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(71) Applicant *(for all designated States except US)*: **LANDIS & GYR** [AU/AU]; 60 O'Riordan Street, Alexandria, New South Wales 2060 (AU).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **DA SILVA, Joseph** [AU/AU]; 6 Monash Pde, Croydon, New South Wales 2132 (AU). **CIRCOSTA, Marc** [AU/AU]; 1/153 Johnston St, Annandale, New South Wales 2038 (AU). **DEMARCO, Marcelo** [AU/AU]; c/- 60 O'Riordan St, Alexandria, New South Wales 2015 (AU).

(74) Agent: **GRIFFITH HACK**; Level 29, Northpoint, 100 Miller Street, North Sydney, New South Wales 2060 (AU).

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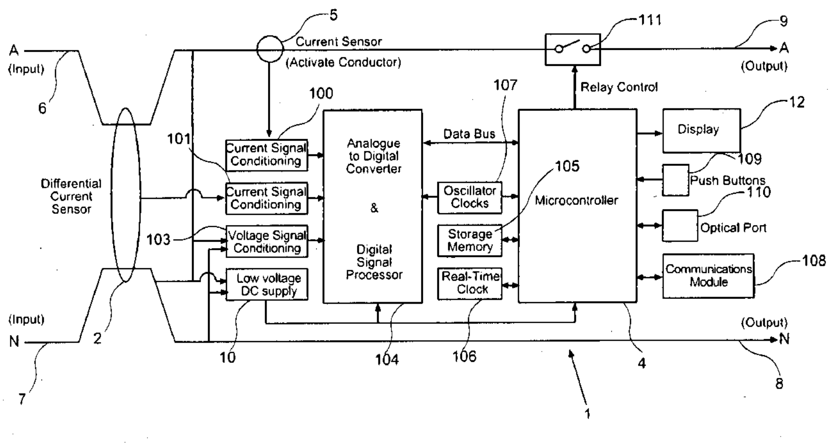

Figure 1

(57) Abstract: The present invention relates to a method and apparatus for detecting faults occurring in Multiple Earth Neutral (MEN) power distribution systems. The apparatus comprises a detector which is arranged to determine an earth current value by determining a differential current between the active and neutral conductors in the MEN system. By Kirchhoff's law, the differential current is the earth current value. The determined earth current value is used to determine what type of fault has occurred, from a number of faults, such as degraded neutral fault condition, degraded earth, and others.

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METHOD AND APPARATUS FOR POWER SUPPLY FAULT DETECTION

Field of the Invention

The present invention relates to a method and apparatus for power supply fault detection and, particularly, but not exclusively, to a method and apparatus that can detect faults occurring in Multiple Earth Neutral power distribution systems.

Background of the Invention

A number of fault conditions can occur with electrical power supplies, both domestic and industrial. It would be advantageous to be able to detect as many power supply faults as possible, so that action can be taken to correct them or, in cases where the faults lead to a dangerous situation, to shut down the power supply until the fault has been repaired.

Multiple Earth Neutral (MEN) power distribution systems are known. A source of three-phase AC power supplies premises within the service area, eg power to domestic/office/industrial buildings in a vicinity. At each premises, connections are made to either one or all three active phases, depending on the power requirements of the premises. At least an Active (A) conductor and Neutral (N) conductor are attached to the premises and also an Earth (E) is also attached to the premises. The power supply is usually routed via an electricity meter, for monitoring an amount of electricity consumed at the premises. Some of the latest electricity meters also provide intelligent functions, such as the ability to remotely read the meter, the ability to provide the end user with information on their electricity consumption, and other functions.

MEN systems are known in some jurisdictions as "PEN" (Protective Earth Neutral) Systems.

A number of fault conditions can occur in MEN power supplies, some of which are extremely dangerous and some of which can be difficult to detect.

In operation, the load requirements of a premises are taken from the relevant active (A) phase, current flowing from the A conductor, via the load and back via the neutral (N) conductor. Faults such as a broken neutral can lead to all the current returning via earth (E), which can be an extremely dangerous situation (for example making items in a dwelling, such as water pipes, "live"). A number of other power supply faults can occur, such as a broken earth, crossed active/neutral, and other faults. Tinkering with the connections to the premise's power supply, or incorrectly wiring the meter, can also lead to a number of faults.

It has been proposed to detect faults such as broken or degraded connection in the neutral or earth paths by measuring current in both the neutral (N) line and the active (A) line. A problem with this is that the active and neutral currents are usually of very similar magnitude, so measurement is required to be very accurate and the corresponding measurement circuitry is costly. Further, short or long term drift in the measurement circuitry can cause errors and may require regular servicing to ensure that calibration is correct.

Other methods of detecting faults have been proposed such as detecting a fault in a neutral line by determining the integrity of the neutral line by measuring impedance of the neutral return line. Impedance can be difficult to measure and leads, again, to expensive solutions.

No prior art solutions present a comprehensive way of determining many of the fault conditions which can be associated with a power supply.

Summary of the Invention

In accordance with a first aspect, the present invention provides an apparatus for detecting fault in a power supply, the power supply comprising neutral, active and earth lines, the apparatus comprising a detector arranged to determine an electrical status of the earth line, and a processor for determining a fault associated with the determined electrical status of the earth line.

In an embodiment, the electrical status of the earth line that is determined is the magnitude of current flowing through earth. Measurement of current in the earth line has the advantage that the result can be used to determine a number of different types of fault condition in a power supply. Fault conditions including broken earth, broken neutral, reversed active and neutral, broken and degraded neutral connections and other fault conditions can be detected.

In an embodiment, the processor for determining a fault is arranged to determine which type of fault is indicated by the determined electrical status of the earth.

In an embodiment, the detector is arranged to determine a differential current between the active and neutral conductors. The differential current is, in effect, the earth current. In an embodiment, the differential current is determined by the detector sensing the net magnetic field produced by the active and neutral lines. The detector may comprise devices such as current transformers, coils, Hall effect devices, magneto-resistive sensors or similar such devices to determine the net magnetic field.

An advantage of determining the differential current between the active and neutral conductors is that it is not necessary to measure the absolute current of each of the active and neutral current conductors, which is associated with the accuracy and drift problems discussed above. Further, it has been appreciated by the present inventors that the differential current between the active and neutral conductors is in fact, by Kirchhoff's laws, the current that is going to earth in a standard power supply system, such as a MEN system.

In an embodiment, instead of measuring differential current between the active and neutral lines, the magnitude of current flowing through earth is measured by a detector arranged to directly measure the current in the earth line.

In an embodiment, the apparatus for detecting fault in a power supply is associated with an electricity meter. In an embodiment, the apparatus is incorporated with the electricity meter and the measurements are taken from conductors incorporated with the electricity meter eg, the active and neutral conductors, routed via the electricity meter.

In the embodiment where the differential current between the active and the earth conductor is measured by determining the value of the net magnetic field, the detector is, in an embodiment, mounted with meter circuitry to measure the magnetic field from the neutral and active conductors running within the meter or proximate the meter.

In the embodiment where the earth current is determined by a detector detecting the current flowing through the earth line, in an embodiment, an electrical meter is wired so that it incorporates an earth conductor via which the earth current flows. The detector directly measures the current flowing in the earth conductor.

In an embodiment, the apparatus further comprises an indicator arrangement to provide notification of a fault condition when a fault condition is detected. In an embodiment, the indicator arrangement may identify the type of fault condition detected. In an embodiment, the indicator arrangement may provide a notification of the fault condition to a local and/or remote location. The notification may be transmitted via power conductors. It may be transmitted to a power supply control location, for example.

In accordance with a second aspect, the present invention provides an electricity meter apparatus, comprising an arrangement for monitoring electricity consumption, and an apparatus in accordance with the first aspect of the invention for detecting a fault in an electrical power supply being monitored.

In accordance with a third aspect, the present invention provides a method of detecting fault in a power supply, the power supply comprising neutral, active, and earth, the method comprising the steps of determining an electrical status of the earth, and determining a fault associated with the determined electrical status of the earth.

