

ELECTRICITY SUPPLY OVER-VOLTAGE PROTECTION DEVICE

Field of the invention

The invention relates generally to the supply of electricity. In particular, the invention relates to over-voltage protection of electricity supply.

Background

Electricity has for many years pervaded our lives both at home and at work and plays a vital role in many homes, workplaces, and industries. Without electricity, electrically powered appliances and equipment become inoperable.

The integrity of electricity supply is especially critical in industrialized countries that depend heavily on industrial machinery powered by electricity. In such countries, the occurrence of a power failure may in extreme circumstances adversely affect the countries' industrial activities. Similarly, a power failure affecting homes and workplaces may also cause many inconvenient situations arising from inoperable electrical appliances and equipment.

Similarly, other electrical faults may occur during the supply of electricity to homes, workplaces, and industries, which may cause problems that range from mere inconveniences to adverse situations. One example of such a fault is a voltage surge or over-voltage situation. This means that the electricity supply has suddenly increased from the nominal electricity supply voltage level to an undesirable voltage level that may cause damage to electrical appliances and equipment.

Electricity is supplied to homes, workplaces and industries through electrical cables, wires and the like electrical conductors. Electricity is typically supplied to premises such as homes and workplaces such as offices through a pair of conductors

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commonly known as the live and neutral conductors. In such cases, the electricity supply may either originate from a single-phase electricity generator or one phase of a polyphase electricity generator such as a three-phase electricity generator. In other workplaces and industries where high-power machinery is in use, three-phase electricity supply is typically provided.

The live and neutral conductors bringing electricity supply to homes and offices typically lead to electrical distribution points and thence to electricity supply points such as electrical wall sockets from which electricity is supplied through a pair of connectors at each electrical wall socket. Typically, these electrical wall sockets are also provided with a third connector known as earth or ground connector. The earth connectors provide electrical connections with good electrical conductivity between the electrical appliances and equipment that are plugged into the electrical wall sockets and the Earth. Such electrical connections are usually made between the chassis or metal cover of electrical appliances and equipment and the Earth so that any electric current leaking to the chassis or metal cover is diverted to the Earth through the earth connection. The diversion protects anyone who touches the chassis or metal cover during the electric current leakage. Consequently, the leakage electric current flows through the Earth and returns to the source of the electricity supply.

Electricity supply conductors are sometimes laid underground. In such circumstances, excavation is necessary for accessing the underground electrical conductors for maintenance or repair purposes. Occasionally, the excavation work may cause damage to the underground electrical conductors. If during such excavation work a live conductor is severed, a power failure occurs. However, if during the excavation work a neutral conductor is severed, the electricity supply voltage level may reach over-voltage situations if the severed neutral conductor is one of several conductors providing polyphase electricity supply. Such over-voltage situations arise if the common neutral conductor of the polyphase electricity supply is severed and in the affected premises the representative loads connected to the different phases of the polyphase electricity supply do not draw the same power.

The electricity supply voltage level of one phase may reach undesirably high electricity supply voltage levels that may cause damage to the loads connected to that phase. The loads include electrical appliances and equipment that are plugged into the electrical wall sockets that are switched on. Examples of such damage to loads may include burnt transformers and motors of electrical appliances and equipment.

Also, when an electrical fault has occurred at an electricity supply source such as a power station which consequently, for example, generates electricity supply voltage levels exceeding the nominal value, electrical appliances and equipment may similarly be damaged if the electricity supply voltage level increases are sufficiently high.

