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UNIFIED FACILITIES CRITERIA (UFC)

INTERIOR ELECTRICAL SYSTEMS

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

INTERIOR ELECTRICAL SYSTEMS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

U.S. ARMY CORPS OF ENGINEERS

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD(AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the more stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Support Agency (AFCESA) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request (CCR). The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://www.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: 3-520-01, Interior Electrical Systems

Superseding: UFC 3-520-01, *Interior Electrical Systems*, dated June 10, 2002.

Description: This UFC 3-520-01 provides design guidance for interior electrical systems. The document has been extensively revised to update the criteria for interior electrical systems. This UFC has also been coordinated with new UFC 3-501-01, *Electrical Engineering*. UFC 3-501-01 provides overall electrical engineering criteria, including electrical design analysis and documentation criteria. This type of material has been removed from UFC 3-520-01 so that duplication of criteria is eliminated.

Explanatory material existing in the prior revision of UFC 3-520-01 has been removed from this revision and has been made available at: http://www.wbdg.org/ccb/browse_cat.php?o=29&c=248. Sections in this UFC will refer to this internet link when appropriate.

Reasons for Document:

- Provide technical requirements for interior electrical system design criteria.
- Develop more concise electrical design guidance with this revision.
- Update the material to reflect new and revised industry standards.

Impact: There are negligible cost impacts associated with this UFC. However, the following benefits should be realized.

- Standardized guidance has been prepared to assist electrical engineers in the development of the plans, specifications, calculations, and Design/Build Request for Proposals (RFPs).
- This revision to 3-520-01 coordinates with all electrical-related UFCs and provides consistent guidance with the other electrical-related UFCs. The material included in this UFC has been streamlined to be more concise.
- Overlap of material with other UFCs has been eliminated with this revision.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This Unified Facilities Criteria (UFC) has been issued to provide guidance for the design of interior electrical systems. 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 UFC, use the applicable referenced industry standards and other documents for design guidance.

UFC 3-501-01 provides the governing criteria for electrical systems, explains the delineation between the different electrical-related UFCs, and refers to UFC 3-520-01 for interior electrical system requirements.

Modernization of electrical systems within existing facilities solely for the purpose of meeting design criteria in this UFC is not required. Upgrades or modifications of existing facilities should consider the design criteria in this UFC, but it is not intended that an entire facility require modernization solely because of a minor modification to a part of the facility.

1-2 APPLICABILITY.

Compliance with this UFC is mandatory for the design of interior electrical systems at all facilities and bases.

Facilities located outside of the United States must also comply with the applicable host nation standards; refer to UFC 3-510-01 for additional information. Different voltages, frequencies, and grounding conventions often apply in other host nations; however, follow the design principles provided in this UFC to the extent practical. Department of Commerce International Trade Administration document, *Electric Current Abroad*, provides additional information and can be obtained at www.ita.doc.gov/media/publications/pdf/current2002final.pdf.

1-3 REFERENCES.

Appendix A contains a list of references used in this UFC. References applicable to a specific topic are also listed and described in the appropriate sections of this UFC.

1-4 DESIGN STANDARDS.

Comply with the requirements of National Fire Protection Association (NFPA) 70 and IEEE C2.

Electrical safety requirements applicable to the installation and operation of electrical systems are provided in UFC 3-560-01.

Codes and standards are referenced throughout this UFC. 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. Refer to Appendix A to determine the publication date of the codes and standards referenced in this UFC.

1-5 **AUTHORITY HAVING JURISDICTION**.

The Authority Having Jurisdiction (AHJ) for each service has the authority to interpret the applicability of the requirements in this UFC, and the codes and standards referenced herein.

- For the Air Force, the AHJ is the Chief Electrical Engineer, Headquarters AFCESA/CEOA.

- For the Army, the AHJ is the Headquarters, U.S. Army Corps of Engineers (HQUSACE), Engineering and Construction (CECW-CE).

- For the Navy, the AHJ is Chief Engineer, Naval Facilities Engineering Command (NAVFAC).

1-6 **TECHNICAL POINTS OF CONTACT**.

For the Air Force, contact the Air Force Civil Engineer Support Agency (AFCESA) at daryl.hammond@tyndall.af.mil.