Brief Description of the Drawings

Features and advantages of the present invention will become apparent from the following description of embodiments thereof, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic block diagram of a meter apparatus in accordance with an embodiment of the present invention;

Figure 2 is a further schematic diagram of the apparatus of Figure 1 illustrating connections to a source and a load;

Figure 3 is a schematic diagram of a meter apparatus in accordance with a further embodiment of the invention;

Figure 4 is a schematic diagram of a meter apparatus in accordance with yet a further embodiment of the invention; and

Figures 5 through 14 are schematic circuit diagrams illustrating faults which may be determined by a meter apparatus in accordance with an embodiment of the present invention.

Detailed Description of Embodiments

Referring to Figures 1 and 2, an apparatus in accordance with an embodiment of the present invention, for detecting fault in a power supply, is generally designated by reference numeral 1. The apparatus comprises a detector 2 (Figure 1) which is arranged to determine an electrical status of an Earth line (reference numeral 3, Figure 2). A processor 4, in this embodiment being a microcontroller 4, is arranged to determine a fault associated with the determined electrical status of the Earth line 3.

In this embodiment, the apparatus for detecting fault 1 is incorporated with an electricity meter 1. The electricity meter 1 is also arranged to carry out metering functions, as well as to carry out determination of faults. The microcontroller 4 is arranged to control metering functions. The meter 1 may provide intelligent functions, such as remote operation, or it may merely be a standard electricity meter with the addition of the apparatus for detecting fault in a power supply. In and out active and neutral connections 6, 7, 8 and 9 are provided to the meter 1. A current detector 5 is arranged to detect the current on the Active line. A power supply 10 provides internal power to the meter, which may be tapped off (eg via a transformer) from the mains power supply. A display 12 is provided for displaying meter information. The meter information may include amount of electricity consumed and, in an embodiment, may include identification of a fault condition. It may display other information.

The meter 1 also comprises a signal conditioner 100 for current signal conditioning from the current sensor 5, and a signal conditioner 101 for current signal conditioning from the detector 2. A voltage signal conditioner 103 is also provided. An analogue to digital converter and digital signal processor 104 is arranged to convert the current and voltage signals to digital. The microcontroller 4 also has a memory 105 and a real time clock 106 associated with it. Further clocks 107 are provided to drive the microcontroller 4 and a D to A converter 104.

A communications module 180 is provided to facilitate remote communications. An interface in the form of push buttons 109 and an optical port 110 are also provided.

A relay control 111 is provided to enable switching of power to/from the premises.

Figure 2 illustrates a nominal arrangement for an M.E.N. (Multiple Earth Neutral) power distribution system. A source of three-phase AC power (typically a transformer), as represented by the generator symbol 20 at the left side of the diagram, provides three active phases (A) and a neutral (N), which provide power to premises within the service area. At each premises, connection is made to either one or all three active phases, dependant on the power requirements of the premises. For simplicity, a single phase connection is shown, although the principles disclosed herein can also be applied to multiple-phase-connected premises.

The load requirements of the premises are taken from the relevant active (A) phase, causing current I to flow through the active terminals of the meter 6, 9, thence the load 21, and eventually returning to the neutral side of the source 20. The return current from the load 21 reaches the neutral block (N/B) and then divides into two branches. The major branch is via the neutral terminals 7, 8 of the meter 1, thence the neutral wiring back to the source 20, as represented by current path I'. The minor branch is via the M.E.N. link, thence the earth block (E/B), thence via various earth paths back to the source 20, as represented by current path I-. The proportion of current returning via these two paths is dependant on the relative impedance of these paths. Since the neutral path normally has a much lower impedance than the earth path, the majority of the return current is via the neutral path.

It will be appreciated that Figure 2 is schematic. The load 21 may include any electrical load in any premises. For example, in a domestic dwelling, the load may include domestic appliances, such as lighting, washing machine, etc.

In addition to the standard metering function of measuring the active current, the meter 1 also incorporates a sensor 2 for the measurement of current flowing via the earth path. The latter is achieved by sensing the net magnetic field produced by the active and neutral conductors within the meter 1. The sensor 2 may be any of current transformers, coils, Hall-effect devices, magneto-resistive sensors or similar such devices as are familiar to practitioners of the art. By such means, processing circuitry in the meter 1 is able to determine the proportion of active current that is returning via the earth path(s) and thereby, detect broken or degraded connections in either the neutral or earth paths from the premises back to the AC power source. It is also able to detect some instances of fraudulent meter connections and misapplication of the meter, and other faults.

In the prior art, detection of broken or degraded connection in the neutral or earth paths is achieved by measuring the neutral current and comparing this to the active current. Since active and neutral currents are usually of very similar magnitude, this requires that these two currents be measured very accurately, with corresponding cost implications. In addition, any short-term or long-term drift in performance of either the active or neutral current measurement places the operation of these neutral/earth integrity features in jeopardy. By contrast, this embodiment of the present invention directly measures the differential current, which by Kirchhoff's current law, corresponds to the earth current.

This advantageously avoids the accuracy requirements and drift vulnerabilities of the prior art.

Figure 3 illustrates an alternative embodiment of the present invention. Here, a neutral current sensor 30 is employed instead of the usual active current sensor. The active current measurement, which is what is actually required for standard metering functions, is derived from the summation 31 of neutral and earth current measurements, either directly by analogue means familiar to practitioners of the art, or by digital means after analogue-to-digital conversion of both measurements, again as familiar to practitioners of the art. The sensor 2, as in the previous embodiment, measures the earth current from net magnetic field produced by the active and neutral conductors within the meter. The processor 4 then uses this measurement to detect faults.

Figure 4 illustrates another alternative implementation of the present invention. Here, the usual neutral link within the meter 1 is substituted by an extension to the M.E.N. (Multiple Earth Neutral) link. The load current now returns to the neutral block (N/B), divides into a major and minor proportion as before, but now it is the minor proportion, the earth current, that passes through the meter. The major proportion, that returning to the source neutral wiring, no longer passes through the meter. Since it is now the earth current that passes directly through the meter, the earth current sensor 40 no longer involves the active conductor in its measurement. Also, what were previously the neutral terminals of the meter, are now designated the M.E.N. terminals of the meter.

The advantages of this implementation are that the neutral path is more direct (has less series connections), the meter can more readily be applied for its intended purpose of detecting the fault conditions described herein on premises where multiple meters are fitted, additional current sensor technologies (such as resistive shunts) are now suited for this application and the meter could now potentially break the M.E.N. connection in the event of a reversed active-neutral condition, thereby reducing the serious hazard this condition presents.

The following description describes the fault conditions that may occur with the M.E.N. power supply and meter 1 and how embodiments of the present invention may determine the fault conditions and deal with them.

In Figures 5 through 14, the embodiment of the present invention which is utilised is the first embodiment (the embodiment of Figures 1 and 2). It will be appreciated that other embodiments could be used to detect the faults.

Broken Neutral Condition

Referring to Figure 5, the neutral connection is broken, anywhere between the street mains and the neutral block following the meter (N/B). In this case, the load current I flows through the active terminals of the meter, through the load, then returns via the M.E.N. link, earth block (E/B) and thence the various earth paths back to the AC power source. In this case, the active and earth currents measured by the meter will be approximately equal, within the uncertainties of the measurement.

Note however, that a "three-wire" connection to the meter (a misapplication of the meter, described later) also presents the same characteristics, so both these conditions are indicated when the active and earth currents are approximately equal in magnitude and phase (an investigation will be required to determine which is the actual fault).

Degraded Neutral Condition

Referring to Figure 6, there is excessive resistance 45 in the neutral path, which may be anywhere between the street mains and the neutral block following the meter (N/B). In this case, the load current I flows through the active terminals of the meter, through the load, then returns via the neutral block (N/B), where it divides into two paths (I′ and I″). What distinguishes this condition from the normal case, is that the proportion of load current flowing via the earth path exceeds what is deemed to be acceptable. Since the object of this test is to validate the neutral path and detect a "degraded" neutral, the threshold for this test should be based on the relevant impedance of the earth path(s) at that site. For a site with a "low" earth impedance, a higher proportion of earth current (and correspondingly, test threshold) is appropriate. Conversely, for a site with a "high" earth impedance, a lower proportion is appropriate.

The processor 4 will be set to an appropriate threshold to determine for a degraded neutral condition.

Broken/Degraded Earth Condition

Referring to Figure 7, there is either a broken earth connection or excessively high resistance in the earth path, anywhere from the neutral block following the meter (N/B), back through to the AC power source via the earth paths. In this case, the load current I flows through the active terminals of the meter, through the load, then returning via the neutral block (N/B), where it divides into two paths (I′ and I″). However, unlike in the normal case, the proportion of this current that flows via the earth path is lower than what is deemed appropriate, indicating an excessively resistive earth path. If the earth current is approximately zero, within the uncertainties of the measurement, then a broken connection is indicated. In the more general case, where the proportion of current returning via the earth path(s) is below an appropriate threshold value, an excessively resistive earth path is indicated.

The meter 1 processor 4 is set with the appropriate threshold for earth current to determine this fault condition.

Adjacent Premises Fault Conditions

As well as being able to detect fault conditions in a premises which the apparatus is associated with (e.g. by being incorporated in the electricity meter for those premises), another advantage of embodiments of the present invention is the ability to detect some fault conditions in adjacent premises. Figures 8 and 9, illustrate two potential situations in which fault conditions can be detected in adjacent premises.

The adjacent premises may include a meter 50 and load 51. The meter 50 may not have the functionality of a meter in accordance with the present invention. It may be a simple electricity meter, for example, without any intelligent functionality. Or it may be an intelligent meter which does not incorporate an apparatus in accordance with an embodiment of the present invention.

It is therefore not possible for the meter 50 to detect fault conditions. This may still be done, however, utilising this embodiment of the present invention.

Figures 8 and 9, illustrate two situations in which a significant "neutral" fault condition exists in an adjacent premises (whose meter is presumed not to include "neutral/earth" integrity features) and how an embodiment of the present invention is able to detect such occurrences. The two fault conditions illustrated are where the neutral path is broken (Figure 8) and where the active and neutral connections to the meter are reversed (Figure 9), both of which conditions are able to inject significant amounts of current through the earth paths from the adjacent premises.

The current being injected into the earth from the adjacent premises (shown on the right) divides itself into the available earth paths, one of which is the meter 1 of the embodiment of the present invention (shown on the left). Since the amount of current involved is significant, the proportion that returns via the earth connection of the meter 1 on the left can be readily detected in accordance with the present invention, indicating a significant fault in an adjacent premises. It will be seen that this earth current as detected by the meter 1 on the left, flows in the opposite direction to the proportion of its load current that normally flows through the earth path. To more accurately measure the earth current that is due to an adjacent premises "neutral" fault (represented by the current symbol I'), the processor 4 may optionally deduct the proportion of its active current that it may expect to return via the earth path(s). Again, to aid in the accuracy of this fault determination, the processor 4 may optionally attempt to correlate the measured earth current with the measured active current, since earth current from an adjacent premise will have no such correlation.

It will be noted that the adjacent premise (with the significant "neutral" fault) may be connected to any of the three active phases of the AC power source. To further improve the accuracy of measurement of current I' and the detection of these fault conditions, the processor 4 may optionally take into account the +/-120° phase shift (relative to the meters active phase voltage, which is taken as reference) that will occur in current I' if the adjacent premises is connected to a different active phase (as is shown in the above two diagrams).

It will be further noted that the actual phase shift of current I' will depend on the nature of the load (i.e. whether it has a significant reactive component or whether it is predominantly resistive) at the adjacent premises, in the event of a broken neutral. In the case where this differs noticeably from 60°, 180° or 300°, the meter may optionally distinguish the specific condition of a broken neutral connection, rather than the combined fault indication for the two conditions.

In the event that the detected earth current is at approximately 180° of phase, the processor 4 will need to apply a threshold test on the magnitude of the current, so as to distinguish a significant "neutral" fault in an adjacent premises from an active-neutral reversal condition in this premises. Larger earth currents will be detected in the latter case, as the entire fault current will be seen by the meter.

Reversed Active-Neutral Condition

Figure 10 illustrates the situation where the active and neutral connections to the meter are reversed. Not only is main voltage present on the neutral wiring of the premises, it is also present on the earth wiring (which connects to the chassis of class I equipment, typical of so-called "white goods" such as refrigerators) and possibly also the plumbing. While there will be a service fuse between the incoming mains and the meter (not shown), this will almost certainly be on the active terminal of the meter, which here is incorrectly connected to neutral potential. Even if it is connected to the active potential, the earth impedance (resistance) will normally be sufficient such that the resultant current flow will be less than the rating of the service fuse.

In this situation, a large earth current (designated here by the symbol I') will flow. In addition, load current (designated by the symbol I") may also flow. The load current flows through the active terminals of the meter and the combined current (designated by the symbol I) flows through the neutral terminals of the meter (sourced by the active phase of the incoming mains).

Although the active current sensed by the meter (designated by the symbol IA) is flowing in reverse, the meter's perspective is also reversed, due to the reversed active and neutral potentials into the meter, thus this is perceived as flowing in the forward direction. Similarly, although the earth current sensed by the meter (designated by the symbol IE) is flowing in the forward direction, it will be perceived as flowing in the reverse direction. Also, as the earth impedance can be expected to be predominantly resistive, there will be little additional phase shift in the earth current.

The meter can therefore detect this fault condition by the presence of a "large" earth current flowing in the reverse direction. It can distinguish this condition from that of a similar fault in an adjacent premises by applying a threshold test on the magnitude of the earth current.

Where the above threshold is exceeded and there is no significant phase shift in the earth current (relative to 180°), either this fault condition or a bypassed meter (electricity theft) is indicated. An investigation will be required to distinguish these two possibilities.

Where there is significant phase shift (relative to 180°) in the earth current, the meter can conclude that this current is not due to this fault condition. Rather, it is due either to a significant "neutral" fault at an adjacent premise (connected to a different active phase) or to bypassing of the meter (electricity theft). A threshold test on the current magnitude can optionally be used to distinguish between these two possibilities, on the basis that fault currents from an adjacent premises will be lower due to "dilution" by multiple alternative earth paths.

Bypassed Meter Condition #1 (Electricity Theft)

Figure 11 and Figure 12 represent situations in which the meter has a fraudulent load connection, such that a portion (IB) of the load current bypasses the meter's active terminals. It is understood that this portion may be 100% of the load current, although the description given here is of the general case where some of the load current may be metered (typically in an attempt to avoid suspicion).

In Figure 11, a separate load 61 is connected to the input side of the meter, its current (IB) returning via the usual neutral wiring, such that the combined neutral current reaching the neutral block (N/B) is the total consumed current. A small portion of this current (I″) returns via the earth path, while the majority returns via the meter's neutral terminals. Since the current flowing through the neutral terminals exceeds that flowing through the active terminals, this is perceived by the meter as an excessive earth current flowing in the reverse direction.

In Figure 12, there is no separate fraudulent load, but rather a parallel path 62 for active current, such that a portion of the consumed current bypasses the meter's active terminals. Again, the total neutral current returning to the neutral block (N/B) is divided into two paths, a small proportion flowing via the M.E.N. link to earth, the majority returning via the meter's neutral terminals. Again, the meter perceives an excessive earth current flowing in the reverse direction.

The excessive earth current perceived by the meter in this "bypassed" condition can be distinguished from that of a significant "neutral" fault condition in an adjacent premise by applying a threshold test, in the same manner as with the "reversed active-neutral" fault condition. If the phase of the perceived earth current is close to 180°, then this condition cannot be distinguished from a "reversed active-neutral" fault condition, and an investigation will be required to determine which is the actual fault.

