An Introduction to Interior Electrical Distribution Systems

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1. INTRODUCTION

1.1 PURPOSE AND SCOPE. The criteria contained herein are intended to ensure economical, durable, efficient, and reliable systems and installations. Whenever unique conditions and problems are not specifically covered by this publication, use the applicable referenced industry standards and other documents for design guidance.

1.2 APPLICABILITY. This publication typically applies up to 5 feet beyond the facility envelope. It also applies to:

- Service(s) supplying power from the utility system utilization transformer to the wiring system of the facility.
- Circuits originating from within the facility that extend beyond the facility envelope.
- Wiring and connections for supplemental grounding systems.
- Wiring from and connections to non-utility equipment supplying power to the wiring system of the facility, including engine-generator sets, photovoltaic power systems and fuel cells.

In addition to NFPA 70 requirements, facilities located outside of the United States must also comply with the applicable host nation standards. Host nation voltage and frequency shall generally apply. Different wiring and grounding conventions usually apply in other host nations; however, follow the design principles provided in this publication to the extent practical.

1.3 GENERAL BUILDING REQUIREMENTS. Comply with applicable building codes.

1.4 REFERENCES. Applicable references are provided in this publication.

1.5 DESIGN STANDARDS. Comply with the requirements of National Fire Protection Association (NFPA) 70, *National Electrical Code*, and the requirements herein. (Note: When a project, or portion of a project, has been designated as requiring Critical Operations Power Systems (COPS) treatment as a Designated Critical Operations Area

(DCOA) per NFPA 70 Article 708, the requirements that are more stringent than this publication take precedence over this publication.) Codes and standards are referenced throughout this publication. The publication date of the code or standard is not routinely included with the document identification throughout the text of the document. In general, the latest issuance of a code or standard has been assumed for use.

2. GENERAL POWER SYSTEM CRITERIA

2.1 VOLTAGE. Unless there are specialty voltage requirements, the facility system voltage shall be based on the interior load requirements as follows:

- Apply 240/120V for small facilities with only single-phase loads.
- Apply three-phase, four-wire, 208Y/120V systems for lighting and power demand loads less than 150 kVA.
- Apply three-phase, four-wire, 480Y/277V systems for lighting and power demand loads greater than 150 kVA unless 208Y/120V systems are shown to be more cost-effective. Use step-down transformers inside the facility as required to obtain lower voltages.

2.2 FREQUENCY. Apply a frequency of 60 Hz for distribution and utilization power. In locations in which the commercially-supplied frequency is other than 60 Hz, such as 50 Hz, use the available supplied frequency to the extent practical. Where frequencies other than that locally available are required for technical purposes, frequency conversion or generation equipment can be installed.

3. POWER DISTRIBUTION AND UTILIZATION

3.1 TRANSFORMERS. The transformer design criteria provided herein apply to interior applications. Commonly, facilities will be supplied by an exterior utility system pad-mounted transformer.

3.1.1 LOW VOLTAGE TRANSFORMERS. Specify dry-type transformers in accordance with NEMA ST 20 and the following:

- For transformers rated for 15 kVA or larger, use transformers with a 220 degree C (428 degrees F) insulation system not to exceed an 115 degree C (239 degrees F) rise capable of carrying continuously 115 percent of nameplate kVA without exceeding insulation rating at a maximum ambient temperature of 40 degrees C (104 degrees F). Provide a transformer of 80 degrees C temperature rise capable of carrying continuously 130 percent of nameplate kVA without exceeding insulation rating when additional overload capacity is required.
- Transformers rated less than 15 kVA can use a 180 degree C (356 degrees F) insulation system not to exceed an 80 degree C (176 degrees F) rise at a maximum ambient temperature of 40 degrees C (104 degrees F).
- When the transformer is located in areas where noise is a factor, specify sound levels at least 3 decibels below recommended values established by NEMA ST 20.
- Derate the transformer in accordance with the manufacturer's guidance for locations with a maximum ambient temperature above 40 degrees C (104 degrees F) and in accordance NEMA ST 20 for altitudes higher than 3,300 feet (1,000 meters).

Include the following as part of the installation:

- Mount the transformer so that vibrations are not transmitted to the surrounding structure. Small transformers can usually be solidly mounted on a reinforced concrete floor or wall. Flexible mounting will be necessary if the transformer is mounted to the structure in a normally low-ambient noise area.

- Use flexible couplings and conduit to minimize vibration transmission through the connection points.
- Locate the transformer in spaces where the sound level is not increased by sound reflection. For example, in terms of sound emission, the least desirable transformer location is in a corner near the ceiling because the walls and ceiling function as a megaphone.
- Transformer spaces shall be adequately ventilated to prevent the temperature rise from exceeding the transformer rating.

Refer to TSEWG TP-5, *Interior Transformer Ratings and Installation*, for additional information regarding transformers and transformer ratings.

3.1.2 OTHER TRANSFORMERS. Do not use unless justified and documented in the design analysis.

3.2 SERVICE ENTRANCE AND DISTRIBUTION EQUIPMENT. Locate service entrance equipment and other major electrical equipment in a dedicated electrical equipment room. Provide a main breaker on each service entrance. Locate other electrical equipment, such as electrical panels, in dedicated spaces. Use 100 percent rated main overcurrent device for sizes 400 ampere and larger. Size circuit breaker interrupting ratings based on the available short circuit current; however, do not select circuit breakers less than 10 kA symmetrical interrupting rating for voltages 240V and below and 14 kA symmetrical interrupting rating for 480V applications. Do not use series-combination rated breakers or fusible overcurrent devices.

