CHAPTER 8

GROUNDING

8-1. Ground maintenance.

The term grounding implies an intentional electrical connection to a reference conducting body, which may be earth (hence the term ground), but more generally consists of a specific array of interconnected electrical conductors. The resulting circuit is often referred to by several terms, such as: ground plane, ground grid, mat or ground system. Grounding systems should be serviced as needed to ensure continued compliance with electrical and safety codes, and to maintain overall reliability of the facility electrical system. Action must be initiated and continued to remove, or reduce to a minimum, the causes of recurrent problem areas. When possible, maintenance inspections should be performed at times which have the least affect on user activities. The complexity of ground systems and the degree of performance expected from such systems is growing all the time. Maintenance or shop personnel are encouraged to become familiar with Article 250 of the National Electrical Code (NEC), which deals with grounding requirements and practices.

8-2. Types of grounding systems.

Six (6) types of grounding systems will be described. They are static grounds, equipment grounds, system grounds, lightning grounds, electronic (including computer) grounds and maintenance safety grounds. All of these systems are installed similarly. However, their purposes are quite different. Some of the systems carry little or no current with no freed frequency. Others carry small to moderate currents at 50 or 60 Hz. Still others must be able to carry currents over a very broad range of frequencies in order to be considered effective. Most grounding system troubles are caused by one of two problems: 1) loss of effectiveness due to poor maintenance and, 2) inadequate ground system for the degree of performance expected.

a. Static grounds. A static ground is a connection made between a piece of equipment and the earth for the purpose of draining off static electricity charges before a spark-over potential is reached. The ground is applied for more than just the comfort of the equipment operator. The possibility of an explosion ignited by an electrical spark must be considered. Dry materials handling equipment, flammable liquids pumps and delivery equipment, plastic piping systems, and explosives storage areas all need static ground protection systems installed and functioning properly. Static ground systems are generally not called upon to conduct much current at any given frequency. Smaller gauge, bare conductors, or brushes with metallic or conductive bristles make up most parts of the static ground system.

b. Equipment grounds. An equipment ground pertains to the interconnection and connection to earth of all normally non-current carrying metal parts. This is done so the metal parts with which a person might come into contact are always at or near zero volts with respect to ground thereby protecting personnel from electric shock hazards. Equipment grounding consists of grounding all noncurrent-carrying metal frames, supports and enclosures of equipment. All these metallic parts must be interconnected and grounded by a conductor in such a way as to ensure a path of lowest impedance for the flow of ground fault current from any line to ground fault point to the terminal at the system's source. An equipment grounding conductor normally carries no current unless there is an insulation failure. In this case the fault current will flow back to the system source through the equipment grounding conductors to protect personnel from electrical shock. The equipment grounding conductor must never be connected to any other hot lines. Equipment grounding systems must be capable of carrying the maximum ground fault current expected without overheating or posing an explosion hazard. Equipment grounds may be called upon to conduct hundreds to thousands of amperes at the line frequency during abnormal conditions. The system must be sized and designed to keep the equipment surface voltages, developed during such abnormal conditions, very low. An example of this system is the bare copper wire (green conductor) connected to the frames of electric motors, breaker panels, outlet boxes, etc., see figure 6-1 for typical equipment grounding. Electrical supporting structures such as metal conduit, metal cable trays or metal enclosures should be electrically continuous and bonded to the protective grounding scheme. Continuous grounding conductors such as a metallic raceway or conduit or designated ground wires should always be in from the ground grid system to downstream distribution switchboards to ensure adequate grounding throughout the electrical distribution system. A typical grounding system for a building containing significant electrical equipment and related apparatus is shown in figure 8-2, The illustration shown depicts three most commonly encountered areas pertaining to the grounding. The grounding grid and grounding body (earth under the building) with the ground rods (electrodes and the water pipe system) are shown. The second part is the conductors associated with the equipment ground. Part of the equipment ground is also formed by the switchgear ground bus.

c. System grounds. A system ground refers to the condition of having one wire or point of an electrical circuit connected to earth. This connection point is usually made at the electrical neutral although not always. The purpose of a system ground is to protect the equipment. This ensures longer insulation life of motors, transformers and other system component A system ground also provides a low impedance path for fault currents improving ground fault relaying selectivity. In a properly grounded system the secondary neutral of a power transformer supplying a building or facility is connected to a transformer grounding electrode. The transformer neutral is a part of the service entrance point which bonds to the grounding electrode system of the building. According to the National Electrical Code (NEC) articles 250-81 and 250-83, metal underground waterpipes, metal building frames, encased electrodes, rods and plates are among the items that can make up the grounding electrode system of a building. The NEC article 250-S3 requires that the size of the grounding electrode iron or steel rod must be at least 5/8 inches in diameter and driven eight feet deep. The resistance of the electrode to ground cannot exceed 25 ohms (NEC 250-84). Otherwise a second electrode should be added and the distance between the two electrodes must be at least six feet. However, in some systems the 25 ohms resistance value cannot achieve the goals of grounding. They require ground resistance values below ten ohms. According to MIL-STD-l88-12A ten ohms ground resistance is acceptable. If the main building load is composed of computers or sensitive electronic equipment, the earth ground resistance should not exceed five ohms. There are many methods of system grounding used in industrial and commercial power systems, the major ones being ungrounded, solid grounding, and low and high resistance grounding (fig 8-3). Technically, there is no general acceptance to use any one particular method. Each type of system grounding has advantages and disadvantages. Factors which influence the choice of selection include voltage level of the power system, transient overvoltage possibilities, types of equipment on the system, cost of equipment, required continuity of service, quality of system operating personnel and safety consideration including fire hazards.

(1) *Ungrounded system. An* ungrounded system is one in which there is no intentional connection between the neutral or any phase and ground. Ungrounded system implies that the system is capacitively coupled to ground. The neutral potential of an ungrounded system under reasonably balanced load conditions will be close to ground potential because of the capacitance between each phase conductor and ground. When a line-to-ground fault occurs on an ungrounded system, the total ground fault current is relatively small, but the voltages to ground potential on the unfaulted phases will be high. If the fault is sustained, the normal line-to-neutral voltage on the unfaulted phases is increased to the system line-to-line voltage (i.e. square root of three (3) times the normal line-to-neutral value). This, over a period of time, breaks down the line-to-neutral insulation and hence results in insulation failure. Ungrounded system operation is not recommended because of the high probability of failures due to transient overvoltages caused by restriking ground faults. The remaining various grounding methods can be applied on system grounding protection depending on technical and economic factors. The one advantage of an ungrounded system that needs to be mentioned is that it generally can continue to operate under a single line-to-ground fault without an interruption of power to the loads.

(2) *Solidly grounded system.* A solidly grounded system is one in which the neutral (or occasionally one phase) is connected to ground without an intentional intervening impedance (fig 8-4). On a solidly grounded system in contrast to an ungrounded system, a ground fault on one phase will result in a large magnitude of ground current to flow but there will be no increase in voltage on the unfaulted phase. Solid grounding is commonly used in low voltage distribution systems. Solid grounding has the lowest initial cost of all Wounding methods. It is usually recommended for overhead distribution systems supplying transformers protected by primary fuses. However, it is not the preferred scheme for most industrial and commercial systems, again because of the severe damage potential of high magnitude ground fault currents. The NEC Article 250-5 (1990) requires that the following classes of systems be solidly grounded:

(a) Where the system can be so grounded that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts.

(b) Where the system is 3-phase, 4-wire, wye-connected in which the neutral is used as a circuit conductor.

(c) Where the system is 3-phase, 4-wire delta-connected in which the midpoint of one phase is used as a circuit conductor.

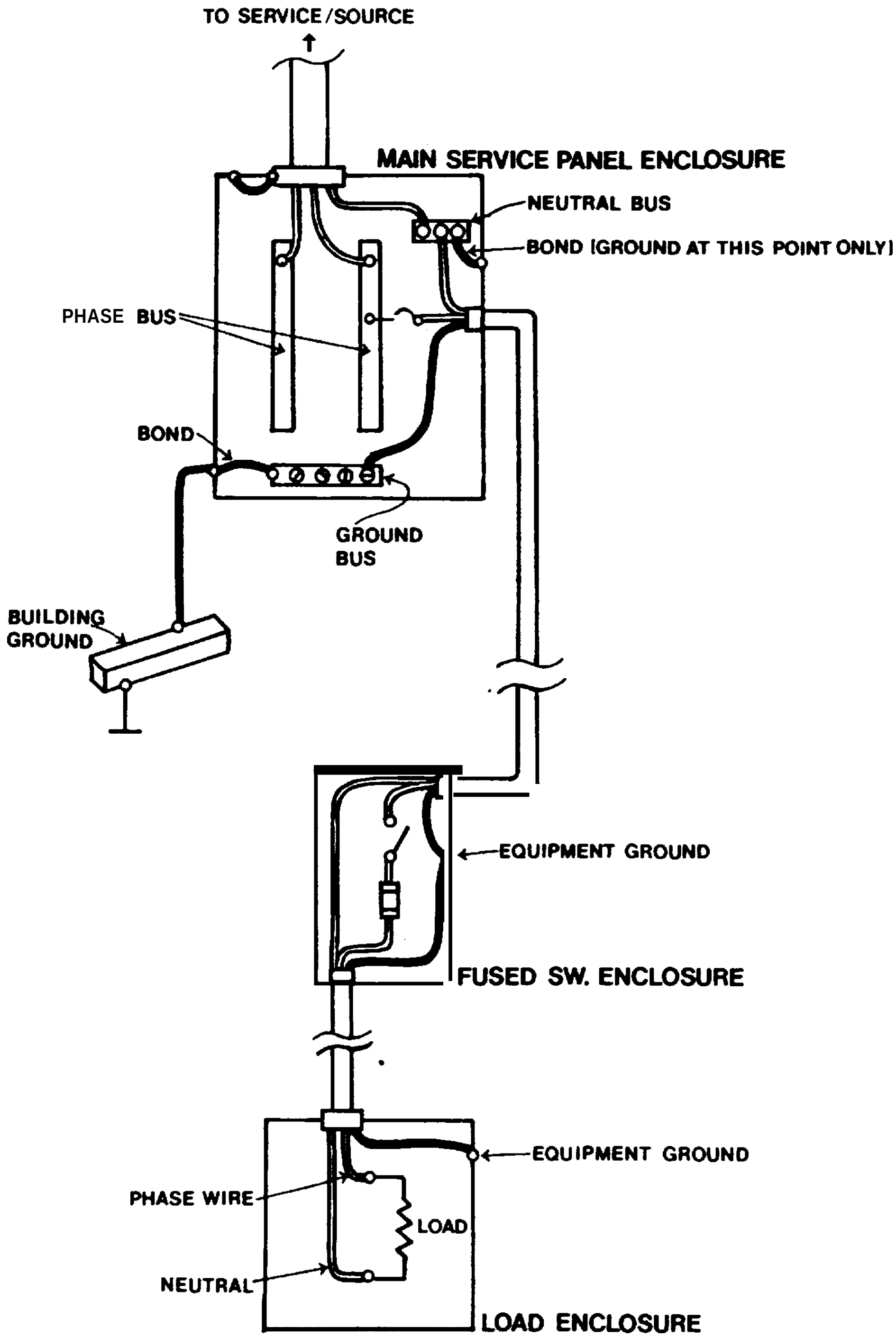


Figure 8-1. Typical Equipment Ground.