Three-Wire Misapplication Condition

The ability of the apparatus of this embodiment to measure earth current, and hence perform the fault detection tasks previously described, is dependant on the correct application of the meter. Whereas the fault conditions previously described represent hazards (financial, in the case of electricity theft), Figure 13 represents a different class of fault, misapplication of the meter.

Here, a "three-wire" connection is made to the meter, such that neutral current doesn't flow through the meter. In this case, the perceived earth current (IE) is approximately equal to the active current (IA), both in magnitude and phase. As this condition cannot be distinguished from the "broken neutral" condition, an investigation is required to determine which is the actual fault.

M.E.N. Misapplication Condition

Figure 14 illustrates another potential misapplication of the meter. In this case, the M.E.N. link is made to a neutral block (N/B) on the input side of the meter. Load current passes through the active terminals of the meter, thence the load, returning in full through the neutral terminals of the meter. Although a portion of this return current flows via the M.E.N. link to earth as usual, this activity bypasses the meter, which perceives zero earth current (within measurement uncertainties).

As this condition cannot be distinguished from an actual "broken earth" condition, an investigation is required to determine which is the actual fault.

Additional Refinements in Earth Current Measurement

Load imbalances in the three phases distributed from the source may, due to the finite impedance of the neutral wiring back to the source, result in a (hopefully small) potential difference between the neutral into a premises and the earth mass. This in turn will result in a finite current flowing through the earth path of the premise, even without a load current being present. It may therefore be advantageous to apply an offset to the earth current measurement (determined empirically or by other means) at individual premises, prior to applying the above-described detection criteria for the various fault conditions described.

As the various loads responsible for the above-described load imbalance condition are liable to vary over time, it may be advantageous to also apply a "creep" threshold (where currents below a certain magnitude are ignored as if non-existent) to the observed earth current. Such a threshold may typically be determined empirically.

It can be seen from the above description, that to better discern the described neutral, earth, and related fault conditions, it is advantageous to measure not only the magnitude of the earth current, but also its direction or phase shift (relative to the incoming mains voltage or alternatively, the load current, taken as reference). As real and reactive power or energy measurements derived from the earth current and the incoming mains voltage may serve as a proxy for the magnitude, direction and phase shift of the earth current, the above disclosed fault detection methods may also be applied using these derived power or energy quantities, within the scope of this invention.

As discussed above, the microcontroller 4 within the meter may include any appropriate electronics/algorithms for carrying out the processing task to detect the faults common as discussed above. The invention is not limited to the architecture disclosed in Figure 1, however. Any appropriate circuitry or processor arrangement may be used to implement an embodiment of the present invention.

In an embodiment, the apparatus 1 includes an indicator arrangement, to provide notification of a fault condition. The indicator arrangement may include the display 12. In an embodiment, the indicator arrangement may also include a transmitter in the meter electronics for transmitting notification of the fault condition to a remote location e.g. a power supply control centre. In response to certain fault conditions, an embodiment of the meter may incorporate additional functionality, such as:

(a) A visual indication of the fault condition. This may consist of an error code or message on a suitable display, such as an LCD (liquid crystal display), or an indicator lamp, such as an LED (light emitting diode). Such an indication may be cycled so as to produce a "flashing" indication, for added effect. The display may be the display 12, or may a display in an alternative location e.g. in a premises associated with the power supply, or at a control centre associated with the power supply.

(b) An audible indication of the fault condition. This may consist of tones produced via a suitable transducer such as a speaker, or by the mechanical action of a switching device such as a relay.

(c) Communication of the fault condition via a suitable communications medium, such as radio, power-line signalling, the telephone network or a local area network (which may in turn be connected to a wider network).

(d) Disconnection of premises power, via a switching device or multiple such devices within the meter, or via external such switching devices controlled by the meter.

(e) An audible and visible fault indication, produced by repetitive switching of the above disconnection device, such that lights and equipment within the premises are noticeably disturbed.

(f) The recording of detected fault conditions, and preferably, their associated parameters and event times, within the memory of the meter, such that these may be retrieved from the meter at a later time.

In the above embodiments, the apparatus for detecting fault is incorporated with an electricity meter. The invention is not limited to this. In other embodiments of the present invention, the apparatus for detecting fault in the power supply may be a separate apparatus. It may be stand-alone, away from the meter for example, or it may be incorporated with other electrical monitoring apparatus.

In the above embodiment, the apparatus is arranged to detect faults in an M.E.N. power supply. The invention is not limited to this. An apparatus in accordance with embodiments of the present invention, with appropriate adaptation, may be utilised with other power supply arrangements.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An apparatus for detecting fault in a power supply, the power supply comprising neutral, active and earth lines, the apparatus comprising a detector arranged to determine an electrical status of the earth line, and a processor for determining a fault associated with the determined electrical status of the earth line.

2. An apparatus in accordance with Claim 1, wherein the detector arranged to determine an electrical status of the earth line is arranged to determine the magnitude of current flowing through earth.

3. An apparatus in accordance with Claim 2, wherein the detector is arranged to determine a differential current between the active and neutral conductors, the differential current being the earth current value.

4. An apparatus in accordance with Claim 3, wherein the detector is arranged to sense a magnetic field produced by the active and neutral lines, in order to determine the differential current.

5. An apparatus in accordance with Claim 2, wherein the detector is arranged to directly measure the current in the earth line.

6. An apparatus in accordance with any one of the preceding claims, the processor for determining the fault being arranged to determine which type of fault is indicated by the determined electrical status of the earth.

7. An apparatus in accordance with any one of the preceding claims, further comprising an indicator arrangement arranged to provide notification of a fault condition, when the fault condition is detected.

8. An apparatus in accordance with Claim 7, arranged to identify the type of fault condition detected.

9. An apparatus in accordance with Claim 7 or Claim 8, the indicator arrangement being arranged to provide a notification of the fault condition to a local and/or remote location.

10. An apparatus in accordance with any one of the preceding claims, wherein if the detected earth current is approximately equal to the active current, the processor is arranged to determine that a fault condition of broken neutral or three line connection has occurred.

11. An apparatus in accordance with any one of the preceding claims, wherein the processor is arranged to determine whether or not the earth current is above a predetermined first threshold value and, if it is so determined, to determine that there is a degraded neutral fault condition.

12. An apparatus in accordance with any one of the preceding claims, wherein the processor is arranged to determine whether the earth current is below a second threshold value, and if so determined, to determine that there is a broken or degraded earth fault condition or an MEN misapplication condition.

13. An apparatus in accordance with any one of the preceding claims, wherein the processor is arranged to determine whether a earth current is above a third threshold value to determine that there is a fault in an adjacent premises.

14. An apparatus in accordance with claim 13, wherein the processor is arranged to determine the phase of the earth current in order to determine the fault in the adjacent premises.

15. An apparatus in accordance with any one of the preceding claims, wherein the processor is arranged to determine whether the earth current exceeds a fourth threshold value and, if it is so determined, to determine the existence of a reversed active-neutral fault condition.

16. An apparatus in accordance with claim 15, wherein the processor is also arranged to determine the phase of the earth current.

17. An apparatus in accordance with any one of the preceding claims, wherein the processor is arranged to determine whether the earth current exceeds a fifth threshold value and, if so, to determine that there is a bypassed meter fault condition.

18. An apparatus in accordance with claim 17, wherein the processor is also arranged to determine the phase of the earth current.

19. An electricity meter apparatus, comprising an arrangement for monitoring electricity consumption, and an apparatus in accordance with any one of Claims 1 to 18 for detecting a fault in an electrical power supply being monitored.

20. A method of detecting fault in a power supply, the power supply comprising neutral, active, and earth, the method comprising the steps of determining an electrical status of the earth, and determining a fault associated with the determined electrical status of the earth.

21. A method in accordance with claim 20, wherein the electrical status of the earth that is determined is the magnitude of current flowing through earth.

22. A method in accordance with claim 21, wherein the step of determining the electrical status of the earth comprises determining a differential current between the active and neutral conductors, the differential current being the earth current value.

23. A method in accordance with claim 22, wherein the step of determining the differential current comprises the step of sensing a magnetic field produced by the active and neutral lines.

24. A method in accordance with claim 21, wherein the step of determining the magnitude of current flowing through earth comprises the step of directly measuring the current in the earth.

25. A method in accordance with any one of claims 20 to

24, wherein the step of determining the fault associated with the determined electrical status of the earth, comprises the step of determining which type of fault is indicated by the determined electrical status of the earth.

26. A method in accordance with any one of claims 20 to 25, comprising the further step of providing notification of a fault condition when the fault condition is detected.

27. A method in accordance with claim 6, comprising the further step of identifying the type of fault condition detected.

28. A method in accordance with claim 26 or claim 27, wherein the step of providing notification of a fault condition comprises the step of transmitting the notification to a local and/or remote location.

29. A method in accordance with any one of claims 20 to 28, wherein the step of determining a fault comprises the step of determining that a fault condition is a broken neutral or three line connection, when the determined status of the earth is that the earth current is approximately equal to the active current.

30. A method in accordance with any one of claims 20 to 29, wherein the step of determining the fault comprises the step of determining that there is a degraded neutral fault condition, when it is determined that the electrical status of the earth is that the earth current is above a predetermined first threshold value.

31. An apparatus in accordance with any one of claims 20 to 30, wherein the step of determining a fault comprises the step of determining that there is a broken or degraded earth fault condition, or an MEN misapplication condition, when the earth current is below a second threshold value.

32. A method in accordance with any one of claims 20 to 31, wherein the step of determining a fault is arranged to determine that there is a fault in adjacent premises, when it is determined that the electrical status of the earth is an earth current above a third threshold value.

33. A method in accordance with claim 32, wherein the step of determining the electrical status of the earth comprises the further step of determining the phase of the earth current.

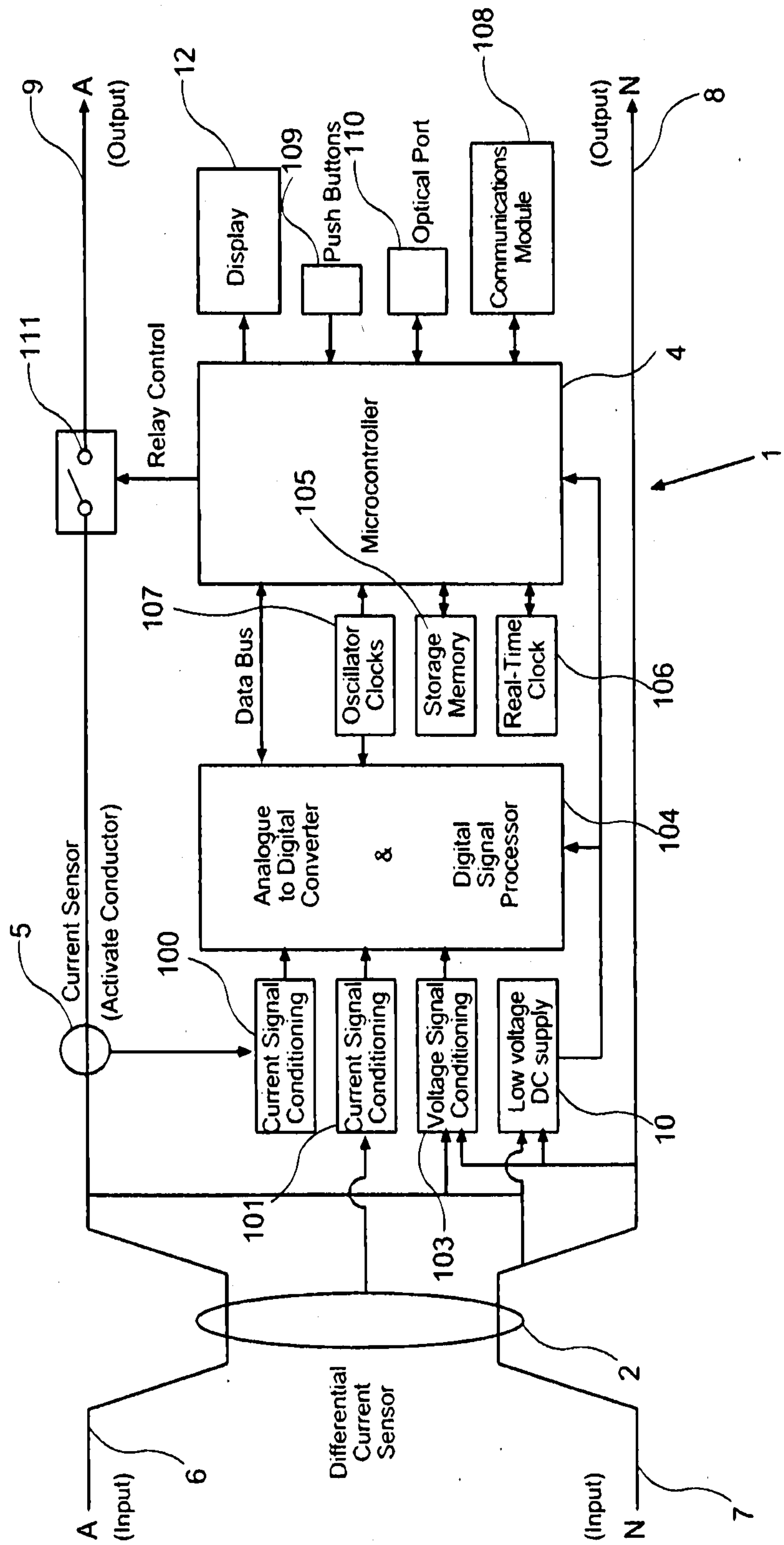
34. A method in accordance with any one of claims 20 to 33, wherein the step of determining a fault comprises the step of determining the existence of a reverse active-neutral fault condition, when it is determined that the electrical status of the earth is that the earth current exceeds a fourth threshold value.

35. A method in accordance with claim 34, when the step of determining the electrical status of the earth comprises the further step of determining the phase of the earth current.

36. A method in accordance with any one of claims 20 to 35, wherein the step of determining a fault comprises the step of determining that there is a bypass meter fault condition, when the determined electrical status of the

earth is that the earth current exceeds a fifth threshold value.

37. A method in accordance with claim 36 wherein the step of determining an electrical status of the earth comprises the further step of determining the phase of the earth current.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101
103
Current Signal Conditioning
100
Current Signal Conditioning
Voltage Signal Conditioning
Low voltage DC supply
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5
Current Sensor (Activate Conductor)
Analogue to Digital Converter & Digital Signal Processor
104
Data Bus
107
Oscillator Clocks
Storage Memory
Real-Time Clock
106
105
Microcontroller
4
1
Relay Control
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Communications Module
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A (Output)
9
N (Output)
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Figure 1

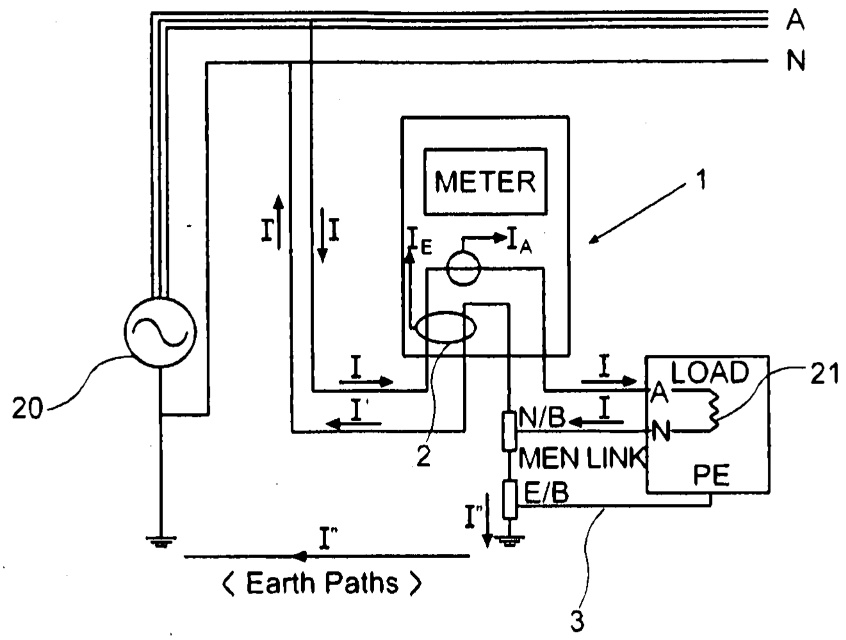
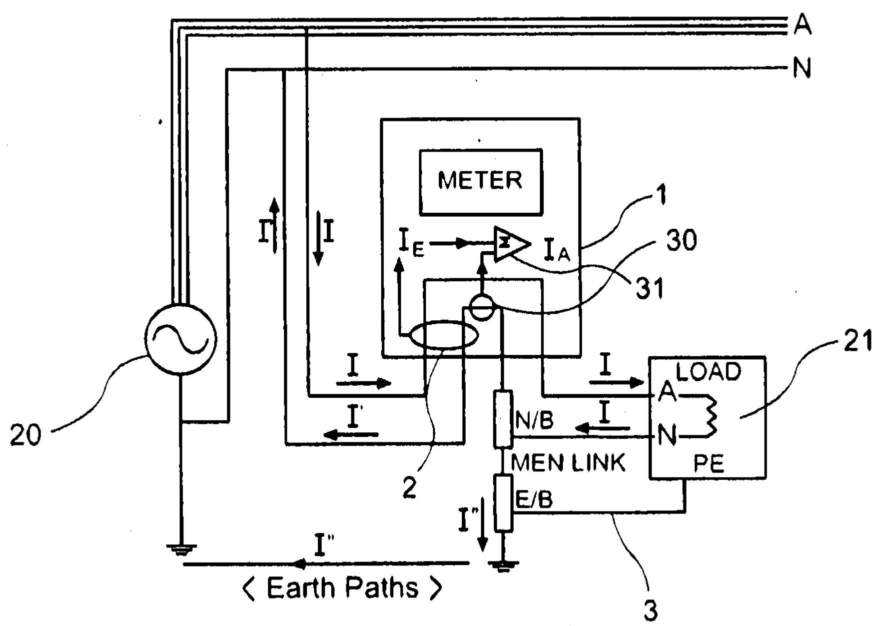


Figure 2



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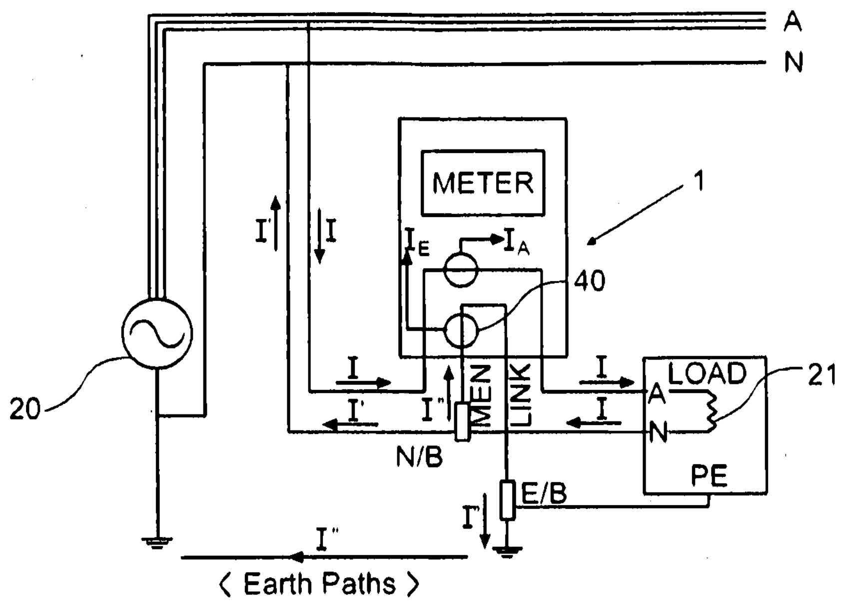

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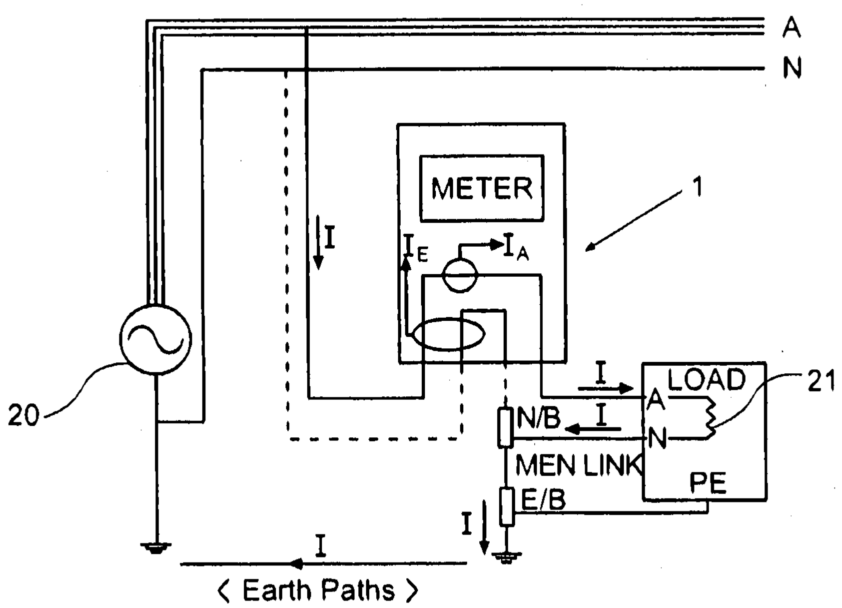

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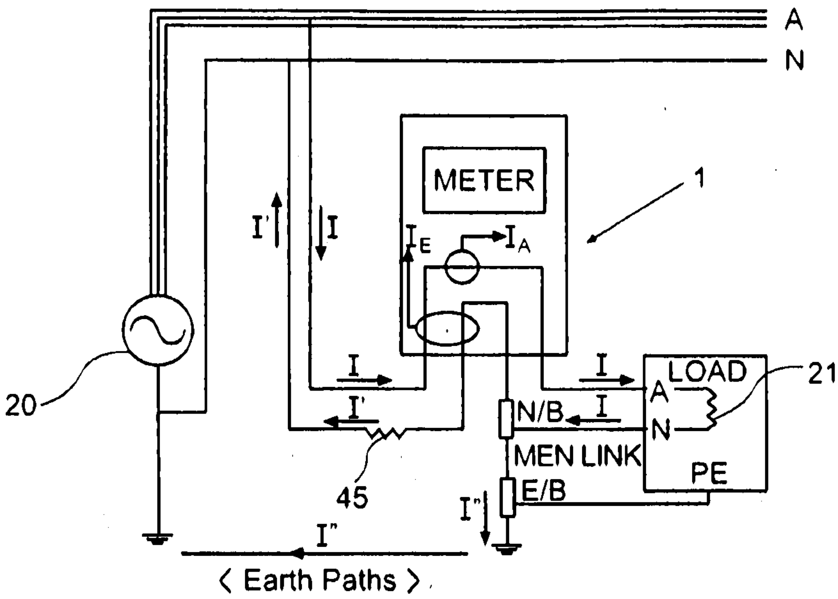

