CHAPTER 9

SURGE PROTECTION AND GROUNDING

9-1. Voltage Surges and Potential Gradients.

Even the best designed electric system is subject to overvoltages resulting from physical conditions not subject to the owners control. Dangerous potential gradients can result also from improper design.

a. Causes. Lightning imposes voltage surges on aerial lines either by direct strokes or by induction. Such surges can be transmitted to underground lines. Opening and closing circuits in large generating plants or switching stations can raise voltages to two or three times normal for a brief period of time. In addition, excessive voltages and currents can result from short-circuit conditions when line-to-line or line-to-ground faults occur, because of inductive/capacitive characteristics of the line between the electric power source and the fault location. Transformer ferroresonance can create overvoltages also as discussed in chapter 5.

b. Elimination. Since voltage surges can result in personnel injuries from electrical shock, insulation damage to equipment, and possibly fire, surge arresters will be used to provide safe dissipation of these surges. Grounding systems will be designed to limit potential gradients to values established by IEEE Std 80. Proper relaying will ensure isolation and disconnection of faulty equipment and lines when a short-circuit occurs.

9-2. Methods of Controlling Voltage Surges and Potential Gradients.

a. Surge arresters. Surge arresters will be of the valve-type or the metal-oxide-varistor type. Gapless, metal-oxide arresters are preferred because of their better operating characteristics. Surge arresters are used to safeguard apparatus against hazards caused by abnormally high voltage surges. Such overvoltage can cause serious damage if arresters are not correctly coordinated with the insulation strength of the protected equipment, and are unable to discharge the energy properly. To function correctly, arrester protective levels must be lower than the insulation withstand strength of equipment to be protected. Surge arrester protective margins will comply with IEEE Std C62.1, IEEE Std C62.2, and IEEE Std C62.11.

b. Characteristics. Arrester characteristics will have protective margins coordinated with the appropriate equipment insulation characteristics in accordance with IEEE Std C62.2. Lead lengths must also be taken into account.

(1) *Impulse sparkover voltage.* Impulse sparkover voltage is the highest value of voltage attained by an impulse of a designated wave shape and polarity applied across the terminals of an arrester prior to the flow of discharge current. This voltage plus the lead length voltage contribution is the highest that can be impressed on protected equipment because, at this level, the arrester will sparkover and discharge the surge to ground. Arrester front-of-wave sparkover voltage will be compared to the insulation lightning impulse (chopped-wave) crest value that the protected equipment is required to withstand for purposes of determining the protective margin.

(2) *Discharge voltage.* Discharge voltage is the voltage that appears across the terminals of an arrester during passage of discharge current. Arrester maximum discharge voltage will be compared to the BIL value that the protected equipment is required to withstand for purposes of determining the protective margin.

(3) *Impulse protective level.* For a defined waveshape, the impulse protective level is the higher of the maximum sparkover value or the corresponding discharge voltage value.

(4) *Maximum continuous operation voltage (MCOV).* the MCOV is the maximum designated root-mean-square (rms) value of power frequency voltage that may be applied continuously between the terminals of a gapless arrester.

(5) *Voltage rating.* The nameplate voltage rating of an arrester is the maximum permissible operating voltage at which the arrester can operate correctly.

(a) Operation. An arrester has a maximum voltage level above which the arrester cannot seal off the 60 Hz line (follow) current, after sparkover on surge voltage. If the correct nameplate rating is used, the arrester can interrupt 60 Hz line current even though there is a line-to-ground fault on another phase. If the 60 Hz follow current is not immediately extinguished, the arrester may fail.

(b) Sizing. On a modern overhead, grounded wye primary distribution system (effectively grounded system), the arrester is able to reseal at a voltage level that does not exceed 1.25 times the nominal line-to-ground voltage. For a main electric supply station with a 13,2OOY/7,620 V secondary, the minimum arrester rating would be 1.25 x 7.62 = 9.53 kV. A 9-kV arrester might not reseal so a 10-kV arrester, which is the next higher standard

rating, must be provided. For ungrounded and high-resistance grounded systems, ratings must equal or exceed the phase-to-phase system voltage dependent upon the size of the maximum ground fault that could occur.

(6) *Lead length.* Lead length is the length of line connecting the line terminal of an arrester to the energized line (line lead) plus the length of the line (ground lead) connecting the ground terminal of an arrester to a common ground. On riser poles the common ground is the conducting shield or sheath of cable at the cable termination. Leads will be kept as short as practicable, since voltage drops of both leads must be added to the sparkover and discharge voltages of the arrester when figuring protective margins. A commonly used figure for lead voltage drop is 2 kV per foot of length.

c. Classification. Arrester classification is based on specified test requirements. Of the six classifications available, only the four arrester types which are designated as station, intermediate, distribution, and secondary have suitable operating characteristics. Table 9-1 indicates protective margins for liquid-filled transformers of various primary voltages. The discharge values are for a 10 kA impulse current crest, the current commonly used as a basis for insulation coordination on a medium-voltage distribution system.