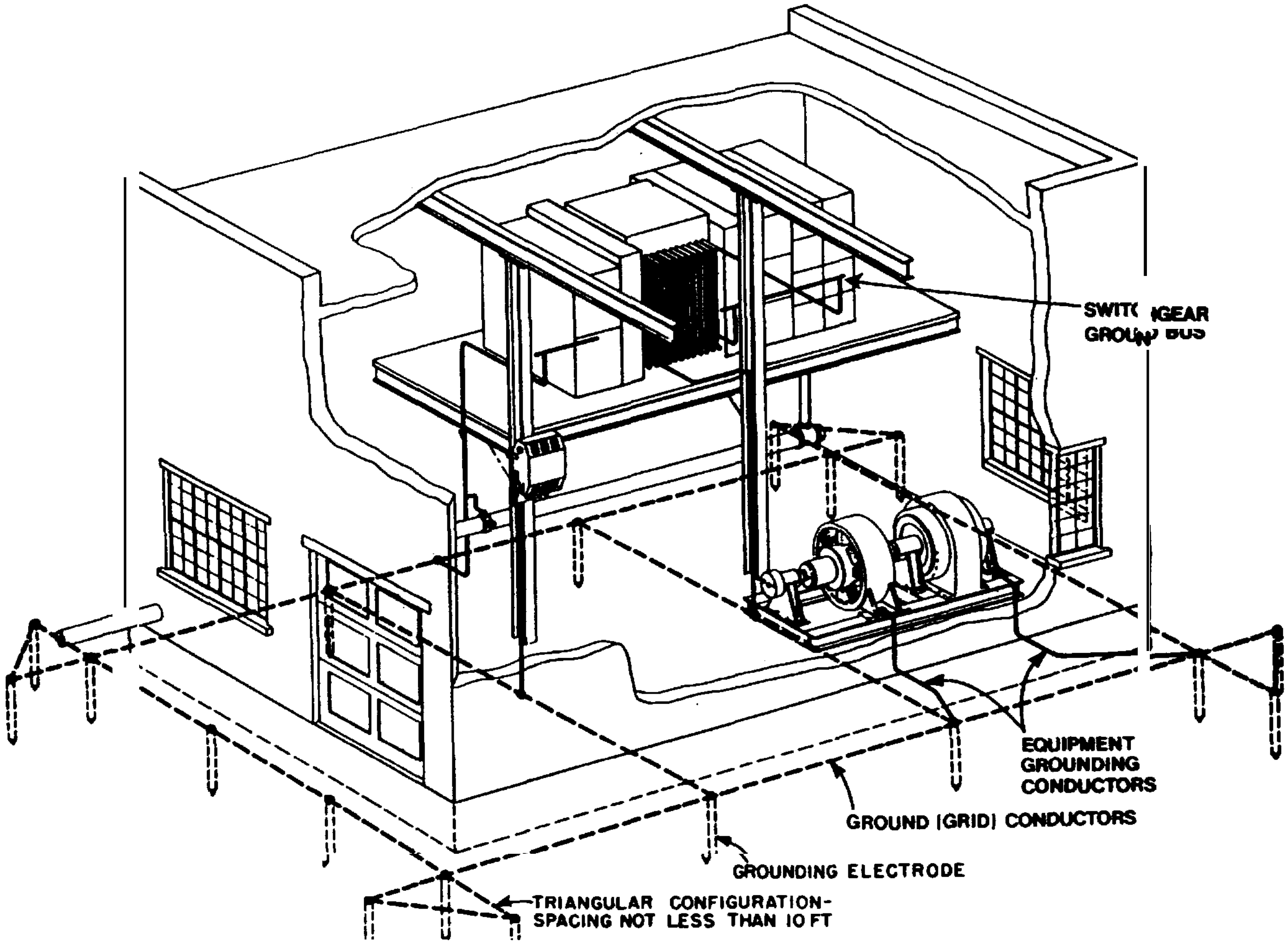
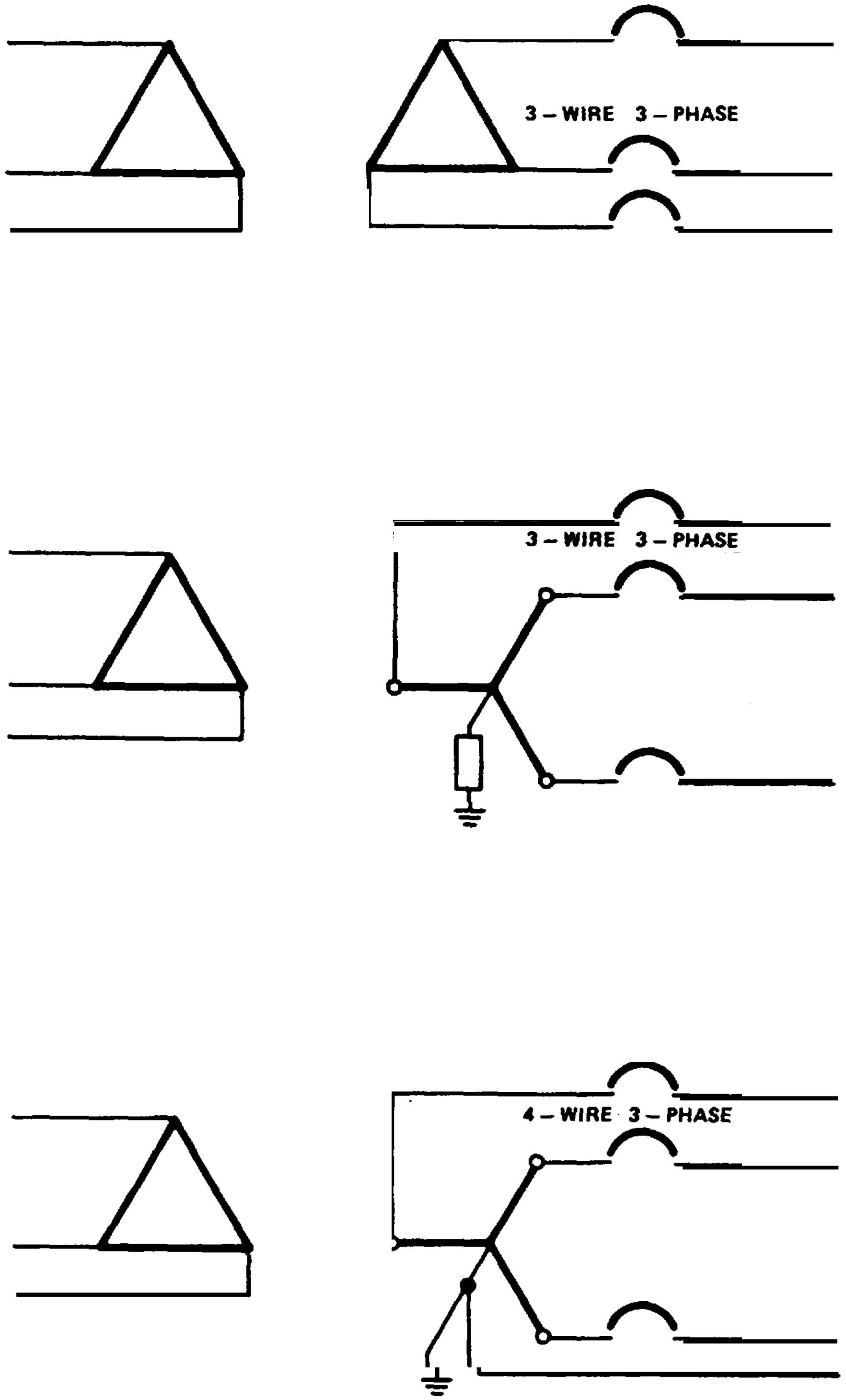


Figure 8-2. Typical grounding system for a building and its apparatus.

(d) Where a grounded service conductor is uninsulated in accordance with the NEC Exceptions to Sections 230-22, 230-30 and 230-41.

(3) *Resistance grounded system.* Limiting the available ground fault current by resistance grounding (fig 6-5) is an excellent way to reduce damage to equipment during ground fault conditions, and to eliminate personal hazards and electrical fire dangers. It also limits transient overvoltages during ground fault conditions. The resistor can limit the ground fault current to a desired level based on relaying needs. At the occurrence of a line-to-ground fault on a resistance grounded system, a voltage appears across the resistor which nearly equals the normal line-to-neutral voltage of the system. The resistor current is essentially equal to the current in the fault. Therefore, the current is practically equal to the line-to-neutral voltage divided by the number of ohms of resistance used. The grounding resistances are rated in terms of current and its duration for different voltage classes.

(a) Low resistance grounding. Low resistance grounding refers to a system in which the neutral is grounded through a small resistance that limits ground fault current magnitudes. The size of the grounding resistor is selected to detect and clear the faulted circuit. Low resistance grounding is not recommended on low-voltage systems. This is primarily because the limited available ground fault current is insufficient to positively operate series trip units and fuses. These trip units and fuses would be dependent upon both phase-to-phase and phase-to-ground fault protection on some or all of the distribution circuits. Low resistance grounding normally limits the ground fault currents to approximately 100-600A. The amount of current necessary for se-



'igure 8–3. Methods of System Grounding: a) Ungrounded, b) High resistance grounded. 480/277V system with 45–50Ω resistor rated 1,800 watts continuously, c) Solidly grounded.

