GFCI

Replacing 2-wire Ungrounded Receptacles

Death from electrocution can occur in less than 1/6th of a second from a touch potential of 50 volts with as little as 50 milliamperes (0.050 amperes) current flow through the human body. To protect against electrical shock and electrocution, it is critical that overcurrent protection devices or the switch contacts of GFCI devices open in less than 0.17 of a second, Figure 1.

Opening Circuit Overcurrent Protection Device to Clear Line-to-Ground Fault

The danger of an electric shock from energized metal parts of an electrical system can be removed by the opening of the circuit's overcurrent protection device (circuit breaker or fuse). The time it takes the protection device to open and remove dangerous voltage is inversely proportional to the magnitude of the fault current. This means that the higher the fault current amperes, the less time it will takes for the overcurrent device to open and remove dangerous voltage. The voltage of the fault and the impedance of the fault current path* determines the magnitude of the ground-fault current. This ampere value can be determined by the formula: I = E/Z

I = fault-current, E = Line-to-ground voltage, Z = Impedance of the fault-current path.

*The impedance of the fault current path equals the sum of the impedances of the power supply; the phase conductors, the ground-fault, and the fault-current return path, Figure 2.

To quickly remove dangerous voltage from a line-to-ground fault, the impedance of the fault current path must allow the fault current amperes to rise to a value of at least 5 times and preferably 10 times the ampere rating of the circuit overcurrent protection device [250-2(d)]. For example, a 100 ampere protected load is located 175 feet from the panelboard and it is wired with No. 3. The equipment grounding conductor for this circuit is No. 8, which meets the NEC requirements as listed in Table 250-122. Under this condition a line-to-ground fault will quickly be removed, because the impedance of the fault current path* permits the fault current amperes to rise to at least 5 times the rating of the 100 ampere overcurrent device, Figure 3:

*****For simplicity, the impedance of the power supply, the feeder conductors and the fault are not included in this example.

For the metal parts of an electrical system to be safe from dangerous touch potential, the electrical system must be effectively grounded so that the overcurrent protection device will open quickly. This is accomplished by bonding the metal parts of the electrical system together to form the equipment grounding conductor [250-118] and then bonding the equipment grounding conductor to the power supply grounded (neutral) conductor at either the service equipment or at the source of a separately derived system [250-2(d)], Figure 4.

The earth cannot be used to provide the low impedance path to clear a line-to-ground fault because its impedance (as it relates to a fault current) will never be less than 50 ohms and likely, it will be above 100 ohms. If the earth were used for equipment grounding, insufficient fault current would flow (less than 1 ampere for a 120 volt line-to-ground fault) and the circuit's overcurrent protection device would remain closed. The result; metal parts of the circuit would remain energized with dangerous touch potential [250-2(d)].

Author's Comment: The resistance of a grounding electrode as determined by the 3-pole fall of potential method is the resistance of the earth between the grounding electrode and the meters voltage test stake. This value could be 3 ohms or less, but it *is not the impedance of the ground-fault return path* and it cannot be used to determine the amperes of a line-to-ground fault. For more information on this subject go to: www.mikeholt.com/Newsletters/Newsletters.htm, Figure 5/6.

Ground-Fault Circuit-Interrupter (GFCI)

A ground-fault circuit-interrupter is the only protection device that can be used to protect against electric shock from an energized conductor. In addition, a GFCI protection device can be used to protect persons against electric shock from energized metal parts that are not effectively grounded. GFCI protection can be incorporated into receptacles, circuit breakers, cord sets, and other types of devices, Figure 6/7.

A GFCI protection device operates on the principle of monitoring the imbalanced current between the ungrounded (hot) and grounded (neutral) conductors. In a typical 2-wire circuit, the current in amperes returning to the power supply will be the same as the current leaving the power supply (except for small leakage). If the difference between the current leaving and returning through the current transformer of the GFCI protection device is 5 milliamperes (+ or – 1 milliampere), the solid-state circuitry activates the shunt trip feature to open the switching contacts of the GFCI, thereby de-energizing the circuit, Figure 7/8.

WARNING: Sever electric shock or death can occur if a person touches the energized (line or hot) and neutral conductor at the same time, even if the circuit is GFCI protected. This is because the current transformer within the GFCI protection device does not sense an imbalance between the departing and returning current and the switching contacts remain closed, Figure 8/9.

WARNING: According to a study (based on data accumulated by the American Society of Home Inspectors) published in the November/December, 1999 issue of the *IAEI News*, out of 1,583 GFCI circuit breakers tested, 21% had failed. Out of 4,585 GFCI receptacles tested, 19% had failed. The failures were primarily attributed to damage from short circuits and voltage surges (lightning and other transients) to the metal oxide varistors (MOV) that are used for built-in surge suppression. In areas of high lighting activity such as Southwest Florida, the failure rate for GFCI circuit breakers was over 57%!

When a GFCI protection device fails, the switching contacts remain closed and the device will continue to provide power without GFCI protection. A new GFCI receptacle from *Leviton Manufactures* de-energized the circuit if the GFCI protection feature fails. This new receptacle, which is listed by UL, is not yet available in the market place. For more information go to: www.levition.com.

Replacing Receptacles to Meet the NEC

The NEC requires receptacles installed on 15 and 20 ampere branch circuits to be of the grounding-type and it requires the grounding contacts of those receptacles to be effectively grounded to the branch circuit equipment grounding conductor [210-7]. However, the *Code* allows the installation of any of the following installations when replacing a 2-wire nongrounding-type receptacle where no ground exists in the outlet box [210-7(d)(3)], Figure 9/10:

(a) Replace the 2-wire receptacle with another 2-wire receptacle.

(b) Replace the 2-wire receptacle with a GFCI-type receptacle and marked the receptacle with the words “No Equipment Ground.”

(c) Replace the 2-wire receptacle with a grounding-type receptacle where protected by a GFCI protection device (circuit breaker or receptacle). Since the grounding terminals for the receptacles are not grounded, the receptacles must be marked with the words “GFCI Protected” and “No Equipment Ground.”

A grounding-type receptacle that is GFCI protected *without an equipment grounding conductor* is a safer installation than a grounding-type receptacle with an equipment grounding conductor (if GFCI protection is not provided). This is because the GFCI protection device will clear a ground-fault when the fault-current is 5 milliamperes (+ or – 1 milliampere), which is less than the current level necessary to cause serious electric shock or electrocution, Figure 10/11.

A grounding-type receptacle without a ground is a safe installation as long as the GFCI protection circuitry within the device has not failed from shorts and voltage transients. To insure proper GFCI protection, test the GFCI monthly in accordance with the manufactures instructions and if the GFCI test does not operate properly, replace the GFCI protection device.

Author’s Comment: The equipment grounding conductor serves no purpose in the operation of a

GFCI protection device, and therefore it has no effect on the function of the GFCI test-button.

Note: When GFCI protection is not provided, Section 250-130(c) allows nongrounding-type receptacle to be replaced with a grounding-type receptacle at an outlet box that does not contain an equipment grounding conductor, if the grounding contacts of the receptacle are bonded to any one of the following locations, Figure 11/12:

(1) Grounding electrode system [250-50]

(2) Grounding electrode conductor

(3) Panelboard equipment grounding terminal

(4) Grounded service conductor

See Section 250-146 on the proper method of grounding receptacles and see Section 250-148 on the proper method of terminating equipment grounding conductors within receptacle outlet boxes.

Author's Comment: The orientation of the grounding terminal on a receptacle is not specified in the NEC. The ground terminal can be up, down, right or left. Proposals to the NEC to specify the mounting position of the grounding terminal were all rejected.

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