(1) *Distribution class.* Distribution arresters, with the lowest protective margins for voltage systems above 1,000 V will be used as an economical way of providing lightning surge protection for distribution equipment. Aerial to underground risers require surge protection, as do transformers, capacitors, and regulators mounted on poles.

(2) *Station class.* Station arresters are capable of discharging the most surge energy and, therefore, will be used at main electric supply stations for protection of incoming aerial lines and where needed for protection of equipment not within the protective radius of an incoming line arrester such as transformers and regulators.

(3) *Intermediate class.* Intermediate class arresters have protective characteristics and costs somewhere between those of station class and distribution class types. Intermediate arresters will be used to protect pole-mounted transformers and aerial-to-underground risers at munitions areas. Elsewhere, when such units are proposed as a substitute for other classifications, their use will be justified, except where such use is the installation's normal policy.

Transformer insulation	Voltage level	Arrester		Protective ratio comparison[a]					
				Sparkover[b]			Discharge[b]		
		Classification	kV	Arrester kV	Trans. kV	Ratio	Arrester kV	Trans. BIL	Ratio
	4,160	Distribution	6	32	69	2.2	24.5	60	2.5
		Intermediate	6	21	69	3.3	16	60	3.7
	12,000Y/6,930	Distribution	9	45	110	2.4	37	95	2.6
	or	Intermediate	9	33	110	3.3	28	95	3.4
	12,470Y/7,200	Station	9	31	110	3.5	21	95	4.5
	13,200Y/7,620	Distribution	10	41	110	2.5	41	95	2.3
	or	Intermediate	12	40	110	2.7	32	95	3.0
Liquid-filled	13,800	Station	12	41	110	2.7	27	95	3.5
		Distribution	18	72	175	2.4	71	150	2.1
	24,940Y/14,400	Intermediate	21	70	175	2.5	56	150	2.7
		Station	21	68	175	2.6	48	150	3.1
		Distribution	27	91	230	2.5	98	200	2.0
	34,500Y/19,920	Intermediate	30	94	230	2.5	80	200	2.5
		Station	30	99	230	2.3	70	200	2.8

[a] Lead length not included.

[b] Characteristics are median of the range of maximums listed in IEEE Std C62.2 and are reproduced with the permission of the Institute of Electrical and Electronics Engineers, Inc., from the Standard entitled "Gapped Silicon-Carbide Surge Arresters for AC Systems," copyright 1987.

Table 9-1. Aerial-Mounted Liquid-Filled Transformer Surge Protective Margins

(4) *Secondary class.* Secondary arresters will be used only for low-voltage services at munitions areas and buildings which house computer and sensitive electronics equipment. Arresters will be located as close to the electrical service entrance as possible and a separate ground conductor from the secondary service entrance will be bonded to the building ground ring. Range of voltage ratings is 0.175 kV to 0.650 kV. Secondary class arresters are required on Air Force facilities.

d. Location. Arresters will be located as close to the equipment protected as is practicable, in accordance with IEEE Std C62.2. Arresters will be connected to line conductors ahead of any overcurrent protective devices to prevent the lightning discharge from passing through the device. For Air Force installations, additional arresters will also be installed at corner poles, deadends, on both sides of switches, riser poles, and on every tenth pole in long, straight distribution line runs.

(1) *Underground connections.* Procedures for estimating magnitudes of surge voltages at distances remote from the transition arrester location are very complex. IEEE Committee Report, Surge Protection of Cable-Connected Equipment on Higher-Voltage Distribution Systems, recommends doubling both the sparkover and the discharge plus lead voltage for the arrester and then requiring a 15 percent margin over the equipment insulation. This recommendation will be followed in areas with numerous lightning storms and may require intermediate arresters at transition poles, arresters at transformer stations, or both provisions for adequate protection.

(2) Main electric supply station connections. On main electric supply stations, the incoming aerial line switching devices and the transformer primary terminals are the main elements requiring surge protection.

(a) Incoming lines. Arresters will be located on the line side of any incoming line fuse to prevent the lightning discharge from passing through the fuse. Arresters need not be installed on the line side of group-operated disconnect switches. However, arresters will be connected close enough to protect the switch adequately when the switch is closed. Line entrance gaps may be used on the line side of any switch for protection when the switch is open. Where two-column structures are provided as in figure 4-6, arresters will be mounted on the load side as this structure configuration does not lend itself to line side connection. Other structures, such as a double square bay structure, have a configuration which makes location of the arrester on the line side of the switch the most practicable arrangement.

(b) Transformers. Arresters will be located and connected as close as practicable to the transformer to be protected, in accordance with IEEE Std C62.2. In regions of high lightning incidence, surge arresters will be mounted on each of the incoming aerial line structures and directly on each of the main supply transformers.

(c) Generators. In addition to surge arresters at transition points between aerial and underground lines, surge protection will be necessary within a generator plant. Surge arresters in parallel with surge protective capacitors will be installed either at the terminals of the generator switchgear bus for overall machinery protection or at the terminals of each generator, dependent upon the degree of protection required. Surge protective capacitors reduce steep wave fronts, which if imposed on rotating machinery could result in stresses exceeding a machine's insulation impulse strength.

e. Overhead ground (or shield) wires. Overhead ground wires are run parallel to and above electrical lines, in order to shield lines from a direct lightning stroke.

(1) *Transmission and distribution lines.* Overhead ground wires are used for protection of transmission lines, but rarely is such an installation economical for distribution lines. Overhead ground wires will not be installed to protect distribution lines, unless such an installation is necessary to be consistent with local usage.

(2) *Main electric supply stations.* Shielding will be provided because of the cost and importance of such stations. Transformer stations with incoming aerial lines above 15 kV will be shielded because of equipment cost. Such shielding reduces possible surge voltages. This shielding may take the form of lightning masts located on top of the station metal structure to provide the required cone of protection for apparatus and circuits within the station area. The incoming line will be shielded for at least 1/2 mile from the station to provide sufficient line impedance between the non-shielded line and the station, otherwise high discharge currents could occur resulting in excessive arrester discharge voltages. When the incoming lines belong to the serving utility and shielding cannot be provided, design calculations must assure adequate surge arrester protection or other methods of limiting magnitudes of traveling waves.

(a) Zone of protection. The zone of protection of a shielding system is the volume of space inside which equipment is considered to be shielded. The shaded areas on figure 9-1 illustrate the zones of protection for both single and double mast or wire

Angle	Degrees range	Degrees recommended
A	20 to 45	30
B	40 to 60	45

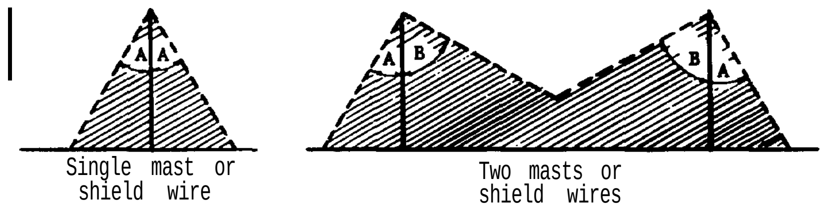

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Figure 9-1. Zones of Protection for Masts and Shield Wires.

systems plus the range of angles often used and the maximum angles recommended.

(b) Strength of wire. Breakage of shield wires could result in outage and damage to equipment. To minimize possible damage, ground wires will be at least 7/16-inch, high-strength, zinc-coated steel (ASTM Std A 475) with a minimum breaking strength of 14,500 pound-force (lbf) and maximum design tension will be limited to 2,000 pounds per conductor.

f. Grounding. For safety reasons, electric power systems and equipment are intentionally grounded, so that insulation failure results in operation of protective devices to deenergize circuits, thus reducing risk to personnel. The word "grounding" is commonly used in electric power system work to cover both "system grounding" and "equipment grounding"; however, the distinction between system and equipment grounding must be recognized. A system ground is a connection to ground from one of the conductors of an electric circuit, normally the neutral conductor. An equipment ground is a connection to ground from non-current carrying metallic parts of the installation such as conduit and equipment cases of apparatus connected to an electric circuit. IEEE Std. 142 and ANSI C2 grounding practices will be used for all power generating and delivery systems.

(1) *System grounding.* System grounding discussed in IEEE Std. 142 includes ungrounded (3-wire); single-grounded (3-wire, source grounded); and multiple-grounded (4-wire) systems. The preferred system for new Army projects is the multiple-grounded four wire system. New Air Force projects will incorporate only multiple-grounded (4-wire) systems. See IEEE Std. 142 discussion of grounding and supply availability. Wye-connected electric distribution systems will be provided with a grounded neutral connection. Such intentional grounding minimizes the magnitude and duration of over-voltages, thereby reducing the probability of insulation failure and equipment damage. Neutrals for each voltage level will be grounded independently at each electric power source; that is, at transformer secondaries and at generators.

(a) Transformer neutral grounding. Transformers which have wye-connected secondaries will be solidly grounded. Solid grounding is the least expensive method of limiting transient over-voltages while obtaining enough ground fault current for fast selective fault isolation. Other methods of grounding are resistance grounding and reactance grounding, but in most cases, reactance grounding of transformers provides no advantages over solid grounding. A disadvantage of systems grounded through resistors is that surge arrestors must be sized as if used on ungrounded systems, that is, with a voltage rating at least equal to the line-to-line voltage. Systems with voltage above 15 kV. will be solidly grounded because of the prohibitive cost of grounding equipment and the increased surge arrester cost. For voltages from 2.4 to 15 kV., solid grounding is preferable because distribution systems which supply transformers protected by primary fuses require enough fault current to melt primary fuses on a ground fault. However, in some cases, low-resistance grounding will be needed to limit ground fault currents to values less than withstand ratings of equipment when such equipment is designed for direct connection to voltages of the 2.4 to 15 kV level. Systems rated 600 V or less will be solidly-grounded except for applications such as continuous processes for industrial systems where shutdown would create a hazard, loss of materials, or equipment damage. For those applications, the designer will evaluate the use of a solidly-grounded wye-system with a back-up power supply, or a high-resistance-grounded wye-system. Use

of high-resistance grounded systems must be justified on the basis of a paramount necessity for service continuity.

(b) Generator neutral grounding. Generating units will be provided with reactor grounding only when solid grounding would cause ground fault current to exceed the short-circuit current for which the unit is braced and when harmonic current circulation needs to be minimized.

(2) *Equipment grounding.* Intentional equipment grounding maintains metallic surfaces at low potentials above ground, thereby decreasing possibility of electric shocks. System grounds and equipment grounds will be interconnected in accordance with ANSI C2 and the NEC. Some state safety orders do not permit grounding of enclosure cases supported on wood poles, when accidental contact with bare aerial lines might occur.

g. Ground fault relaying. Two types of ground fault relays are in general use. Ground overcurrent relays are used on medium-and high-voltage systems, and the less expensive ground fault protection device is used on low-voltage systems. Since no current or voltage is present in the ground conductor under normal system operation, ground relays can be made very sensitive. Ground relays can also be set to operate very quickly since coordination between voltage levels is not a constraint. Their use permits isolation of faulty equipment before short-circuits can cause damage.

(1) *Medium- and high-voltage sytems.* The ground fault relay used will have the same time overcurrent characteristics as the overcurrent relays used for phase protection. The ground fault relay is interposed in the residual connection between the current transformers in each of the three phases and senses the fault current of a grounded wye connection. For further information on ground fault relaying see IEEE 141, IEEE 242 and TM 5-811-14.

(2) *Low-voltage sytems.* Where low-voltage ground fault protection is required by the NEC, protection will be installed as a part of the switchboard, but some instances make installation advisable at the exterior transformer station. Although overcurrent relays can be used to meet the NEC requirements, the less expensive ground fault protection device is satisfactory.

(a) Single electric source systems. Ground fault protectors will utilize sensors of the vectorial summation type which either requires one sensor for each phase and the neutral (residual sensing) or one window type sensor around all three phases and the neutral (zero sequence sensing). Use of a single sensor on the main bonding jumper is not acceptable, because the additional grounding connection at the transformer station provides a second path of fault current which is not sensed.

(b) Multiple source electric systems. Erroneous ground fault response can occur in multiple-source, three-phase, four-wire distribution systems. The common neutral conductors have multiple ground points providing alternate paths for fault currents, which if not properly monitored, can cause nuisance tripping or failure to trip. For such systems, a detailed analysis will be necessary to ensure ground fault protection that will trip appropriate circuit breakers dependent upon the fault location.

9-3. Ground Electrodes.

The most elaborate grounding system that can be designed may prove ineffective unless the connection of the system to earth is adequate and has a sufficiently low resistance. Since the desired resistance varies inversely with the fault current to ground, the larger the fault current the lower the resistance must be. For main electric supply stations and plants generating at medium voltages, the earth resistance will not exceed one ohm, and the ground grid will be designed in accordance with IEEE Std 80. For secondary unit substations and pad-mounted compartmental transformers larger than 500 kVA, earth resistance will not exceed five ohms, and the grounding system will be designed in accordance with IEEE Std 142 and IEEE Std 80. For electrical installations other than those listed above, the NEC requirement of 25 ohms maximum is acceptable.

a. Resistivity of the soil. The resistivity of the earth varies dependent upon its composition, as indicated in table 9-2. More moisture in the soil or a higher soil temperature decreases soil resistivity. The methods of providing earth connections given in this manual will be used to provide the required resistance to ground, except when the installation or the local utility indicates that special techniques are necessary. In that case, local practice will be followed.

b. Elements of the system. Ground cables will be copper. Other metals or metal combinations will be used only in those cases where the mechanical strength of copper is inadequate. Driven copper-clad steel ground rods will be specified as ground electrodes since such rods have a higher conductivity than most other types. Where low soil resistivities are encountered and galvanic corrosion may occur between adjacent ferrous metallic masses and the copper clad rods, consider the use of zinc coated steel or stainless steel rods. Stainless rods have a much longer life than zinc coated steel rods, especially in soils with high lime content, but