Although electricity supply protection devices such as Earth Leakage Circuit Breakers (ELCBs) and Micro-circuit Breakers (MCBs) are commonly installed at electrical distribution points of premises for detecting and preventing excessive earth leakage and electric current overloading, respectively, the above problems arising from over-voltage situations are not addressed by such devices. ELCBs detect excessive electric currents flowing in the earth connections and thereafter “break” electrical circuits or cut the electricity supply to the electrical wall sockets protected by these ELCBs when there is earth leakage. MCBs detect excessive electric currents drawn from the electrical wall sockets in electric current overload situations and similarly break the electrical circuits protected by these MCBs. Where over-voltage situations occur and inductive loads such as transformers or motors in electrical appliances and equipment are plugged into the electrical wall sockets, the MCBs are slow in detecting excessive electric currents accompanying high electricity supply voltage levels. This is because increases in electric currents lag increases in electricity supply voltage levels in inductive loads. Hence the sudden increases in electricity supply voltage levels may have already caused damage to the electrical appliances and equipment with inductive loads before the MCBs detect the corresponding electric current overload. In the same situations, the ELCBs are unable to detect the fault because there would not be any earth leakage.

Figure 1 shows a conceptual representation of a three-phase electricity generator 100 supplying electricity to premises where there is a representative electrical load receiving power from each of the red 102, yellow 104, and blue 106 phases. In certain circumstances, all three phases of electricity supply are provided to, for example, a single localized area such as a factory floor where heavy machinery with three-phase motors operate using only three-phase electricity supply. In some other circumstances, the three-phase electricity supply is distributed where electricity supply from each phase is provided to, for example, a localized area such as each floor in a three-floor building.

The three-phase electricity supply is provided to the factory floor or the three-floor building through four electrical conductors. A red-phase or R conductor 114 carries the red-phase electricity supply, and a yellow-phase Y conductor 116 carries the yellow-phase electricity supply, and a blue-phase B conductor 118 carries the blue-phase electricity supply. The electric current for each of the three phases (hereinafter known as a color phase) returns to the three-phase electricity generator 100 through a single common electrical conductor known as a neutral N conductor 120. Therefore in the case of the three-floor building, each color phase electricity supply is provided to each floor in the three-floor building.

On each floor of a building, which may consist of apartment or office units, there are electrical appliances and equipment that are collectively represented by a single electrical load. For example, a Load_R 108 represents the electrical load of a first floor, a Load_Y 110 represents the electrical load of a second floor, and a Load_B 112 represents the electrical load of a third floor.

If the electrical loads Load_R 108, Load_Y 110, and Load_B 112 are electrically equivalent, the loads are considered balanced. In such situations, the N conductor 120 carries little or no electric current back to the three-phase electricity generator 100.

However, if the loads Load_R 108, Load_Y 110, and Load_B 112 are not electrically equivalent, the loads are then considered unbalanced. For example, an extreme scenario may be where Load_B 112 is not present because the third floor is not occupied, and the load Load_R 108 has greater impedance value than the load Load_Y 110. In such circumstances, damage to the electrical appliances and equipment on these floors may occur if a fault has occurred that causes an open circuit at any point along the common N conductor 120. Because the N conductor 120 can no longer carry the electric current from any color phase electricity supply back to the three-phase electricity generator 100, the electricity supply is consequently applied across the loads Load_R 108 and Load_Y 110 in series. The resultant electricity supply voltage level due to the phase difference between the red-phase electricity supply and the yellow-phase electricity supply, which is for example $\sqrt{3} \times 230$ volts (rms) $\simeq$ 400 volts (rms) in countries using a 230 volts (rms) electricity supply, is therefore applied across the series loads Load_R 108 and Load_Y 110. As a result, the loads Load_R 108 and Load_Y 110 form a voltage divider and where there is a large difference in the electrical values of the loads, a proportionately large difference in the impedance supply voltage level is additionally applied across each load. In extreme circumstances the difference may be large enough to give rise to an over-voltage situation and therefore result in damage to electrical appliances and equipment on the respective floors.

There is therefore clearly a need for a device for alleviating or overcoming the disadvantages associated with the foregoing the over-voltage situations.

Summary

In accordance with a first aspect of the invention, there is provided a device connectable to live and neutral conductors providing electricity supply and to an earth connection for detecting an electricity supply voltage level increase. The device includes a voltage increase detector for detecting the electricity supply

voltage level increase. The device also includes an electric current diversion means actuable upon detection by the voltage increase detector for diverting an electric current from the electricity supply to the earth connection.

