuit condition of the trip coil 210. The system 200 also includes an electrical distribution panel, such as a panelboard 218, including a housing 220 housing a number of circuit breakers, such as 202,202A,202B, and a receiver 222 structured to receive the open circuit condition of the trip coil 210 from the communication circuit 216 and annunciates the open circuit condition.

Example 12

The receiver 222 is preferably in (as shown), at, on or near the electrical distribution panel 218.

Example 13

The annunciation can be through example wireless communications from the circuit breaker 202 to the receiver 222 in, at, on or near an electrical distribution panel 218, which houses the number of circuit breakers 202,202A,202B. In turn, the receiver 222 provides an alert 224 that annunciates the failure condition to a user (not shown).
Example 14

Although separable contacts 4,104,204 are disclosed, suitable solid state separable contacts may be employed. For example, the disclosed circuit breakers 2,102,202 include a suitable circuit interrupter mechanism, such as the separable contacts 4,104,204 that are opened and closed by the operating mechanism 6,108,206, although the disclosed concept is applicable to a wide range of circuit interruption mechanisms (e.g., without limitation, solid state or FET switches; contactor contacts) and/or solid state based control/protection devices (e.g., without limitation, drives; soft-starters).

Referring to Figure 5, a system 300 includes a number of electrical switching apparatus 302. Each of the electrical switching apparatus 302 includes separable contacts 304, an operating mechanism 306 structured to open and close the separable contacts 304, a trip mechanism 308 cooperating with the operating mechanism 306 to trip open the separable contacts 304, a test circuit 310 structured to test the trip mechanism 308 and determine a failure to protect condition 312 thereof, and a communication circuit 314 structured to communicate the failure to protect condition 312. An electrical distribution panel 316 includes a housing 318 housing the number of electrical switching apparatus 302, and a communication interface 320 structured to receive the failure to protect condition 312 from the communication circuit 314 and annunciate 322 the failure to protect condition 312.

Example 15

Figure 6 shows a communication interface apparatus 400 including a receiver 402 structured to receive a failure to protect condition 404 from a number of electrical switching apparatus, such as the example circuit breakers (CBs) 406. The CBs 406 can be the same as or similar to the electrical switching apparatus 302 of Figure 5. The communication interface apparatus 400 also includes a processor apparatus 408 structured to input the received failure to protect condition from the signal receiver 402 and responsively annunciate the failure to protect condition through a number of example interfaces 410,412,414,416, as will be discussed.

In this example, the communication interface apparatus 400 is in, at, on or near an electrical distribution panel, such as the example load center 418. For
example, the communication interface apparatus 400 can be mounted at, on or near the housing 420 of the load center 418, although the apparatus 400 could alternatively be mounted within (not shown) the housing 420 in the manner of the receiver 222 of Figure 4.

Example 16
The example load center 418 includes a line voltage 422 (e.g., without limitation, 120 VAC) for a number of the CBs 406. The communication interface apparatus 400 includes a local power supply 424 powered from the line voltage 422. The power supply 424 outputs a number of direct current voltages 426 to the processor apparatus 408, which is structured to monitor one, some or all of the number of CBs 406.

Example 17
In this example, the load center housing 420 includes an opening 428 (e.g., without limitation, a knockout opening). The example signal receiver 402 is structured to mount within the opening 428, as shown. Hence, it will be appreciated that the example communication interface apparatus 400 is mounted within the opening 428 in order to provide access to both inside and outside of the housing 420, as will be explained. In this manner, the signal receiver 402 advantageously receives a number of signals for the number of failure to protect conditions 404 from inside the housing 420, while the processor apparatus 408 includes the interfaces 410,412,414,416, which are outside the housing 420. Furthermore, in this example, circuit breaker cost is minimized since the annunciation function of the communication interface apparatus 400 can be global for a plurality or all of the CBs 406.

Example 18
The CBs 406 (and/or the communication circuit 314 of the electrical switching apparatus 302 of Figure 5) and the communication interface apparatus 400 are both preferably structured to communicate employing wireless communications, as shown in Figure 6.
Example 19

The communication interface apparatus 400 is preferably structured to communicate both inside (e.g., through the signal receiver 402) and outside (e.g., through the interfaces 414,416) of the load center housing 420, as shown.

Example 20

The processor apparatus 408 includes a signal processor 430, which cooperates with the signal receiver 402 to input the number of failure to protect conditions 404, a controller 432, such as a suitable processor, and a local alarm interface 434. For example, the local alarm interface 434 can output the number of failure to protect conditions 404 for local annunciation by the interface 410 (e.g., visual) and/or the interface 412 (e.g., audible).

Example 21

The processor apparatus 408 further includes a communications controller 436, which cooperates with the controller 432 to output the number of failure to protect conditions 404, an RF transmitter 438 and a power line carrier interface 440. For example, the communications controller 436 and the RF transmitter 438 can output the number of failure to protect conditions 404 for remote annunciation by the interface 414 (e.g., RF antenna). Here, the communications controller 436 can function, for example, as a network device in a wireless communication network and communicate the number of failure to protect conditions 404 to another network device (not shown) or to the network coordinator (not shown) of the wireless communication network. This permits the remote annunciation of the failure to protect conditions. A non-limiting example of such a wireless communication network is the HOME HEARTBEAT® building monitoring system marketed by Eaton Corporation of Cleveland, Ohio.

Example 22

For example, the communications controller 436 and the power line carrier interface 440 can output the number of failure to protect conditions 404 for remote annunciation through the interface 416 (e.g., power line). This permits the remote annunciation of the failure to protect conditions. A non-limiting example of such a power line carrier communication network is a SMARTHOME™ XIO.
compatible home monitoring system marketed by Smarthome, Inc. of Irvine, California.

**Example 23**

While the various interfaces 410,412,414,416 can simply annunciate that the load center 418 has a failure to protect condition, preferably, a number of the interfaces (e.g., without limitation, 414,416) further include communications 442,444, which identify one of the number of CBs 406 and/or the cause of the failure to protect condition 404. Preferably, the local visual and audible signals from the local interfaces 410,412 and/or the remote communications 442,444 identify the individual CB 406 (e.g., circuit interrupter number) and/or the cause of the failure to protect condition 404 (e.g., "loss of protection" caused by an open trip coil, such as trip coil 10 of Figure 1).

**Example 24**

The communications for the failure to protect conditions 404 can use, for example, a digital on/off signal, which indicates that the corresponding CB 406 has failed to provide its protection function.

**Example 25**

Within an electrical distribution panel (e.g., without limitation, the load center 418), wireless communications can be, for example, RF, magnetic field (e.g., audio to about 200 kHz) or light (e.g., infrared; infrared light emitting diode (IRLED)). A key fob magnetic field communication (e.g., without limitation, 100 kHz) is preferred from the perspective of cost and performance. For example, a suitable key fob receiver for the disclosed signal receiver 402 and a suitable key fob transmitter for the disclosed CBs 406 are a low frequency receiver IC ATA5282 and a low frequency antenna driver IC ATA5278, respectively, marketed by Atmel Corporation of San Jose, California.

**Example 26**

A single sensor unit, such as the example communication interface apparatus 400 (e.g., internal to the electrical distribution panel 418 or mounted external, but to, the electrical distribution panel 418) detects the wireless communications 404 from the CBs 406 and provides a number of output signals.
Outputs can be, for example, a local annunciator (e.g., audible; visual; indicator; alarm; alert) or a remote signal (e.g., power line carrier; wireless).

**Example 27**
For example, the remote communications 442,444 can be communicated to outside of the load center 420 by the communication interface apparatus 400 in the manner of a slave device to a master controller (e.g., without limitation, employing an RF signal; employing a power line carrier signal).

**Example 28**
The self test feature of a circuit interrupter is useless if it finds a failure to protect condition and cannot alert a user (e.g., without limitation, homeowner) of the failure (e.g., without limitation, an open trip coil, such as 10 of Figure 1). Hence, the example communication interface apparatus 400 can annunciate for the user as much information as is desired, including that an electrical switching apparatus has lost the ability to protect its power circuit and needs servicing.

While specific embodiments of the disclosed concept have been described in detail, it will be appreciated by those skilled in the art that various modifications and alternatives to those details could be developed in light of the overall teachings of the disclosure. Accordingly, the particular arrangements disclosed are meant to be illustrative only and not limiting as to the scope of the disclosed concept which is to be given the full breadth of the claims appended and any and all equivalents thereof.
What is Claimed is:

1. A system (300) comprising:
   a number of electrical switching apparatus (302) comprising:
   separable contacts (304),
   an operating mechanism (306) structured to open and close said separable contacts,
   a trip mechanism (308) cooperating with said operating mechanism to trip open said separable contacts,
   a test circuit (310) structured to test said trip mechanism and determine a failure to protect condition thereof (312), and
   a communication circuit (314) structured to communicate said failure to protect condition; and
   an electrical distribution panel (316) comprising:
   a housing (318) housing said number of electrical switching apparatus, and
   a communication interface (320) structured to receive said failure to protect condition from said communication circuit and annunciate (322) said failure to protect condition.

2. The system (300) of Claim 1 wherein said communication interface is in, at, on or near said electrical distribution panel.

3. The system (300) of Claim 1 wherein said communication circuit is further structured to output (29) a magnetic loop or wireless signal including said failure to protect condition to said communication interface.

4. The system (300) of Claim 1 wherein said communication circuit is further structured to output (29) an infrared light emitting diode signal including said failure to protect condition to said communication interface.

5. The system (300) of Claim 4 wherein said communication circuit is an infrared light emitting diode having a periodic pulsed current; and wherein said infrared light emitting diode directs infrared light into said electrical distribution panel.

6. The system (300) of Claim 1 wherein said number of electrical switching apparatus are a plurality of circuit interrupters (302).
7. The system (300) of Claim 1 wherein said number of electrical switching apparatus are a plurality of arc fault / ground fault circuit breakers (302).

8. An electrical distribution panel (218;316;418) comprising:
   a number of electrical switching apparatus (202;302;406) comprising:
   - separable contacts (204;304),
   - an operating mechanism (206;306) structured to open and close said separable contacts,
   - a trip mechanism (208;308) cooperating with said operating mechanism to trip open said separable contacts,
   - a test circuit (214;310) structured to test said trip mechanism and determine a failure to protect condition thereof (212;312), and
   - a communication circuit (216;314) structured to communicate said failure to protect condition;
   - a housing (220;318) housing said number of electrical switching apparatus; and
   - a communication interface (222;320;400) structured to receive said failure to protect condition from said communication circuit and annunciate (224;322;410;412;414;416) said failure to protect condition.

9. The electrical distribution panel of Claim 8 wherein said communication interface is in, at, on or near the housing of said electrical distribution panel.

10. The electrical distribution panel (218;316;418) of Claim 8 wherein said electrical distribution panel is a load center (418).

11. The electrical distribution panel (218;316;418) of Claim 8 wherein said electrical distribution panel is a panelboard (218).

12. The electrical distribution panel (218;316;418) of Claim 8 wherein said number of electrical switching apparatus further comprise a line voltage (422); and wherein said communication interface is powered (424,426) from said line voltage and is further structured (408) to monitor a number of said number of electrical switching apparatus.
13. The electrical distribution panel (218;3 16;4 18) of Claim 8 wherein said housing is an enclosure (420) comprising a knockout opening (428); and wherein said communication interface (400,402) is mounted within said knockout opening in order to provide access to both inside and outside of said enclosure.

14. The electrical distribution panel (218;3 16;41 8) of Claim 8 wherein said communication circuit and said communication interface are both structured to communicate employing wireless communications (404).

15. The electrical distribution panel (218;316;418) of Claim 8 wherein said communication interface is structured (408) to communicate both inside and outside of said housing.

16. The electrical distribution panel (218;3 16;4 18) of Claim 8 wherein said communication interface is further structured (434,410,412) to locally annunciate said failure to protect condition.

17. The electrical distribution panel (218;316;418) of Claim 8 wherein said communication interface is further structured (436,438,440,414,416) to remotely annunciate said failure to protect condition.

18. The electrical distribution panel (218;316;418) of Claim 17 wherein said communication interface is further structured to remotely annunciate said failure to protect condition employing a power line carrier (444) or a wireless signal (442).

19. The electrical distribution panel (218;316;418) of Claim 8 wherein said communication interface is further structured to annunciate (444,442) said failure to protect condition by identifying one of said number of electrical switching apparatus or the cause of said failure to protect condition.

20. A communication interface apparatus (400) for an electrical distribution panel (4 18) comprising a housing (420) housing a number of electrical switching apparatus (406), each of said number of electrical switching apparatus being structured (3 10) to determine a failure to protect condition (404) thereof and to communicate said failure to protect condition, said communication interface apparatus comprising:

   a receiver (402) structured to receive said failure to protect condition from a number of said number of electrical switching apparatus; and
a processor apparatus (408) structured to input said received failure to protect condition from said receiver and responsively annunciate (410;412;414;416) said failure to protect condition.

21. The communication interface apparatus (400) of Claim 20 wherein said receiver is structured to communicate inside of said housing; and wherein said processor apparatus comprises a transmitter (438;440) structured to communicate said failure to protect condition remote from said housing.

22. The communication interface apparatus (400) of Claim 20 wherein the housing of said electrical distribution panel includes an opening (428); and wherein said receiver is structured to mount within said opening.

23. The communication interface apparatus (400) of Claim 22 wherein said receiver is structured to communicate inside of said housing; and wherein said processor apparatus comprises a transmitter (438;440) structured to communicate said failure to protect condition remote from said housing.
FIG. 5
A. CLASSIFICATION OF SUBJECT MATTER

INV. G01R31/327 H02H3/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

GO1R H02H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<td>X</td>
<td>US 5 963 406 A (NEIGER BENJAMIN B [US] ET AL) 5 October 1999 (1999-10-05) column 7, line 28 - column 10, line 26; figures 6-14 column 17, line 12 - column 18, line 66 ------</td>
<td>1-23</td>
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<tr>
<td>Y</td>
<td>US 2004/037018 A1 (KIM BYUNG-KOOK [KR]) 26 February 2004 (2004-02-26) paragraphs [0047], [0049], [0051], [0052], [0056], [0057]; figures 1, 2 ------</td>
<td>1-23</td>
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Further documents are listed in the continuation of Box C

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* Special categories of cited documents

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

Date of the actual completion of the international search 8 March 2010

Date of mailing of the international search report 15/03/2010

Name and mailing address of the ISA/ European Patent Office, P B 5818 Patentaan 2 NL-2280 HV Rijswijk Tel (+31-70) 340-2040, Fax (+31-70) 340-3016

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<td>Y</td>
<td>US 5 825 599 A (ROSENBAUM SAUL [US]) 20 October 1998 (1998-10-20) column 3, line 62 - column 5, line 23; figure 1</td>
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<tr>
<td>A</td>
<td>US 5 334 939 A (YARBROUGH GARRETT S [US]) 2 August 1994 (1994-08-02) column 4, lines 20-67; figures 1,2</td>
<td>1-23</td>
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