For the Army, contact the US Army Corps of Engineers (USACE) at robert.b.billmyre@usace.army.mil.

For the Navy, contact Code CIEE, NAVFAC Atlantic Office at john.peltz@navy.mil.

CHAPTER 2 GENERAL POWER SYSTEM CRITERIA

2-1 **VOLTAGE**.

Refer to UFC 3-550-01 for voltage criteria associated with the primary distribution supply 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 loads less than 150 kVA.
- Apply three-phase, four-wire, 480Y/277V systems for lighting and power 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. The facility user will normally provide this equipment.

CHAPTER 3 POWER DISTRIBUTION AND UTILIZATION

3-1 **TRANSFORMERS**.

The transformer design criteria provided herein apply to interior applications. Many facilities will be supplied by an exterior pad-mounted transformer. Comply with UFC 3-550-01 for exterior applications and for medium voltage transformers used inside facilities.

Size transformers in accordance with UFC 3-501-01.

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*, at http://www.wbdg.org/ccb/browse_cat.php?o=29&c=248 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 10,000A asymmetrical interrupting rating for voltages 240V and below and 14,000A asymmetrical 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. Space-only cubicles and appropriate bus provisions should be installed for future protective device additions, as necessary 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. 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 BEQ/BOQ facilities. Load centers with plug-in breakers can be used in housing units and BEQ/BOQ 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 panelboards 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 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*, at http://www.wbdg.org/ccb/browse_cat.php?o=29&c=248 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:

a. 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.

b. 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.

c. Locate the dedicated emergency panel near the service entrance equipment.

d. 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 **TRANSIENT VOLTAGE SURGE SUPPRESSION (TVSS)**.

Provide TVSS to provide surge protection for sensitive or critical electronic equipment or when specifically required. When a lightning protection system is included, typically TVSS is required on the service entrance equipment in accordance with NFPA 780 to meet the UL Lightning Protection Inspection Certificate requirements. The design criteria provided here apply to permanently installed, hard-wired surge protectors and should not be applied to plug-in type surge protectors. Refer to TSEWG TP-3, *Surge Protector Performance and Evaluation Criteria*, at http://www.wbdg.org/ccb/browse_cat.php?o=29&c=248 for additional information regarding surge protector performance criteria.

TVSS equipment must be Listed by Underwriters Laboratories UL 1449 and UL 1283, and designed, manufactured, tested and installed in compliance with IEEE C62.41, IEEE C62.45, NFPA 70, NFPA 75, and NFPA 780.

For buildings with high concentrations of electronics equipment, employ a two-stage or cascaded system. Coordinate multiple stage surge protection.

Install TVSS on the load side of a 3-pole breaker and locate as close as practical to the main breaker/lugs. Provide leads as short as possible. Maximum lead length: 3 ft (900 mm), or for cascaded systems: 5 ft (1500 mm) for service panels and 3 ft (900 mm) for branch panels.

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

Use point-of-use (plug-in type) surge protectors to protect specific critical equipment that plugs into wall receptacles.

3-4.1 **Service Entrance Surge Protection**.

Provide the following specification requirements for TVSS on the service entrance equipment

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

b. The manufacturer must provide written specifications showing the clamping voltage in accordance with NEMA LS 1 and with 6 in (150 mm) leads external to the enclosure, must be no higher than:

Voltage C3 (20kV, 10kA, combination wave)

208/120 or L-N 500

240/120	L-G	500
	N-G	500
	L-L	1000
480/277	L-N	1000
	L-G	1000
	N-G	1000
	L-L	1500

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

L-N	200kA
L-G	200kA
N-G	200kA
L-L	200kA

d. Protection Mode: All ten modes, have discrete suppression circuitry in L-G, L-N, N-G, and L-L and have bi-directional, positive, and negative impulse protection. Line-to-neutral-to-ground protection is not acceptable where line-to-ground is specified.

e. Fusing: Individually fuse suppression components. Do not use single fuses that protect multiple suppression. Do not render the entire suppression device inoperative because of a failure of a fuse or suppression component.

f. MCOV: 125% of nominal voltage.

g. Surge Life: Greater than 6500 surges of repetitive sequential IEEE C62.41 Category C3 waveforms with less than 10% degradation of clamping voltage.