In accordance with a second aspect of the invention, there is provide a method for disconnecting electricity supply provided through live and neutral conductors upon detecting an electricity supply voltage level increase. The method includes the step of detecting said electricity supply voltage level increase. The method also includes the step of diverting an electric current from the electricity supply to an earth connection upon detection of the electricity supply voltage level increase.

Brief description of the drawings

Embodiments of the invention are described hereinafter with reference to the drawings, in which:

Figure 1 is a conceptual representation of a prior art three-phase electricity generator providing three-phase electricity supply and the electrical connections between the three-phase electricity supply and loads in premises such as homes, offices, or factories;

Figure 2 is an electrical circuit diagram depicting the electrical connections between the electricity supply provided by either a single-phase electricity generator or one phase of a three-phase electricity generator, an ELCB, an over-voltage protection device in accordance with the embodiments of the invention, and loads in a localized area such as a home or an office;

Figure 3 is a block diagram depicting the modules in the over-voltage protection device, the ELCB module, and the electricity supply module, all shown in Figure 2, electrically interconnected to form a over-voltage protection system;

Figure 4 is a electrical circuit diagram depicting components in the over-voltage protection device electrically interconnected according to a preferred embodiment of the invention; and

Figure 5 is a conceptual electrical representation of an opto-coupled isolator used in the electrical circuit shown in Figure 4.

Detailed description

An over-voltage protection device and system, and a method for disconnecting electricity supply in over-voltage situations are disclosed. The electricity supply originates either from a single-phase electricity generator or one phase of a polyphase electricity generator such as a three-phase electricity generator.

Damage to electrical appliances and equipment may occur in over-voltage situations. Electricity supply protection devices such as ELCBs and MCBs as such are not designed or suited for addressing such problems. A need therefore arises for an over-voltage protection device that protects electrical appliances and equipment in over-voltage situations.

In particular, an over-voltage protection device (hereinafter generally referred to as a device) is disclosed where the device is used in a localized area or premises for sensing increases in the electricity supply voltage level. Upon detection of an increase considered undesirable for possibly causing damage to any electrical appliances and equipment powered by the electricity supply in the premises, the device diverts the electric current from the electricity supply to the earth connection to simulate an earth leakage. An ELCB at the electrical distribution point in the premises detects the earth leakage and as a result disconnects the electricity supply.

A device 200 for addressing and ameliorating problems arising from over-voltage situations which cause damage to electrical appliances and equipment (e.g., in each apartment or office unit on each floor in the exemplified three-floor building in

Figure 1) is shown in Figure 2. Alternatively, each floor may be provided with single-phase electricity supply and due to a fault occurring at the single-phase electricity generator, reaches over-voltage situations thereby causing such damage. The electricity supply is provided to the unit through a local electrical distribution point, which distributes the electricity supply through a local electrical circuit 202. A representative electricity supply voltage level is shown in Figure 2, however, the embodiments of the invention can be practiced with other voltage levels. The device 200 is connected to the local electrical circuit 202, and preferably to the portion of the local electrical circuit 202 protected by an ELCB 204 for earth leakage. The ELCB 204 is a point through which the earth connections between each electrical wall socket (not shown) protected by the ELCB 204 and the Earth converge. Therefore, all electric currents, if any, resulting from earth leakage caused by a faulty electrical appliance or equipment plugged into the electrical wall sockets flow through the ELCB 204 before flowing to the Earth through an Earth point at the local electrical distribution point. The Earth point provides an earth connection between the converged earth connections at the ELCB 204 and the Earth. For distinguishing the earth connection between the ELCB 204 and the Earth point and the earth connections between the ELCB 204 and the electrical wall sockets, the latter connections are hereinafter referred to as ground connections.