3.2.1 SWITCHGEAR AND SWITCHBOARDS GENERAL CRITERIA. Select low-voltage switchboards versus switchgear as follows:

- Specify switchboards for service entrance equipment when the service is 1200A or larger, and branch and feeder circuits are combined sizes from 20A up to 800A. Utilize switchboards throughout the distribution system where feeders are 1200A or larger. Devices must be front accessible and must be completely isolated between sections by vertical steel barriers. Switchboards should have hinged fronts to allow safer maintenance access.

- Specify metal clad switchgear for service entrance equipment only when the service is 1200A or larger, and all branch and feeder circuits are large, such as 600A or 800A each. The circuit breakers must be electrically operated. The switchgear and circuit breakers must be the product of the same manufacturer. Consider remote racking device designs (robots) to rack breakers in and out.

Select switchgear and switchboards of the dead-front, floor-mounted, freestanding, metal-enclosed type with copper bus and utilizing circuit breakers as circuit protective devices. Provide a minimum of 20 percent space-only cubicles and appropriate bus provisions for future protective device additions to accommodate planned load growth. Ensure switchboards are designed in accordance with NEMA PB 2 and UL 891 listed. Place a safety sign on any cubicles containing more than one voltage source. Refer to ANSI Z535.4 for safety sign criteria.

3.2.2 PANELBOARDS. Specify panelboards for service entrance equipment when the service is less than 1200A and feeder circuits will fit in one panelboard. Equip panelboards with separate ground bus bars and insulated neutral bus bars to isolate the bus bar, when required by code, from the panelboard. Circuit breakers must be bolt-on type. Do not use dual section panelboards. Provide a minimum of 20% empty space for all panelboards. For flush-mounted panelboards, provide spare conduits extending up above the ceiling and down below raised floors when applicable. Provide one spare conduit, minimum of ¾-inch (18 mm), for every three empty spaces. Use panelboards for service entrance equipment and electrical distribution in residential facilities. Load center style panelboards, /1/ with plug-in breakers, can be used in housing units and residential rooms. Ensure circuit breakers used as switches in 120V and 277V lighting circuits are listed for the purpose and are marked “SWD” or “HID” (switching duty or high-intensity discharge lighting). Provide arc-fault circuit interrupter protection for branch circuits supplying 120V, single-phase, 15A and 20A outlets installed in dwelling units as specifically required by NFPA 70. Distribution and branch circuit panelboards should be of the wall-mounted, dead-front type, equipped with circuit breakers. Circuit breaker size should be a minimum 1 inch (25 millimeters) per pole with bolt-on breakers. Load center style panelboards, with plug-in breakers, should be used only where eight or fewer circuits are supplied, and where light duty can be expected, except as authorized for military family housing. Place panelboards as close as possible to the center of the loads to be served. Panelboards should have hinged fronts to allow safer maintenance access. Clearly fill out panelboard circuit directories indicating the specific load and location, such as “Lights, Room 102”. Optimize equipment layout and circuit arrangement. All homeruns (identifying conduit and wiring back to panel) should be shown on the design drawings. Combine one-pole branch circuits to minimize the number of homeruns. Do not show more than a 3-phase circuit; or 3-phase conductors, a neutral conductor and an equipment grounding conductor in a single conduit. When more conductors are required, provide detailed calculations showing compliance with NFPA 70 for derating conductors and conduit fill. Refer to TSEWG TP-6, *Low Voltage Breaker Interrupting Ratings*, for additional information regarding low voltage breaker interrupting ratings.

3.2.3 MOTOR CONTROL CENTERS (MCCS). MCCs shall meet UL 845 and NEMA ICS 2.

3.2.4 POWER FOR FIRE PROTECTION SYSTEMS. Provide power for the fire protection systems from the service entrance equipment as follows:

3.2.4.1 208Y/120 V OR 120/240V SYSTEMS: Provide lock-on breaker in the service equipment. If more than one fire protection circuit is required, provide a dedicated emergency panel (sized for a minimum of six circuits) powered from the lock-on breaker in the service equipment.

3.2.4.2 480Y/277 V SYSTEMS: Provide circuit from the service entrance equipment (as above) to a dedicated emergency panel through a step-down transformer. Consider using a packaged power supply for this transformer/emergency panel combination. Size the emergency panel for a minimum of six circuits.

3.2.4.3 LOCATE THE DEDICATED EMERGENCY PANEL near the service entrance equipment.

3.2.4.4 IN ALL CASES paint the lock-on breaker in the service entrance equipment and the dedicated emergency panel enclosure red. At the service entrance equipment, in addition to the panel nameplate, provide a label with the following inscription: “Fire Protection/Life Safety Equipment.” Construct and fasten the label identical to the panel nameplate, except the label must be red laminated plastic with white center core.