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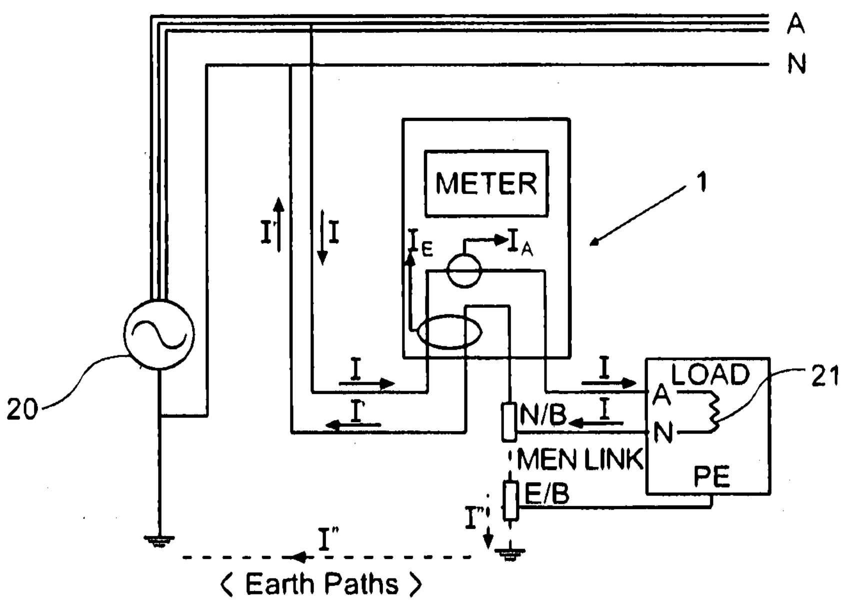

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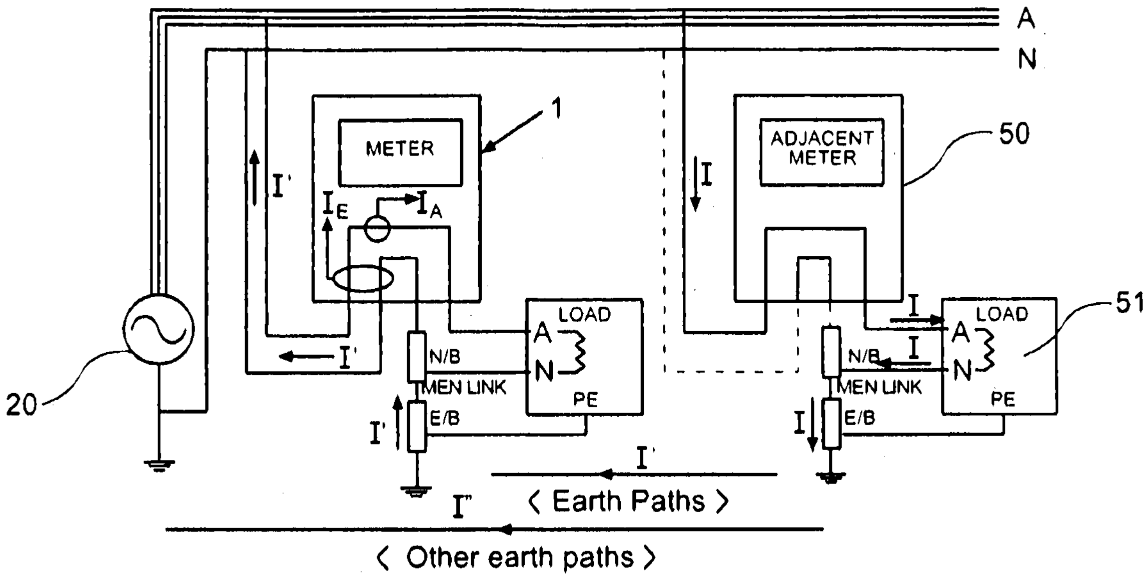