The device 200 is connected to both live and neutral conductors 206 and 208 in the local electrical circuit 202. The live and neutral conductors 206 and 208 may be electrically connected to the R conductor 114 or Y conductor 116 and the N conductor 120, respectively, in the case of the exemplified three-phase electricity supply. Alternatively, the live and neutral conductors 206 and 208, respectively, may be electrically connected to the live and neutral conductors of a single-phase electricity supply. The device 200 is also connected to the ELCB 204 via a ground connection 210.

The device 200 is preferably built from standard miniature electrical components soldered to a printed circuit board (PCB) whereby the shape and size of the device 200 is configured to fit into the casing of a typical electrical three-pin plug of an

electrical appliance or equipment. A load 212 represents the electrical appliance or equipment. Typically, the electrical three-pin plug houses a fuse placed in the electrical path of the live conductor 206 and is a point of electrical contact between the electrical wall socket and the electrical appliance or equipment. Two of the pins on the electrical three-pin plug correspond with the live and neutral conductors 206 and 208 when connected to the electrical wall socket, and the third pin corresponds with the ground connection 210. The device 200 has electrical connectors for making electrical contacts with the pins in the electrical three-pin plug corresponding to the live and neutral conductors 206 and 208, and the ground connection 210 when connected to the electrical wall socket. In this case, the device 200 need only be fitted to one electrical three-pin plug for the device 200 to provide electricity supply over-voltage protection. Other electrical wall sockets supplying electricity to other electrical appliances and equipment represented by a load 214 being protected by the ELCB 204 are protected by the device 200 as well.

Alternatively, the device 200 may be built to fit into the ELCB 204 casing, where electrical connections are made between the device 200 and the electrical connections to the live and neutral conductors 206 and 208, and the ground connection 210 within the ELCB 204. As long as the device 200 is connected to the live and neutral conductors 206 and 208, and the ground connection 210 within the local electrical circuit 202, the device 200 functions to protect any electrical appliance or equipment connected to the local electrical circuit 202 in over-voltage situations regardless of the form of the device 200.

The operation of the device 200 is described in more detail with reference to Figure 3. The electricity supply to the device 200, represented by an alternating current (AC) input module 302, undergoes rectification by a direct current (DC) rectifier module 304. The rectified electricity supply is provided as input to a voltage divider module 306 and a DC power supply module 308. The voltage divider module 306 taps from the rectified electricity supply and provides a proportionately reduced signal according to a predetermined voltage division ratio as input to a voltage comparator module 310. The DC power supply module 308 converts the rectified

electricity supply into DC voltage supply for powering the voltage comparator module 310. The voltage comparator module 310 is also connected to a voltage reference module 312 which provides a predetermined reference voltage with which the input from the voltage divider module 306 is compared. When the voltage comparator module 310 detects an over-voltage situation through the comparison between the input from the voltage divider module 306 and the reference voltage from the voltage reference module 312, the voltage comparator module 310 generates a trigger signal. Such a trigger signal is provided as an input to a switch module 314 which includes a switch and a current limiting device for providing an electrical path between the live conductor 206 and the ground connection 210. The trigger signal closes the switch thereby electrically connecting the live conductor 206 to the ground connection 210. An electric current limited by the current limiting device thus flows through the ground connection 210 to the ELCB 204. Upon detection of the electric current, the ELCB 204 breaks the electrical path of the live conductor 206 providing electricity supply to the local electrical circuit 202, thereby protecting any electrical appliances or equipment plugged into any electrical wall sockets in the local electrical circuit 202.

The device 200 according to a preferred embodiment of the invention is shown in detail in Figure 4. Figure 4 is an electrical circuit diagram depicting electrical connections between electrical components in the various modules in the device 200 described with reference to Figure 3. The device 200 has a live (L) node 402, a neutral (N) node 404, and a ground (G) node 406. These electrical nodes are connectable to the live and neutral conductors 206 and 208, and the ground connection 210, respectively. Between the L node 402 and the N node 404, a diode D1 408, a resistor R1 410 and a potentiometer P1 412 are connected in series. The anode terminal of D1 408 is connected to L node 402. By doing so, D1 408 provides means for rectifying the electricity supply from L node 402 and N node 404. Therefore, at the junction between D1 408 and R1 410, a half-wave rectified electricity supply is provided. A resistor R2 414 is connected to this junction to tap the half-wave rectified electricity supply. Connected between the other terminal of

R2 414 and N node 404 is an electrolytic capacitor C2 416. A zener diode DZ1 418 is connected in parallel with C2 416. The anode terminal of DZ1 418 is connected to N node 404. By this arrangement, a DC voltage supply is provided in accordance with the reference voltage set by DZ1 418 at the junction 415 between R2 414 and C2 416.

R1 410 and P1 412 form a voltage divider where a proportionately reduced signal is derived from the rectified electricity supply at the junction between D1 408 and R1 410. The proportionately reduced signal is tapped from variable port 420 on the P1 412 with reference to N node 404. A capacitor C1 422 is also connected between the variable port 420 and N node 404.

The proportion by which the signal is reduced is determined by the resistance ratio formed by R1 410 in series with the resistive portion of P1 412 between R1 410 and the variable port 420 and the resistance formed by the resistive portion of P1 412 between the variable port 420 and N node 404.

Between the DC voltage supply junction 415 and the variable port 420, a resistor R5 424 and the collector and emitter of a PNP bipolar junction transistor (BJT) Q1 426 are connected in series. A terminal of R5 424 is connected to the DC voltage supply junction 415 while the other is connected to the emitter of Q1 426. The collector of Q1 426 is connected to the variable port 420 while the base of Q1 426 is connected to the collector of an NPN BJT Q2 428. The base of Q2 428 is connected to the collector of Q1 426 and the variable port 420. A zener diode DZ2 430 is connected to the emitter of Q2 428 at the cathode. The anode of DZ2 430 is connected to N node 404.

One terminal of a resistor R4 432 is connected to the DC voltage supply junction 415. The other terminal of R4 432 is connected to an opto-coupled static switch IC1 433 having at least four pins, namely Pin 434, Pout 436, Pac1 438, and Pac2 440. As conceptually shown in Figure 5, the Pin 434 is internally connected to the anode of an optical diode and the Pout 436 to the cathode. The other pins Pac1 438 and

Pac2 440 are connected to terminals of a bi-directional diode that is functional only in the presence of an optical emission from the optical diode. R4 432 is therefore connected to Pin 434 and the collector of Q2 428 is connected to the Pout 436. A resistor R3 442 connects L node 402 to Pac1 438 while Pac2 440 is connected to G node 406.

In the device 200, the proportionately reduced signal tapped from the variable port 420 is compared with a reference voltage set by DZ2 430. If the difference between the proportionately reduced signal and the reference voltage set by DZ2 430 exceeds the forward biasing voltage of the base-emitter junction of Q2 428, Q2 428 turns on. Hence, the voltage division ratio must be adjusted by varying the variable port 420 so that the moment the electricity supply voltage level exceeds 10% of the nominal value in an over-voltage situation, the difference between the proportionately reduced signal and the reference voltage set by DZ2 430 exceeds the forward biasing voltage. A large current is then pushed into the base of Q2 428 which as a result reaches saturation, and Q1 426 also turns on because of the arrangement of R5 424, Q1 426, and Q2 428. When Q1 426 turns on, a current drawn from the DC voltage supply junction 415 through R5 424 flows through Q1 426 and then into the base of Q2 428, thereby keeping Q2 428 turned on. This is to ensure that Q2 428 remains turned on when the proportionately reduced signal follows the electricity supply voltage level and returns to zero.

When Q2 428 turns on, a current is also drawn from Pout 436. This current is drawn from Pin 434 which originates from the DC voltage supply junction 415 through R4 432. When this current flows through the pins Pin 434 and Pout 436, and therefore the optical diode, optical emission occurs internally within IC1 433 which consequently renders the bi-directional diode between pins Pac1 438 and Pac2 440 functional. Hence, the electric current is diverted from L node 402, at the same time being limited by the resistivity of R3 442, to G node 406. As a consequence, an earth leakage is simulated and the ELCB 204 breaks the local electrical circuit 202. All electrical appliances and equipment receiving electricity supply from the local

electrical circuit 202 are hence disconnected from the electricity supply and are thus protected from any damage consequential from the over-voltage situation.

In the foregoing manner, an over-voltage protection device and system, and a method for disconnecting electricity supply in over-voltage situations are disclosed. In view of the disclosure, one skilled in the art will appreciate that numerous changes and/or modifications can be made without departing from the scope and spirit of the invention.



Claims

1. A device connectable to live and neutral conductors providing electricity supply and to an earth connection for detecting an electricity supply voltage level increase, said device including:

a voltage increase detector for detecting said electricity supply voltage level increase; and

an electric current diversion device actuatable upon detection by said voltage increase detector for diverting an electric current from said electricity supply to said earth connection.
2. The device as in claim 1, wherein said electric current is diverted to an earth leakage circuit breaker through said earth connection.
3. The device as in claim 2, wherein said voltage increase detector includes a voltage sensor for sensing a signal substantially representative of electricity supply voltage levels and providing a sensed signal.
4. The device as in claim 3, wherein said voltage increase detector further includes a voltage referencing means for providing a reference voltage.
5. The device as in claim 4, wherein said voltage increase detector further includes a voltage comparator for comparing said sensed voltage with said reference voltage and providing a trigger signal for actuating said electric current diversion

device upon detection of a predetermined difference between sensed voltage and said reference voltage.



6. The device as in claim 5, wherein said signal substantially representative of electricity supply voltage levels is a rectified signal.

7. The device as in claim 6, wherein said voltage sensor is a voltage divider whereto said rectified signal is applied and said sensed signal is a divided voltage of said rectified signal.

8. The device as in claim 7, wherein said voltage referencing means is a zener diode.

9. The device as in claim 8, wherein said electric current diversion device is a bi-directional static switch for providing a connection between said electricity supply and said earth connection for diverting said electric current, said bi-directional static switch being actuatable by said trigger signal.

10. The device as in claim 9, wherein trigger signal is a driving current provided by a current driver, said current driver actuatable by occurrence of predetermined difference between sensed voltage and said reference voltage.

11. A method for disconnecting electricity supply provided through live and neutral conductors upon detecting an electricity supply voltage level increase, said method including the steps of:

detecting said electricity supply voltage level increase;



diverting an electric current from said electricity supply to an earth connection upon detection of said electricity supply voltage level increase.

12. The method as in claim 11, wherein said diverting step includes the step of diverting said electric current to an earth leakage circuit breaker through said earth connection.

13. The method as in claim 12, wherein said detecting step includes the step of sensing a signal substantially representative of electricity supply voltage levels and providing a sensed signal.

14. The method as in claim 13, wherein said detecting step further includes the step of providing a reference voltage.

15. The method as in claim 14, wherein said detecting step further includes the step of comparing said sensed voltage with said reference voltage and providing a trigger signal for actuating said diverting step upon detection of a predetermined difference between sensed voltage and said reference voltage.

16. The method as in claim 15, wherein said sensing step includes the step of sensing a rectified signal.



17. The method as in claim 16, wherein said sensing step further includes the step of voltage-dividing said rectified signal and providing a divided voltage of said rectified signal.

18. The method as in claim 17, wherein said voltage referencing step includes the step of providing a voltage reference using a zener diode.

19. The method as in claim 18, wherein said diverting step further includes the step of diverting said electric current using a bi-directional static switch, wherein said bi-directional static switch provides a connection between said electricity supply and said earth connection for diverting said electric current and is actuable by said trigger signal.

20. The method as in claim 19, wherein said comparing step includes the step of providing a driving current from a current driver, said current driver actuable by occurrence of predetermined difference between sensed voltage and said reference voltage.