3.2.5 DISCONNECT SWITCHES. Fusible disconnect switches should be used only where special considerations require their use. Provide heavy duty type safety switches on systems rated for greater than 240V. Use fused switches that utilize Class R fuseholders and fuses. Use NEMA 4X stainless steel switch enclosures for switches located on building exteriors in areas where salt spray or extended high humidity is a concern. Utilize non-fused disconnect switches as local disconnects only, properly protected by an upstream protective device.

3.2.6 CIRCUIT LOCKOUT REQUIREMENTS. Circuit breakers, disconnect switches, and other devices that are electrical energy-isolating must be lockable in accordance with NFPA 70E and OSHA 1910.303.

3.3 MOTORS AND MOTOR CONTROL CIRCUITS.

3.3.1 BASIC MOTOR CRITERIA. All motors shall have premium efficiency ratings per the Energy Policy Act of 2005 (EPACT 2005). Use three-phase motors if more than 0.5 horsepower (373 watts) rating when such service is available. If three-phase service is not available, operate motors 0.5 horsepower (373 watts) and larger at phase-to-phase voltage rather than phase-to-neutral voltage. Motors smaller than 0.5 horsepower (373 watts) should be single phase, with phase-to-phase voltage preferred over phase-to-neutral voltage. Do not use 230V motors on 208V systems because the utilization voltage will commonly be below the -10% tolerance on the voltage rating for which the motor is designed (a 230V motor is intended for use on a nominal 240V system).

3.3.2 MOTOR CONTROL CIRCUITS. Provide motor controllers (starters) for motors larger than 0.125 horsepower (93.25 watts) and apply the design criteria of NEMA ICS 1 and NEMA ICS 2. Use full voltage-type starting unless the motor starting current will result in more than a 20% transient voltage dip or if the analyzed voltage dip is otherwise determined to be unacceptable. For other than full voltage starting, apply one of the following methods for motor starting:

- Reduced Voltage Starters.
- Adjustable Speed Drives (ASDs) are also referred to as Variable Frequency Drives (VFDs). If an ASD is required for other reasons, it can also address motor starting current design needs. Refer to NEMA ICS 7 for design criteria related to the selection and design of ASDs. Appendix B provides additional information regarding the sizing and operational design of ASDs.

Provide manual control capability for all installations having automatic control that operates the motor directly. Use a double-throw, three-position switch or other suitable device (marked MANUAL-OFF-AUTOMATIC) for the manual control. Confirm that all safety control devices, such as low- or high-pressure cutouts, high-temperature cutouts, and motor overload protective devices, remain connected in the motor control circuit in both the manual and automatic positions.

3.4 SURGE PROTECTIVE DEVICES (SPDS). Provide SPDs for surge protection of sensitive or critical electronic equipment and when specifically required.

3.4.1 POWER SYSTEM SURGE PROTECTION. Use Type 1 or Type 2 SPD and connect on the load side of a dedicated circuit breaker of the associated main distribution or branch panelboard, switchboard, or switchgear. Locate as close as practical to the breaker with a maximum lead length of 3 ft (900 mm). The term *transient voltage surge suppression* (TVSS) is also used to describe SPDs. The design criteria provided here apply to permanently installed, hard-wired surge protectors and should not be applied to plug-in type surge protectors (Type 3). Use point-of-use (plug-in type) surge protectors to protect specific critical equipment that plugs into wall receptacles. For buildings with high concentrations of electronics equipment, employ a two-stage or cascaded system.

Coordinate multiple stage surge protection. Do not install SPD inside a panelboard or switchboard enclosure. However, SPD can be installed in a separate compartment of a switchboard provided that it is supplied by a dedicated circuit breaker.

3.4.1.1 SERVICE ENTRANCE SURGE PROTECTION. Provide the following specification requirements for SPD on the service entrance equipment:

a. Use SPD to protect the electrical service entrance equipment.

b. The SPD must meet or have a voltage protection rating that is less than the UL 1449 voltage protection ratings listed below. If surge protection is required as part of a lightning protection system, comply with the more stringent voltage protection ratings specified in NFPA 780.

System Voltage	Protection Modes	Voltage Protection Rating
208/120 or 240/120	L-N L-G N-G L-L	700 700 700 1,200
480/277	L-N L-G N-G L-L	1,200 1,200 1,200 2,000

c. Per mode single pulse surge current rating for an 8x20 ms waveform must be no less than:

L-N 40kA

L-G 40kA

N-G 40kA

L-L 80kA

d. Protection Mode: Provide the following six modes (additional modes are permitted): Line-to-line, Line-to-ground or line-to-neutral SPDs at grounded service entrances shall be wired in a line-to-ground (L–G) or line-to-neutral (L–N) configuration. For services without a neutral, SPD elements shall be connected line-to-ground (L–G).

e. MCOV for L-N and L-G modes of operation: 125% of nominal voltage for 240 volts and below; 120% of nominal voltage above 240 volts to 480 volts.

f. Surge Life: Greater than 5000 surges of repetitive sequential IEEE C62.41 Category C3 waveforms with less than 10% degradation of measured limiting voltage.

g. Listing: The total unit as installed must be UL 1283 and UL 1449 listed, and not merely the components or modules.

h. Warranty: Not less than a 5-year warranty and include unlimited free replacements of the unit if destroyed by lightning or other transients during the warranty period.

i. Diagnostics: Visual indication unit has malfunctioned or requires replacement. Provide Form C dry contacts for remote monitoring.

3.4.1.2 BRANCH PANELBOARD SURGE PROTECTION. Provide the following specification requirements for SPD on all the branch panelboards for facilities requiring cascaded suppression system protection.

a. Use SPD to protect the distribution branch panelboards.

b. The SPD must meet or have a voltage protection rating that is less than the UL 1449 voltage protection ratings listed below.

System Voltage	Protection Modes	Voltage Protection Rating
208/120 or 240/120	L-N L-G N-G L-L	700 700 700 1,200
480/277	L-N L-G N-G L-L	1,200 1,200 1,200 2,000

c. Per mode single pulse surge current rating for an 8x20 ms waveform must be no less than:

L-N 20kA

L-G 20kA

N-G 20kA

L-L 40kA

d. Protection Mode: Provide the following six modes (additional modes are permitted): Line-to-line Line-to-ground or line-to-neutral SPDs at grounded service entrances shall be wired in a line-to-ground (L–G) or line-to-neutral (L–N) configuration. For services without a neutral, SPD elements shall be connected line-to-ground (L–G).

e. MCOV for L-N, L-G, and N-G modes of operation: 125% of nominal voltage for 240 volts and below; 120% of nominal voltage above 240 volts to 480 volts.

f. Surge Life: Greater than 5000 surges of repetitive sequential IEEE C62.41 Category B3 waveforms with less than 10% degradation of measured limiting voltage.

g. Listing: The total unit as installed must be UL 1283 and UL 1449 listed, and not merely the components or modules.

h. Warranty: Not less than a 5-year warranty and include unlimited free replacements of the unit if destroyed by lightning or other transients during the warranty period.

i. Diagnostics: Visual indication unit has malfunctioned or requires replacement. Provide Form C dry contacts for remote monitoring.

3.4.1.3 DWELLING UNITS SURGE PROTECTION. Install as close as practical to the main breaker/lugs. All leads must be as short as possible, with no leads longer than 24 in (610 mm). Provide protection in accordance with branch panelboard surge protection criteria listed above.

3.4.2 SURGE PROTECTION FOR COMMUNICATIONS AND RELATED SYSTEMS. Provide surge protection for the following systems, including related systems:

- Fire alarm systems.
- Telephone systems.
- Computer data circuits.
- Security systems.
- Television systems.
- Coaxial cable systems.
- Intercom systems.
- Electronic equipment data lines.

Surge protection equipment used for communications and related systems shall be UL Listed or third-party verified and tested to UL 497A. If surge protection is required as part of a lightning protection system, comply with the more stringent voltage protection ratings specified in NFPA 780.

- Telephone communication interface circuit protection shall provide a minimum surge current rating of 9,000A.
- Central office telephone line protection shall have multi-stage protection with a minimum surge current rating of 4,000A.

- Intercom circuit protection shall have a minimum surge current rating of 9,000A. Provide protection on points of entry and exit from separate buildings.
- Provide fire alarm and security alarm system loops and addressable circuits that enter or leave separate buildings with a minimum of 9,000A surge current rating. Annunciation shall be UL Listed or third-party verified and tested to UL 497B.

Protect coaxial lines at points of entry and exit from separate buildings. Single stage gas discharge protectors can be used for less critical circuits. Multistage protectors utilizing a gas discharge protector with solid-state secondary stages should be used to obtain lower let-through voltages for more critical equipment.

3.4.3 ACCEPTANCE TESTS. Perform the following installation checks:

- Inspect for physical damage and compare nameplate data with drawings and specifications.
- Verify that the surge protector rating is appropriate for the voltage.\2\ /2/
- Inspect for proper mounting and adequate clearances.
- Verify that the installation achieves the minimum possible lead lengths. Inspect the wiring for loops or sharp bends that add to the overall inductance.
- Check tightness of connections by using a calibrated torque wrench. Refer to the manufacturer's instructions or Table 10-1 of International Electrical Testing Association (NETA) ATS for the recommended torque.
- Check the ground lead on each device for individual attachment to the ground bus or ground electrode.
- Perform insulation resistance tests in accordance with the manufacturer's instructions.
- For surge protectors with visual indications of proper operation (indicating lights), verify that the surge protector displays normal operating characteristics.
- Record the date of installation.

3.5 METERING. Provide smart metering systems (e.g., with remote reading, monitoring, or activation capabilities) in accordance with owner-specific criteria to comply with requirements. Coordinate meters, system components, and meter locations to be compatible with the owner's central system.

3.6 RACEWAY AND WIRING.

3.6.1 WIRING DEVICES. Wiring devices and faceplate colors must match and be consistent with the interior wall types and colors. Use grounding type wiring devices. Outlet boxes must not be placed back to back. Provide a minimum of 12 inch (300 mm) of separation between outlet boxes located on opposite sides on common walls.

3.6.1.1 SWITCHES. Toggle switches must be specification grade, quiet type, and rated minimum 120/277V, 20A, totally enclosed with bodies of thermoplastic and/or thermoset plastic and mounting strap with grounding screw. Use silver-cadmium contacts and one-piece copper alloy contact arm. When specified, pilot lights must be integrally constructed as a part of the switch's handle.

3.6.1.2 RECEPTACLES. Provide general purpose convenience outlets that are specification grade, 20A, 120V, duplex. In addition to the location requirements specified by NFPA 70, locate general purpose and dedicated (on an individual circuit) outlets in accordance with the following:

a. Mechanical equipment: Provide receptacle within 25 ft (7.6 m) of mechanical equipment on the interior and exterior of buildings.

b. Office, staff-support spaces, and other workstation locations: One receptacle for each workstation with a minimum of one for every 10 ft (3 m) of wall space. When less than 10 ft (3 m) of wall at the floor line, provide a minimum of two receptacles spaced appropriately to anticipate furniture relocations. Limit loads to a maximum of four (4) workstations per 20A circuit.

c. Conference rooms and training rooms: One for every 12 ft (3.6 m) of wall space at the floor line. Ensure one receptacle is located next to each voice/data outlet. Provide one receptacle above the ceiling to support video projection device. Extend circuit to wall location for connection to motorized screen. When it is expected that a conference room table will be specifically dedicated to floor space in a conference room, locate a floor-mounted receptacle under the table. This receptacle may be part of combination power/communications outlet.

d. Provide power outlets throughout the building to serve all proposed equipment, including government furnished equipment, and allow for future reconfiguration of equipment layout. Provide power connections to all ancillary office equipment such as printers, faxes, plotters, and shredders. Provide dedicated circuits where warranted.

e. In each telecommunications room provide a dedicated 20A circuit with a receptacle adjacent to each rack or backboard for each of the following:

- CCTV for training systems
- CCSTV for security systems
- CATV
- Voice systems
- Data systems.

f. Provide dedicated receptacles as required throughout the facility for television monitors. These outlets will typically be located at the ceiling level for wall mounted television monitors. However, similar specialty equipment can share the same circuit.

g. Corridors: One every 50 ft (15 m) with a minimum of one per corridor.

h. Janitor’s closet and toilet rooms: One GFI receptacle per closet. Provide GFI receptacles at counter height for each counter in toilets such that there is a minimum of one outlet for each two sinks.

i. Space with counter tops: One for every 4 ft (1.2 m) of countertop, with a minimum of one outlet. Provide GFI protection of outlets when located within 6 ft (1.8 m) of plumbing fixtures.

j. Building exterior: One for each wall, GFI protected and weatherproof.

k. Kitchen non-residential: One for each 10 ft (3 m) of wall space at the floor line. Provide GFI protection when located within 6 ft (1.8 m) of plumbing fixture.

l. Dwelling units, child development centers, and other child occupied spaces (including toilets): Provide listed tamper-resistant receptacles.

m. All other rooms: One for every 25 ft (7.6 m) of wall space at the floor line. When 25 ft (7.6 m) or less of wall at the floor line exists in a room, provide a minimum of two receptacles spaced appropriately to anticipate furniture relocations.

n. Special purpose receptacles: Coordinate with the user to provide any special purpose outlets required. Provide outlets to allow connection of equipment in special use rooms.

3.6.2 RACEWAY CRITERIA. Install all wiring in raceways unless specifically indicated otherwise. Minimum permitted size conduit permitted is 1/2 in (16 mm). Provide an insulated green equipment grounding conductor for all circuit(s) installed in raceways. Conceal raceways above ceilings and in finished areas that have finished walls or finished surfaces. Do not use electrical non-metallic tubing (ENT) or flexible non-metallic tubing and associated fittings. The following summarizes approved raceway types and their limitations of use:

- Galvanized Rigid Steel (GRS) Conduit. Specify GRS conduit \1\ where exposed to weather, where subject to physical damage, and where exposed /1/ on exterior of buildings.

- Intermediate Metal Conduit (IMC). IMC may be used in lieu of GRS as allowed by NFPA 70.

- Electrical Metallic Tubing (EMT). Specify EMT for branch circuits and feeders above suspended ceilings or exposed where not subject to physical damage. Do not use EMT underground, encased in concrete, mortar or grout, in hazardous locations, where exposed to physical damage, outdoors or in fire pump rooms. Use die-cast compression connectors.

- Flexible Metal Conduit. Flexible metal conduit can be used, limited to 6-foot length, for recessed and semirecessed lighting fixtures; for equipment subject to vibration; and for motors other than pumps. Use liquidtight flexible metal conduit in damp and wet locations and for pumps.

- Polyvinyl Chloride (PVC). Specify Schedule 40 PVC (minimum) for service entrance conduits from the service utility to the substation or underground below floor slabs. PVC is not approved for use when restrictions are stipulated in other industry standards or UFCs for specific types of buildings such as medical facilities.

- Surface Metal Raceways. Specify two-piece painted steel, totally enclosed, snap-cover type, multiple outlet-type raceway only for shops, laboratories, and medical facilities.

- Convert nonmetallic conduit, other than PVC Schedule 40 or 80, to plastic-coated rigid, or IMC, steel conduit before rising through the floor slab.

Use surface metal raceways or multi-outlet assemblies only for building improvements or renovations, or for applications where a variety of cord-and-plug connected equipment will be utilized in a limited space, such as in some areas of medical facilities, shops, and laboratories. Refer to TSEWG TP-8, *Electrical Equipment Enclosures and Hazardous Locations*, at http://www.wbdg.org/ccb/browse_cat.php?o=29&c=248 for additional information regarding equipment enclosures and hazardous locations.

3.6.3 CONDUCTORS. Conductors #6 AWG and smaller must be copper. Aluminum conductors of equivalent ampacity can be used instead of copper for #4 AWG and larger sizes. Branch circuit conductors, including power and lighting applications, will in no case be less than #12 AWG. Branch circuit breakers shall be 20 amperes minimum, except where lesser ratings are required for specific applications

3.7 LIGHTING. Lighting design is not part of this publication.

3.8 EMERGENCY GENERATORS.

3.8.1 APPLICATIONS. Emergency generators and related wiring systems are authorized for use when needed to support mission-critical functions in the following types of facilities and locations in accordance with paragraph 3.8.2:

- Medical treatment facilities
- Air transportation navigation aids and facilities
- Refrigerated storage rooms
- POL storage and dispensing facilities
- Critical utility plants and systems
- Civil engineer control centers
- Communication facilities and telephone exchanges
- Fire stations, including fire alarm, fire control, and radio equipment
- Critical computer automatic data processing facilities
- Airport traffic control towers
- Weather stations
- Surveillance and warning facilities
- Central control facilities
- Security lighting systems
- Law enforcement and security facilities
- Emergency operations centers (EOCs)
- Critical activity, property, and life support facilities at remote and not readily accessible sites
- Industrial facilities that have noxious fumes requiring removal—provide power for exhaust system only

3.8.2 LOAD ANALYSIS. Determine what loads or facilities need to continue to function following a loss of normal power. Evaluate which loads must be uninterruptible, can experience momentary power loss, or can experience a longer duration power loss.

Apply the following documents to determine which loads require backup power and should be reviewed as part of a backup power need analysis:

- IEEE Std 446—provides a detailed discussion of how to evaluate the need for backup power.
- NFPA 110—provides specific criteria for backup power systems.
- NFPA 111—establishes the NFPA requirements associated with backup power systems.

3.8.3 SERVICE ENTRANCE DESIGN. If the facility has a permanently installed emergency power source, provide a separate panel to supply only the loads requiring emergency power. This panel will normally be supplied by the upstream main distribution panel. Do not design the system in a manner that allows non-essential loads to be carried by the emergency power source. If the facility is intended to have the capability to connect portable emergency power generation, install a manually operated safety switch designed for this purpose on the exterior of the facility. Alternatively, an approved cable connection system can be installed with the cable connector located on the exterior of the facility and connected on the interior of the facility to a normally open safety switch or circuit breaker.

3.9 AUTOMATIC TRANSFER EQUIPMENT. Provide an open transition transfer scheme unless the system requires paralleling with the utility. Closed transition transfer is rarely required for backup power applications. Closed transition will require coordination with the local utility and will require designing for the higher available short circuit current of the combined parallel sources. Provide four-pole ATS designs to ensure that the neutral is switched with the circuit. If allowed by the facility layout, locate the transfer switch near the load. This increases system reliability by minimizing the length of the run common to both power sources from the transfer switch to the load. Design feeder routing with physical separation between the normal power feeders and the emergency feeders. This minimizes the possibility that both power sources will be simultaneously interrupted by a localized problem within the facility. Where possible, use a greater number of small transfer switches rather than a lesser number of large transfer switches. By this approach, failure of a single transfer switch should not affect the entire facility. Include a fully rated break and load maintenance bypass switch in parallel with a closed transition ATS. The ATS must be designed for maintenance and repair without requiring shutdown of the associated system. Refer to NFPA 99 for any transfer switch applications involving medical facilities. The following references provide additional information regarding automatic transfer switches:

- EGSA 100S—contains classifications, applications and performance requirements for transfer switches for emergency and standby transfer switches.

- IEEE Std 446—discusses ATS applications.

- NFPA 99—provides specific electrical requirements for medical facilities and addresses transfer switch requirements in detail.

- NFPA 111—establishes the NFPA requirements for ATS designs.

- UL 1008—establishes ATS certification requirements and is a useful reference source for ATS ratings.

3.10 STATIONARY BATTERIES AND BATTERY CHARGERS.

3.10.1 SELECTION. Use vented lead acid batteries preferentially for switchgear control power and UPS applications. Batteries for switchgear or backup power applications should be rated for general purpose, switchgear, or utility use. Batteries for UPS applications should be rated for UPS or high-rate use. Nickel-cadmium batteries are often more expensive than vented lead-acid batteries and should be considered primarily for extreme temperature environments or engine-starting applications. Nickel-cadmium batteries are preferred for engine starting applications because of their high-rate discharge capability and their more predictable failure modes. As a general practice, do not use a valve-regulated lead acid (VRLA) battery if a vented lead-acid battery will satisfy the design and installation requirements. VRLA batteries have exhibited a shorter service life than vented equivalents and have shown a tendency to fail without warning. Refer to IEEE Std 1189 for additional information regarding the unique failure modes and shorter service life of this battery type. VRLA batteries are allowed to be used in the following types of applications:

• Installations with small footprints such that a vented battery with adequate power density will not fit within the available space.

• Locations in which the consequences of electrolyte leakage cannot be allowed. UPS systems are often located in areas that necessitate the use of a VRLA battery.

Do not use VRLA batteries in the following types of applications:

- Unregulated environments that can experience abnormally high and low temperatures.

- Unmonitored locations that seldom receive periodic maintenance checks. VRLA batteries have shown a tendency to fail within only a few years after installation.

- Critical applications, unless the installation location requires the features available only in a VRLA battery.

Apply the following service life for life-cycle cost comparisons of stationary batteries:

- Small VRLA batteries – 3 years.
- Large VRLA batteries – 7 years.
- Small vented lead acid batteries – 10 years.
- Large vented lead acid batteries – 15 years.
- Nickel-cadmium batteries – 15 years.

3.10.2 BATTERY AREAS AND BATTERY RACKS. Comply with owner requirements.

3.10.3 INSTALLATION DESIGN.

3.10.3.1 INDUSTRY STANDARDS. Review the following IEEE standards, as applicable for the battery type, prior to the installation:

- IEEE Std 450—provides maintenance and test criteria for vented lead acid batteries.
- IEEE Std 484—provides installation criteria for vented lead acid batteries.
- IEEE Std 485—defines battery sizing requirements for lead acid batteries.
- IEEE Std 1106—provides maintenance and test criteria for nickel cadmium batteries.
- IEEE Std 1115—defines battery sizing requirements for nickel cadmium batteries.
- IEEE Std 1184—provides application and sizing criteria for UPS applications.
- IEEE Std 1187—provides installation criteria for valve-regulated lead acid batteries.
- IEEE Std 1188—provides maintenance and test criteria for valve-regulated lead acid batteries.
- IEEE Std 1189—explains application limitations for valve-regulated lead acid batteries.

3.10.3.2 DESIGN REQUIREMENTS. Size the battery in accordance with IEEE Std 485, IEEE Std 1115, or IEEE Std 1184 as appropriate for the selected battery type and application.

3.10.3.3 INSTALLATION REQUIREMENTS. Design and install the battery in accordance with IEEE Std 484, IEEE Std 1187, or IEEE Std 1106 as appropriate for the selected battery type. Refer to the above industry standards and NETA ATS for acceptance test criteria.

3.10.4 BATTERY CHARGERS. Use single-phase chargers for smaller applications. Rate single-phase battery chargers for 240V single phase, unless only 120V is available. Use three-phase chargers if the charger's DC output current rating will be greater than 75A. Unless the battery has specific requirements to the contrary, all chargers should be of the constant voltage type.

3.10.5 BATTERY PROTECTION. Install a circuit breaker or fused protection device as close to the battery as possible. Provide overcurrent protection for each string in a parallel battery system. Refer to IEEE Std 1375 for additional guidance.

3.11 GROUNDING, BONDING, AND STATIC PROTECTION. Comply with NFPA 70 for grounding and bonding requirements.

3.11.1 GROUND RODS. Ground rod composition, minimum spacing requirements and connections shall conform to the requirements of NFPA 70 Section 250 except that minimum length dimensions shall be 10 feet (3.0 m) in length and ¾ inch (19 mm) diameter. Ground rods shall be copper-clad steel, solid copper, or stainless steel. 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). Install ground rods (and ground ring, if applicable) 3 ft to 8 ft (0.9 m to 2.4 m) beyond the perimeter of the building foundation and at least beyond the drip line for the facility.

3.11.2 GROUND RINGS. Provide a ground ring (counterpoise) for facilities with sensitive electronic equipment or other applications when identified by project requirements. A ground ring shall have at least two ground rods located diagonally at opposite corners. When required by a specific activity or facility, provide a ground rod at each change in direction of the ground ring and install test wells for at least two of the corner ground rods to allow for testing of the system. Assemble test wells with bolted connections to facilitate future testing.

3.11.3 COMMUNICATION-ELECTRONICS FACILITIES. Provide grounding electrode systems for communications-electronics (c-e) facilities in accordance with owner requirements.

3.11.4 STATIC ELECTRICITY PROTECTION. Comply with owner requirements for static protection.

3.12 LIGHTNING PROTECTION SYSTEMS. Provide lightning protection systems in accordance with best practices and owner requirements.

3.13 400-HERTZ DISTRIBUTION SYSTEMS. Design 400 hertz power systems in accordance with best practices and owner requirements.

3.14 270-VOLT DC DISTRIBUTION SYSTEMS. System design requirements are not part of this publication.

3.15 POWER FACTOR CORRECTION. The power factor within a facility is normally 0.9 lagging or greater; therefore, power factor correction is not routinely required for interior electrical systems.

3.16 POWER QUALITY. Design secondary electrical systems to mitigate the harmonic effects of non-linear loads as a result of connections to electronic loads, including computer work stations, file servers, UPS, and electronic ballasts.

3.17 SYSTEMS FURNITURE. When systems furniture is utilized, the electrical engineer, the architect, and the interior designer must coordinate during the design process. Systems furniture is typically specified and ordered when construction is nearing completion; therefore, if proper coordination has not occurred earlier in the design process, field interface problems will occur. Systems furniture is pre-wired to a wiring harness. Unless specified otherwise, select a standard wiring harness that meets one of the following configurations:

- 5-wire harness consisting of 3 circuit conductors, 1 oversized neutral conductor and 1 equipment grounding conductor.

- 8-wire harness consisting of 4 circuit conductors, 1 oversized neutral conductor, 1 full sized neutral conductor and 2 separate equipment grounding conductors.

Serve 5-wire harnesses with 3 separate circuits and 8-wire harnesses with 4 separate circuits. Provide oversized neutrals to match the harness configuration and balance loads between circuits and phases. A single circuit must not serve more than 4 cubicles under any circumstances.

4. GLOSSARY

Abbreviations and Acronyms:

A—Amperes

AC—Alternating Current

AHJ—Authority Having Jurisdiction

ANSI—American National Standards Institute

ASD—Adjustable Speed Drive

ATS—Automatic Transfer Switch

AWG—American Wire Gauge

CCTV—Closed Circuit Television

CATV—Cable Television

CFR—Code of Federal Regulations

COPS—Critical Operations Power System /1/

DC—Direct Current

DDC—Direct Digital Control

EGSA—Electrical Generating Systems Association

EMT—Electrical Metallic Tubing

ENT—Electrical Non-Metallic Tubing

FE—Full Electric

ft—Feet

GRS—Galvanized Rigid Steel

HID—High Intensity Discharge

HVAC—Heating, Ventilating, and Air Conditioning

Hz—Hertz

IEEE—formerly Institute of Electrical and Electronics Engineers

IMC—Intermediate Metal Conduit

kA—Kilo-Amperes

kVA—Kilo-Volt-Amperes

kW—Kilowatt

m—Meter

MCC—Motor Control Center

MCOV—Maximum Continuous Overvoltage Rating

MI—Mineral Insulated

MOV—Metal Oxide Varistor

mm—Millimeter

MVA—Megavolts-Ampere

NEC—National Electrical Code

NEMA—National Electrical Manufacturers Association

NETA—International Electrical Testing Association

NFPA—National Fire Protection Association

OSHA—Occupational Safety and Health Administration

PVC—Polyvinyl Chloride

RMS—Root-Mean-Square

SPD—Surge Protective Devices /1/

SWD—Switching Duty

TVSS—Transient Voltage Surge Suppressor

UFC—Unified Facilities Criteria

UL—Underwriters Laboratories

UPS—Uninterruptible Power Supply

V—Volts

VFD—Variable Frequency Drive (see ASD)

VRLA—Valve-Regulated Lead Acid

Terms:

Note: The terms listed here are provided for clarification of the design criteria provided in this publication. Refer to IEEE Std 100 for additional electrical-related definitions.

Automatic Transfer Switch (ATS)—A switch designed to sense the loss of one power source and automatically transfers the load to another source of power.

Branch Circuit—The circuit conductors and components between the final overcurrent device protecting the circuit and the equipment.

Closed Transition Switch—Transfer switch that provides a momentary paralleling of both power sources during a transfer in either direction. The closed transition is possible only when the sources are properly interfaced and synchronized.

Existing Facility—A facility is existing if changes to be made are cosmetic or minor in nature.

Harmonic—A sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency.

Linear Load—An electrical load device that presents an essentially constant load impedance to the power source throughout the cycle of applied voltage in steady-state operation.

Listed—Applies to equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction. The organization periodically inspects production and certifies that the items meet appropriate standards or tests as suitable for a specific use.

Low Voltage System—An electrical system having a maximum root-mean-square (rms) voltage of less than 1,000 volts.

Medium Voltage System—An electrical system having a maximum RMS AC voltage of 1,000 volts to 34.5 kV. Some documents such as ANSI C84.1 define the medium voltage upper limit as 100 kV, but this definition is inappropriate for facility applications.

Molded Case Circuit Breaker—A low voltage circuit breaker assembled as an integral unit in an enclosed housing of insulating material. It is designed to open and close by nonautomatic means, and to open a circuit automatically on a predetermined overcurrent, without damage to itself, when applied properly within its rating.

Motor Control Center—A piece of equipment that centralizes motor starters, associated equipment, bus and wiring in one continuous enclosed assembly.

New Construction—A facility is considered new if changes to be made are more than cosmetic or minor, such as major renovations, additions, or new facilities.

Nonlinear Load—A steady state electrical load that draws current discontinuously or has the impedance vary throughout the input ac voltage waveform cycle. Alternatively, a load that draws a nonsinusoidal current when supplied by a sinusoidal voltage source.

Power Quality—The concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment.

Service Voltage—Voltage at the facility service entrance location.

Short Circuit—An abnormal condition (including an arc) of relatively low impedance, whether made accidentally or intentionally, between two points of different potential.

Surge Protector—A device composed of any combination of linear or nonlinear circuit elements and intended for limiting surge voltages on equipment by diverting or limiting surge current; it prevents continued flow of current and is capable of repeating these functions as specified.

Transfer Switch—A device for transferring one or more load conductor connections from one power source to another.

Uninterruptible Power Supply System—A system that converts unregulated input power to voltage and frequency controlled filtered AC power that continues without interruption even with the deterioration of the input AC power.

Utilization Voltage—The voltage at the line terminals of utilization equipment