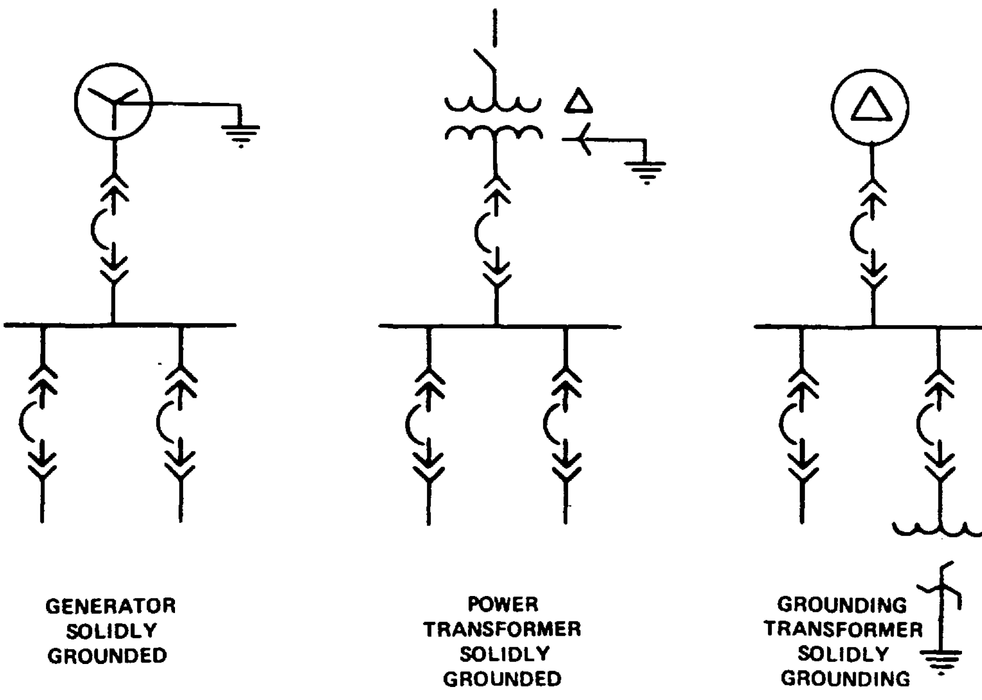


Figure 8-4. Methods of solidly grounding the neutral of three-phase systems.

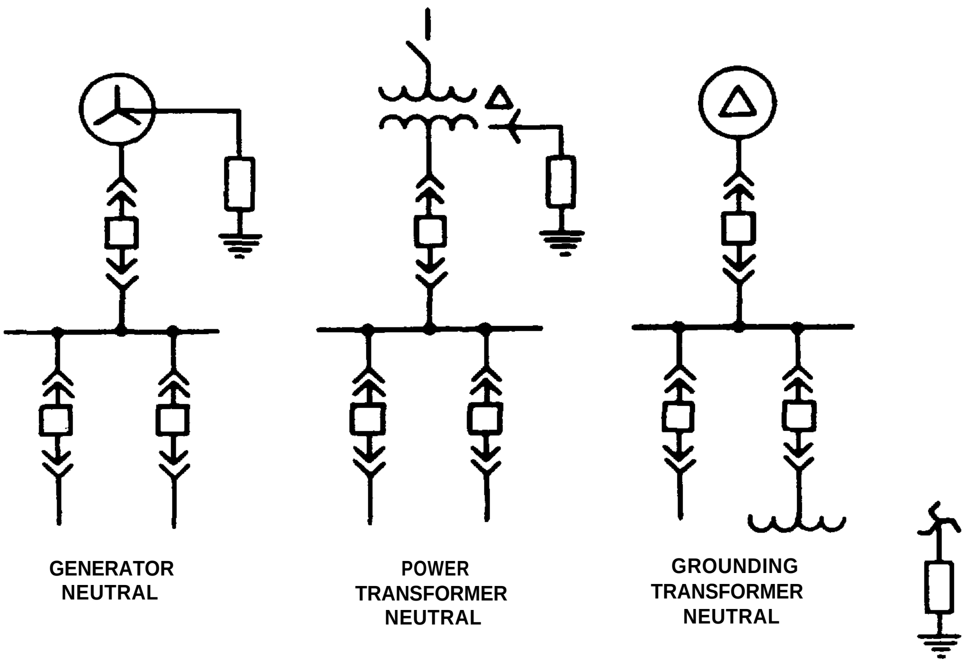


Figure 8-5. Methods of Resistance Grounding the Neutral of Three-Phase Systems: Left–High Res. 150–175Ω, 15A for 60 sec. on a 4160V system. three-phase, 3 W. Center—Low Res. 0.55Ω, 500A for 10 sec. on a 480V system, three-phase, 3W. Right—Derived neutral with grounding Resistor.

lective relaying determines the value of resistance to be used.

(b) High resistance grounding. High resistance grounding refers to a system in which the neutral is grounded through a predominantly resistive impedance whose resistance is selected to allow a ground fault current through the resistor equal to or slightly more than the capacitive charging current of the system. Because grounding through a high resistance entails having a physically large resistance that is both bulky and costly, high resistance grounding is not practical and is not recommended. However, high resistance grounding through a grounding transformer is cost effective and accomplishes the same objective. High resistance grounding accomplishes the advantage of ungrounded and solidly grounded systems and eliminates the disadvantages. It limits transient overvoltages resulting from a single phase-to-ground fault by limiting ground fault current to approximately 8A This amount of ground fault current is not enough to activate series overcurrent protective devices, hence no loss of power to downstream loads will occur during ground fault conditions. Special relaying must be used on a high resistance grounded system in order to sense that a ground fault has occurred. The fault should then be located and removed as soon as possible so that if another ground fault occurs on either of the two unfaulted phases, high magnitude ground fault currents and resulting equipment damage will not occur. High resistance grounding is normally applied in situations where it is essential to prevent unplanned system power outages, or previously the system has been operated ungrounded and no ground relaying has been installed. Once the ground point has been established through the resistor, it is easier to apply protective relays. The user may decide to add a ground overcurrent relay ANSI/IEEE device 50/51G. The relay maybe either current actuated using a current transformer or voltage actuated using a potential transformer. Depending on the priority of need, high resistance grounding can be designed to alarm only or provide direct tripping of generators off line in order to prevent fault escalation prior to fault locating and removal. High resistance grounding (arranged to alarm only) has proven to be a viable grounding mode for 600V systems with an inherent total system charging current to ground (31CO) of about 5.5A or less, resulting in a ground fault current of about 8A or less. This, however, should not be construed to mean that ground faults of a magnitude below this level will always allow the successful location and isolation before escalation occurs. Here, the quality and the responsiveness of the plant operators to locate and isolate a ground fault is of vital importance. To avoid high transient overvoltages, suppress harmonics and allow adequate relaying, the grounding transformer and resistor combination is selected to allow current to flow that equals or is greater than the capacitive changing current.

d. Lightning grounds. Lightning grounds are designed to safely dissipate lightning strokes into the earth. They are part of a lightning protection system which usually consists of air terminals (lightning rods), down conductors, arresters and other connectors of fittings required for a complete system. A lightning protection system's sole purpose is to protect a building, its occupants and contents from the thermal, mechanical and electrical effects of lightning. Effective grounding for lightning strokes is sometimes difficult to achieve because it is nearly impossible to predict the maximum discharge current. Currents from direct strikes can reach magnitudes of 100,000 amperes or more with frequencies of tens to hundreds of kilohertz. Fortunately, the event is very short, thus allowing most properly sized and maintained systems to survive the "hit".

(1) *Requirements.* Main lightning protection requirement is dependent upon the height of the building. According to NFPA 78-1986, there are two classifications for a building. Class I is a building with less than 75 feet height. The Class II building is higher than 75 feet or has a steel frame with any height. For further information about the lightning protection code see NFPA 78-1986 which contains more detail.

e. Electronic and computer grounds. Grounding for all electronic systems, including computers and computer networks, is a special case of the equipment ground and the system ground carefully applied. In fact, grounding systems for electronic equipment are generally the same as for system ground with an additional requirement: the degree of performance required. Electronic equipment grounding systems must not only provide a means of stabilizing input power system voltage levels, but also act as the zero voltage reference point. However, the need to do so is not restricted to a low frequency of a few hundred hertz. Grounding systems for modem electronic installations must be able to provide effective grounding and bonding functions well into the high frequency megahertz *range.* Effective grounding at 50-60 Hz may not be effective at alI for frequencies above 100 kilohertz.

(1) *Requirements.* There are several aspects to the requirement for good grounding performance for electronic equipment; all of which are due to electrical circuit behavior. Digital systems operate at high

frequencies. Modem systems achieve clock and data rates at 4 megahertz and higher. Clock rate is the rate at which a word or characters of a word (bits) are transferred from one internal computer element to another. Data rate is the rate at which data is transferred (bauds or bits per second) between computers. At these frequencies, due to the impedance, a regular ground wire acts as conductor for only a few feet. Compare the frequency and wavelength of these systems with those used for 60 Hz power. Electricity is conducted on a wire at very nearly the speed of light (186,000 miles/sec.). Dividing the speed by the frequency gives the full wavelength. For 60 Hz, one wavelength is about 3,100 miles. Communications and radar personnel know that interesting things begin to happen at one fourth of the wavelength. The voltage and the current no longer have the same relationship at this point on the wire. The quarter wavelength for 60 Hz is about 775 miles. However, the quarter wavelength for ten megahertz is only 24.5 feet. This is not the worst case; the change in the current and voltage relationship along a wire occurs gradually over the distance travelled. To maintain a close relationship between the voltage and current at all points along the conductor's path, it cannot be much longer than l/20th of a wavelength. Therefore, effective ground conductor length for a ten megahertz signal is only about 4.9 feet. This does not mean electronic grounding systems cannot be longer than four or five feet. The important conductor is the equipment grounding (bonding) conductor, which may be a copper cable, strap, sheet, or braid. It is this particular conductor which limits how far the electronic or computer equipment may be placed from the signal reference grid (equipotential plane) or system.

(2) *Noise interference.* Coupled and induced electrical noise is also a problem at higher frequencies. This effect is rarely a concern for systems operating at the 60 Hz powerline frequency. Very little, if any, current is induced or coupled to the ground conductors at low frequency. At high frequency, relatively more current is induced into the ground conductors through shields, cable trays, conduit, and the enclosures used to house the electronic system- As a result, these conductors must deal with more noise current than 60 Hz systems. In addition, they must hold the reference voltage very near zero at all points on the equipotential system.

(3) *Power system grounding. The* input power system ground resistance is important because it keeps the system voltage at nominal values. This "resistance" is not only a simple resistance measurement but also a frequency dependent impedance measurement. The best test instruments (para 14-5) actually apply an alternating current which returns a measurement of the conductors' inductance plus the grounding system's contact resistance. If the ground resistance reading is high at the low frequencies applied by test instrument, it will be much higher at the higher frequencies. The manufacturers of some electronic systems call for system grounding resistance of one ohm or less. This low resistance is many times more difficult to achieve than the 25 ohm maximum grounding resistance of a made electrode for power systems (NEC article 250-84). To put that in perspective; aircraft do not maintain an earth ground, but do maintain a low impedance between on-board electronic devices by using the aircraft skin and framework as a zero voltage equipotential plane.

(4) *Loop-flow.* A low resistance to ground in the input power system is no promise of trouble-free performance. It is necessary to understand that the earth is not a magic dumping area where unwanted signals and currents simply disappear. Currents always flow in complete circuit loops that may include various portions of the earth, the grounding electrodes, the grounding conductors, equipment bonds, and the equipment enclosures.

(5) *Isolated ground system.* Loop currents flowing through one portion of the earth into another usually include a substantial amount of induced high frequency common mode noise. Many designers have tried to solve the noise problem with a single point, isolated ground system. This system uses an insulated ground wire from the load to the service entrance panel board. All isolated ground outlets are of a special design such that the ground wire is isolated from the normal connections to the metal mounting frame and electrical outlet box. The isolated ground system is actually a very high impedance at high frequencies. This high impedance does attenuate this noise, but causes problems as high frequency voltages build up over its length, due to the high frequency current through the impedance of the conductor (IZ). Most manufacturers now include surge protection with their isolated ground receptacles to protect the equipment from the high voltages that develop at high frequencies across these types of receptacles (common and transverse mode). All exposed metal parts still require the equipment ground conductor. Therefore, two ground conductors are required: the equipment safety ("dirty") ground, and the isolated system ("clean") ground. All of the equipment grounds are routed and bonded in the normal way. All isolated ground conductors must be brought back to one point in the subpanel. The subpanel isolated ground bus must not be bonded to the subpanel enclosure. This ground bus must be isolated and only connected with insulated conductor(s) to the service

entrance ground bus. The input power system neutral must also be grounded only at the service entrance. The isolated ground system stops loop currents and common mode electrical noise, but has several major disadvantages: The long branch feeder and isolated ground conductors are effective only for low data transfer frequencies (fig 8-6c. High voltages occur between the conductors during surges. It is also a very difficult system to inspect and maintain. Frequency inspections must be made to ensure the system has not been defeated by inadvertent or deliberate installation of a jumper or conductor between the two systems. Inspections and tests on this type of grounding must be carried out after each electrical system modification. It is best not to use isolated ground systems at all unless forced to by the equipment manufacturers. It is also best to restrict such systems to small areas or only one floor of the building.

(6) *Electronic system grounding. Good* electronic system grounding performance is achieved with a properly laid out distribution of multipoint, well-bonded grounding connections. This system can use bare, braided, sheet, or stranded copper conductors for grounding or bonding functions. This system requires conduit and equipment enclosure bonding at all junction points. In other words, simple metallic contact between the enclosures, wiring conduits, and power panels is not enough. The multipoint bonding provides low impedance grounding for the electronic equipment. The low impedance between the separate items of electronic equip ment keeps the noise voltages at or near zero between them and, therefore, provides an "equipotential plane". This system is much easier to inspect and test. No special requirements must be met during modifications or expansion of the electrical system. All power panels and all supply transformers feeding an installation with this type of grounding system must be grouped and bonded together using short lengths of bare, braided, sheet, or stranded copper conductors in order to achieve the effective high frequency grounding performance described above. As shown in figure 8-6d, a single area of power entry with a large equipotential ground plane and short equipment grounding conductors forms the preferred grounding system for large automated data processing (ADP) and computer applications.

f. Maintenance safety grounds. Grounds used for maintenance work are usually intentional, but temporary, connections between equipment power conductors and ground. These connections are always applied after the power source has been turned off and the circuit(s) have been tested and are known to be de-energized. The ground is intended to protect maintenance personnel from an inadvertent reenergization of the circuit. The ground is removed tier maintenance operations have been completed. Application of a maintenance ground is discussed in more detail in paragraph 12-2d.

g. Ground system tests. Periodic testing should be done to assure grounding system effectiveness. The following are points that should be addressed during inspection and maintenance:

(1) Inspect and test single point, isolated ground systems after every electrical system modification. visually inspect outlets and panels for conductors forming loops between the equipment ground and the isolated ground.

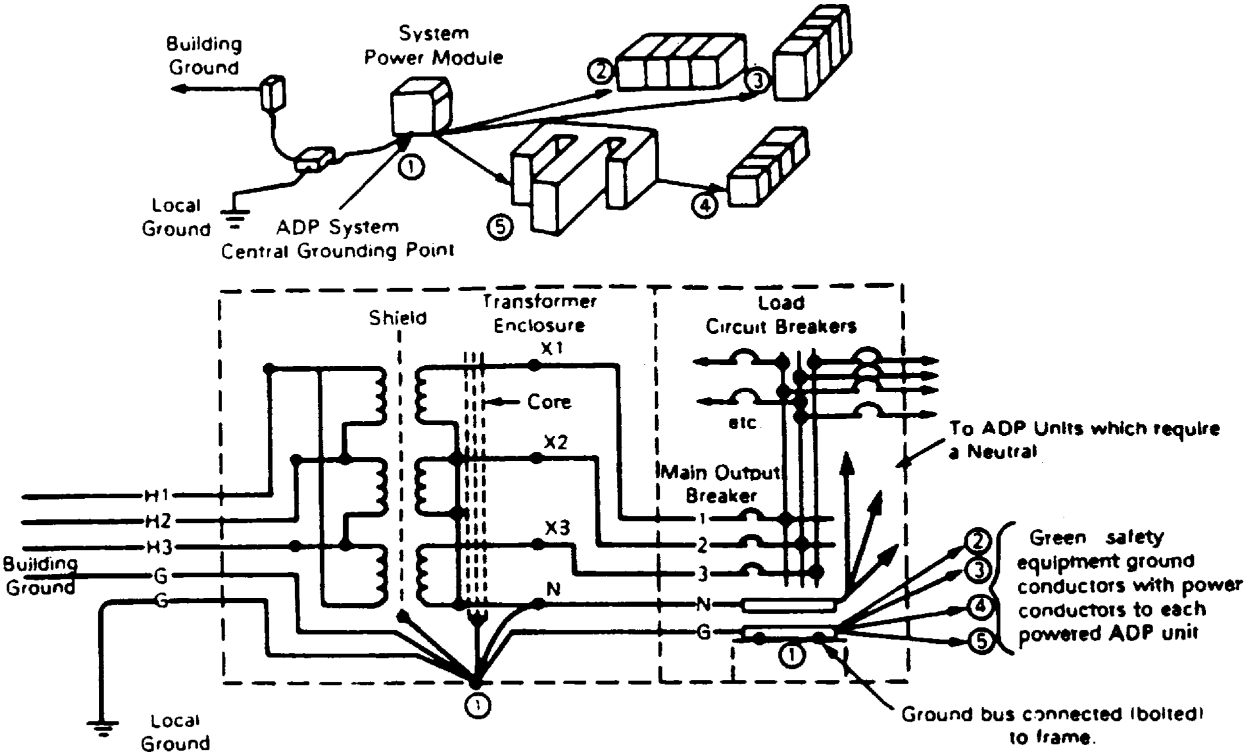
(2) Test the ground to neutral voltage at each power distribution panel included in the particular system. The voltage should be taken using a high impedance AC voltmeter and an accurate record should be kept. The voltage should be very low; on the order of l0-150 millivolts (0.01-0.150V). Any sudden changes or increasing trends should be investigated and the cause corrected.

(3) The made electrode, rod, plate, or selected ground body contact point should be tested every 12-24 months. A record should be kept. Any increasing impedance indicates need for remedial action.

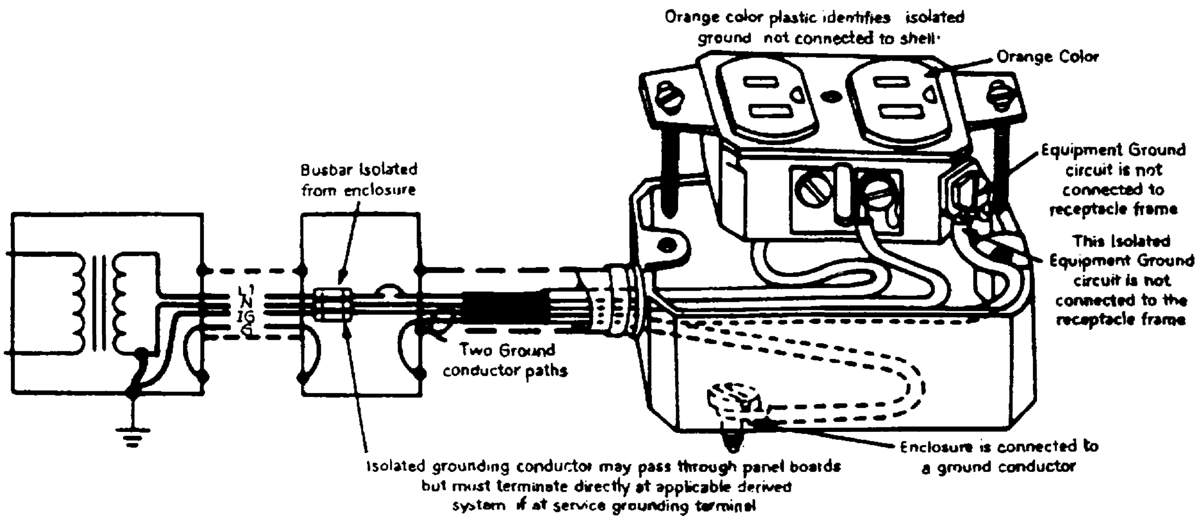
8-3. Ground fault interrupting methods.

Ground faults result when an electrical components insulation deteriorates allowing an above normal current leakage to ground. Minute current leakage may normally occur from virtually every electrical device. Ground faults become dangerous when an unintended ground return path becomes established. This ground return path could be through the normal electrical components and hardware (equipment ground for instance), conductive material other than the system ground (metal, water, plumbing, pipes, etc.), a person or, any combination of the above. Ground fault leakage currents of much lower levels than is needed to trip conventional circuit breakers can be hazardous. Therefore, to reduce the possibility of fire, injury, or fatality, the NEC requires additional ground fault protection for certain types of circuits. Ground fault protective devices are of two distinct types: ground fault circuit interrupters and ground fault protectors. It is extremely important to understand the difference between them.

a. Ground fault circuit interrupters (GFI). A GFI is designed to protect a person from electrocution when contact between a live part of the protected circuit and ground causes current to flow through a person's body. A GFI will disconnect the circuit when a current equal to or higher than the calibration point (4 to 6 mA) flows from the protected

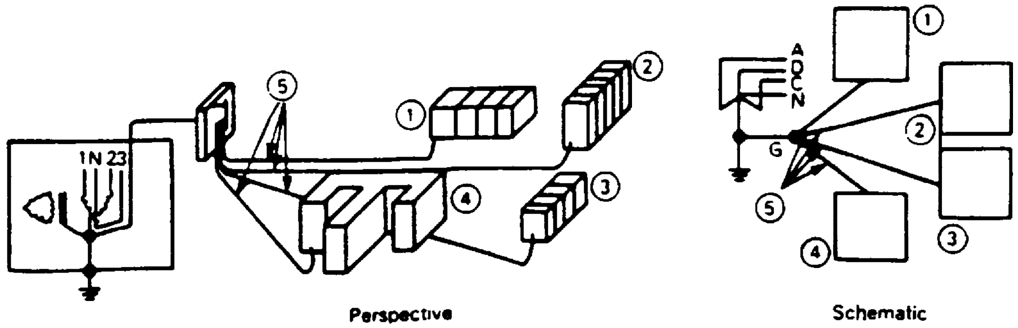


a.



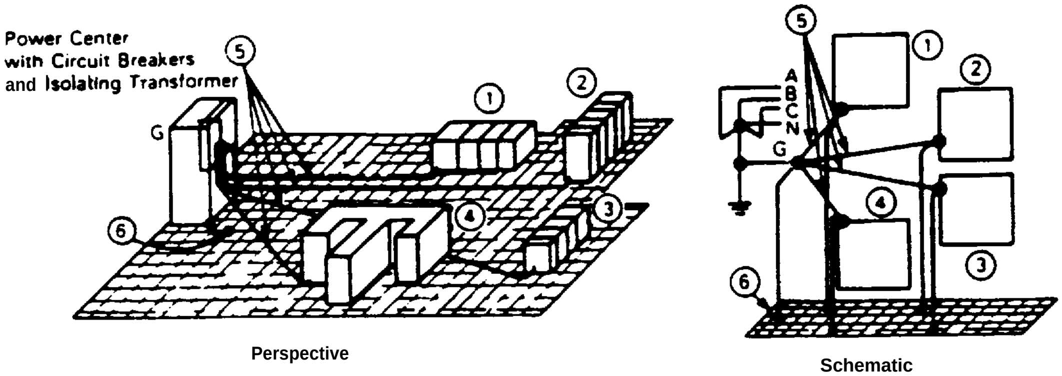
b.

Figure 8-6. Grounding for Electronic and ADP Systems: a) Establish a central grounding point, b) Principal features of an isolated grounding system.



Computer Conductors Subject to High Frequency Resonance with RF Signals

c.



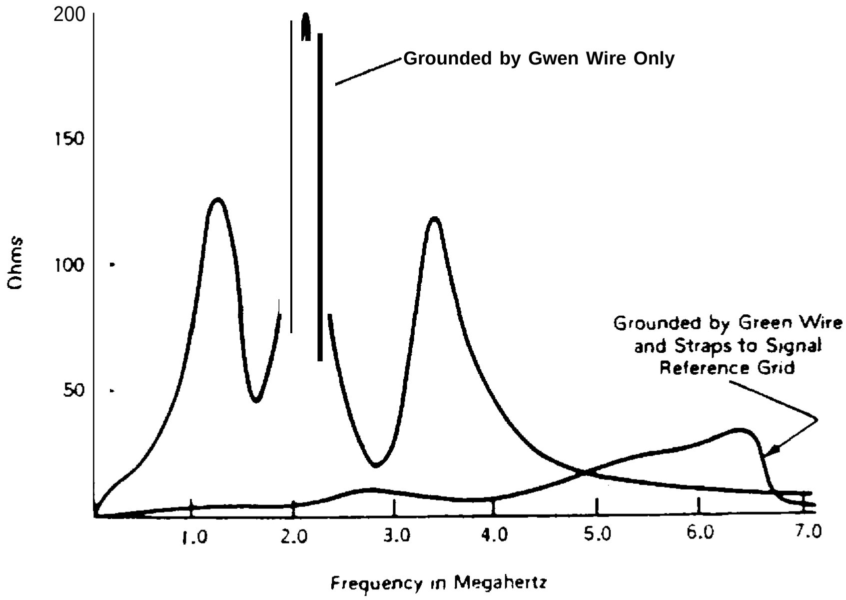
Computer Units Connected to Signal Reference Grid and to A-C Ground

(1) through (4) are typical computer system modules

(5) is the "Green Wire" safety equipment ground conductor

(6) is safety ground for raised floor structure

d.



e.

Figure 8-6. (Continued) Grounding for Electronic and ADP Systems: c) Avoid long runs of single grounding conductors, d) An effective multi-point grounding system for high frequencies, e) Comparison of single conductors us a multi-point grid at high frequencies.

circuit to ground (fig 8-6). It will not eliminate the shock sensation since the normal perception level is approximately 0.5 mA. It will not protect from electrocution upon line-to-line contact since the nature of line-to-line loads cannot be distinguished by a line-to-ground device. GFIs are sealed at the factory, and maintenance should be limited to that recommended by the manufacturer. Tripping tests should be performed with the test button on the unit in accordance with the frequency recommended by the manufacturer. Results and dates of tests should be recorded on the test record label or card supplied with each permanently installed GFI unit. There are four types of GFIs. There are circuit breaker type, receptacle type, portable type, and permanently mounted type.

(1) Circuit breaker type. A circuit breaker type GFI is designed in the form of a small circuit breaker and is completely self-contained within the unit housing. The circuit breaker type GFI provides overload and short-circuit protection for the circuit conductors in addition to ground-fault protection for personnel. It is intended to be mounted in a panelboard or other enclosure. For required maintenance refer to paragraph 5-4c.

(2) *Receptable type.* A receptacle type GFI is designed in the form of a standard receptacle that is completely self-contained within the unit housing, and does not provide overload or short-circuit protection. It is intended for permanent installation in conventional device outlet boxes or other suitable enclosures. Maintenance required for a GFI receptacle is the same as any standard receptacle outlet. If the GFI receptacle does not reset, is badly worn, cracked, or broken, or if contacts are exposed, the GFI must be replaced. It should also be replaced if accidental disengagement of a plug from the receptacle is a recurring problem. Proper wire connections on the receptacle and proper polarity of power connections should be checked including the integrity of the equipment ground. If there is abnormal heating on the GFI receptacle face, check for loose terminal connections and correct or replace. If there is evidence of burning or arc-tracking, it should be replaced.

(3) *Portable type.* A portable type GFI is a unit intended to be easily transported and plugged into any grounded receptacle outlet. Cords, tools or other devices to be provided with ground-fault protection for personnel are then plugged into receptacles mounted in the unit. Required maintenance would include that recommended in paragraph (2) above for receptacle type GFIs along with the following cord care recommendations:

(a) Keep the cord free of oil, grease and other material that may ruin the rubber cover. Avoid tangling knots or dragging across sharp surfaces.

(b) Make sure that the power tool is grounded through the additional grounding conductor in the cord and the grounding prong of the plug. The integrity of this ground circuit is necessary for the Protection of personnel.

(c) Make sure that the cord is not cut, broken, spliced or frayed. Cords maybe replaced or the damaged portion may be cut out and the two sections rejoined by attaching a plug and connector.

(d) Make sure that the green conductor is connected to the frame of the tool and the grounding prong of the attachment plug.

(4) *Permanent type. A* permanently mounted type GFI is a self-contained, enclosed unit designed to be wall or pole mounted and permanently wired into the circuit to be protected. Maintenance beyond tightening of connections and cleaning should not be attempted. Any repairs needed should be referred to the manufacturer.

b. Ground fault protectors (GFP). A GFP is designed to limit damage to electrical equipment in the event of a fault (either solid or arcing) between a live part of the protected circuit and ground. A GFP will cause the circuit to be disconnected when a current equal to or higher than its setting flows to ground (fig 8-7). GFPs are available with settings typically ranging from five to 1200 amperes. It will not protect personnel from electrocution. A GFP system is designed to be installed in a grounded distribution system. It consists of three main components: sensors; relay or control unit; and a tripping means for the disconnect device controlling the protected circuit. Detection of ground-fault current is done by either of two basic methods. With one method, ground current is detected by sensing current flow in the grounding conductor. With the other method, all conductor currents are monitored by either a single large sensor, or several smaller ones. Sensors are generally a type of current transformer and are installed on the circuit conductors. The relay or control unit maybe mounted remotely from the sensors or maybe integral with the sensor assembly. Circuit breakers with electronic trip units may have a GFP system integral with the circuit breaker. Any maintenance work performed on the electronic circuitry should adhere to manufacturer's instructions. Maintenance on the mechanical operating mechanism components should be performed as recommended in chapter 5. Maintenance requirements for the sensors are as specified in chapter 2 for instrument transformers. Tighten all terminal connections and clean. Any repairs needed should be performed by the manufacturer. If interconnections between components are disconnected, they must be marked and replaced to maintain the proper phasing and circuitry. If the system is equipped with a test panel, a formal program of periodic testing should be established. When the system is not equipped with a test panel, refer to the manufacturer for test instructions.

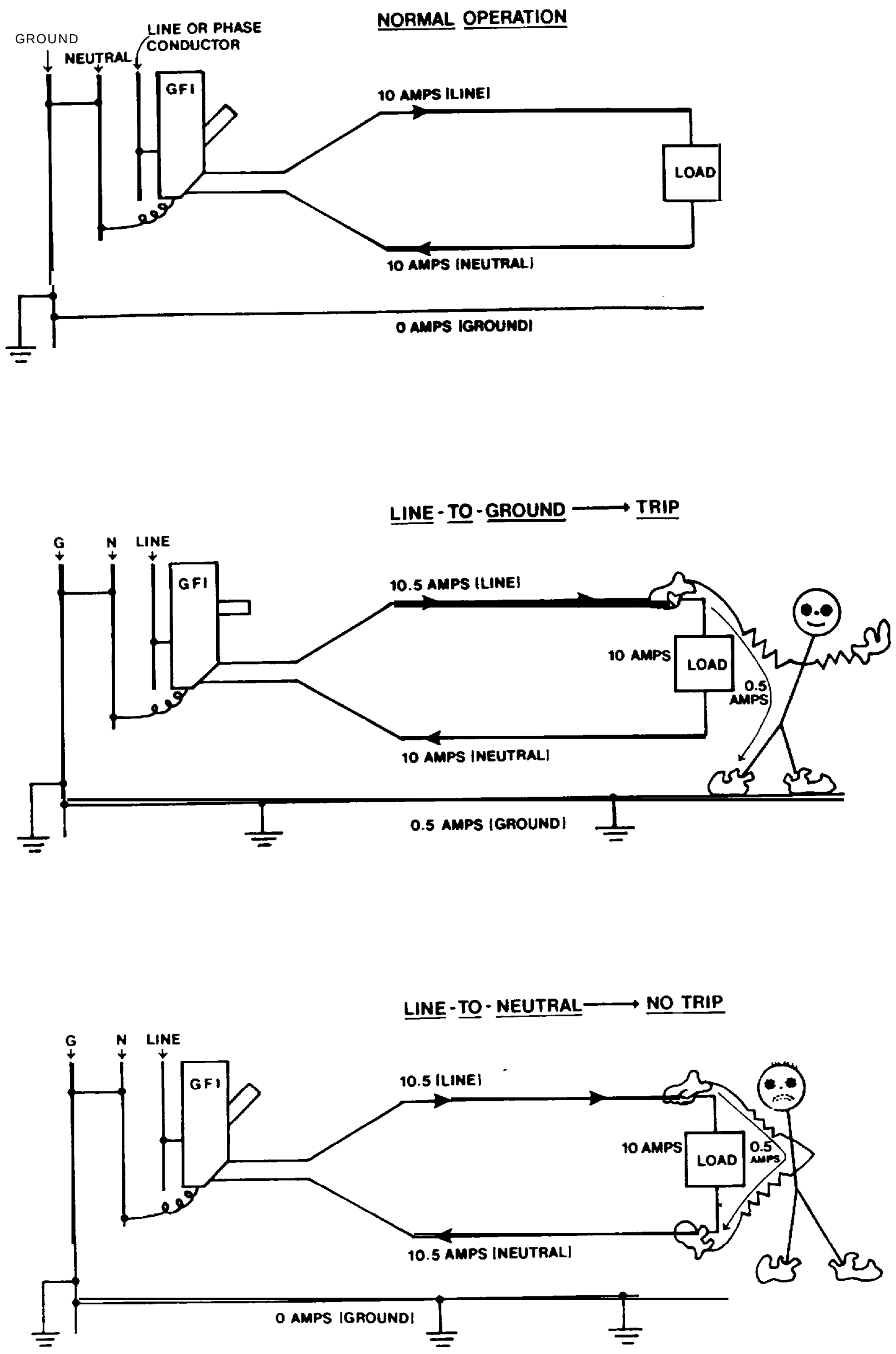


Figure 8-7. Ground fault circuit interrupter operation.