

EXTERIOR ELECTRICAL POWER DISTRIBUTION

By

J. Paul Guyer, P.E., R.A.

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J. Paul Guyer, P.E., R.A.

Paul Guyer is a registered civil engineer, mechanical engineer, fire protection engineer, and architect with over 35 years experience in the design of buildings and related infrastructure. For an additional 9 years he was a senior-level advisor to the California Legislature. He is a graduate of Stanford University and has held numerous national, state and local positions with the American Society of Civil Engineers and National Society of Professional Engineers.

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1. INTRODUCTION This publication provides policy and guidance for design criteria and standards for electrical power and distribution systems. The information provided here must be utilized by electrical engineers in the development of the plans, specifications, and calculations, and must serve as the minimum electrical design requirements. It is applicable to the traditional electrical services customary for Design-Bid-Build construction contracts and for Design-Build construction contracts. Project conditions may dictate the need for a design that exceeds these minimum requirements. Onsite generation is not addressed by this publication. The design criteria and standards contained within are the minimum requirements acceptable for installations for efficiency, economy, durability, maintainability, and reliability of electrical power supply and distribution systems. The criteria and standards herein are not intended to be retroactively mandatory. Comply with the requirements of NFPA 70 and IEEE C2.

2. ELECTRICAL POWER REQUIREMENTS

2.1 ELECTRICAL POWER REQUIREMENTS: GENERAL. Virtually all military bases have an existing overhead and underground distribution system that has been in service for many years. As part of any new design project, review the existing design with base personnel to determine which existing features should not be duplicated in future designs. Address design preferences with responsible engineering and operations personnel as part of the system design analysis.

2.2 SELECTION OF PRIMARY VOLTAGE. NEMA C84.1 establishes typical voltages and voltage ranges for 60 Hz systems. Facilities located outside of the United States must also comply with the applicable host nation standards.

2.3 DESIGN FOR MAINTENANCE. Design primary distribution system equipment installations with future periodic maintenance as a principal consideration. Equipment must be capable of removal from service while minimizing the outage time of affected facilities and missions. Looped and alternate feed designs are essential to allow periodic maintenance. Provide maintenance criteria with the design analysis as part of the basis for the design.

3. DESIGN CRITERIA

3.1 MAIN AND ELECTRIC SUPPLY STATIONS/SUBSTATIONS. All main and electric supply stations/substations shall conform to the requirements of IEEE C2 Part 1, *Rules for the Installation and Maintenance of Electric Supply Stations and Equipment*, as follows:

- Electric Supply Stations shall be defined as stations that transform the energy level (voltage) for further bulk distribution at medium voltage levels.
- The low voltage equipment in a main or electric supply station (equipment that is being served from a Utilization Electric Supply Station) shall conform to the requirements of NFPA 70.

3.1.1 MAIN ELECTRIC SUPPLY STATIONS. The main electric supply station is the installation/utility interface point where further transmission, distribution and utilization of electrical power, the monitoring and control of such power or equipment and the protection of electrical equipment or systems usually becomes the sole responsibility of the owner or their contracted representatives. Coordinate the design of new stations, or modifications to existing stations with the supplying utility and with any other suppliers or users of power supplied.

3.1.2 UTILIZATION ELECTRIC SUPPLY STATIONS. Utilization Electric Supply Stations are defined as equipment such as pole or pad-mounted transformers or secondary unit substations that transforms the energy level (voltage) to a utilization voltage for consumer use. Some examples of Utilization Electric Supply Stations are service transformers (serving low voltage equipment in a Main Electric Supply Station), a lighting transformer (serving equipment for a roadway lighting system), a pole or pad-mounted transformer (serving a building), or a secondary unit substation (serving other electrical systems).

3.2 GENERAL ELECTRICAL REQUIREMENTS. Overhead facilities shall conform to the requirements of IEEE C2 Part 2, *Safety Rules for the Installation and Maintenance of Overhead Electric Supply and Communication Lines*. Underground facilities shall conform to the requirements of IEEE C2 Part 3, *Safety Rules for the Installation and Maintenance of Underground Electric Supply and Communication Lines*. Design new primary distribution systems as four wire, multi-grounded systems that are wye connected at the source transformer. Provide a system grounded neutral conductor throughout the system. The neutral shall be bare conductor for overhead systems. When a project is limited to connecting to an existing three wire system and the primary electrical characteristics are established and defined, continuation of the existing system shall be permitted with the following requirements:

- For extensions from underground structures, provide a four wire extension. Bond the grounded neutral conductor at each end of the extension to the applicable grounding electrode systems.
- For extensions from overhead pole lines, provide a four wire extension. Bond the grounded neutral conductor at each end of the extension to the applicable grounding electrode systems.

- Note: Design of the extensions as four wire systems does not change any circuit classifications. It provides an extended grounding electrode system to facilitate any future circuit conversions to four wire systems

Provide equipment foundation pads and ensure a minimum of 10 ft (3 m) clear workspace in front of pad-mounted equipment for hot stick work. Orient equipment so that adjacent equipment will not interfere with the clear workspace. Provide bollards in areas where equipment is subject to vehicular damage.

3.3 PRIMARY UNIT SUBSTATIONS. Provide primary unit substations to distribute underground medium voltage circuits. Primary unit substations shall comply with the following industry standards as applicable for the specified configuration:

- IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.
- IEEE C57.12.00, *General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.12.80, *Terminology for Power and Distribution Transformers*.
- IEEE C57.12.90, *Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.96, *Loading Dry-Type Distribution and Power Transformers*.
- IEEE C57.98, *Guide for Transformer Impulse Tests*.
- IEEE C37.74, *IEEE Standard Requirements for Subsurface, Vault, and Padmounted Load- Interrupter Switchgear and Fused Load-Interrupter Switchgear for Alternating Current Systems up to 38 kV*.

3.4 SECONDARY UNIT SUBSTATIONS. Provide secondary unit substations when secondary currents exceed 3,000 amperes. Secondary unit substations shall comply with the following industry standards as applicable for the specified configuration:

- IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.
- IEEE 57.12.50, *Ventilated Dry-Type Distribution Transformers, 1 to 500 kVA, Single-Phase, and 15 to 500 kVA Three-Phase, with High-Voltage 601 to 34,500 Volts, Low-Voltage 120-600 Volts.*
- IEEE 57.12.51, *Ventilated Dry-Type Power Transformers, 501 kVA and larger, Three-Phase, with High-Voltage 601 to 34,500 Volts, Low-Voltage 208Y/120 to 4160 Volts.*
- IEEE C57.12.00*, General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.*

- IEEE C57.12.01*, General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid-Cast and/or Resin-Encapsulated Windings*.
- IEEE C57.12.80, *Terminology for Power and Distribution Transformers*.
- IEEE C57.12.90, *Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.12.91, *Test Code for Dry-Type Distribution and Power Transformers*.
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- IEEE C57.96, *Loading Dry-Type Distribution and Power Transformers*.
- • IEEE C57.98, *Guide for Transformer Impulse Tests*.
- • IEEE C57.124, *Detection of Partial Discharge and the Measurement of Apparent Charge in Dry-Type Transformers*.

3.5 PAD-MOUNTED DISTRIBUTION TRANSFORMERS.

3.5.1 REFERENCE CRITERIA. Pad-mounted transformers shall comply with the following industry standards:

- • IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.
- • IEEE C57.12.00, *General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- • IEEE C57.12.34, *Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers (2500 kVA and Smaller) – High-Voltage, 34,500 GrdY/19,200 Volts and Below; Low-Voltage: 480 Volts and Below*.
- • IEEE C57.12.80, *Terminology for Power and Distribution Transformers*.
- • IEEE C57.12.90, *Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*.

- • IEEE C57.98, *Guide for Transformer Impulse Tests*.
- • IEEE C57.12.22, *Transformers – Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers with High-Voltage Bushings, 2500 kVA and Smaller: High Voltage, 34,500 Grd Y/19,920 Volts and Below; Low Voltage, 480 Volts and Below*.

3.5.2 CONFIGURATION. Use dead-front construction for pad-mounted transformers unless not available within system parameters. Use pad-mounted transformers, separately protected with vacuum fault interrupter equipped switches for 34.5 kV systems. Do not use pad-mounted transformers with secondary currents exceeding 3,000 amperes because of the size and quantity of secondary conductors. Transformers rated above 1,000 kVA serving 208Y/120 volt loads and above 2,500 kVA serving 480Y/277 volt loads must be in a secondary unit substation configuration. Minimize double transformations to reduce energy consumption and to minimize items of equipment. Provide two oil-filled pad-mounted transformers in lieu of one 480Y/277 volt service if the required 208Y/120 volt load using dry-type transformers exceeds 40 percent of the 480 volt service transformer capability. Connect equipment at the highest available voltage to minimize the capital cost and energy losses of transformation equipment. Three-phase pad-mounted transformers must be loop-feed capable with 6 bushings. Provide two-position, oil-immersed, load break switches that are appropriate for the application. If the transformer might be used as part of a loop-feed design, provide three switches to permit closed transition loop feed and sectionalizing. If the transformer will be installed at the end of a radial supply with no intention of future loop feed capability, provide a single on-off switch. Provide a spare conduit in the high voltage section extending 5 ft (1.5 m) out from the transformer pad.

3.5.3 TRANSFORMER CONNECTIONS. Connections shall be delta-wye for three phase systems.

3.5.4 SURGE PROTECTION. Provide bushing-mounted elbow type arresters at the ends of all radials and in normally open locations in loops. Provide arresters for all voltage levels above 5 kV.

3.6 MEDIUM VOLTAGE SWITCHGEAR.

3.6.1 METAL-CLAD SWITCHGEAR. Metal-clad switchgear can include either SF6 or vacuum style breakers and must consist of a single section or multiple section line-up of NEMA 1 or NEMA 3R enclosures. Either walk-in or non-walk-in construction can be provided. Medium voltage metal-clad switchgear can be provided as unit substation construction or as stand-alone switchgear. The sections must contain the breakers and the necessary accessory components. The equipment must be factory-assembled (except for necessary shipping splits) and be operationally checked before shipment. Consider remote racking device designs (robots) to rack breakers in and out. Metal clad switchgear shall comply with the following industry standards:

- IEEE C37.06, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities*.
- IEEE C37.121, *Switchgear – Unit Substations Requirements*.
- IEEE C37.04, *Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*.
- IEEE C37.20.2, *Metal-Clad Switchgear*.
- IEEE C37.90, *Relays and Relay Systems Associated with Electric Power Apparatus*.

Provide batteries for dc opening and closing of circuit breakers. Do not use ac or capacitor control methods.

3.6.2 METAL-ENCLOSED SWITCHGEAR. Do not use metal-enclosed switchgear. Instead, use either a vacuum fault interrupter (VFI) in a unit substation configuration or an upstream pad-mounted switchgear.

3.7 PAD-MOUNTED SWITCHGEAR (SWITCHES). For some installations as directed by the owner, utilize multi-way pad-mounted switchgear when switching, isolation, or electrical protection is required. Specify SF6 gas or high fire point liquid (non-temperature dependent) insulation technology and vacuum bottle interruption technology. Specify dead front construction with stainless steel tanks and operator full size viewing windows for each switching way. Specify three position (On/Off/Ground) switch ways for all new construction. For switch replacements when existing switching arrangement is On/Off/Tie, a similar arrangement without ground position is permissible. Specify switch design which incorporates operating handles on the opposite side of the tank from the cable entrance bushings, terminations and cables. Specify 600 ampere dead break connectors with 200 ampere interface bushings for each switch way. Air Insulated (fused or non-fused) technology is not permitted. Pad-mount switchgear shall comply with the following industry standards:

- IEEEcC57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.
- IEEE C37.60, *Requirements for Overhead, Pad-Mounted, Dry Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for Alternating Current Systems Up to 38 kV*.
- IEEE C37.74, *IEEE Standard Requirements for Subsurface, Vault, and Padmounted Load- Interrupter Switchgear and Fused Load Load-Interrupter Switchgear for Alternating Current Systems up to 38 kV.*

For other installations as directed by the owner, air-insulated and fused switches can be used in either a live-front or dead-front configuration. Do not use air-insulated switches in corrosive and high humidity areas unless the installation experience for the installed location confirms that switch corrosion and tracking is not a problem.

3.8 PAD-MOUNTED SECTIONALIZING TERMINATION CABINETS. Apply pad-mounted sectionalizing termination cabinets only when switching, isolation, or electrical protection for the downstream circuit is not required or anticipated. Sectionalizing

termination cabinets can be used instead of in-line splices in manholes or for minor loads that do not warrant the expense of pad-mounted switchgear. Sectionalizing cabinets are available up to 35 kV. Provide low profile sectionalizing termination cabinets when the conductor size is 4/0 awg or smaller.

3.9 CAPACITORS. Do not use capacitors unless they are needed for power factor correction or to minimize line losses. Verify the need by a system analysis; the analysis must consider the potential adverse effects of transients caused by capacitor switching. Refer to TSEWG TP-2: *Capacitors for Power Factor Correction*, at for additional information if power factor correction is considered. Underground distribution has more capacitance than equivalent overhead distribution. When converting from overhead distribution to underground distribution, provide pad-mounted capacitors on a distribution system only if supported by the design analysis. Do not automatically replace existing pole-mounted capacitors with equivalent pad-mounted capacitors. For safety purposes, include an oil switch disconnect with pole-mounted capacitors.

3.10 OVERHEAD POWER DISTRIBUTION. Design overhead lines to IEEE C2 Grade B construction complying with the following:

a. Limit the initial loaded conductor tension to a maximum of 50% of the conductor rated breaking strength. Lesser tensions are usually applicable and generally more preferred. Utility distribution line design is generally in the range of 25% to 35% of the rated breaking strength.
b. Provide clearance requirements using final sag values in conformance with IEEE C2 Part 2.
c. Limit the maximum design tensions for any conductors to 4,750 pounds (2,154 kg). All clearance values shall be based on the following maximum conductor temperatures:

- Copper phase conductors – 167 degrees F (75 degrees C).
- Aluminum/aluminum alloy phase conductors – 194 degrees F (90 degrees C).
- Neutral conductors for multi-phase circuits – 120 degrees F (49 degrees C).

- The maximum conductor temperature for single-phase neutral conductors shall be identical to the phase conductors.

Match the existing base construction methods. Match those construction methods used by the local utility when directed. Where new overhead distribution is required, route the overhead distribution along roadways and other major topographical features; the poles must be accessible for future maintenance or work. Coordinate pole locations with land-use planning to ensure that new poles do not interfere with future facility plans. In situations where an applicable pole detail has not been developed, provide new detail drawings as required. Designer developed details shall contain a level of detail equivalent to standard pole details and include material requirements.

3.10.1 POLE TYPES. Use solid wood poles for electric distribution lines; concrete and steel poles can be used for roadway or area lighting circuits carried underground or separately from distribution lines. Concrete or steel poles may be justified for medium-voltage distribution circuits where wood poles do not provide adequate strength, or where climatic conditions cause wood poles to deteriorate rapidly. Do not use laminated wood poles for electric distribution lines.

3.10.2 CONDUCTORS. Due to the increasing technology improvements with aluminum conductors and connectors, and the economic disadvantage of providing copper conductors, provide aluminum conductor steel reinforced (ACSR) or aluminum alloys for new overhead lines and extensions of existing lines. Except for grounding systems, the use of copper conductors is prohibited without specific approval and documentation by the applicable local engineering authority. Do not use ACSR conductors in corrosive and high humidity areas. For corrosive and high humidity areas, provide Type ACSS conductors.

3.10.3 POLE-MOUNTED TRANSFORMERS. Provide pad-mounted transformers rather than pole-mounted transformers for new three-phase installations larger than 75 kVA. Use only single phase transformers for pole-mounted installations. For single

phase installations and when banking single phase transformers for three phase applications, apply phase-to-neutral primary connections unless installed on three wire distribution systems. Limit pole-mounted transformer sizes (except for projects involving system conversions to a different operating voltage) as follows:

- Three-phase installations – limited to three 25 kVA transformers or smaller.
- Single-phase installations – limited to one 75 kVA transformer or smaller.

Do not use pole-platform mounting (two-pole structure or H-frame). Do not use self-protected transformers. Self-protected transformers have internal primary fuses that must be replaced by experienced personnel. Aerially mounted installations might supply several buildings. When that is the case, install the transformers at the pole location closest to the building with the greatest load. Secondary wiring should drop directly to the buildings served, if the span does not exceed 125 feet; otherwise, intermediate poles are required.

3.10.4 POLE TOP SWITCHES. Pole top switches are installed at important system locations to allow either isolation of the downstream circuit or cross-connection to a different circuit. Where ground operated, gang type, three phase, air break switches are used with non-insulated operator handles, provide a metal plate or grate at ground level for the operator to stand on when operating the switch. Connect the metal plate or grate to the pole ground conductor as well as through a braided conductor connection to the switch handle mechanism. Include a provision for locking ground accessible switch handles in the open and closed position. Single-pole knife blade switches and copper barrels inside distribution cutouts are only acceptable for use in locations where frequent switching is not expected.

3.10.5 SURGE ARRESTERS. Provide surge arresters on the line side of:

- Pole mounted transformers.
- Overhead to underground terminal poles.

- All “normally open” switch ways of pad-mounted sectionalizing switches connected to and served from overhead lines.
- Underground primary metering installations connected to and served from overhead lines.

Provide surge arresters on the line and load sides of:

- Gang operated airbreak switches on overhead lines.
- Primary metering applications on overhead lines.
- Recloser/sectionalizer applications on overhead lines.

3.10.6 FUSE PROTECTION. Provide IEEE C37.41 rated backup current limiting fuses in series with Type K expulsion fuses on systems that are:

- Greater than 15 kV.
- 15 kV and lower that have available fault currents equal to or greater than 7,000 asymmetrical amperes.

Note: Existing systems should continue to use the expulsion fuse link type that represents the standard for that system.

3.10.7 AUTOMATIC CIRCUIT RECLOSING. Do not provide automatic circuit reclosing on underground distribution circuits.

3.10.8 GROUNDING CONNECTIONS. Keep ground wires straight and short. Minimize bends in all ground connections.

3.11 UNDERGROUND ELECTRICAL SYSTEMS.

3.11.1 UNDERGROUND DISTRIBUTION GENERAL CRITERIA. Provide underground distribution as follows:

- In areas where the primary distribution is already underground.
- In locations where overhead distribution is operationally hazardous, such as within airfield clearance zones.
- As required to supply pad-mounted equipment and transformers.
- Near electronics or munitions facilities that have clearance requirements for overhead power lines.
- Near piers and loading areas where overhead cranes operate.
- In congested industrial areas.
- In areas where storm and hurricane damage can damage \1\ /1/overhead distribution.

Due to the increasing technology improvements with aluminum conductors and connectors and the economic disadvantage of providing copper conductors, provide aluminum conductors for new underground lines and extensions of existing lines. This includes all new medium voltage system designs that do not require interface (splicing copper to aluminum in underground structures) with existing copper infrastructure. Grounding electrode systems shall always be copper. The use of copper conductors is authorized for extensions of existing systems in which the use of aluminum results in technical limitations, such as:

- Maintaining required circuit ampacity, including derating associated with number of circuits in a common ductbank or burial depth.
- Maintaining base infrastructure capacity, including feeder cross-tie capability.
- Conduit size. All phases are required to be installed in the same conduit.
- Undersized or congested structures necessitating tape splices of aluminum cable to existing copper cable. *Note: If adequate space exists for the use of improved technology "heat shrink or cold shrink" splices, or if proper aluminum to copper compression connectors designed for the natural offset of size difference between the conductor materials is available as a standard manufactured product, provide the copper to aluminum cable extension*.

Do not route primary underground utilities under buildings. Systems greater than 600 volts shall also not be routed under buildings except as a direct service entrance to a single interior transformer. Tag all underground cables in all accessible locations such as in manholes, transformers, switches and switchgear. Install a detectable locator tape above all buried underground circuits. Marking must meet the base utility standards.

3.11.2 DUCTBANKS. The definition of the terms *ductbank, conduit*, and *duct* are often confused. Within this publicarion, a ductbank consists of two or more conduits (or ducts) routed together in a common excavation with or without concrete encasement.

3.11.2.1 CONDUIT SIZE. Minimum conduit sizes must be as follows:

- Primary Distribution Conduits (along main run between underground structures) – 6 in concrete encased (155 mm). *With owner's permission, this conduit size can be 5 in (127 mm) if the conductor size is 500 kcmil or smaller for 15 kV and below.* Primary Distribution Conduits (on laterals) and Secondary Distribution Conduits – 4 in (103 mm). Secondary distribution conduits refer to the conduit routing from the distribution transformer to the service entrance panel. This requirement does not apply to street lighting circuits, housing service drops, or secondary circuits originating from an interior panel. /1/
- Telecommunication Conduits – 4 in (103 mm).

3.11.2.2 INSTALLATION.

- Use Type EB Schedule 20 PVC conduits (minimum thickness) for conduits installed in concrete encasement. Provide at least 3 in (75 mm) of concrete encasement.
- Use Schedule 40 PVC conduit (minimum thickness) for conduits that are not installed in concrete encasement.

- Bury conduit at a minimum depth of 18 in (450 mm) below grade. Conduits must be 24 in (600 mm) minimum depth under roads and pavement, and for voltages between 22 kV and 40 kV. Apply conductor ampacity derating when exceeding the NFPA 70 maximum burial depths.
- Provide 3 in (75 mm) clearance between conduits utilizing interlocking plastic spacers.
- Provide spare conduits such that at least 1/3 of the ductbank contains empty conduits.
- Include pull wires (pull string or pull rope) in all spare ducts.
- Provide a transition from Type EB conduit to Schedule 40 PVC conduit before emerging from underground.
- Use directional boring or jack-and-bore techniques for routing conduit(s) under existing pavement for roadways, aircraft aprons, runways and taxiways. Directional boring can be used for other locations where excavation can adversely affect daily operations.
- For permafrost locations, use ductbank installation methods that are the standard for the base, post, or local utility.

3.11.3 DIRECT BURIED WIRING METHODS. The term direct buried wiring refers to the direct burial of conductors without any conduit or concrete encasement.

3.11.3.1 OPTION 1.

- Direct buried wiring for medium voltage systems is not allowed.
- Direct buried wiring for low voltage systems from the distribution transformer to the facility service entrance is not allowed.
- Direct buried wiring for low voltage systems is acceptable in large open areas only.
- Sleeve all direct buried conductors under existing roads, paved areas and railroad tracks. Use galvanized rigid steel conduit.

- Sleeve all direct buried conductors under new roads and use concrete encased conduits extending 5 ft (1.5 m) beyond the edge of the pavement. Use galvanized rigid steel or minimum Schedule 40 PVC conduit.

3.11.3.2 OPTION 2.

- Direct buried wiring methods for low or medium voltage systems may be allowed for certain applications. as follows: All applications must be submitted to the owner for approval and supported with the required documented justification during the planning process of subject design project. Any application which constitutes a part of the facility core distribution infrastructure will not be authorized.
- All direct burial systems shall meet ANSI C2 requirements for multi-grounded systems and shall be energized at a maximum nominal system voltage of 34.5 kV.
- All approved direct burial medium voltage systems shall be allowed to utilize standard concentric neutral cable design instead of the typical power cable design utilizing a separate 600 insulated volt neutral conductor.
- Direct buried systems shall also provide a spare conduit system with associated enclosures under all streets, roads, and parking areas to provide for future maintenance capability without having to disrupt pavements. Provide minimum Schedule 40 PVC extending 5 feet on each side and capped for future use.
- For crossing existing paved areas, the direct boring (DB) technology authorized by the owner shall apply for installation of the direct buried system.

The following are examples of applications that merit consideration:

- Installations for special applications in remote or extremely controlled areas. Examples of such applications could be ranges or range facilities, renewable energy projects such as wind farms or bulk photovoltaic (PV) facilities provided for the purpose of supplementing system demand loading .

- Housing projects utilizing residential type distribution principles of single-phase, pad-mounted transformer designs and single-phase distribution principles for balanced three phase system loading.
- Bulk power transfer (feeder) from point to point crossing remote or controlled real estate which will revert to public utility ownership and maintenance upon completion.

3.11.4 DIRECTIONAL BORING. Directional boring (DB) is a trenchless technology method to install high density polyethylene electrical (HDPE) conduit used for underground electrical distribution systems.

3.11.4.1 AUTHORIZED LOCATIONS. DB methods shall not be chosen as an installation means in lieu of concrete encasement or other approved jack-and-sleeve techniques, based solely on cost. Concrete encasement and jack-and-sleeve techniques always provide the best means to protect conduit and conductors; therefore, DB is authorized only for crossing under the following:

- Roads.
- Parking lots.
- Airfield aprons, taxiways, or runways (not airfield lighting circuits).
- Bodies of water.
- Environmentally sensitive areas with appropriate federal, state, and local government approval.
- Historical preservation areas with appropriate federal, state, and local government approval.

3.11.4.2 LIMITATIONS. DB is applicable to medium-voltage (HV) underground distribution systems between 1000 volts (V) and 34.5 kilovolts (kV) (nominal) and all low-voltage distribution systems (less than 1000 V). It is not applicable to airfield lighting circuits. Use of DB techniques to install electrical conduit distribution for voltages greater than 34.5 kV (nominal) is prohibited. Refer to appropriate standards regarding

depth of DB. The depth can be less if a detailed survey is performed and documented before starting boring.

3.11.5 UNDERGROUND STRUCTURES (MANHOLES AND HANDHOLES). Provide separate power and communication manholes. When power and communication duct lines follow the same route, use a common trench and locate power and communication manholes in close proximity to one another and staggered. Use manholes for main duct runs and wherever shielded medium voltage cable is installed. For the Air Force, pad-mounted sectionalizing termination cabinets can be used instead of manholes for locations that do not have multiple feeders. Handholes can only be used for airfield lighting circuits, for other non-shielded medium voltage circuits, and for low-voltage and communication lines. All in-line splices must be in underground structures. Do not use handholes for splicing shielded power cables. The following equipment is prohibited inside underground structures:

- Load junctions.
- Separable splices (bolt-T connections).
- T-splices and Y-splices on systems rated for greater than 15 kV.
- For the Air Force, T-splices and Y-splices on medium voltage systems rated for less than 15 kV.
- Power distribution equipment, including transformers and switches.

Individually fireproof medium voltage cables in all underground structures. Specify H20 highway loading for most locations. Structures subject to aircraft loading must be indicated to the Contractor. Design decks and covers subject to actual loadings. Determine the size of power manholes by the number of circuits, voltage ratings and splicing requirements of the cables within. Manholes shall be a minimum 2 m (6.5 ft) deep. Provide cable racks in all new manholes. When reworking cables in existing manholes, provide racks for new cables. Route cable installations inside manholes along those walls providing the longest route and the maximum spare cable lengths. For circuits rated above 15 kV, manholes shall be a minimum of 9 ft by 12 ft (2.8 m by

3.7 m) in interior size. Size communications manholes for equipment and splices contained, including future projections. Manholes must accommodate racking of splice closure of largest multi-pair cable while keeping cable bending radii greater than 10 times cable diameter. Provide manhole foldout details or exploded views for all multiple-circuit primary systems and all primary systems requiring splices. Indicate the entrance of all conduits and the routing of all conductors in the manholes.

3.11.6 LOCATING UNDERGROUND STRUCTURES. Provide where splices are required, where duct lines change direction, and within 100 ft (30 m) of every riser pole, pad mounted transformer, or unit substation unless a calculation is provided to justify a greater distance. The distance must not exceed 200 ft (60 m). Separation on straight runs must not exceed 400 ft (120 m). In situations where greater separation is desired and this greater separation is not prohibited by either excessive pulling tension or site requirements, separation of up to 600 ft (180 m) is permitted.

3.11.7 PULL BOXES. Pull boxes are used for electric circuits supplying low-voltage electric loads which require conductors no larger than 1/0 awg and no more than one 2-inch (52 mm) conduit entrance at each side. Wherever larger conduits are installed, use handholes or manholes. Do not use pull boxes in areas subject to vehicular traffic.

3.11.8 MEDIUM VOLTAGE CABLE. Medium voltage cables shall comply with NEMA WC 74, be type MV (105°C) aluminum or copper based on the specific applications as defined, and shall contain a 600 volt insulated neutral when required. For some owners, concentric neutral conductors are also authorized. Cables shall meet the following criteria:

- Cable Jacket – PVC or polyethylene jacket suitable for wet conditions.
- Insulation Type – Provide ethylene propylene rubber (EPR). For the Army and Air Force, cross-linked polyethylene is also authorized. Do not use paper insulated lead covered (PILC) for new installations.

- Insulation Level – The insulation level for all circuits classified as multi-grounded (4 wire systems throughout the entire circuit) shall be 100% minimum. Insulation level for all other classification of circuits shall be 133%.
- Cable Shields – Use copper-tape shielded cables and ensure minimum bending radii of 12 times the overall cable diameter. Use copper-wire shielded cables only where existing manholes are utilized and the minimum cable bending radii of tape shielded cables cannot be realized. Refer to NEMA WC 74 for cable bending radii. /1/
- Number of Conductors – Use single conductor cable as a general rule. Three conductor cable may be used only when splicing to existing three conductor cable.

3.12 CONCRETE FOR UNDERGROUND ELECTRICAL SYSTEMS. Concrete for encasement of underground ducts must be 3000 psi (20 MPa), minimum 28-day compressive strength. Concrete associated with electrical work for other than encasement of underground ducts must be 4000 psi (30 MPa), minimum 28-day compressive strength unless specified otherwise.

3.13 RESIDENTIAL AREAS DISTRIBUTION. The following requirements shall be met for electrical distribution to residential areas:

- Serve single dwelling units, duplexes and quadraplexes in housing areas by single-phase, 240/120V transformers.

- Serve no more than 6 dwelling units; 4 duplexes; or 2 quadraplexes per transformer.

- Minimum conductor size from the transformer to the service entrance equipment should be 3/0 copper in underground conduit.

- Maximum length of service lateral conductors from the distribution transformer to the service entrance device (or meter base) shall be 220 ft (67 m).

- Design the distribution system such that the available fault current at the service equipment is less than 10,000 amperes.

Where an underground 3-phase circuit is used to feed single-phase transformers, provide a separate 3-phase pad-mounted switch or sectionalizing cabinet with a radial supply to the single-phase transformers.

3.14 DISTRIBUTION SYSTEM GROUNDING. Distribution system grounding (medium voltage systems classified as multi-grounded, single point grounded at source transformer either solidly or with grounding resistors, and ungrounded) shall comply with the requirements of IEEE C2 Section 9 entitled Grounding Methods for Electric Supply and Communication Facilities.

3.14.1 MAIN ELECTRIC SUPPLY STATION Main electric supply stations and all supply stations consisting of equipment for the purpose of transforming the voltage level for further bulk distribution shall be designed in conformance with IEEE Standard 80. The station grounding system shall require measurement prior to inter-connection with other systems and prior to station energization to assure the limits of step and touch potentials as required by IEEE Standard 80 have been attained.

3.14.2 UTILIZATION ELECTRIC SUPPLY STATION A *Utilization Electric Supply Station* is defined as any station where the medium voltage system transforms the energy level (voltage) to utilization for consumer use on any kind of facility. Examples of some utilization electric supply stations are roadway lighting transformers, a building pad-mounted transformer, or a pier or wharf secondary unit substation.

3.14.3 SEPARATION OF GROUNDING CONDUCTORS The requirement for separation of grounding conductors between classes of equipment operating in excess

of 750 volts and below 750 volts shall be complied with for the design for all facilities. The exception for connecting the different classes of equipment “to a sufficiently heavy ground bus or system ground cable that is well connected to ground at more than one place” is the engineering basis for interconnecting the different classes of equipment connected to existing systems.

3.14.4 MATERIALS AND SPECIAL REQUIREMENTS

3.14.4.1 GROUND RODS. Ground rod composition, minimum spacing requirements and connections shall conform to requirements of IEEE C2 Section 9 except that minimum dimensions shall be 10 ft (3.0 m) in length and ¾ inch (19 mm) in diameter. Ground rods shall be copper-clad steel, solid copper, or stainless steel. Sectional ground rods are permitted. All connections to ground rods below ground level must be by exothermic weld connection or with a high compression connection using a hydraulic or electric compression tool to provide the correct circumferential pressure. Accessible connections above ground level and in test wells can be accomplished by clamping. Spacing for driving additional grounds must be a minimum of 10 ft (3.0 m). Bond these driven electrodes together with a minimum of 4 AWG soft drawn bare copper wire buried to a depth of at least 12 in (300 mm). Pole–butt plates and wire wraps recognized by IEEE C2 Section 9 shall not be recognized as grounding electrodes.

3.14.4.2 GROUND RINGS. Ground rings shall conform to the requirements of NFPA 70 Section 250. If the system is not classified as multi-grounded, utilization electric supply stations, switchgear, and sectionalizing cabinets require a 4/0 bare copper ground ring with a minimum of four ground rods for three phase service. Single phase service installations can be modified to minimum 1/0 copper and two ground rods for the ground ring. Test wells are permitted on specific applications as required. If metal bollards are installed and are within 8 feet of the pad-mounted equipment, bond each bollard to the ground ring.

3.14.5 LOW VOLTAGE GROUNDING INTERFACE WITH UTILIZATION ELECTRIC SUPPLY STATIONS For design purposes, the secondary terminals of the utilization electric supply station shall be the demarcation point between IEEE C2 and NFPA 70. The transition between the grounded neutral conductor (functioning as a neutral and a grounding conductor per IEEE C2) and the grounded conductor (functioning as a neutral conductor only per NFPA 70) shall be at the "service point" .

- The service point for low-voltage conductors from utilization electric supply stations containing no secondary overcurrent protection device shall be defined as the line side terminals for the facility service equipment.
- The service point for utilization electric supply stations containing an overcurrent protection device shall be at the main breaker on the secondary side of the utilization electric supply station. This is the transition point from IEEE C2 to NFPA 70 grounding where the service main bonding jumper is located.

3.14.6 GROUNDING REQUIREMENTS – FENCES Metal fences for electrical equipment and ordnance facilities shall be grounded in accordance with IEEE C2 Section 9. Other metal fences that are electrically continuous with metal posts extending at least 24 inches (610 mm) into the ground require no additional grounding unless specifically required by other criteria. Ground all metal fences at or near points crossed by overhead power lines in excess of 600 volts and also at distances of 150 ft (46 m) on each side of the line crossing. Where plastic coated fabric is used, remove plastic coating where it overlaps the post to be grounded and braze or bolt conductor to post.

3.15 METERING. Supply housing units with meter sockets only. Sockets must be single phase, four terminal, and ring-less with manual bypass device and polycarbonate blank cover plate. For all other services, provide electronic programmable watt-hour meters with solid-state demand registers. Include necessary KYZ initiation hardware for Energy Management and Control System (EMCS) coordinated with the mechanical Direct Digital Control System (DDC). Locate watt-hour meters directly on pad mounted transformers or integral to unit substations.

3.16 EXTERIOR SITE LIGHTING. Provide exterior lighting in accordance with appropriate standards.

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3.17 CATHODIC PROTECTION SYSTEMS. Provide cathodic protection in accordance with appropriate standards.

3.18 ENVIRONMENTAL CONSIDERATIONS. Consider oil spill containment for substation transformers. Containment is not authorized for pad-mounted oil-filled distribution transformers and switches. Do not use askarel-insulated and nonflammable, fluid-insulated transformers because of environmental concerns as to their insulation liquid.

3.19 FIRE PROTECTION CONSIDERATIONS. Provide fire protection and specify installation location for oil-filled equipment in accordance with appropriate standards. Oil-filled transformers using mineral oil can only be used outdoors. Less-flammable liquid transformers may be used either outdoors or indoors; these liquids shall have a fire point of not less than 300 degrees C (575 degrees F).

4. DIRECTIONAL BORING

4.1 CONDUIT TYPE. HDPE conduit shall be smoothwall, approved/listed for directional boring, approved/listed for electrical system installations, and minimum Schedule 80 meeting ASTM D2447/F2160/NEMA TC-7 (latest editions). *Note: HDPE conduit shall always be installed below freeze lines and in no case shall the conduit be installed less than the minimum depths noted below.*

4.1.1 Minimum size HDPE conduit shall be 5 inches for distribution voltages greater than 1,000 V and less than 34.5 kV (nominal).

4.1.1.1 Conduit fill shall not exceed 30 percent.

4.1.1.2 Installed HDPE conduit shall have a minimum ground cover of:

- 120 inches in non-pavement-covered areas.
- 48 inches in pavement-covered areas.

4.1.2. Minimum size HDPE conduit shall be 4 inches for distribution voltages less than 1,000 V.

4.1.2.1 Conduit fill shall not exceed 35 percent.

4.1.2.2 Installed HDPE conduit shall have a minimum ground cover of 48 inches in pavement- or non-pavement-covered areas.

4.1.3 Minimum size HDPE conduit for branch circuit wiring less than 600 V shall be determined by calculation, addressing, as a minimum, branch circuit conductor size, maximum allowable pulling tension, and maximum 5 percent voltage drop.

4.1.3.1 Conduit fill shall not exceed 40 percent.

4.1.3.2 Installed HDPE conduit shall have a minimum cover of 24 inches in pavement- or non-pavement-covered areas.

4.2 INSTALLATION METHODS. The use of specific conductor or insulation types for either high- or low-voltage installations is not mandated here. However, the combination of a chosen conductor and insulation type may not meet the requirements for the installation methods required in the following paragraphs where length, depth, and routing of the directional bore conduit may require an alternative conductor material and/or insulation type (i.e., maximum pulling tensions are different for aluminum and copper conductors).

4.2.1 If the directional bored portion of the cable run is more than 25 percent of the total run length, evaluate and document the conductor derated ampacity in accordance with NFPA 70 Article 310.60 (C) (2).

4.2.2 Water-jetting is not permitted.

4.2.3 Pre-installed cable-in-conduit is not permitted.

4.2.4 Drilling fluids used for DB methods shall be approved by federal, state, and local codes and authorized for use by the BCE.

4.2.5 The conduit(s) shall be installed immediately after the conduit hole is completed.

4.2.6 There is no restriction on DB distances provided the allowable pulling tension of the conduit and installed conductors are not exceeded, conductor splices are not within the conduit, and maximum ampacity of conductors due to depth derating is not exceeded.

4.2.6.1 A registered Professional Engineer (PE) shall calculate pulling tension requirements for each directional bore, taking into consideration the HDPE conduit(s)

size and type, bend radius, elevation changes, vertical and horizontal path deviations, installed electrical conductor size and type, and any conductor ampacity derating due to depth of HDPE conduit.

4.2.6.2 The electrical contractor shall provide certification of compliance with the PE‘s design requirements.

4.2.6.3 The professional engineering design process must include consideration of tensile forces and bend radii created during the installation so that allowable limits are not exceeded.

4.2.6.4 Allowable tensile forces must be determined by a PE. The PE certifying the installation shall account for the conduit’s allowable bend radius to prevent ovalization and kinking from installation. Ovalization of the conduit shall not exceed 5 percent.

4.2.7 HDPE conduits shall terminate into concrete-pad-mounted electrical equipment from either a pavement or non-pavement transitional area as indicated in Figures 4-1 through 4-5. HDPE or rigid conduit shall be routed and terminated within the concrete pad such that no conductor exiting the conduit shall be bent past the vertical plane formed with the equipment pad when routed to conductor terminations and with approved insulated bushings (Figure 4-1).

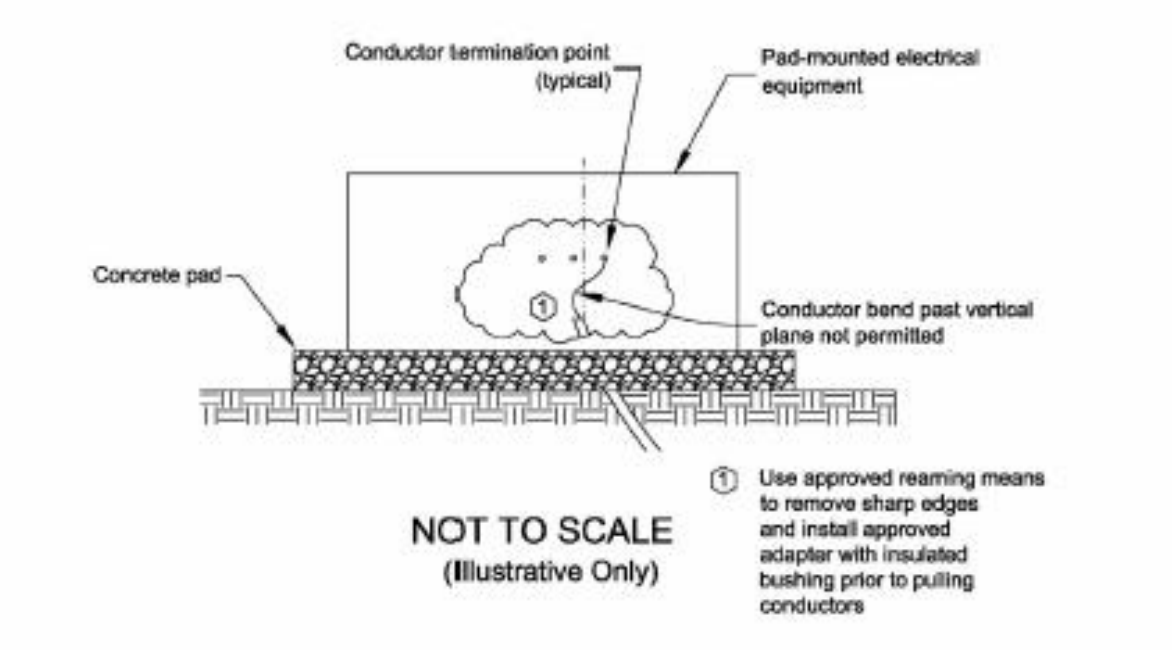


Figure 4-1

HDPE or Rigid Conduit Electrical Equipment Transition

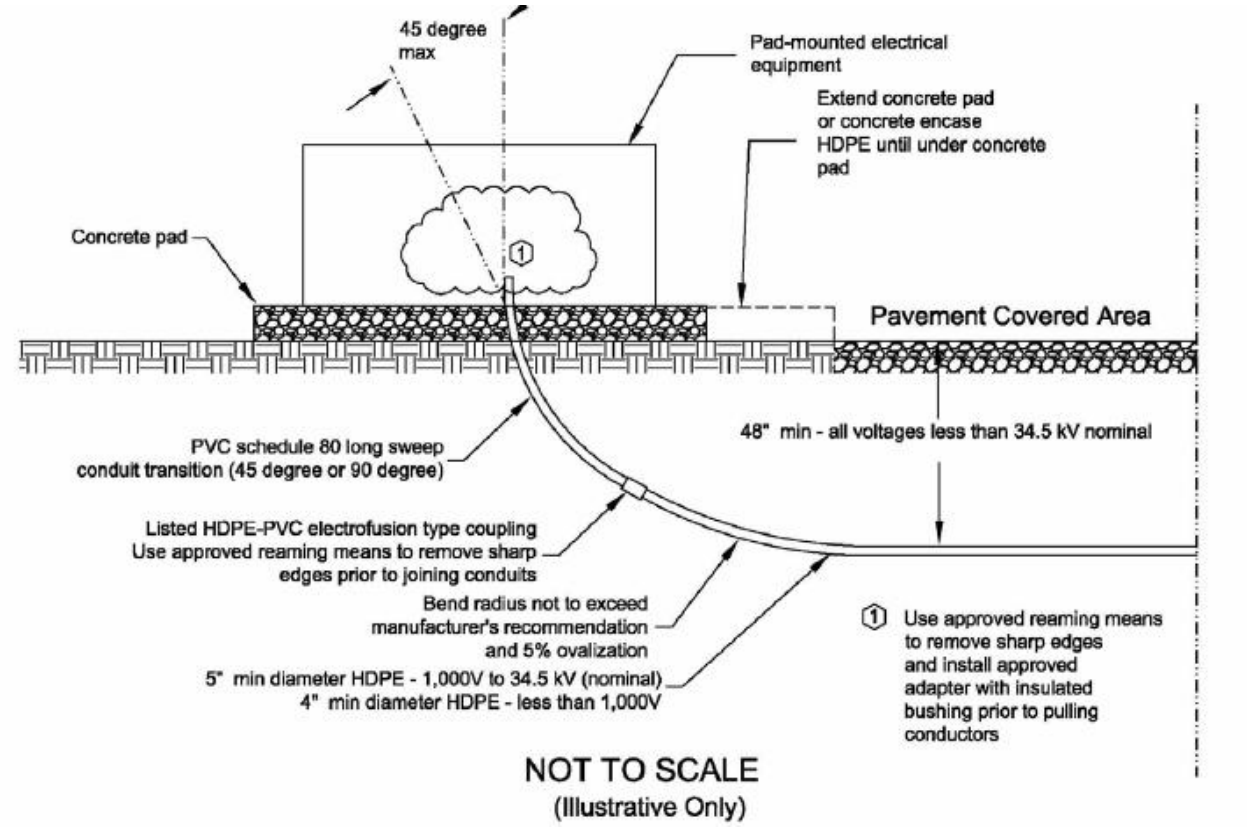


Figure 4-2

Pavement Covered Area to Electrical Equipment Transition

Rigid Conduit (45˚–90˚)

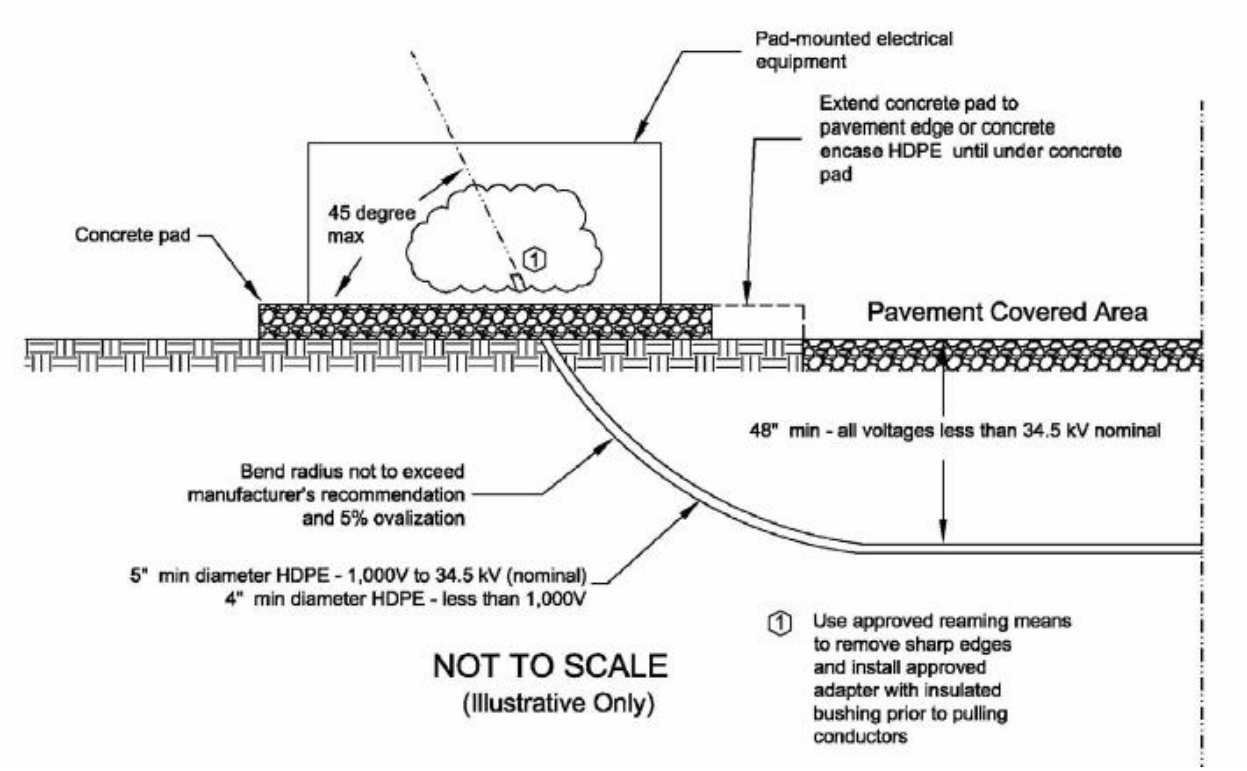


Figure 4-3

Pavement Covered Area to Electrical Equipment Transition –

HDPE Conduit (20˚–45˚)

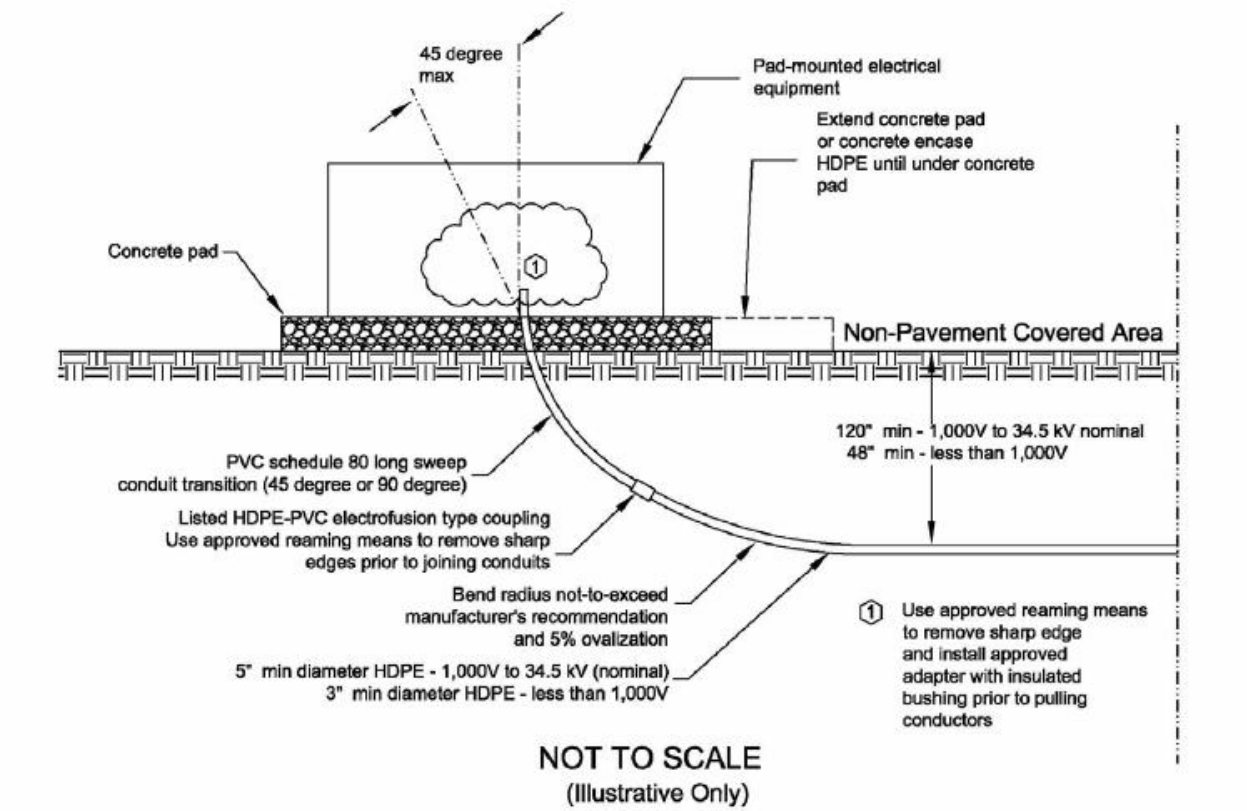


Figure 4-4

Non-Pavement Covered Area to Electrical Equipment Transition

Rigid Conduit (45˚–90˚)

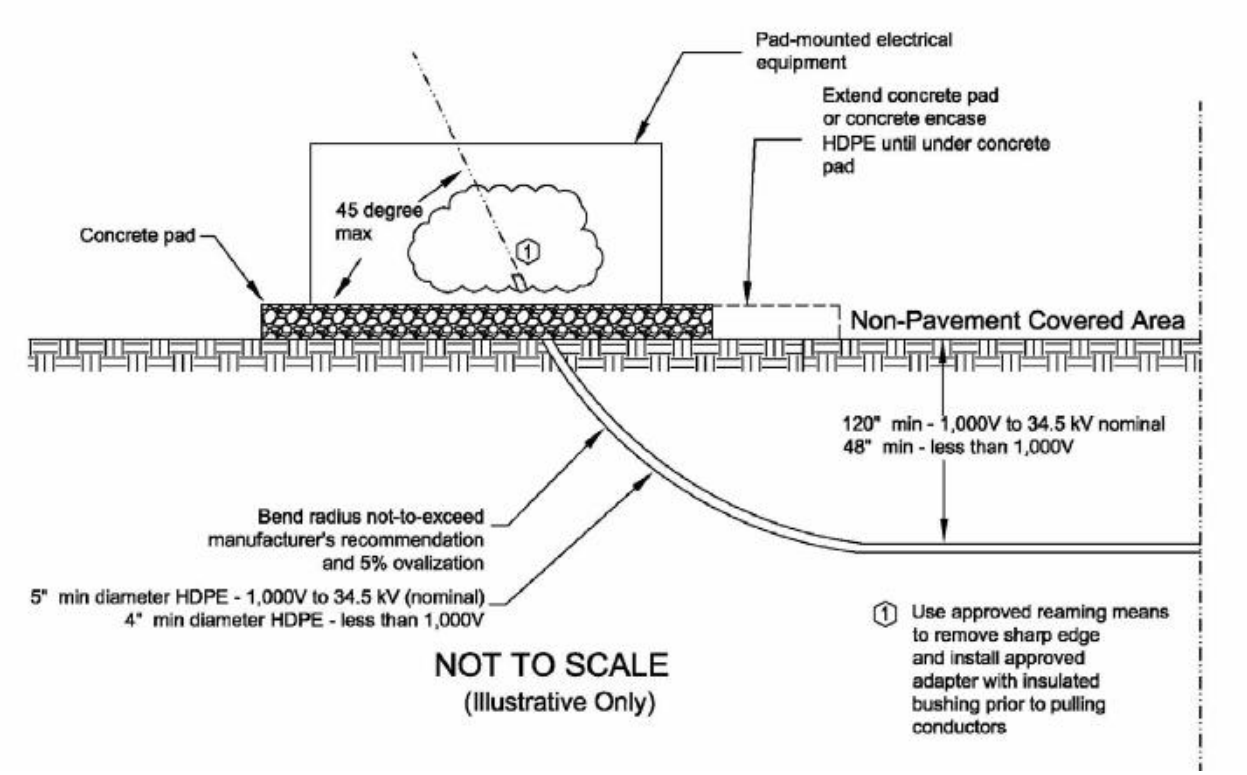


Figure 4-5

Non-Pavement Covered Area to Electrical Equipment Transition

HDPE Conduit (20˚–45˚)

4.2.8 MULTIPLE CONDUITS AND WIRING METHODS.

4.2.8.1 Multiple HDPE conduits are permitted to be pulled through each bore. Designs requiring multiple conduits to accommodate parallel conductor installations must comply with NFPA 70 grounding and wiring methods requirements. As an example, one set of paralleled conductor requirements is illustrated in the following excerpt from NFPA 70, Article 310.4, which states: “The paralleled conductors in each phase, polarity, neutral, or grounded circuit conductor shall comply with all of the following:

(1) Be the same length
(2) Have the same conductor material
(3) Be the same size in circular mil area
(4) Have the same insulation type
(5) Be terminated in the same manner”

Thus, using DB methods to comply with (1) from the NFPA 70 excerpt, as well as other requirements, may not be possible, especially for long boring distances. NFPA 70 has other requirements for paralleled conductor installations that must also be considered when designing for these types of installations. Note: Any deviations from NFPA 70 requirements must be approved by the engineer

4.2.8.2 If the directional bored portion of the cable run is more than 25 percent of the total run length, evaluate and document the conductor derated ampacity in accordance with NFPA 70 Article 310.60 (C) (2).

4.2.9 JOINING METHODS. Butt and electrofusion joining means are the only joining methods approved for HDPE conduit installations and shall be accomplished by persons certified in the process and in accordance with the manufacturer’s procedures.

4.2.10 TRANSITION FROM HDPE TO PVC. Transition from HDPE to PVC shall be made using only electrofusion coupling means with approved and listed materials.

Coupling means shall be accomplished by persons certified on the equipment and process.

4.2.10.1 Coupling between HDPE and concrete-encased duct banks from pavement or non-pavement transitional areas shall be accomplished as indicated in Figures 4-6 and 4-7.

4.2.10.2 Transition from HDPE to concrete manholes from pavement or non-pavement transitional areas shall be accomplished as indicated in Figures 4-8 and 4-9.

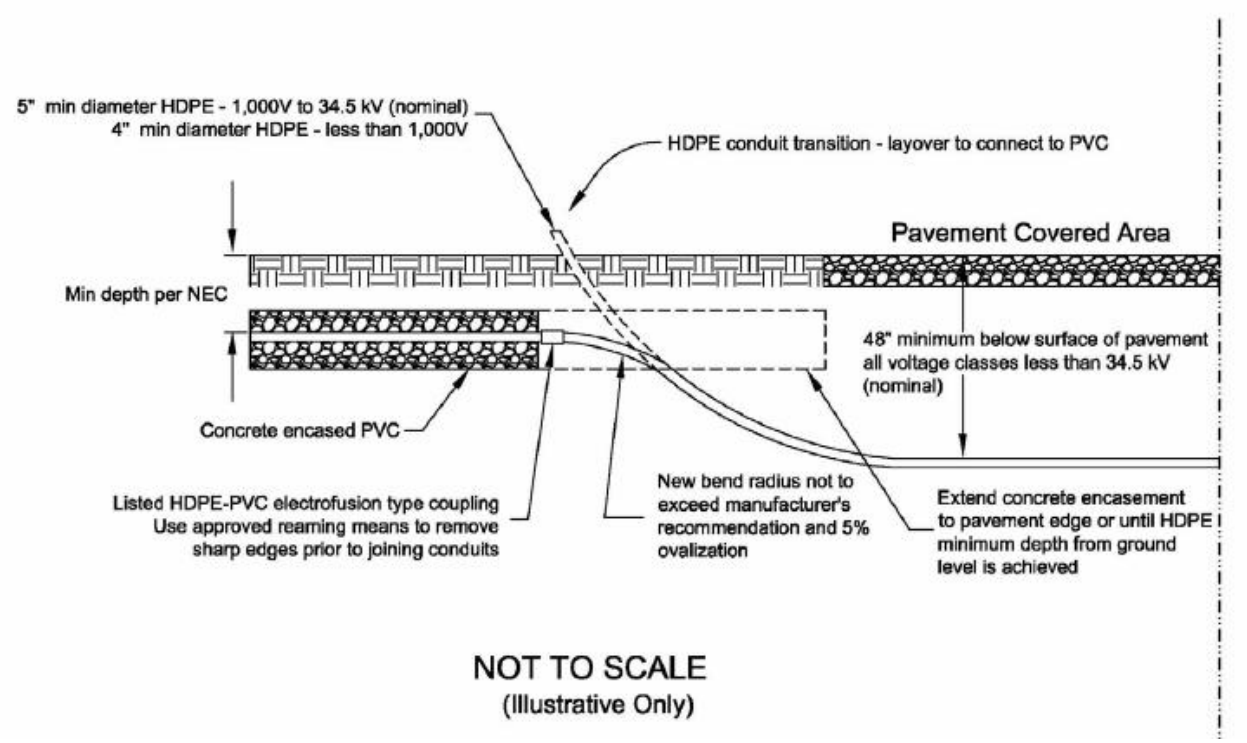


Figure 4-6

HDPE-to-PVC Pavement Covered Area Concrete Ductbank Transition

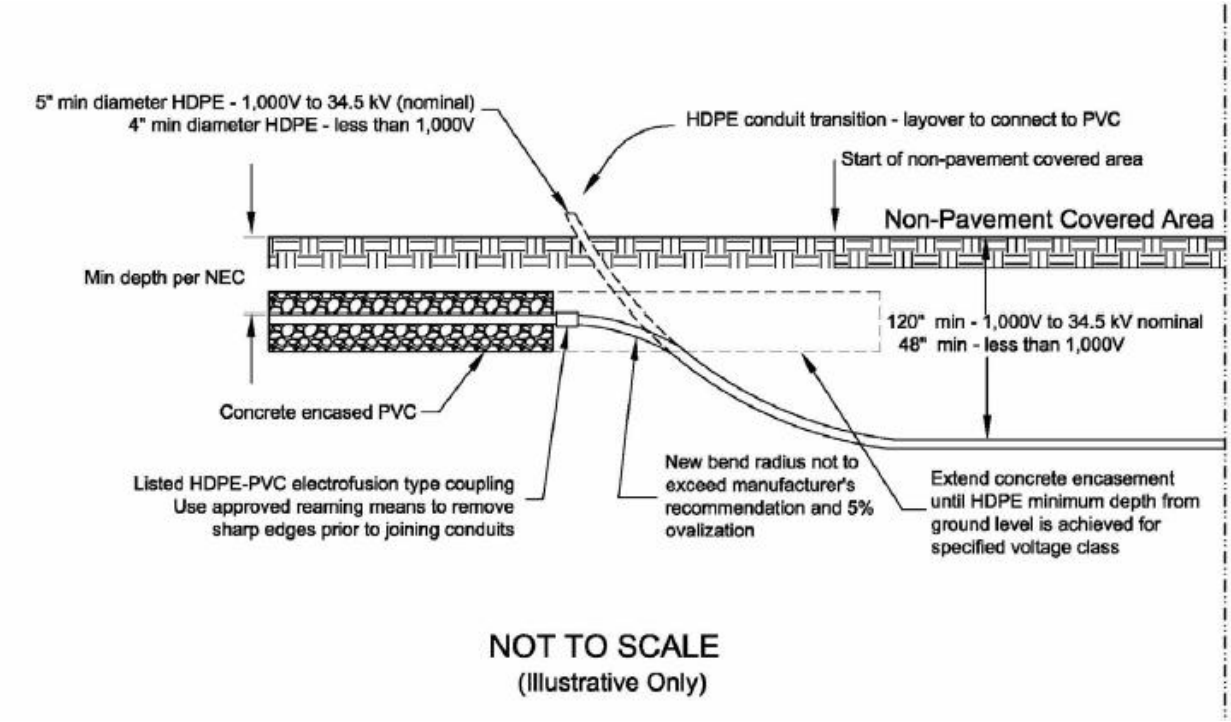


Figure 4-7

HDPE-to-PVC Non-Pavement Covered Area Concrete Ductbank Transition

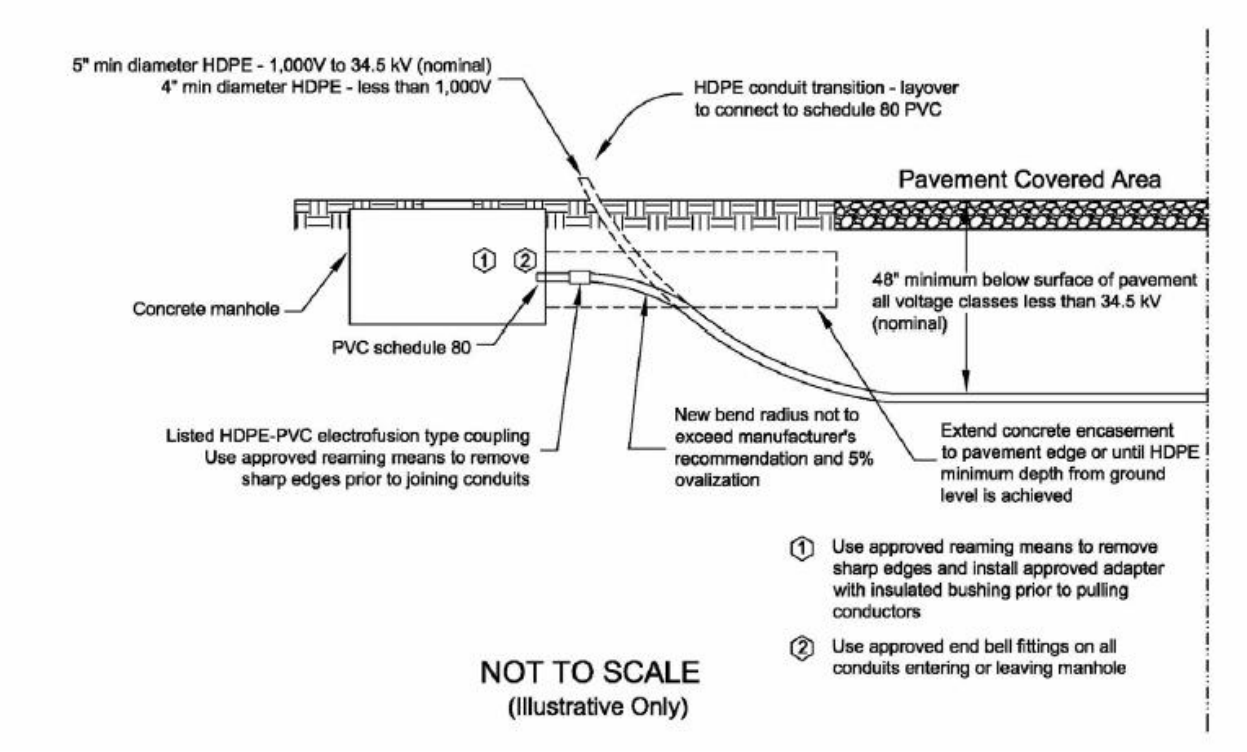


Figure 4-8

HDPE-to-Manhole Pavement Covered Area Transition

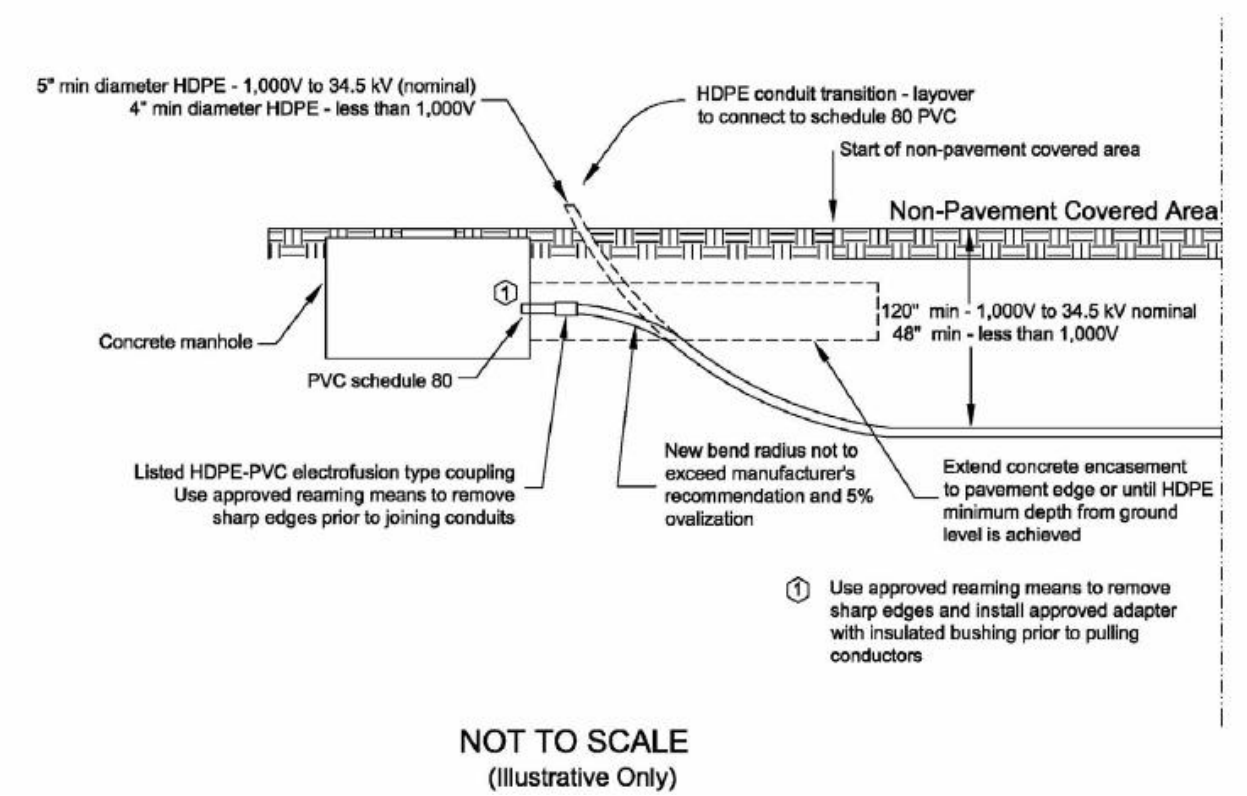


Figure 4-9

HDPE-to-Manhole Pavement Covered Area Transition

5. BEST PRACTICES – GENERAL ELECTRICAL POWER REQUIREMENTS

5.1 Consider the following general criteria as part of any exterior electrical system design:

• **LOOPED VERSUS RADIAL PRIMARY DISTRIBUTION.** The alternate supply capability of a looped system for primary distribution system feeders can enable the system to continue operation even with a failed conductor. Evaluate design changes to the existing system to ensure that the potential impact of conductor failure is minimized.

• **CROSS-TIE (ALTERNATE SUPPLY) CAPABILITY.** The ability to remove a feeder supply from service while ensuring continuity of power is essential for a reliable and maintainable design. Feeder cross-tie capability should be provided near the beginning of the feeder (to reduce voltage drop) and at key points downstream (to provide alternate supply capability for a portion of the feeder). Address cross-tie capability and how it is improved in the design analysis.

• **ESSENTIAL FACILITIES.** These facilities require additional consideration for the exterior electrical system design. Even if the facility is equipped with standby generation, minimize single points of failure in the exterior electrical system design. Provide redundant power supplies to the facility fed from different feeders, if multiple feeders are available.

• **COMMUNICATION.** Determine communication requirements for the system, including SCADA, security, access, metering, and breaker control. Include security requirements as an input to the electrical system design criteria. .

• **SAFETY.** Include electrical safety as a design consideration. Equipment selection, redundancy, installation approach, and how the equipment can be removed from service can all affect equipment and personnel safety.

• **RELIABILITY AND MAINTENANCE.** NFPA 70B, NETA MTS, and the manufacturers' documents provide periodic maintenance criteria applicable to

exterior electrical equipment. Consider maintenance requirements in the specification of equipment and in the installation design of the equipment. As an example, a single manhole located near a substation should not contain the cables for all base feeders; in this example, the design should install multiple manholes with fewer distribution feeders located inside each manhole.

5.2 Coordinate metering, system design, protection, electrical coordination, load requirements, and short circuit limitations with the local utility. If the supply station/substation is owned by the utility, obtain sufficient design information for the utility-owned equipment to help establish design requirements for downstream equipment.

5.3 Coordinate revenue metering requirements with the local utility. Provide an owner-owned revenue meter for the supply station/substation even when the local utility meters the incoming supply.

5.4 Clearly define the point of demarcation between the utility-owned system and the owner owned equipment. Define ownership for the incoming utility supply lines if there are any shared equipment, such as overhead distribution with utility and owner-owned lines sharing the same power poles.

5.5 Design a main electric supply station/substation for reliability of service and maintenance. The design analysis for the supply station/substation shall address the following:

- **FORMAL DESIGN.** Substations require a formal design. Address the structure and foundation design, lightning protection, manholes and vaults, grounding, lighting, protective relaying, and the other electrical items listed below.
- **DUAL SUBSTATION TRANSFORMERS.** Coordinate with the utility to provide separate utility feeders, if available. The transformers should be sized so that

either transformer and incoming supply line can carry the entire substation peak demand, including load increase projections for the next 10 years.

• **VOLTAGE REGULATION**. Either transformer load-tap changing (LTC) transformers or separate voltage regulators are acceptable. Separate voltage regulators, wherever installed, must be provided with bypass and disconnect switches.

• **CIRCUIT BREAKER OR CIRCUIT SWITCHER ON EACH SUBSTATION TRANSFORMER PRIMARY SIDE FOR LOCAL ISOLATION OF THE INCOMING SUPPLY.** For substations with overhead bus structure, include a load-break or non-load break switch as an additional isolation device.

• **CIRCUIT BREAKER ON EACH SUBSTATION TRANSFORMER SECONDARY SIDE.** This is typically the main breaker to the substation switchgear. For substations with overhead bus structure, include a load-break or non-load break switch as an additional isolation device.

• **SEPARATE SWITCHGEAR FOR EACH TRANSFORMER WITH CROSS-TIE CAPABILITY BETWEEN SWITCHGEAR.** Provide spare breakers and evaluate the need for additional distribution system feeders.

• **ELECTRONIC PROTECTIVE RELAYS** to allow circuit protection, monitoring, and event recording.

• **STATION CLASS SURGE ARRESTERS.**

• **SCADA CONTROLS.** If remote SCADA control is included, provide dedicated fiber-optic lines between the facility and the desired control location. Obtain approval from the AHJ for communication systems that enable remote access.

• **CONNECTIONS BETWEEN THE TRANSFORMER SECONDARY AND THE MAIN CIRCUIT BREAKER.** Preferred connection methods include cables in conduit or cable trays. Busway transitions are discouraged, but if they are used, it

must be labeled for the application by Underwriter's Laboratories, or equivalent; designed for outdoor service, including a stainless steel housing and hardware for corrosion control; rated and braced for the maximum expected continuous current and short circuit current; designed to control condensation and its effects; and designed to allow access for periodic inspection following the NETA MTS guidance.

QUIZ

AN INTRODUCTION TO
EXTERIOR ELECTRICAL POWER DISTRIBUTION

1. Typical voltages and voltage ranges for 60 Hz primary voltage systems are established for the United States in _____ .

a. IEEE C22
b. NEMA C84.1
c. NFPA 70
d. IEEE C2

2. The _____ is the installation/utility interface point where further transmission, distribution and utilization of electrical power, the monitoring and control of such power or equipment and the protection of electrical equipment or systems usually becomes the sole responsibility of the owner or their contracted representatives.

a. utility service transformer
b. power generation station
c. substation
d. main electric supply station

3. _____ are defined as equipment such as pole or pad-mounted transformers or secondary unit substations that transforms the energy level (voltage) to a utilization voltage for consumer use.

a. Switchyards
b. Conduction points
c. Distribution circuits
d. Utilization electric supply stations

4. It is recommended new primary distribution systems be designed as four wire, multi-grounded systems that are _____ connected at the source transformer.

a. delta
b. wye
c. parallel
d. serial

5. Provide a system _____ throughout the system.

a. grounded neutral conductor
b. ground fault detector
c. metering panel
d. collimator

6. Provide equipment foundation pads and ensure a minimum of _____ feet clear workspace in front of pad-mounted equipment for hot stick work.

a. 15
b. 10
c. 5
d. 3

7. Primary unit substations to distribute underground medium voltage circuits shall comply with the following industry standards as applicable for the specified configuration:

a. IEEE C37.74
b. IEEE C57.12.28
c. both of the above
d. routine inspection

8. Provide secondary unit substations when secondary currents exceed _____ amperes.

a. 500
b. 1,000
c. 2,000
d. 3,000

9. Use dead-front construction for pad-mounted transformers unless not available within system parameters. Use pad-mounted transformers, separately protected with vacuum fault interrupter equipped switches for _____ kV systems.

a. 5
b. 12
c. 34.5
d. 47

10. Transformers rated above 1,000 kVA serving 208Y/120 volt loads and above _____ kVA serving 480Y/277 volt loads must be in a secondary unit substation configuration.

a. 2,500
b. 2,000
c. 1,750
d. 1,000

11. Provide two oil-filled pad-mounted transformers in lieu of one 480Y/277 volt service if the required 208Y/120 volt load using dry-type transformers exceeds _____ percent of the 480 volt service transformer capability.

a. 70
b. 60
c. 50
d. 40

12. Provide bushing-mounted elbow type arresters at the ends of all radials and in normally open locations in loops. Provide arresters for all voltage levels above _____ kV.

a. 5
b. 12
c. 37.5
d. 41

13. Medium voltage metal-clad switchgear can include either SF6 or vacuum style breakers and must consist of a _____or multiple section line-up of NEMA 1 or NEMA 3R enclosures.

a. multipanel
b. two level
c. single section
d. neutral grounded

14. For medium voltage switchgear, do not use metal-enclosed switchgear. Instead, use either a/an _____ in a unit substation configuration or an upstream pad-mounted switchgear.

a. carbon fiber enclosure
b. liquid intercooler
c. vacuum fault interrupter
d. rotary

15. The term direct buried wiring refers to the direct burial of conductors without any conduit or concrete encasement. Sleeve all direct buried conductors under new roads and use concrete encased conduits extending _____ feet beyond the edge of the pavement.

a. 2
b. 5
c. 10
d. 15

16. Directional boring (DB) is a trenchless technology method to install _____ electrical conduit used for underground electrical distribution systems.

a. polyvinyl chloride
b. acrylobutylnitiride
c. high density polyethylene
d. aluminum

17. Directional boring (DB) is applicable to medium-voltage (HV) underground distribution systems between 1000 volts (V) and 34.5 kilovolts (kV) (nominal) and all low-voltage distribution systems (less than _____ V).

a. 1000
b. 440
c. 220
d. 110

18. Provide separate power and _____ manholes.

a. domestic water distribution
b. wastewater collection
c. exterior lighting
d. communication

19. Provide underground structures such as manholes and boxes where splices are required, where duct lines change direction, and within 100 feet of every riser pole, pad mounted transformer, or unit substation unless a calculation is provided to justify a greater distance. The distance must not exceed _____ feet.

a. 500
b. 400
c. 300
d. 200

20. Pull boxes are used for electric circuits supplying low-voltage electric loads which require conductors no larger than 1/0 awg and no more than one _____ inch conduit entrance at each side. Wherever larger conduits are installed, use handholes or manholes.

a. 1
b. 2
c. 3
d. 4

21. Medium voltage cables shall comply with NEMA WC 74, be type MV (105°C) aluminum or copper based on the specific applications, and shall contain a _____ volt insulated neutral when required.

a. 600
b. 440
c. 220
d. 110

22. Concrete for encasement of underground ducts must be _____ psi minimum 28-day compressive strength.

a. 3000
b. 2500
c. 2000
d. 1500

23. Ground rod composition, minimum spacing requirements and connections shall conform to requirements of IEEE C2 Section 9 except that minimum dimensions shall be _____ feet in length and ¾ inch in diameter.

a. 3
b. 5
c. 7
d. 10

24. Metal fences for electrical equipment and ordnance facilities shall be grounded in accordance with IEEE C2 Section 9. Other metal fences that are electrically continuous with metal posts extending at least _____ inches into the ground require no additional grounding unless specifically required by other criteria.

a. 36
b. 24
c. 18
d. 12

25. Minimum size HDPE conduit shall be _____ inches for distribution voltages greater than 1,000 V and less than 34.5 kV (nominal).

a. 3
b. 4
c. 5
d. 6