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

i. Validation: Independent laboratory verification of performance and durability.

j. 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.

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

3-4.2 **Branch Panelboard Surge Protection**.

Provide the following specification requirements for TVSS on all the branch panelboards for facilities requiring cascaded suppression system protection.

a. Use a TVSS to protect the distribution branch panelboards.

b. The manufacturer must provide written specifications showing the clamping voltage in accordance with NEMA LS 1 and with 6 in (150 mm) leads external to the enclosure, must be no higher than:

Voltage C1 (6kV, 3kA, combination wave)

208/120 or	L-N	450
240/120	L-G	450
	N-G	500
	L-L	800
480/277	L-N	900
	L-G	900
	N-G	900
	L-L	1500

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

L-N	100kA
L-G	100kA
N-G	100kA
L-L	100kA

d. Protection Mode: All ten modes, have discrete suppression circuitry in L-G, L-N, N-G, and L-L and have bi-directional, positive, and negative impulse protection. Line-to-neutral-to-ground protection is not acceptable where line-to-ground is specified.

e. Fusing: Individually fuse suppression components. Single fuses that protect multiple suppression devices must not be used. The suppression device must not become inoperative because of a failure of a fuse or suppression component.

f. MCOV: 125% of nominal voltage.

g. Surge Life: Greater than 4500 surges of repetitive sequential IEEE C62.41 Category B3 waveforms with less than 10% degradation of clamping voltage.

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

i. Validation: Independent laboratory verification of performance and durability.

j. 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.

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

3-4.3 **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 the following specification requirements for TVSS equipment.

a. The unit must have a 35 kA per mode (70 kA per phase) or greater single pulse surge current capacity.
b. MCOV: 150 V or greater.
c. Listing: UL
d. Testing: Tested in all modes per IEEE C62.41 and IEEE C62.45.
e. Warranty: Not less than a 10-year warranty.
f. Diagnostics: Visual indication unit has malfunctioned or requires replacement.

3-4.4 **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 (this is a common error).
- 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.

3-4.5 **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.

Ensure surge protection equipment used for communications and related systems is listed with UL 497A or UL 497B, as applicable.

Ensure telephone communication interface circuit protection is listed to UL 497A and it should provide a minimum surge current rating of 9,000A. Ensure central office telephone line protection is listed to UL 497A and has multi-stage protection with a minimum surge current rating of 4,000A.

Ensure intercom circuit protection is listed to UL 497A and has a minimum surge current rating of 9,000A. Protection should be provided 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. Ensure the protection is listed to UL 497A for data communications and UL 497B for annunciation.

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.

3-5 **METERING**.

Provide Smart metering systems (e.g., with remote reading, monitoring, or activation capabilities) in accordance with service-specific criteria and the DoD directives to comply with EPACT 2005 requirements. Coordinate meters and system components to be compatible with the Activity’s central system.

Upon Activity request, limit housing units to meter sockets only. Sockets must be single phase, four terminal, and ring-less with manual bypass device and polycarbonate blank cover plate.

Locate meters directly on pad mounted transformers, on the exterior of the associated facility, or integral to unit substations.

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. Child occupied spaces (including toilets): One for every 12 ft (3.6 m) of wall space. Use child safety type such as those that require rotating an integral surface cover plate to access current. Removable caps and plugs are not acceptable.

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 conduit 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 conduits and raceways. Conceal conduit in finished spaces. Do not use wiring gutters in lieu of conduits.

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 for all runs in masonry or concrete walls and slabs, if exposed to weather, where subject to physical damage, and exposed conduits 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 Metallic Conduit. Flexible metallic conduit can be used for recessed and semirecessed lighting fixtures; for equipment subject to vibration; and for motors.

- Polyvinyl Chloride (PVC). Specify Schedule 40 PVC for service entrance conduits from the service utility to the substation or underground below floor slabs. Do not use PVC above the ground-level slab of buildings.

- 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 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 #8, #10, and #12 AWG must be copper.

Aluminum conductors of equivalent ampacity can be used instead of copper for #4 AWG and larger sizes.

3-7 **LIGHTING**.

Design lighting in accordance with UFC 3-530-01*.*

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 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.
- Air traffic control towers.
- Base weather stations.
- