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(54) **Portable arc preventing device**

(57) The present invention provides a portable shunt device for preventing arcing in an electrical connection to be opened or closed under load conditions. The portable shunt device comprises a zero cross circuit; a control unit adapted to send control impulses for controlling the conduction state of the zero cross circuit in response to a control signal; and a pair of terminals connected to the zero cross circuit for releasably connecting the portable shunt device across the electrical connection to be opened or closed so as to bridge the electrical connection.

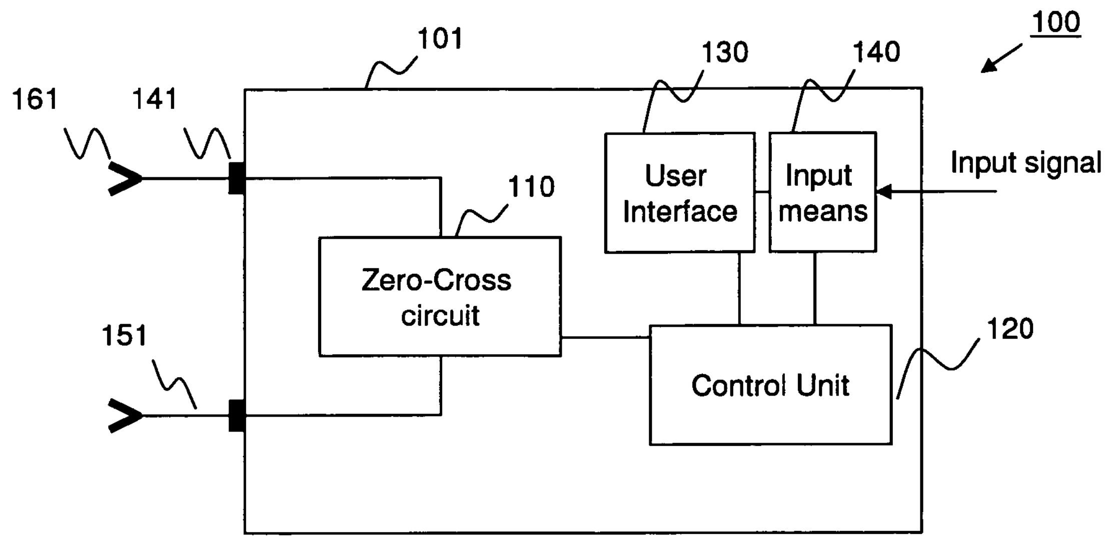

Fig. 1

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Description

[0001] The present invention relates to devices for preventing arc, and in particular, to a device that can be connected to an electrical connection that has to be opened or closed under load conditions. Further, the present invention relates to a method for opening or closing an electrical connection under load conditions. Finally, the present invention relates to the use of a portable device for opening or closing an electrical connection under load conditions.

[0002] The energy supply to private consumers and factories is nowadays ensured by complex and sophisticated distribution networks, such as low voltage (LV) distribution networks. Urban low voltage network in the United Kingdom are for instance supplied from medium voltage/low voltage (MV/LV) substations having a primary voltage of 11 kV and a secondary voltage of 240 V.

[0003] Maintenance works of such distribution networks or restoration of the network after a fault is at the present time performed manually by specialized teams or technicians. These operations on the network generally involve sectioning the affected network portion by breaking an electrical connection or making a new one.

[0004] A fundamental issue related to high power AC distribution networks is the large arc flashing generated when making or breaking an existing connection. Arc discharge is caused when a connection is opened or closed at a random part of the AC sine wave cycle, thereby suddenly switching the current to zero or full load.

[0005] It is well known that the arcing phenomenon can cause deterioration of the portion of the network being connected or disconnected, thereby shortening the life of the electrical connection or also permanently welding the two terminals of the electrical connection together. Moreover, an arc flash is an explosive electrical event that represents a hazard to the technicians working on the line. For these reasons, during maintenance or repairing works on the network lines, the current load on the electrical connection to be maintained or repaired is interrupted, by for instance, switching off the link box to which the affected electric line is connected. This leads to an interruption of the energy supply to the customers possibly for a number of hours, thereby representing a clear economic damage for the electricity provider and the customers.

[0006] Electronic circuits, such as triacs and the like, embedded in automatic control circuits or similar systems for preventing arc flashing, are known in the art.

[0007] US 2008/0048807 A1 describes an alternating-current (AC) relay including a circuit for avoiding the arc discharge phenomenon. A triac is connected to an AC input and further connected in parallel to an electromechanical switch. When a signal for closing the mechanical contact of the switch is issued, a control circuit waits for the next zero-crossing of the AC input and subsequently turns on both the triac and a winding coil driving the switch. The triac switches on immediately while the winding coil needs more time to move the armature and close the contact.

[0008] The arc-preventing circuitry described above can be implemented in switch gear modules to be embedded in link boxes across the low voltage distribution network. However, if a fault occurred on a different portion of the network or if a connection along an electric line has to be maintained or replaced, this solution requires switching off the node (link box) to which the affected portion of the electric line is connected thereby causing disruption of the electricity supply to a wide portion of the network.

[0009] Therefore, the present invention aims at providing a device that allows a technician to make or break a connection at any arbitrary location along the network without cutting off the energy supply. A further object of the present invention is to provide a method for breaking or making an electrical connection under load condition without causing arc.

[0010] This is obtained by a portable shunt device that can be connected at any arbitrary location of an electric line in a LV network or the like so as to form a bridge for redirecting the flow of current and bridging a portion of the electric line including the electrical connection that has to be opened or closed.

[0011] The object of the invention is solved by the subject matter of the independent claims. Advantageous embodiments of the present invention are defined by the dependent claims.

[0012] A first advantageous embodiment of the present invention provides a portable shunt device for preventing arcing in an electrical connection to be opened or closed under load conditions. The portable shunt device comprises a zero cross circuit; a control unit adapted to send control impulses for controlling the conduction state of the zero cross circuit in response to a control signal; a pair of terminals connected to the zero cross circuit for releasably connecting the portable shunt device across the electrical connection to be opened or closed so as to bridge the electrical connection.

[0013] Since the current is redirected through the portable device, the section of the electrical line bridged by the portable shunt device is in an "off-load" condition. Hence a connection included in the bridged section of the electric line can be broken or closed without causing arcing. Further, since the current keeps flowing through the shunt device, the current supply does not need to be interrupted.

[0014] The pair of terminals of the portable shunt device of the present invention may include two insulated leads. A first end of each insulated lead may be connected to the zero-cross circuit, and a second end thereof may include a clamping means for releasably connecting the insulated lead across the electrical connection.

[0015] In a yet alternative advantageous realization, the pair of connection terminals are conducting terminals located on the housing of the portable shunt device and are connectable across a section of the electric line including an the electrical connection by means of a pair of flying leads. The pair of flying leads may be fixed to the connection terminals and to the electric line by means of clamping means.

[0016] Accordingly, the portable device is designed to be connected to any kind of electric line or cable.

[0017] In portable shunt device according to a further advantageous embodiment of the present invention the first one of the pair of terminals is connectable to a cable terminal connected to a voltage supply and a second one of the pair of terminals is connectable to a cable terminal connected to a load.

[0018] The portable shunt device may further include a user interface for inputting a control signal to the portable shunt device. Accordingly, the conduction state of the zero-cross circuit may be controlled by the control unit based on the input control signal.

[0019] In a yet alternative advantageous realization the user interface may comprise means for manually activating the portable shunt device. According to this realization, the user can decide when the portable shunt device has to start conducting.

[0020] The user interface may further include a visual indicator for indicating when the connection across which the device is connected can be safely opened or closed.

[0021] In the portable shunt device of the present invention, the zero-cross circuit may include a thyristor module. The thyristor module can be activated by sending a burst of signals to its gate. In its active mode is conducting and it turns off automatically at the zero crossing of the AC current. Further, once the connection has been safely closed, the resistance of the contact making the connection will be very little. Thus, the presence of the thyristor will make little or no difference. In case the connection is opened, the voltage drop across the terminals being disconnected is determined by the thyristors in the thyristor module and is only a few volts. This suppresses the arcing at break.

[0022] The portable shunt device may further advantageously include a power supply unit for energising the control unit and the user interface. Thus the portable shunt device can be used as a standalone device.

[0023] The present invention further provides a method for preventing arcing in an AC electrical connection to be opened under load conditions. The method includes the step of connecting a first and a second terminal of a portable shunt device across the electrical connection so as to bridge the electrical connection to be opened. The first and second terminals are connected to a zero cross circuit. Further, the portable shunt device can be switched on so as to activate the zero-cross circuit, wherein the zero-cross circuit is conducting in its active state. The electrical connection may be opened at a position within a section bridged by the portable shunt device. Subsequently, the portable shunt device will break the current now flowing in it at the zero crossing and then may be disconnected from the electrical connection.

[0024] The present invention further provides a method for preventing arcing in an AC electrical connection to be closed under load conditions. Accordingly, a first and a second terminal of the portable shunt device are connected to the electrical connection so as to form a bridge across a first open terminal and a second open terminal of the electrical connection, wherein the first and second terminals are connected to a zero-cross circuit. The portable shunt device is switched on so as to activate the zero-cross circuit at the zero crossing point of the AC current, so that the zero-cross circuit starts conducting. Then, the first open terminal can be connected to the second open terminal. Finally, the portable shunt device can be disconnected from the first and second open terminals.

[0025] Accordingly, a section of an electric line including a connection to be opened or closed is bridged by the shunt device. Consequently, the connection is opened or closed in an "off-load" condition, since the current is redirected through the thyristor module 210 in the portable shunt device. This allows preventing arc flashover, which could damage the terminals to be opened, connectors, fuses or relays present on the electric line. In this manner, a faulty or obsolete connection or switch on an electric line may be repaired or replaced without switching off the entire node of the network, to which the electric line including the connection to be opened is connected, and without exposing specialized teams working on the line to any hazard.

[0026] Advantageously, connecting the first and a second terminal may comprise connecting a connection element to the second open terminal of the electrical connection and connecting the first connection terminal of the portable shunt device to the connection element, and the second terminal of the portable shunt device to the first open terminal of the electrical connection.

[0027] According to an advantageous embodiment, the first open terminal of the electrical connection may be connected to a voltage supply and the second open terminal of the electrical connection may be connected to a load.

[0028] In yet another advantageous realization of the present invention, the step of connecting the first open terminal to the second open terminal may comprise connecting the first open terminal to the connection element.

[0029] Advantageously, the portable shunt device of the present invention may be used for bridging a section of an electric line comprising an electrical connection to be opened or closed under load conditions.

[0030] The accompanying drawings are incorporated into and form part of the specification to illustrate several embodiments of the present invention. These drawings together with the description serve to explain the principles of the invention. The drawings are only for the purpose of illustrating preferred and alternative examples of how the invention can be made and used, and are not to be construed as limiting the invention to only the illustrated and described embodiments. Further features advantages will become apparent from the following and more particular description of the various embodiments of the invention, as illustrated in the accompanying drawings, in which like reference numbers refer to like elements, wherein:

Figure 1 is a schematic drawing illustrating a portable shunt device including a zero cross circuit in accordance with an embodiment of the present invention;

Figure 2 is a schematic drawing illustrating a portable shunt device according to a further realization of the present invention;

Figure 3 is a schematic drawing illustrating a further realization of the shunt device according to an embodiment of the present invention;

Figures 4 to 6 are schematic drawings illustrating a possible use of the portable shunt device according to the present invention for opening or closing an electrical connection along an electric line;

Figure 7 is a flow chart illustrating a method for closing an electrical connection along an electric line without causing arcing according to the present invention;

Figure 8 is a flow chart describing a method for opening electrical connection along an electric line without causing arcing according to the present invention.

[0031] In the following description, for explanatory purposes, specific details are set forth in order to provide a thorough understanding thereof. However, it may be evident that the present invention can be practiced without these specific details. Furthermore, well known structures and devices are only described in a more general form in order to facilitate the description thereof.

[0032] The problem underlying the present invention is based on the observation that commonly used security circuitry for preventing arcing when connecting or disconnecting electric lines are normally embedded in link boxes located along current networks. If an electrical connection needs to be opened or closed at an arbitrary location along an electric line in the network, the node to which the affected electric line is connected has to be shut off completely by switching off the switch gear module embedded in a link box, thereby causing economical losses for the current provider and for the users attached to the particular node of the LV network.

[0033] The present invention provides a portable shunt device that can be connected at any arbitrary location of an electric line in a LV network or the like so as to form a bridge for redirecting the flow of current and bridging a portion of the electric line including the electrical connection that has to be opened or closed. In this manner, since the current is redirected through the portable device, two portions of the electrical line can be broken or closed without the risk of causing arcing. Further, since the current keeps flowing through the shunt device, the current supply does not need to be interrupted.

[0034] The use of the portable shunt device of the present invention therefore allows performing maintenance on an arbitrary portion of an electrical line under load conditions in a safe manner.

[0035] Figure 1 illustrates an example of a portable shunt device 100 according to an embodiment of the present invention.

[0036] The portable shunt device 100 is a standalone device and includes a zero-cross circuit 110 connected to a control unit 120. The control unit 120 is connected to a user interface 130 and to input means 140 adapted to receive an input signal for controlling the portable shunt device. The zero-cross circuit 110 is connected to a first and a second terminal 141, which may be electrical contacts arranged on a housing 101 of the portable shunt device 100. A first and a second insulated electric cable 151 may be connected through clamping means (not shown) to the first and second electric contacts. Each of the first and second electric cables 151 may include at a free end thereof a conducting clamping means 161 for temporary clamping the first and second cables 151 to an electrical line (not shown). Alternatively, the electric cables 151 may be soldered to the zero-cross circuit 110 at the manufacturing stage.

[0037] The zero-cross circuit 110 includes an electrical circuit that starts conducting upon a signal from the control unit when the AC load voltage is at or close to the zero-phase. The control circuit 120 may include a voltage zero-crossing detection circuit (not shown), which is adapted to be driven from the portion of the electrical connection to be opened or closed connected to the voltage supply. The voltage zero-crossing detection circuit is capable of detecting the timing of the zero voltage crossing and issues a control signal to the zero-cross circuit 110 for controlling its conduction state. The zero-cross circuit 110 may include any kind of relay, such as triacs, silicon-controlled rectifiers, or thyristor modules. The function of the zero-cross circuit and its possible configurations will be described in more detail with reference to figures 2 and 3. The portable shunt device 100 may further include a power supply (not shown) for powering the user interface and the control unit. The power supply may be a battery or a power cable to be connected to a current network.

[0038] Figure 2 illustrates a portable standalone shunt device 200 according to a further realization of present invention. The parts of the portable shunt device 200, which were already described in relation with figure 1 are indicated with the same reference signs and will not be described again.

