

Changes shown by ↗

SCOPE

- I 1.1 This practice covers bonding, grounding, overvoltage protection, and lightning protection facilities for electrical power systems and equipment, structures and buildings, and product loading stations.
- I ↗ 1.2 **This practice does not cover process instrumentation systems.** However, overall grounding system design shall include requirements specified in other practices, e.g. instrumentation. Contractor shall submit overall grounding design to the Owner's Engineer for approval.
- I 1.3 **An asterisk (*) indicates that additional information is required.** If a job is contracted, this additional information is furnished in the Job Specification.

SUMMARY OF ADDITIONAL REQUIREMENTS

- I ↗ 2.1 **Table 1** lists standards that shall be used with this practice. Equivalent regional or national standards may be used when approved by the Owner's Engineer.

TABLE 1

STANDARDS	
ANSI / NFPA	
70	National Electrical Code (NEC) Article 250
780	Standard for the Installation of Lightning Protection Systems
IEEE	
837	IEEE Standard for Qualifying Permanent Connections Used in Substation Grounding

- I ↗ 2.2 **ANSI / IEEE Std 80, IEEE Guide for Safety in AC Substation Grounding** shall be used as indicated in this practice.

DEFINITIONS

- I * 3.1 **Acceptable and preferred practices.** Where this practice lists more than one type of equipment or method as acceptable, the contractor shall make the selection based on the installed cost. Where one particular type of equipment or method is listed as preferred, it shall be selected, provided: (1) it is lower or equivalent in installed cost than other acceptable types or methods, (2) it has reduced maintenance and operating costs that provide sufficient cost benefit to offset an initial added investment. Owner's Engineer shall approve alternative choices.
- I 3.2 **Bonding.** Two or more objects are considered to be bonded if connected together through a conducting path. Objects which are not inherently in contact with each other through a conducting path may be bonded by connecting them together with a bonding conductor. The conductor shall be sized to safely conduct the current or dissipate the charge likely to be imposed.
- I 3.3 **Grounding.** An object is considered to be grounded when connected by a conducting connection either inherently or by a grounding conductor to the earth, or to some conducting body that serves in place of the earth such as where rock or high resistivity soil is present.
- I 3.4 **Grounds are the grounding electrode system. The electrodes** may be buried grounding conductors, underground metallic water piping, large underground metallic objects in intimate contact with earth such as metallic building frames, pile casings, or concrete encased electrodes consisting of reinforcing bars or copper conductors in underground foundations or footings, and driven rods.
- I 3.5 **The zone of lightning protection** is that space adjacent to a lightning protection system that is substantially immune to direct lightning flashes.
ANSI / NFPA 780 Chapter 3 "Protection for Ordinary Structures" and Chapter 6 "Protection for Structures Containing Flammable Vapors, Flammable Gases or Liquids That Can Give Off Flammable Vapors" cover the cone and rolling sphere concepts for determining the zone extent. Specific regional or national standards, while using the same concepts, may have requirements that result in different extents of the zone of protection.
- I ↗ 3.6 **Lightning arrester (surge arrester)** is a protective device for limiting surge voltages on equipment by discharging or bypassing surge current. It prevents continued flow of follow current to ground, and is capable of repeating these functions. Use of arcing horns and/or rod gaps is not an acceptable method of suppressing electrical surges.

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- I 3.7 **Liquids are classified as static electrical charge accumulators** if their conductivity is 50 picomhos/meter (50 pS/m) or less. Distilled petroleum products including petroleum solvents, are generally accumulators. Crude oil, residual fuel oil, asphalts (both penetration or cutback), Bunker C, residual products with Conradson carbon above 1% and water soluble products such as alcohol have high conductivity and are classified as non-accumulators.
- I 3.8 **Ground return path** is a metallic connection between the metal enclosure of electrical equipment and the system neutral ground of the power supply to the equipment. If the systems neutral is grounded through impedance, the ground return path must connect on the ground side of the impedance. The path is a low-impedance path from the equipment enclosure to the neutral ground. It serves as the equipment grounding conductor in grounded neutral systems.
- I 3.9 **Switch loading** is loading a high flash product into a tank truck, tank car, or container previously containing a low flash product, without cleaning or gas-freeing the tank or container. The high flash product must be treated as low flash during loading in such cases.

BONDING AND GROUNDING MATERIALS AND METHODS

- S 4.1 **Bonding shall be provided** where necessary to insure the electrical continuity of grounding circuits and where necessary to provide a path for the dissipation of static charges.
- S 4.2 **Bonds provided for the dissipation of static charges** shall have a resistance of one megaohm or less.

BONDING AND GROUNDING CONDUCTORS

- R * 4.3 Unless otherwise specified, **bonding and grounding conductors** shall be bare stranded medium-hard-drawn copper. **Minimum sizes** shall be 2 Awg (35 mm²) for underground conductors and 6 Awg (16 mm²) for aboveground conductors where the size is not specified elsewhere in this practice. **Conductor sizes** shall be **increased** above the minimum sizes if required to:
 - a. Insure adequate mechanical strength.
 - b. Withstand the thermal stresses of ground fault currents.
- R * 4.4 **Ground return conductors located within cable assemblies** or run with or enclosing individual circuit conductors are preferred. When specified, common ground return conductors run with underground conduits or buried cable are acceptable.
- I 4.5 **Ground return conductors located within cable assemblies** may be **uninsulated** and shall be of the same material and stranding as the cable line conductors. If insulated, color coding shall comply with requirements of the applicable regulations.
- R 4.6 **Grounding conductor burial depths** shall be at least 18 in. (450 mm). Burial depths in switch or transformer yards graded with stone shall be at least 12 in. (300 mm) below the stone.
- R 4.7 If the wiring method is buried cable, **common grounding conductors run with the buried cable shall be laid in the cable trenches** as far as routing permits.
- R 4.8 If the wiring method is **underground conduit**, **common grounding conductors** run with the conduits shall be **laid along a formed side of the duct banks**.
- S 4.9 **Grounding conductors leaving the ground** at grade shall be protected as follows:
 - a. Conductors except those used for lightning protection and lightning arrester grounding shall be protected by rigid metal or non-metallic conduit or pipe sleeves where they extend above grade. Lightning protection and arrester ground conductors shall be protected by non-metallic conduit sleeves.
 - b. Sleeves shall extend a minimum of 6 in. (150 mm) below grade and 10 in. (250 mm) above grade.
 - c. Metal sleeves shall be encased in concrete 3 in. (75 mm) thick all around.
 - d. Concrete encasement shall extend 6 in. above grade.
 - e. Non-metallic sleeves shall be rigid heavy wall polyvinyl chloride or high density polyethylene conduit.
 - f. Sleeves are not required within switch or transformer yards or under elevated substations.



BONDING AND GROUNDING CONNECTIONS

- S 4.10 **All conductor connections to structures and equipment** shall be made **aboveground** as follows:
- Conductors shall be installed in one length between aboveground connection points.
 - Single cable lengths shall also be installed between aboveground connection points and grounding electrodes or taps on common ground return cables.
 - If splices or taps are required on underground runs, they shall be made with tool-installed compression connectors or by brazing or welding.
 - Bolted or screw type solderless connectors or similar mechanical connectors shall not be used underground.
 - Splices or taps in underground runs shall be buried.
- M 4.11 On equipment, **conductor connections that are regularly disconnected for maintenance of the equipment** shall be made with bolted or screw type solderless connectors. **Other connections** shall be made by brazing, welding, or with connectors that qualify as permanent grounding connections per **IEEE Std 837**.

GROUNDS

- S 4.12 **All Grounds shall have a resistance to earth** not exceeding 5 ohms throughout the year considering seasonal variations in soil conditions. Grounds for low resistance grounded systems shall not exceed 2 ohms.
- R 4.13 **Grounding Electrodes.** If permanently installed and located within a reasonable distance of the equipment or structure to be grounded, the following may be used as grounding electrodes:
- Buried grounding conductors having a length of not less than 20 ft (6 m) and burial depth of 30 in. (760 mm). Minimum size shall be No. 2 Awg (35 mm²).
 - Underground metallic water piping if buried portion is more than 10 ft (3 m) in length.
 - Large underground metallic objects in intimate contact with earth such as metallic building frames, pile casings or concrete encased electrodes consisting of reinforcing bars or copper conductors that are part of an underground foundation or footing. These electrodes shall provide the conductive equivalent of at least 20 ft (6 m) of electrically conductive reinforcing bar not less than 1/2 in. (13 mm) diameter or 20 ft (6 m) of No. 2 Awg (35 mm²) copper conductor. Concrete encasement shall not be less than 2 in. (50 mm) thickness.
 - * Artificial (made) electrodes consisting of driven copper-clad steel rods or equivalent. Unless specified otherwise, rods shall be copper-clad steel equivalent to Copperweld with minimum diameter of 5/8 in. (16 mm) and minimum length of 8 ft (2.5 m). Tops of rod and grounding conductor connection shall be buried at least 18 in. (450 mm) below grade. A ground well shall be provided for each rod and its connector when specified.
 - If more than one electrode is connected to a grounding system, the electrode spacing shall be spaced at least 10 ft (3 m) apart.
 - Electrodes of different systems shall be bonded together when in reasonable proximity.
- M 4.14 **Electrode grounding conductor and connections** shall comply with the following:
- A grounding conductor shall connect the top of each electrode to an accessible above ground connection point. Minimum size shall be No. 2 Awg (35 mm²).
 - The connection point may be located on the structure or equipment to be grounded or on a nearby permanent structure to serve as a tie-in point for other grounding conductors. At tie-in points, conductors from electrodes shall be identified with corrosion resistant metal bands to facilitate their removal for test purposes.
 - The grounding conductor shall be connected to the electrode by brazing or welding, and to the connection points by a bolted or screw type solderless connector. In ground wells the rod connection may use bolted or screw type connectors.

SUBSTATION AND GENERATING STATION GROUNDS

- S 4.15 **All grounding electrodes at substations and generating stations shall be interconnected** by grounding conductors.

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- S 4.16 **Design of grounding systems shall provide protection** from step, touch, mesh and transfer potentials at the following areas:
- a. Outdoor switchyards and main substations that are supplied by overhead lines at utility company voltage.
 - b. Substations adjacent to a utility-supplied switchyard or main substation.
 - c. Generating stations.
 - d. Gas-insulated substations (GIS)
- * Grounding system design shall be evaluated using the guidelines presented in **ANSI / IEEE Std 80**, or equivalent regional or national standard. Grounding system design for these areas shall be submitted to Owner's Engineer for approval.

SYSTEM NEUTRAL GROUNDS

GROUNDING CONDUCTOR SIZE

- R,O 5.1 **Grounding conductors** used to ground power transformer or generator neutrals shall have a **cross sectional size** not less than 2 Awg (35 mm²). In addition, the size shall limit temperature reached by the conductor, when carrying maximum ground fault current for the time allowed by the slowest responsive relay, to the following:
- a. For insulated conductors, to within the transient temperature for no damage to the insulation.
 - b. For bare conductors: to 250°C rise if connections to cable are made with pressure connectors; to 450°C rise if connections to cable are brazed or welded. For copper conductor and 26°C ambient, required size is: $F I \sqrt{t}$
- where:** I = current, amp
 t = time, seconds
 F = 0.0106 for answer in kCM and 250°C rise
 = 0.0087 for answer in kCM and 450°C rise
 = 0.0054 for answer in mm² and 250°C rise
 = 0.0044 for answer in mm² and 450°C rise
- c. For impedance grounded systems, the grounding conductor ampacity for the time allowed by the lowest responsive relay shall be not less than the maximum current rating of the impedance and the minimum size specified by the applicable regulations.

GROUNDING CONDUCTOR ROUTING

- I,R 5.2 **For solidly grounded systems**, the grounding conductor shall be routed as follows:
- a. If the neutral grounding connection is made at a transformer or generator, or at an adjacent neutral current transformer, the conductor shall be routed via the shortest path to ground. For transformers, the shortest path is usually via the transformer ground pad.
 - * b. If the neutral ground connection is made in the transformer or generator switchgear, route the conductor to ground via the switchgear ground bus. All connections in the grounding path between the neutral point and the outdoor ground shall be accessible for visual inspection. When specified, the conductor shall be insulated between the neutral and the grounding point in the switchgear.
 - c. For grounded lighting systems having individual lighting transformers and panels, transformer neutral shall be grounded only at the transformer.
- I,R 5.3 **For impedance grounded systems**, the neutral impedance element shall be located as close as practicable to the neutral. The neutral grounding conductor should be routed from the impedance element via the shortest path to ground.