Table 9-2. Resistance of One 5/8-Inch by 10-Foot Ground Rod in Various Soils [a],

Type of Soil	Resistance in ohms		
	Minimum	Average	Maximum
Ashes, cinders, brine waste	1.9	7.6	22
Clay, shale, gumbo, loam	1.1	13	53
Same, but with sand and gravel	3.3	50	433
Gravel, sand, stones, little clay or loam	19.2	300	1,460

[a] Based on the resistivity of soils and formulas for calculation of resistance given in IEEE Std 142-1982. Use of a 3/4-inch diameter rod of the same length decreases resistance less than five percent.

stainless steel will corrode in certain soils and the higher cost of stainless steel must be justified. Stainless steel rods will not be used for Air Force installations. Use of pure copper rods must be justified because of the high cost and susceptibility of copper to damage during installation. The designer will coordinate and standardize grounding materials selection for each facility based on corrosive conditions, grounding materials requirements, cathodic protection, and lightning protection. Note that zinc coated rods do not conform to requirements of NFPA 78. While connection to an existing metallic water system provides low ground resistance, there is the possibility that water main maintenance or other work might result in accidental disconnection of grounds and create a hazardous condition. Therefore, such connections will only be provided as a secondary backup to made electrodes.

(1) *Additional electrodes.* Whenever the ground rod does not provide the required ground resistance, either longer or additional ground rods will be necessary. Since ground resistance decreases with an increase in ground rod depth, the use of longer ground rods is the most economical method. However, where rock is encountered, use of more rods, a ground mat, or a ground grid may be necessary. The space between rods will not be less than the length of a rod, and never less than six feet. The optimum spacing of ground rods is twice the length of the rod. Where the above methods do not result in the required resistance, electrolytic ground rods filled with nonhazardous metallic salts or bentonite slurry grounding wells may be used. Bentonite wells will be designed to meet criteria in IEEE 80.

(2) *Other made electrodes.* Butt grounds or ground plates may be provided on poles as an economical method of grounding the overhead ground wire, but their use is permitted only in areas where such an installation is local practice. These made electrodes will not be used as the sole grounding electrode for apparatus or neutral grounds, which require a ground rod installation as a minimum.

9-4. Grounding Details and Requirements.

Grounding will be provided in accordance with NESC, NEC, and IEEE Std 80.

a. Main electric supply stations. Because of the equipment layout within a station, steep voltage gradients might occur if each apparatus “island” were separately grounded.

(1) *Ground grid.* In order to prevent steep-voltage gradients and also to design for maximum voltage excursions at the station, without the use of an excessive conductor size, a grid system designed in accordance with IEEE Std 80 will be installed below grade enveloping the fenced area. Figure 9-2 shows a typical substation grounding grid, Ground wire spacings of approximately 10 to 12 feet are commonly used. Exact spacing may be slightly more or less to suit station configurations. The perimeter ground wire will be installed not less than two feet outside the station fence to protect approaching personnel from step-and-touch potential exposure.

(2) *Special danger points.* Equipment operating handles are a special danger point because of the higher probability for coincidence of adverse factors, namely, the presence of a person contacting grounded equipment and performing an operation that can lead to electrical breakdown. If the grounding system is designed conservatively for safe mesh potentials, then the operator is not exposed to unsafe voltages. However, due to the uncertainty inherent in substation grounding design, a metal grounding platform, connected to the operating handle and to the grid in at least two places, will be placed so the operator must stand on the platform to operate the device (see fig. 9-2). This arrangement will be provided regardless of whether the operating handle is insulated.

b. Transformer installations.

(1) *Multigrounded systems.* Primary and secondary grounding conductors will be interconnected as required by the NESC. Spark gaps will not be used. Grounding conductors will be sized in accordance with NEC and NESC standards.

(a) For aerial transformer installations (multi-grounded, common-neutral systems),

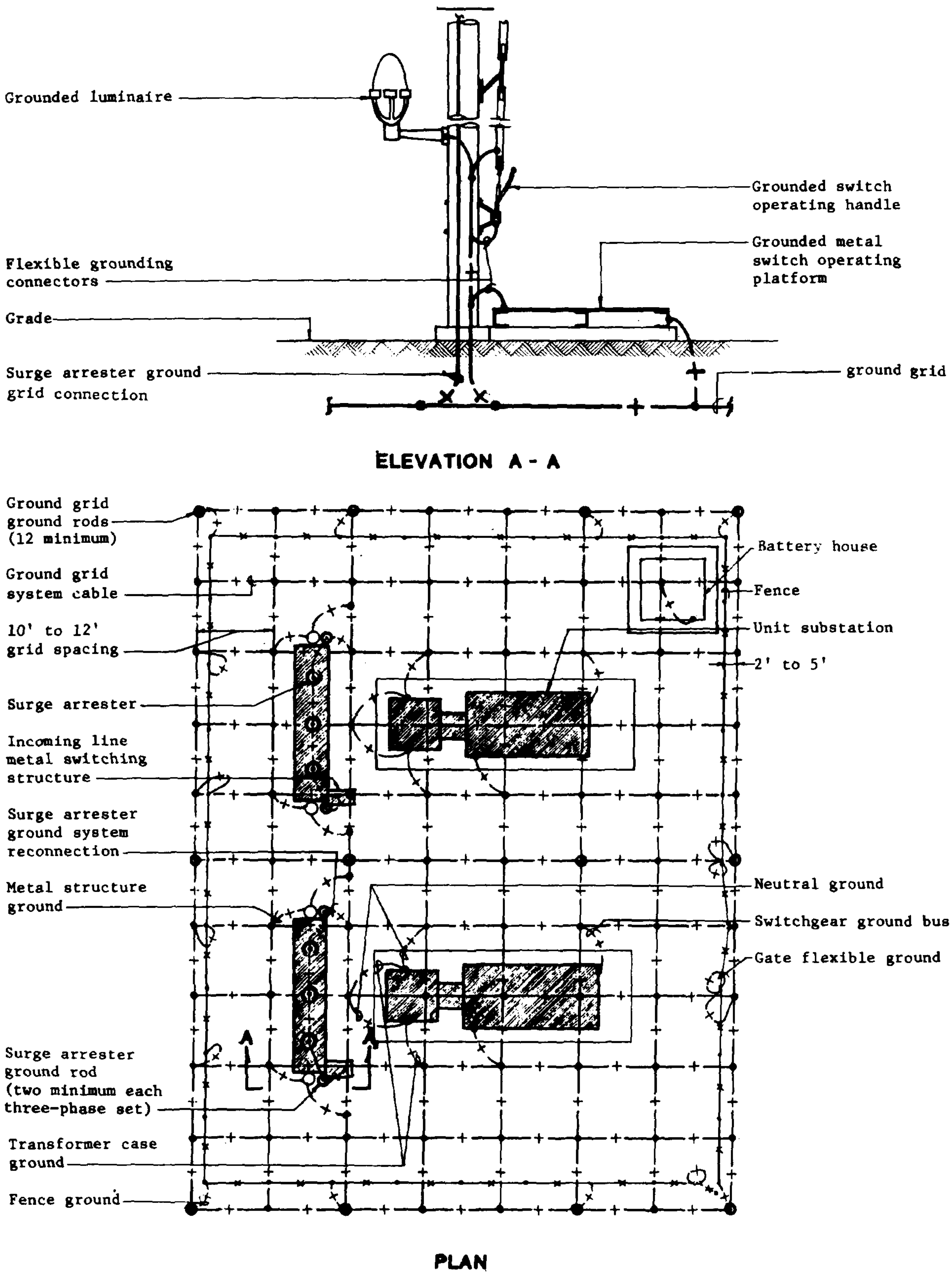

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Figure 9-2. Grounding of a Main Electric Supply Substation.

grounding conductors will be directly interconnected at the transformer and then connected to a single, continuous, vertical grounding conductor run down the pole to a driven ground rod installation. Pole-butt grounds will not be used. Figures 8-1 and 8-2 illustrate aerial transformer grounding. All equipment, neutrals, surge arresters, and other items required to be grounded will be connected to this vertical grounding conductor.

(b) For pad-mounted transformer installations, grounding conductors will be connected directly to the transformer enclosure and then to the buried ground rods, mat, or ring. Figure 8-3, 8-4, 9-2, and 9-3 illustrate pad-mounted transformer grounding.

(2) *Ungrounded and single-grounded systems.* Primary and secondary grounding conductors of ungrounded or single-grounded systems will not be interconnected except through a secondary surge arrester as permitted by ANSI C2. Grounding conductors will be run separately to separate ground rods located not less than 20 feet apart as required by the NESC. The secondary grounding conductor will be insulated to the same level as the secondary connectors. Interconnection of grounding conductors below grade will not be permitted. Spark gaps will not be used.

c. Medium-voltage riser poles. Medium-voltage riser poles will be provided with surge arresters,

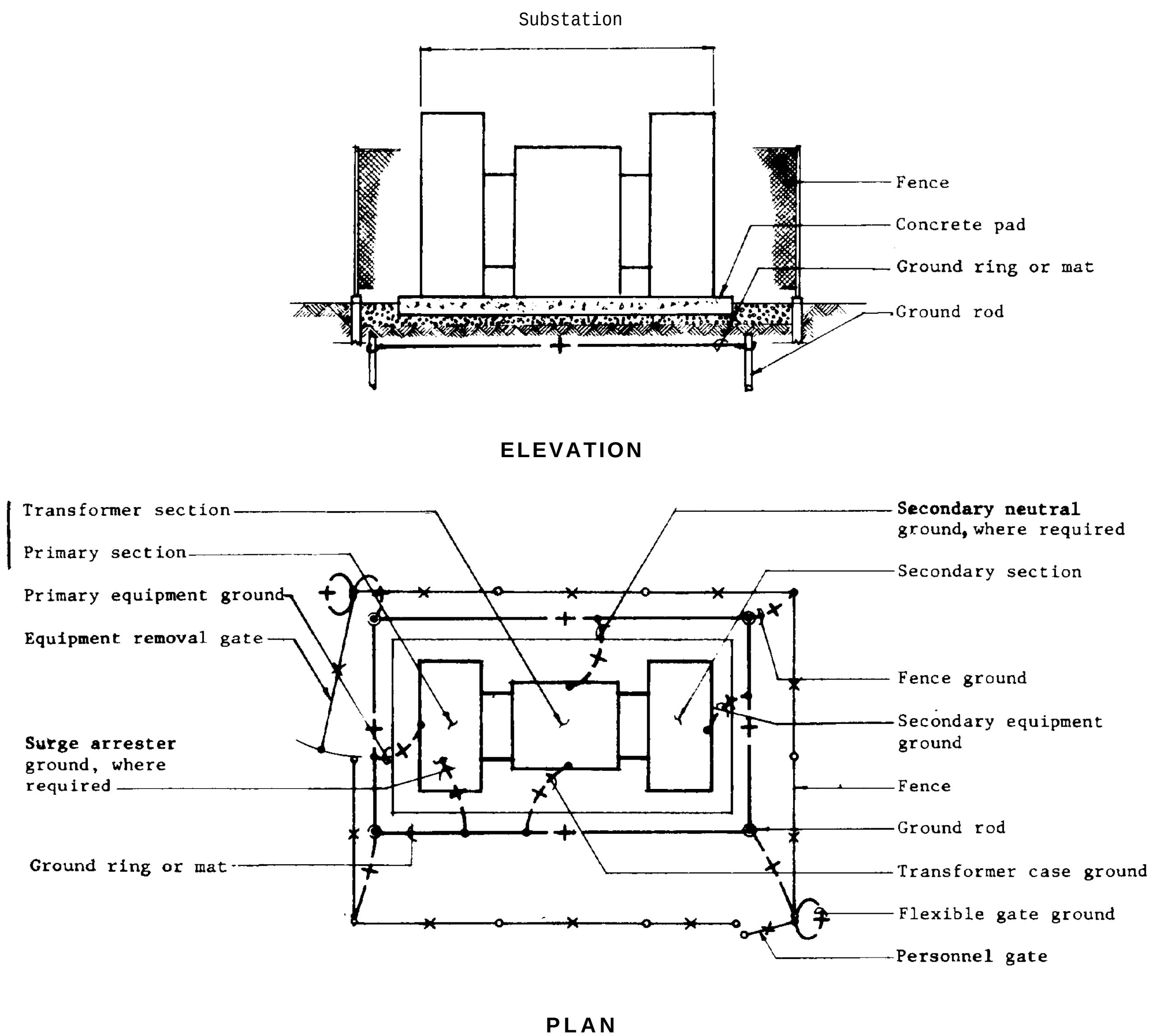

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Figure 9-3. Grounding of Secondary Unit Substation Installation even in areas having a low lightning incidence. Except for riser poles supplying critical facilities, the configuration for placement of surge arresters (i.e., at the cable termination or ahead of the fuse cutout) will follow local utility practice. For critical facilities, one set of arresters will be placed at the cable termination and another set ahead of the fuse cutout. Figure 9-4 illustrates a medium-voltage riser pole with arresters placed ahead of the fuse cutout to prevent lightning current from flowing through the fuse. Arresters are sometimes placed at the cable termination to reduce the length of the grounding conductor (and thus the voltage drop). However, this configuration allows the lightning current to flow through the fuse.

d. Miscellaneous. Conductive elements such as metal poles or reinforced concrete will be provided with an individual ground electrode connection in addition to the required equipment grounding conductor. Possibility of mechanical damage, corrosion, and other conditions which can degrade the continuity of a grounding system make such multiple-grounding points necessary.

e. Instrumentation systems. Instrumentation systems will be grounded in accordance with NFPA 70. Because of the low-frequency nature of instrumentation systems, single-point grounding will be specified in accordance with MIL-HDBK-419A and FIPS Pub 94. For widely-separated installations, where it becomes impractical to implement single-point grounding, fiber-optic cable systems should be used for data transmission. Where fiber-optic cable is not practicable, follow grounding recommendations in MIL-HDBK-419A. Where transducers and associated devices are installed as an integral part of a facility, the instrumentation

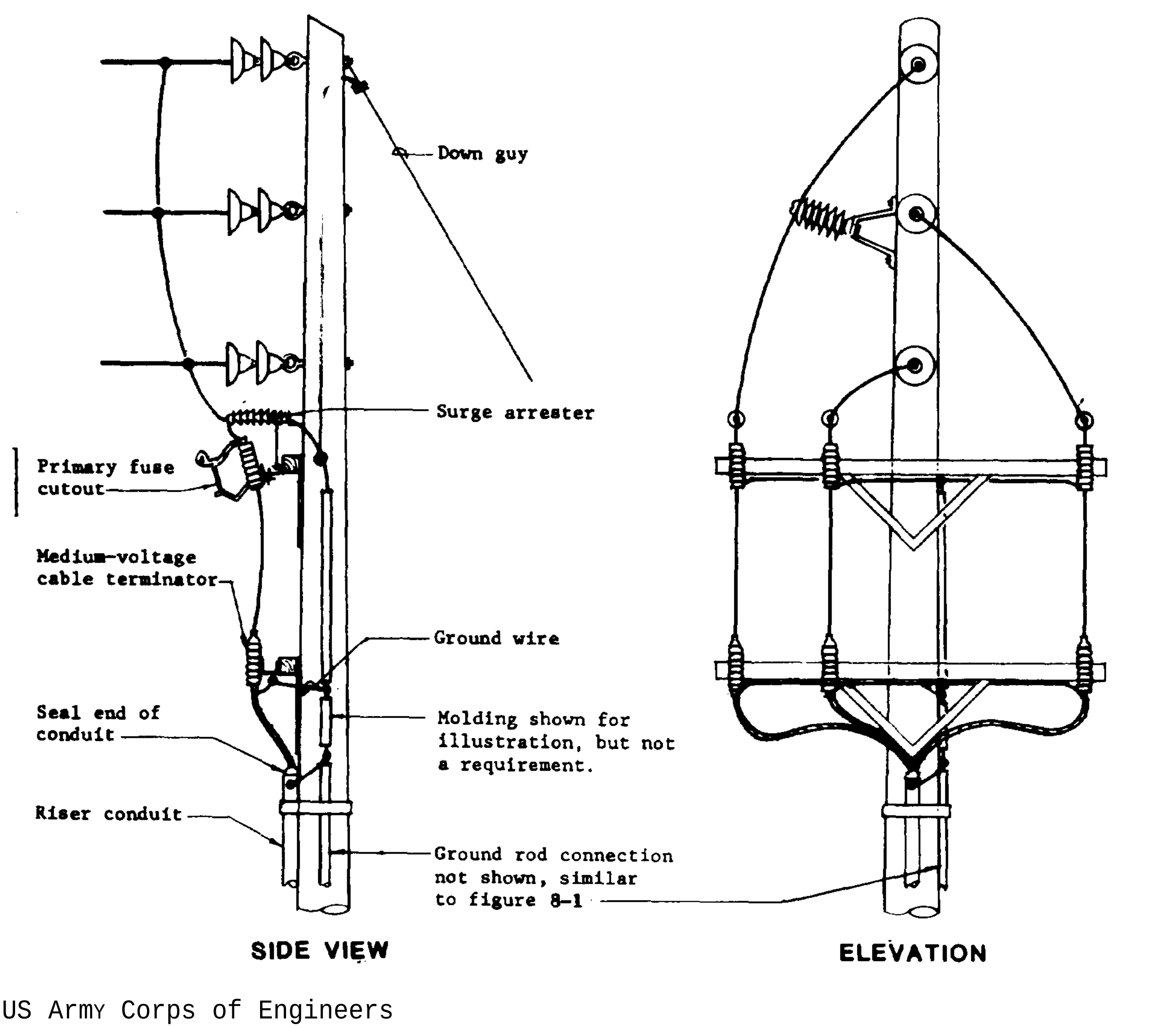

Figure 9-4. Provision of Surge Arresters at a Medium-Voltage Riser Pole.

grounding system will be coordinated with the single-point grounding system of other low-frequency networks. Inter-connection of such grounding systems will be made at a single point. Separate or isolated earth connections called "quiet grounds" (or any other such "name") will not be provided. Installations located less than 25 feet apart, with interfacing data cables, will have interconnected earth electrode systems. Installations located greater than 25 feet apart, with interfacing data cables, will be considered as stand alone installations, with individual earth electrode systems.

f. Ground fault return conductor. Medium voltage cable systems will incorporate a grounding conductor connected in parallel with the cable shields and bonded at each point where they are connected to ground. The conductor will be sized for the available system ground-fault, but will not be less than a # 2/0 AWG copper conductor. Metallic conduit is not an acceptable substitute for the conductor. The ground fault return conductor will not be required when concentric neutral cable is specified.