[0039] In the embodiment of figure 2, the zero-cross circuit 110 includes a thyristor module 210. The thyristor module 210 is controlled by the control unit 120 and its functioning is described in full detail in the co-pending application PCT/GB/2010/052151, which is hereby incorporated by reference.

[0040] In particular, the control unit 120 may be controlled by a relay on/off signal provided from an external source. The input signal could be directly input into the control unit 120 or it could be input to the control unit 120 through a user interface 130. The control unit 120 is connected to the thyristor module 210, which includes a pair of thyristors 210, 212 connected in an anti-parallel arrangement across the connecting terminals 141. In other words, the thyristor pair is connected with reversed polarities and in parallel.

[0041] The gate terminals of the thyristors 211, 212 are respectively connected to the control unit 120 so that the control unit 120 can control the state of the thyristor module. One of the thyristors conducts current during positive AC half-cycles and the other thyristor conduct current during negative AC half-cycles. The thyristor module 210 has an Inactive mode, whereby the thyristor module in non-conductive, and an Active Mode. Upon receiving a switch-on signal through the user interface 130, the control unit 120 sends a switch-on pulse to the thyristor module 210, which changes its state from the Inactive Mode to the Active Mode and starts conducting.

[0042] In the conducting state one of the thyristors 211, 212 conducts current during positive AC half-cycles and the other thyristor conducts current during the negative AC half-cycle. Current will then flow through the first and second terminals 141 via the thyristor module 210. If the first and second connecting terminals 141 are connected to an AC load so as to bridge a section of an electric line that has to be connected, the current continues to flow in the thyristors until a number of AC cycles later, when the connection is completely closed. Once the connection operation is completed, a signal is sent by the control unit 120 to the thyristor module 210 so as to remove drive to the thyristors at the first available zero-crossing of the AC voltage. Subsequently, the thyristor module 210 reverts to the non-conducting, Inactive Mode. As the connection has been closed, AC-current will then flow through the primary electrical line. Since during the connection of the two sections of the electric line current was flowing through the thyristor module 210 in the portable shunt device 200, the section of the electric line bridged by the portable shunt device 200 was in an "off-load" condition. Therefore, there is no arc flashover that could damage the electrical line or could represent a hazard for the technician working on the line.

[0043] Similarly, the portable shunt device 200 can be connected through the first and second connection terminals 141 to a cable of an electric line across a portion including an electrical connection to be opened. The first and second connection terminals 141 may be connected to the electric line through a connection cable 151, which can be clamped via a clamping means 161. The clamping means 161 may be any means adapted to be releasably connected to an electric cable or to a connector so as to establish a stable and firm connection. If the thyristor module 210 is in the inactive mode, no current will flow to the portable shunt device 200. Upon activating the portable shunt device 200, the control unit 120 will issue a pulse signal to switch the thyristor module 210 from the inactive to the active mode. After this operation, the thyristor module 210 will be in a "latent' conduction mode, so that it can conduct AC current once the electric line is broken. The control unit 120 sends a burst of pulses to the thyristor module 210 to turn the thyristors 211 and 212 on at the zero-crossing of the AC current and keep the thyristors 211, 212 in a conductive state. While the thyristor module 210 is in its "latent" conduction mode, the electric line (not shown) can be cut or opened and as a consequence of opening the electric line under load conditions, the AC current will be redirected through the portable shunt device 200 and will begin to flow through the thyristor module 210.

[0044] Once the electric line has been fully opened, the portable shunt device can be switched off. Upon a switch-off signal, the control unit 120 removes the drive from the thyristor module 210 prior to the first subsequent AC zero-crossing, which causes the thyristor module 210 to revert to the non-conducting state at the zero-crossing of the AC current.

[0045] In this scenario, the section of the electric line bridged by the shunt device 200 is opened in an "off-load" condition, since the current is redirected through the thyristor module 210 in the portable shunt device 200. This allows preventing arc flashover, which could damage the terminals to be opened, connectors, fuses or relays present on the electric line. In this manner, a faulty or obsolete connection or switch on an electric line may be repaired or replaced without switching off the entire node of the network, to which the electric line to be opened is connected, thereby preventing exposing a technician working on the line to any hazard.

[0046] As an alternative to a burst of pulses to initiate conduction, a high-frequency signal such as a square wave may be used. This would allow for simpler implementation of the coupling arrangement to the thyristor gates, generally using a transformer to provide voltage isolation. Also, when the electric line is being opened, it is essential for the thyristor module to be in a conducting state prior to the opening, even though the precise time when this occurs is unknown. A high frequency gate drive would ensure that the thyristors are in a "latent" conductive state, and will conduct as soon as current flows through them instead of through the electric line. Such a gate drive signal could be obtained by gating the output from a high-frequency source with a logic signal that defines the "ON" time required of the thyristors.

[0047] An insulating transformer (not shown) may be provided across the control unit 120 and the connection terminals 141. The insulating transformer enables the AC path through the switching circuit to be completely isolated from the control unit, for improved safety and reduced EMC interference.

[0048] Although the use of a high-frequency signal fro driving the thyristor module 210 is described with reference to the embodiment of figure 1, it has to be understood that this solution can be implemented in all the embodiments of the present invention.

[0049] The switch-off or switch-on command can be generated according to several design options. According to a preferred embodiment, the zero-cross circuit 110 can be activated in a fully automatic manner. Accordingly, the control unit 120 detects that the first and second connection terminals 141 of the portable shunt device 200 are connected across an electrical connection and automatically sends the signal pulse for switching the thyristor module 210 to the active or inactive mode. The circuit will have a start delay of a predetermined time and the control unit 120 sends an input signal to the user interface 130, which will visually indicate to a user of the portable shunt device 200 when it is safe to make or break the connection in the electric line and when not. Accordingly, the user interface 130 may include a display for displaying a counter indicating the time left for opening or breaking the connection safely. Alternatively, the device may include visual indicators, such as an LED of a predetermined colour, which turns on when operation on the electric line can be safely performed. In the case that the portable shunt device is used for closing a connection, once the connection is fully closed the control circuit 120 will detect a drop in the current through the thyristor. After a further predetermined time delay, a further indicator in the user interface may indicate that the portable shunt device can be safely removed.

[0050] According to an alternative realization, the portable shunt device 200 can be switched off or on by a user operation through the input means 140. The input means may be a push button 140 to be pushed and held in order to enable the thyristor module 210. In this case, releasing the button would turn off the portable shunt device 200 and cause the control unit 120 to remove the drive from the thyristor module 210 so as to revert same to the non-conducting state at the first next zero-crossing of the AC current.

[0051] In yet another alternative realization, the portable shunt device may include a button to be pushed down a first time for starting the portable shunt device 200 and cause the control unit 120 to send a burst of pulses for activating the thyristor module 210. Upon pushing the start button a second time, the portable shunt device 200 can be switched off so that the control unit 120 can remove the drive from the thyristor module 210.

[0052] In a further alternative embodiment, the portable shunt device 200 may include a push button for switching on the device and make the thyristor module 210 conductive as explained above. The control unit 120 has in this realization an incorporated timer, which automatically switches off the thyristor module 210 once the connection has been made.

[0053] In any of the embodiment described above, the push button may be provided on the housing 201 of the portable shunt device 200 so as to be activated with a hand. Alternatively, the input means 140 may be a detachable control panel that can for instance be activated by a foot.

[0054] Co-pending European patent application 11003205, the content of which is hereby incorporated by reference, discloses an arrangement that avoids failure of the thyristor module 210 in case a fault current that exceeds the surge overload current rating of the thyristors 211, 212 flows through the electric line. Accordingly, the thyristors 211, 212 are closed just prior to the zero-crossing point of the voltage and the thyristor module 210 will switch off automatically at the zero-crossing point.

[0055] According to the energizing method described in the co-pending European patent application 11003205, while the thyristor module 210 is energized, the load current flowing in the portable shunt device 200 is measured. If the load current is within a normal range of switching load currents, a closing operation sequence is initiated, in which an additional firing of the thyristors 211, 212 will take place just prior to the zero-crossing voltage point and at a timing that would be incrementally earlier from the zero-crossing point used for the first thyristor energization. Thus, after the first thyristor energization, each subsequent firing takes place at an instant of time, with respect to the next zero-voltage crossing point that differs from the immediately proceeding firing instant by a predetermined time increment.

[0056] The firing process is repeated for each consecutive zero-crossing until a stage is reached when the thyristors 211, 212 are conducting for the full duration of the half-cycle. At this stage, the control unit 120 provides a signal to the user interface 130, which in turn indicates to the user of the portable shunt device 200 that an open connector or the like in the portion of the electric line bridged by the portable shunt device 200 can be safely closed.

[0057] Measurement results as a function of time obtained during energisation sequences of the thyristor module are described in figures 3 to 5 and the corresponding text portions of co-pending European patent application 11003205.

[0058] If the measured current exceeds a threshold level during any of the stages of the thyristor energization cycles described above, then the control unit 120 no longer fires the thyristors 211, 212 prior to the zero-crossing point.

[0059] Further, a signal will be sent to the user interface, which will then be visually indicate to the user that the electric line cannot be safely closed.

[0060] This feature might be implemented by providing a current sensor 213 connected across a connection terminal 141 and the control unit 120. The current sensor 213 may be adapted to detect the current flowing though the shunt device and to generate a signal based on the sensed value of current. The generated signal could be analogue voltage or current. Alternatively, the current sensor may generate a digital output. The generated signal can be fed to the control unit 120, which drives the thyristor module 210 accordingly as described above. Additionally, the generated signal can be utilized to display the measured current through the user interface. The generated signal may be also stored in a memory (not shown), which may be provided in the shunt device, for further analysis.

[0061] The current sensor 213 may provide sensor data also to an over-current detection circuit (not shown). For example, a current transformer or a Hall-Effect device could be used, but whatever means is used, it must have sufficient bandwidth to respond accurately to the narrow current pulses that may occur at the start of the Active Mode; otherwise, the response to a potentially severe overload condition could take too long.

[0062] Abnormal currents occurring when opening or closing the electric line may for example be detected as follows. A first means of detection is by direct comparison of the peak level of the current signal generated by the current sensor 213, on a cycle-by-cycle basis, with a predetermined reference value. The second means of detection is by the detection of the absolute peak amplitudes of successive pulses, and then performing a calculation to establish the rate of rise of the current. This can be compared to a predetermined value. The latter method may be implemented by a software algorithm.

[0063] In the event of a fault condition being detected, the Active Mode can be aborted thereby preventing overheating and/or damage to the thyristor module. In addition, the control unit 120 may issue a signal to the user interface 130, which may in turn indicate to the user of the portable shunt device 200 to brake up the closing operation of an open connector or the like in the portion of the electric line bridged by the portable shunt device 200. The closing of the electric line into a fault condition can therefore be prevented.

[0064] The same methods can also be applied during the opening operation of the electric line.

[0065] Although the configuration including the current sensor has been described in relation to the embodiment of figure 2, it has to be understood that such a solution can also be implemented in the shunt device of all the embodiments of the present invention.

[0066] The visual indicators indicating whether the electric line can be safely closed or opened may be any kind of indicators suitable for this purpose. For example, a green light indicator may indicate that the electric line can be safely closed, while a red light indicator may indicate that the conditions for safely closing the electric line are not met. Alternatively, the portable shunt device 200 may include only one light indicator, which emits light only if a connection can be safely opened or closed.

[0067] Figure 3 is a schematic drawing illustrating a portable standalone shunt device 300 according to a further embodiment of the present invention. In this figure, the elements already described with reference to figures 1 and 2 are indicated with the same reference numbers and will not be discussed further. The portable shunt device 300 includes a zero-cross circuit 110 comprising a thyristor module 210 arranged and connected to the control unit 120 and to the first and second terminals 141 as already described with reference to figure 2. The thyristors 211, 212 may have a high overload current rating and the zero-cross circuit 110 further comprises an over-current protection device 320 installed in series with the pair of anti-parallel thyristors 211, 212.

[0068] The additional over-current protection device may be a positive temperature coefficient PTC referred to as PTC device 320. The resistance of the PTC device 320 varies significantly with temperature and/or when the current flowing through the PTC device 320 is significantly increased. In the event of a short circuit, the control unit 120 senses the fault current and decides whether it is safe to open or close the electrical line or whether to blow the fuse. The current may be sensed by means of a current sensor (not shown) connected as described with reference to the embodiment of figure 2. If the control unit 120 decides that the electric line can be safely opened, the thyristors 211, 212 are driven to their active mode so as to prevent arcing. Subsequently, the control unit 120 issues a command to the user interface 130 to visually indicate that the connection can be safely opened as already described with reference to figure 2. Once the electric line is opened or closed, the control unit 120 switches off the thyristors 211, 212 at the first zero-crossing.

[0069] The insertion of the PTC device 320 in series with the pair of anti-parallel thyristors 111, 112 limits the current flowing into the thyristors, which can otherwise fail above a moderate fault current (2.5-5 Ka) in case of large short circuit currents.

[0070] Under normal operating conditions of distribution networks, the load current ranges from 400 to 800A and the operating voltage is 240 Vac/50 Hz for the UK and 110 Vac/60 Hz for the US. Thus, it is desirable to achieve a protector rating of 9 to 10 kA, 15 Ka or preferably 25 kA. The dimensions of the PTC element 320 are preferably selected so as to allow the PTC element 320 to be accommodated underneath the pair of anti-parallel thyristors 211, 212.

[0071] Alternatively or in addition, the portable shunt device of the present invention may comprise an over-current protection device or a fuse (not shown), for instance, a 315A or 400A LV J-tag fuse, which is connected across the connection terminals 141. The purpose of the fuse is to provide additional backup protection and also to clear network faults above the overload current rating of the thyristors.

[0072] In this configuration, the thyristor module 210 is used to redirect currents flowing in the electric line to be opened or closed up to a certain threshold level, e.g. 6kA rms. The fuse is configured to blow if a current above this level is sensed. Existing network safety and protection is guaranteed by this arrangement.

[0073] The current may be sensed by means of a current sensor (not shown) connected as described with reference to the embodiment of figure 2. Based on the sensed current values sampled at a predetermined timing, for instance, 256 times per cycle, and depending on the threshold level the control unit 120 determines if the thyristor module 210 should be driven into the Active Mode or the fuse should be blown. The operating time characteristic of the shunt device is matched to the fuse operational curve.

[0074] Further additional safety features may be provided to a technician operating the portable shunt device of the present invention.

[0075] More precisely, the shunt device may warn the user not to close an open electric line if there are two different phases on the connection terminals 141. This may be achieved by checking the voltage on both the connection terminals 141 or by measuring the time difference between the zero voltage crossings of the voltage on both sides. This prevents the shunt device creating a phase-phase fault on the network.

[0076] Similarly, the user interface 130 will indicate not to open the electric connection if load current exceeds a predefined threshold. This is achieved by verifying the load current before commencing an opening operation and allows preventing damage to the thyristors.

[0077] The above safety features may be provided alone or in combination and in all the embodiments of the present invention.

[0078] Figures 4 to 6 show an electric line 400 connected to an AC load (not shown) and a portable shunt device 100, 200, 300 according to the present invention, and illustrates the steps needed for safely closing or opening an electrical connection 450 in the electric line 400 under load conditions. This process is summarized in the flowcharts of figure 7 and 8.

[0079] Figure 7 is a flow chart illustrating a method for closing an electrical connection along an electric line without causing arcing.

[0080] In step S71, a connector 450 is connected to a live terminal 420 of the electric line 400. The live terminal 420 is the portion of the electric line connected to the voltage supply. Once the connector 450 is connected to the live conductor 420, in step S72, the portable shunt device 100, 200, 300 is connected to the connector 450 and to a dead cable 410 of the electric line 400. In this context, the dead cable 410 is the portion of the electric line 400 that supplies the load. The portable shunt device 100, 200, 300 is connected to the dead cable 410 and to the live cable 420 by means of two insulated cables or fly leads 151 connected to the terminals of the zero-cross circuit 110 and depicted in figure 5. The fly leads 151 are fixed to the dead cable 410 and to the live portion of the connector 450 through clamping means 161.

[0081] In step S73, the portable shunt device 100, 200, 300 is turned on so that the control unit 120 can drive the zero-cross circuit 110 from the inactive to the active mode. Accordingly, the zero-cross circuit 110 driven by the control unit 120 starts conducting at the zero crossing point of the AC voltage, as described with reference to figures 1 to 3. In step S74, the dead cable 410 and the live cable 420 of the electric line 400 can be connected together by connecting the dead cable 410 to the connector 450 as illustrated in figure 6. Although figure 6 illustrates a situation, wherein the electric line is connected through a connector 450, such a connection can also be established in alternative ways, such as by operating a switch, a conductor, a link or a fuse or by piercing the insulation with a conducting bolt or the like.

[0082] In step S75, the dead connector 410 is connected to the connector 450 and activated, while the zero-cross circuit 110 is in its active mode. Since the current is flowing to the portable shunt device 100, 200, 300, the electric line 400 can be activated without risk of arc flashing. In step S76, the control unit 120 turns off the zero-cross circuit at the first zero-crossing point of the AC. Subsequently, the portable shunt device can be disconnected from the electric line 400.

[0083] Figure 8 is a flowchart diagram describing a method for opening a connection 450 of an electric line 400 under load conditions. In step S81, the two insulated file leads 151 of the portable shunt device 100, 200, 300 are connected across a section of the electric line 400 including the connection to be opened. The section to be opened may be a connector 450 as shown in figure 6. However, the use of the portable shunt device 100, 200, 300 of the present invention is not limited to this type of connections and may also be used for opening a switch, a conductor, a link, a fuse or the like. In step S82, the portable shunt device 100, 200, 300 is switched on and the control unit 120 drives the zero-cross circuit 110 to its active mode. Accordingly, the zero-cross circuit 110 will be in a "latent" conduction mode as described in the previous paragraphs. While the zero-cross circuit 110 of the portable shunt device 100, 200, 300 is conducting (active mode), the electric line 400 can be opened by removing one portion of the electric line 400, such as the dead terminal 410 from the connector 450 in step S83. Alternatively, opening the electric line may be obtained by removing a link or a fuse, or operating a switch or a contactor.

[0084] The voltage drop across the dead terminal 410 and the live terminal 420 being disconnected will be determined by the voltage drop across the zero-cross circuit 110. In particular, if the zero-cross circuit includes a pair of anti-parallel thyristors 211, 212 as depicted in figures 2 and 3, the voltage drop will be determined by the voltage drop across the thyristors 211, 212. Since the voltage drop across the zero-cross circuit will only be of a few volts, arcing caused by electric discharge due to the high voltage difference between the two terminals 410, 420 of the connection 450 being opened is suppressed. The zero-cross circuit 110 will then turn off automatically at the zero-current point. In step S84, the device can be turned off and disconnected from the opened terminals 410, 420 of the electric line 400.

[0085] According to the present invention, a zero-cross circuit 110 including a semiconductor device, such as a thyristor module 210 is integrated in a portable shunt device 100, 200, 300 including two open terminals 141, 142 adapted to be connected across a section of an electric line 400 including a connection 450 to be opened or closed. The portable shunt device of the present invention allows opening or closing an electrical connection under load condition, while preventing arc discharge. In this manner, any arbitrary portion of an electric line along a current network can be opened or closed for repair or maintenance work in a safe manner under load conditions.

[0086] Further, since the portable shunt device of the present invention allows to open or close a connection while preventing arc discharge, detrimental effects on the terminals on the terminals being connected or disconnected is avoided, thereby extending the lifetime of the electric line.

[0087] Again, since the use of the portable device of the present invention allows opening or closing an arbitrary portion of an electric line under live load conditions, customer minutes lost (CML) for utilities are reduced, thereby reducing economic losses of the electricity provider and the customers of said provider. Finally, since the portable shunt device of the present invention prevents arcing while making or breaking a connection, switches, connectors, contactors, link, fuses or the like used for opening or closing the connection no longer need to be designed so as to withstand arc damage. Consequently, costs related to such parts can be drastically reduced.

Reference Numeral	Element
100,200,300	Portable shunt device
101,201,301	Housing
110	Zero-cross circuit
120	Control unit
130	User interface
141	First and second connection terminals
151	Insulated electric cable
161	Clamping means
210	Thyristor module
211,212	First and second thyristors
213	Current sensor
320	Over-current protection device
400	Electric line
411	Isolation of the electric line
410	Dead cable
420	Live cable
450	Connector

Claims

1. A portable shunt device (100, 200, 300) for preventing arcing in an electrical connection (450) to be opened or closed under load conditions, the portable shunt device (100, 200, 300) comprising:

a zero cross circuit (110);
a control unit (120) adapted to send control impulses for controlling the conduction state of the zero cross circuit (110) in response to signal input to the portable shunt device (100, 200, 300); and
a pair of connecting terminals (141) connected to the zero cross circuit (110) for releasably connecting the portable shunt device (100, 200, 300) across the electrical connection to be opened or closed so as to bridge the electrical connection.

2. The portable shunt device (100, 200, 300) of claim 1, wherein the pair of connecting terminals (141) include two

insulated leads (151), wherein
a first end of each insulated lead (151) is connected to the zero cross circuit (110), and
a second end of each insulated lead (151) includes a clamping means (161) for releasably connecting the insulated lead (151) across the electrical connection.

3. The portable shunt device (100, 200, 300) of claim 1, wherein the pair of connecting terminals (141) are conducting terminals adapted to be connected across the electrical connection (450) by means of a pair of fly leads (151), the pair of fly leads (151) being fixed to the terminals (141) and to the electrical connection by means of clamping means (161).

4. The portable shunt device (100, 200, 300) of any one of claims 1 to 3, wherein the first one of the pair of connecting terminals (141) is adapted to be connected to a cable terminal (410) connected to a voltage supply and a second one of the pair of connecting terminals (141) is adapted to be connected to a cable terminal (420) connected to a load.

5. The portable shunt device (100, 200, 300) of any one of claims 1 to 4, further including a user interface (130) for inputting a control signal to the portable shunt device (100, 200, 300), wherein the conduction state of the zero-cross circuit (110) is controlled by the control unit (120) based on the input control signal.

6. The portable shunt device (100, 200, 300) of claim 5, wherein the user interface (130) comprises means for manually activating the portable shunt device (100, 200, 300).

7. The portable shunt device (100, 200, 300) of claim 3, wherein the user interface includes a visual indicator for indicating when a safe connection can be safely opened or closed.

8. The portable shunt device (100, 200, 300) of any one of claims 1 to 7, wherein the zero-cross circuit (110) includes a thyristor module (210).

9. The portable shunt device (100, 200, 300) of any one of claims 1 to 8, further including a power supply unit for energising the control unit (120) and the user interface (130).

10. A method for preventing arcing in an electrical connection (450) to be opened under load conditions, the method including the steps of:

connecting a first and a second connecting terminal (141) of a portable shunt device (100, 200, 300) across the electrical connection (450) so as to bridge the electrical connection to be opened, the first and second connecting terminals (141) being connected to a zero cross circuit (110);
switching on the portable shunt device (100, 200, 300) so as to activate the zero-cross circuit (110), the zero-cross circuit (110) being conducting in its active state;
opening the electrical connection (450) at a position within a section bridged by the portable shunt device (100, 200, 300); and
disconnecting the portable shunt device (100, 200, 300) from the electrical connection (450).

11. A method for preventing arcing in an AC electrical connection (450) to be closed under load conditions, the method including the steps of:

connecting a fist and a second connecting terminals (141) of a portable shunt device (100, 200, 300) to the electrical connection so as to form a bridge across a first open terminal (419) and a second open terminal (420) of the electrical connection, the first and second connecting terminals (414) being connected to a zero-cross circuit (110);
switching on the portable shunt device (100, 200, 300) so as to activate the zero-cross circuit (110) at the zero crossing point of the AC current, the zero-cross circuit (110) being conducting in its active state;
connecting the first open terminal (410) to the second open terminal (420);
disconnecting the portable shunt device (100, 200, 300) from the first open terminal (410) and the second open terminal (420).

12. The method of claim 11, wherein the step of connecting the fist and a second connecting terminals (141) comprises:

connecting a connection element (450) to the second open terminal (420) of the electrical connection; and connecting the first connecting terminal (141) of the portable shunt device (100, 200, 300) to the connection element (450), and the second connecting terminal (141) of the portable shunt device to the first open terminal (410) of the electrical connection.

13. The method of any one of claims 10 or 11, the first open terminal of the electrical connection is connected to a voltage supply and the second open terminal of the electrical connection is connected to a load.

14. The method of claim 12 or 13, wherein the step of connecting the first open terminal (410) to the second open terminal (420) comprises connecting the first open terminal (410) to the connection element (450).

15. Use of the portable shunt device of any one of claims 1 to 7 for bridging a section of an electric line (400) comprising an electrical connection (450) to be opened or closed under load conditions.

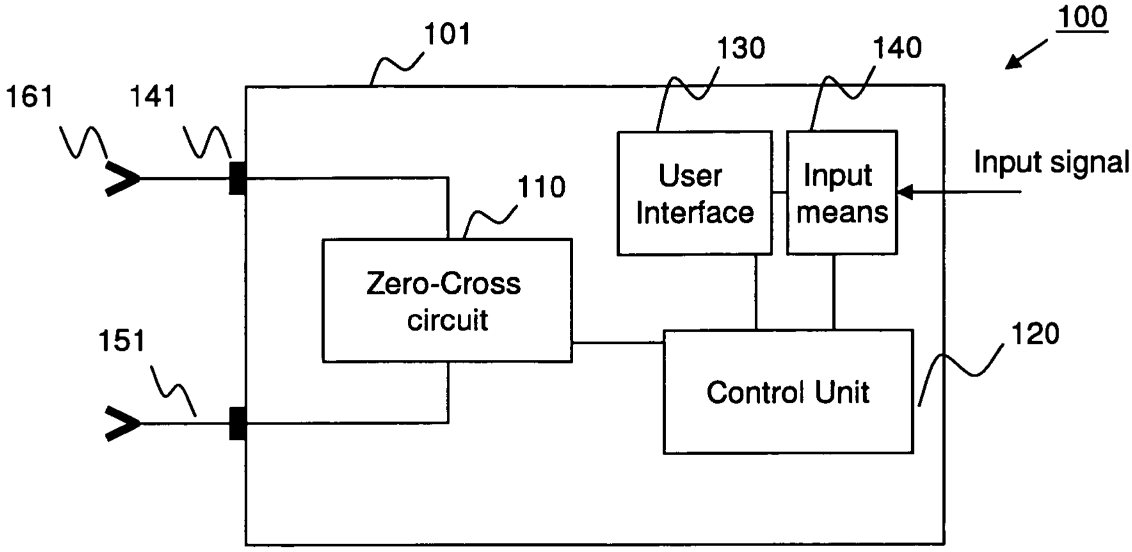
100
101
130
140
161
141
User
Interface
Input
means
Input signal
110
Zero-Cross
circuit
151
120
Control Unit

Fig. 1

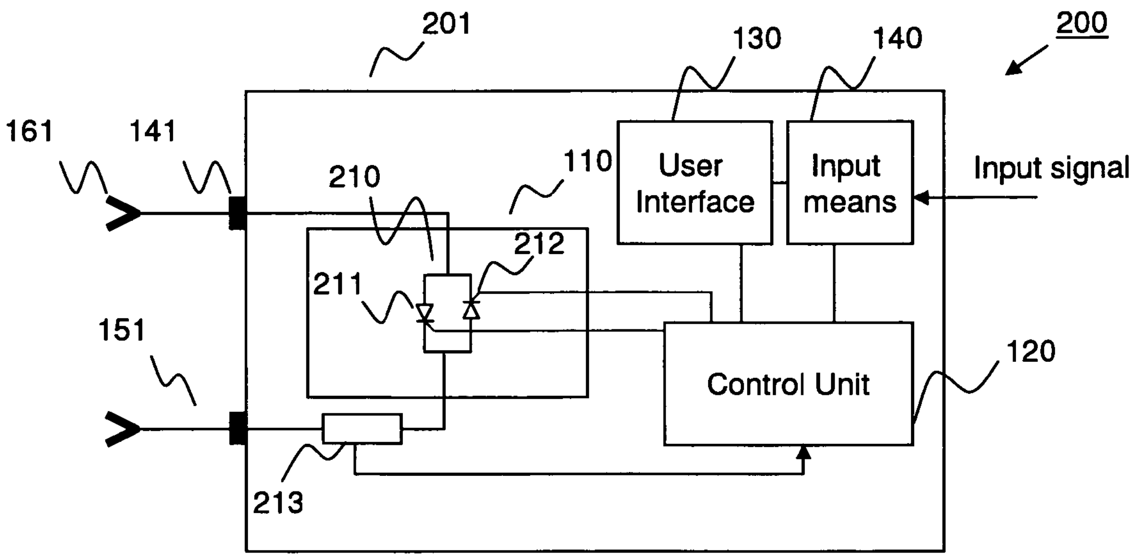
200
201
130
140
161
141
User
Interface
Input
means
Input signal
210
110
212
211
151
120
Control Unit
213

Fig. 2

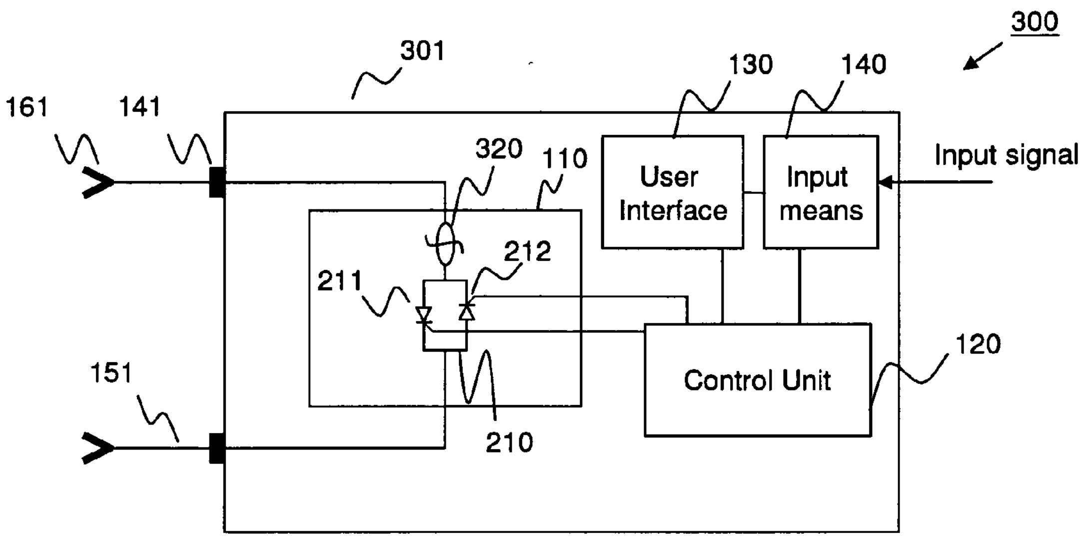
300
301
130
140
161
141
320
110
User Interface
Input means
Input signal
212
211
120
Control Unit
151
210

Fig. 3

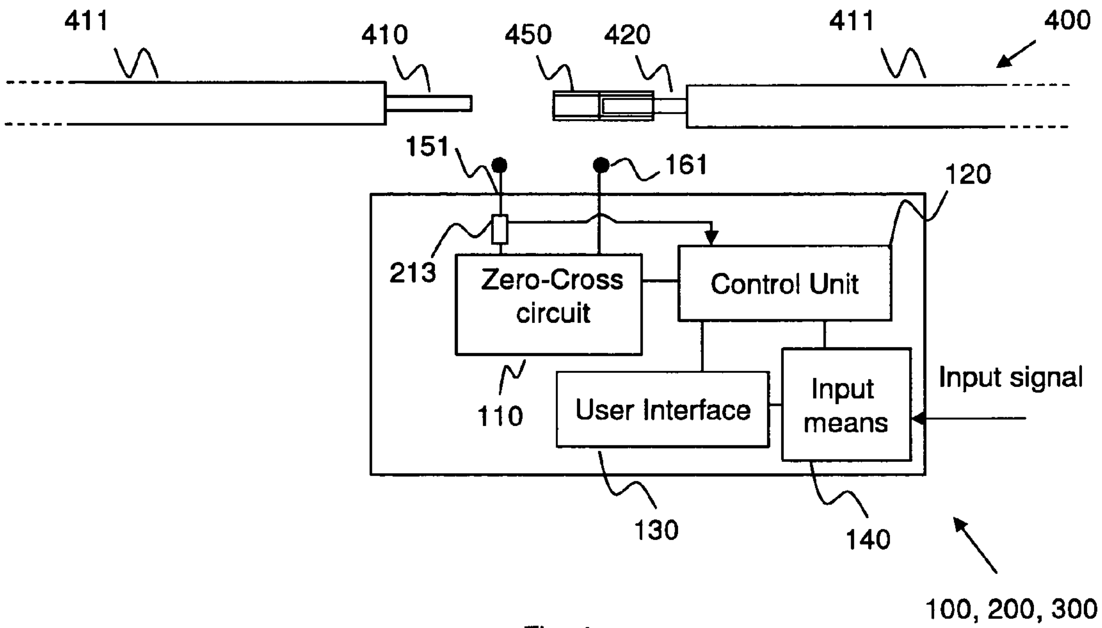
411
410
450
420
411
400
151
161
120
213
Zero-Cross circuit
Control Unit
110
User Interface
Input means
Input signal
130
140
100, 200, 300

Fig. 4

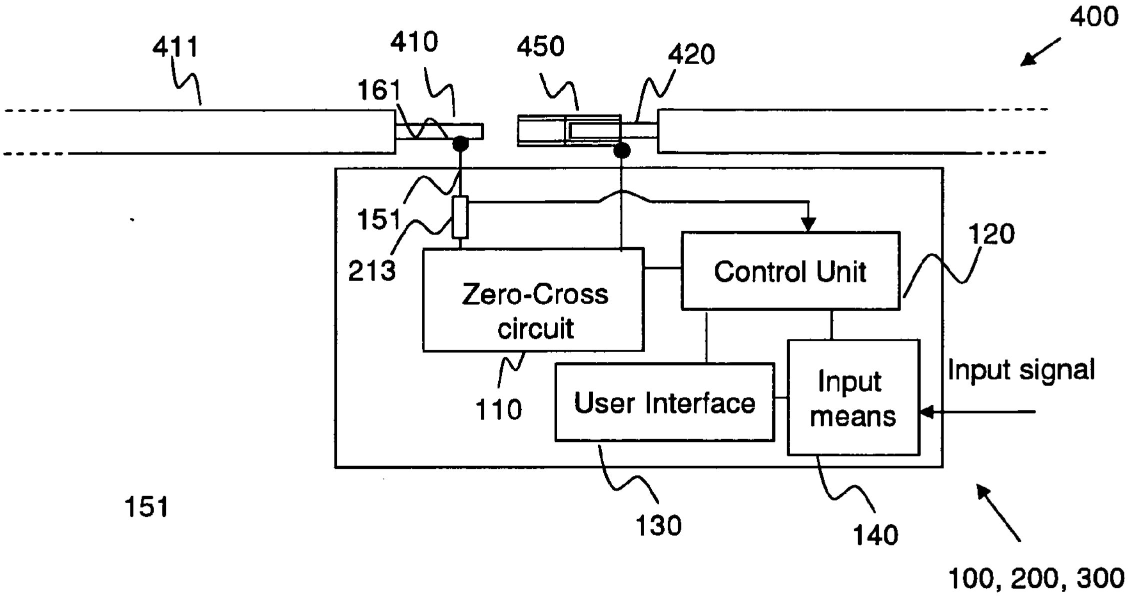
400
411
410
450
420
161
151
213
120
Control Unit
Zero-Cross
circuit
110
User Interface
Input
means
Input signal
130
140
100, 200, 300
151

Fig. 5

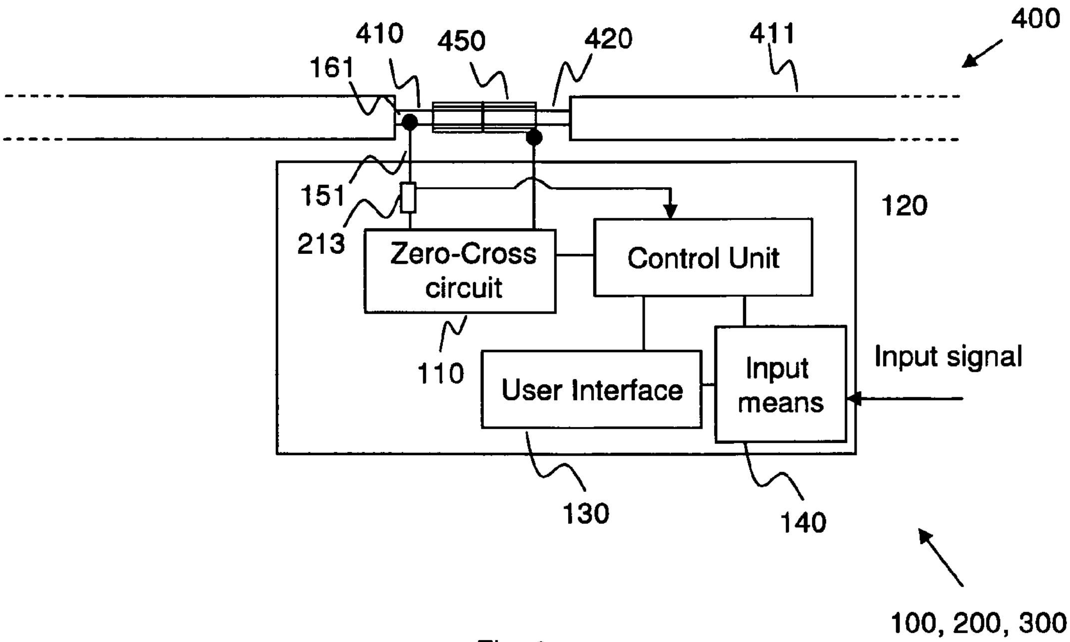
400
410
450
420
411
161
151
213
120
Zero-Cross
circuit
Control Unit
110
User Interface
Input
means
Input signal
130
140
100, 200, 300

Fig. 6

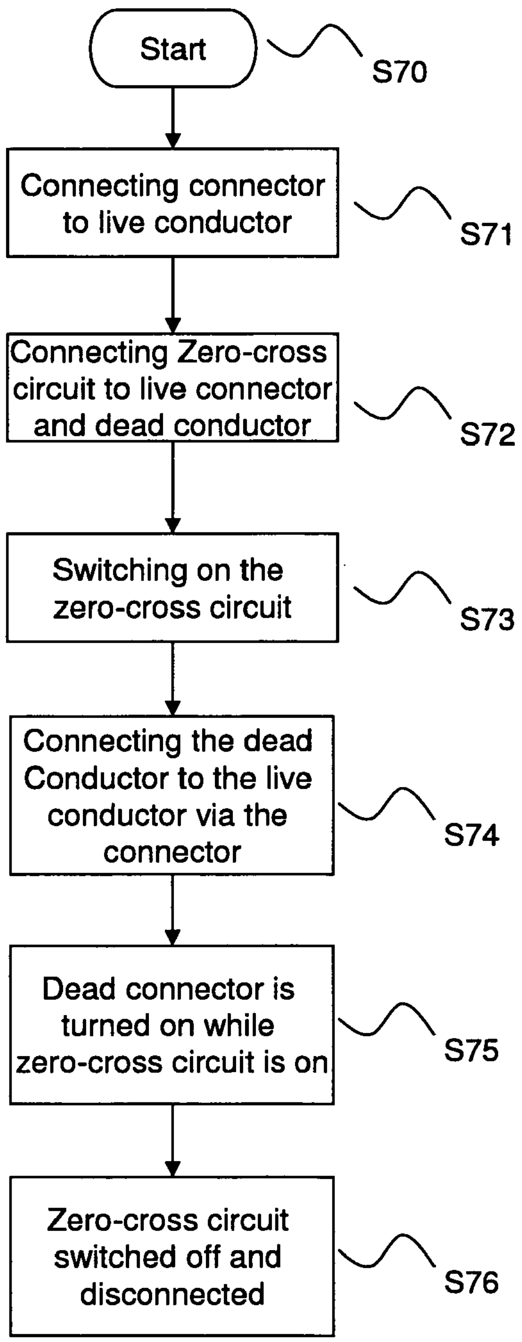
Start
S70
Connecting connector to live conductor
S71
Connecting Zero-cross circuit to live connector and dead conductor
S72
Switching on the zero-cross circuit
S73
Connecting the dead Conductor to the live conductor via the connector
S74
Dead connector is turned on while zero-cross circuit is on
S75
Zero-cross circuit switched off and disconnected
S76

Fig. 7

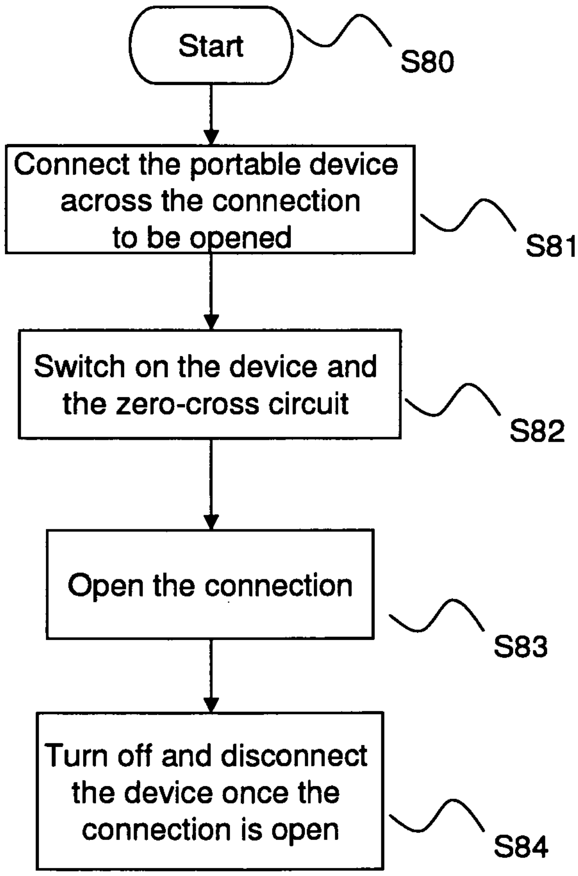
Start
S80
Connect the portable device across the connection to be opened
S81
Switch on the device and the zero-cross circuit
S82
Open the connection
S83
Turn off and disconnect the device once the connection is open
S84

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 11 00 7967

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 5 818 710 A (LEVAN SUU MAURICE [FR]) 6 October 1998 (1998-10-06) * the whole document * -----	1,8,10 2-4,11, 12,14	INV. H01H9/54
Y	US 3 388 295 A (JOHN MISENCIK ET AL) 11 June 1968 (1968-06-11) * figures * -----	2-4,11, 12,14	
A,D	US 2008/048807 A1 (YAO LI [CN] ET AL) 28 February 2008 (2008-02-28) * figure 3 * -----	1,10	

TECHNICAL FIELDS SEARCHED (IPC)

H01H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	1 March 2012	Socher, Günther

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 00 7967

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01-03-2012

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US 5818710	A	06-10-1998	NONE	
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			US 2008048807 A1	28-02-2008

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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- US 20080048807 A1 **[0007]**
- GB 2010052151 W **[0039]**
- EP 11003205 A **[0054] [0055] [0057]**