Figure 8

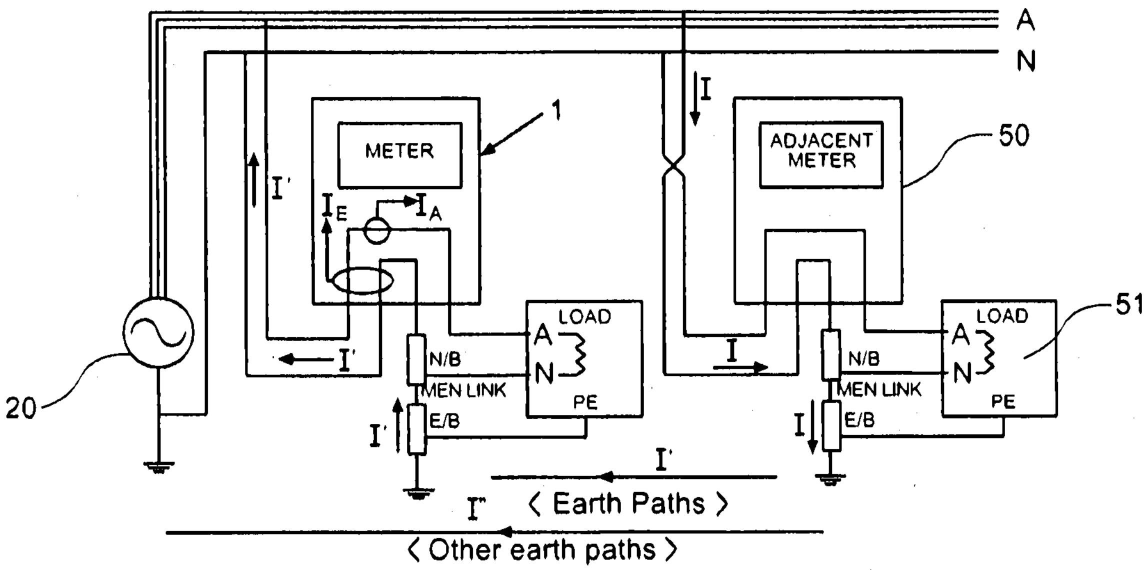

Figure 9

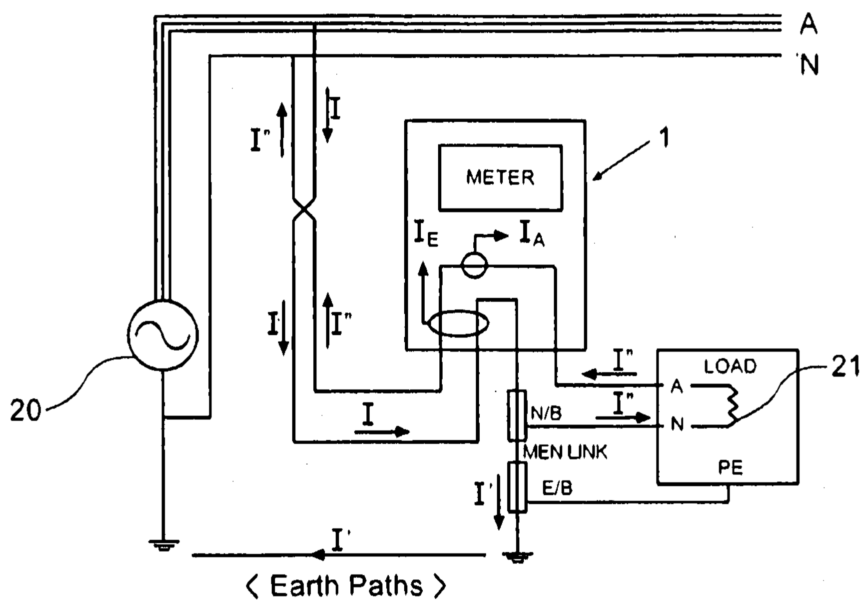

Figure 10

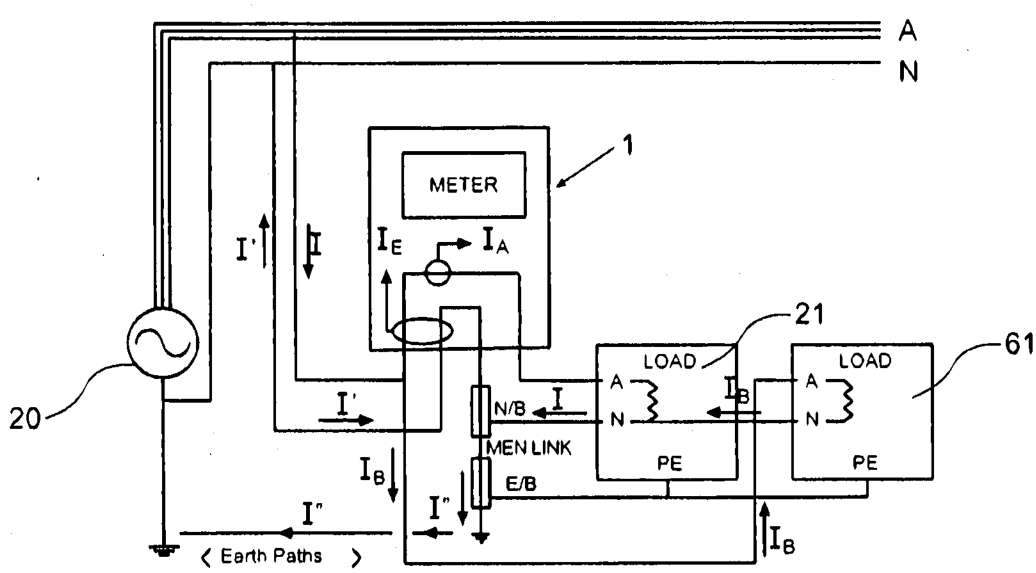

Figure 11

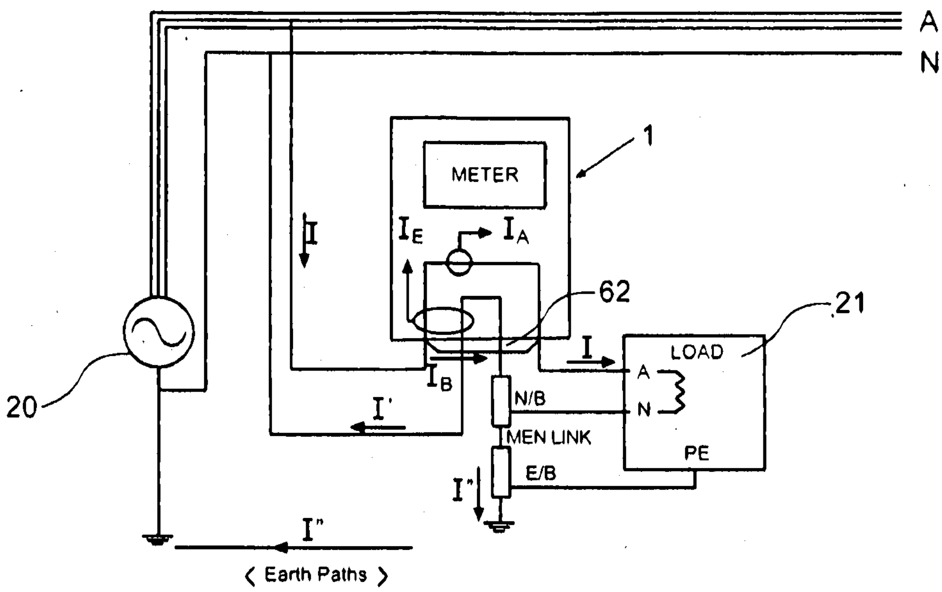

Figure 12

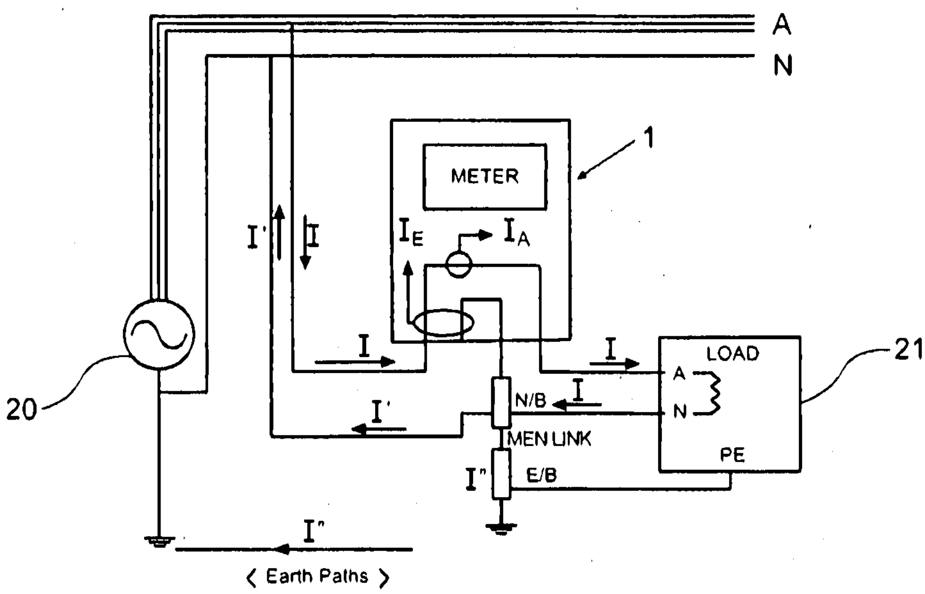

Figure 13

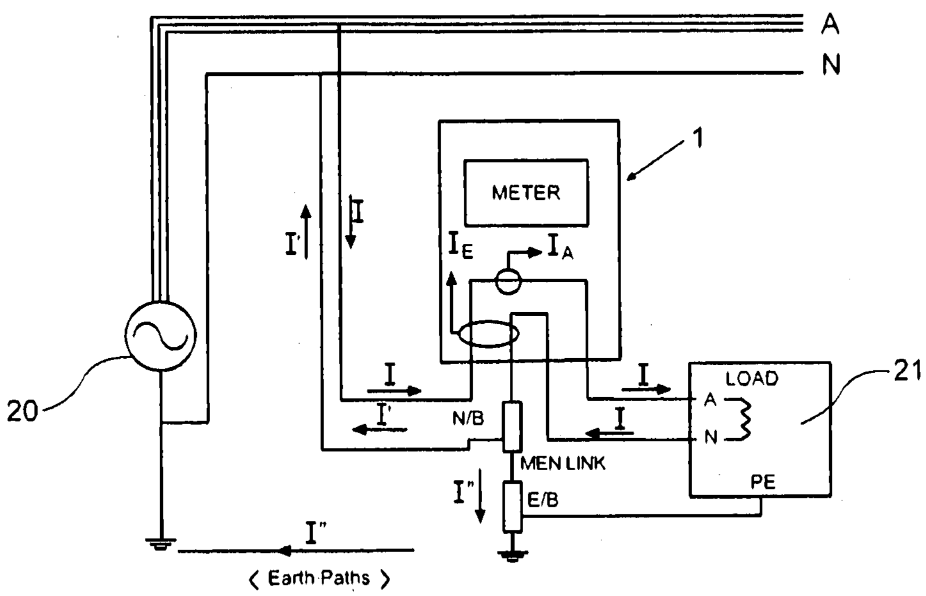

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Figure 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2011/000354

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

G01R 31/40 (2006.01)

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)

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 practicable, search terms used)
EPODOC, WPI: Fault, earth, ground, processor, processing unit, controller, current and like words.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6421618 B1 (KLIMAN et al.) 16 July 2002 Fig.2, 5A, 5B, col.2 lines 45-53, col.10 lines 35-51, col.11 lines 11-17, Claims 1, 2, 17, 22, 39, 41, 48	1-9, 12, 20-28, 31
X	GB 2268011 A (SHAKIRA LIMITED) 22 December 1993 Abstract, fig.2, page 5 lines 5-10, page 11 line 1-page 14 line 17, page 20 lines 21-27	1-12, 15, 19-31, 34

☐ Further documents are listed in the continuation of Box C   ☒ See patent family annex

* 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 application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 May 2011	30 MAY 2011 30 MAY 2011

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	**ARPIT DIXIT** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2879

International application No.
PCT/AU2011/000354

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member	
US	6421618	NONE	
GB	2268011	IE	930442

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX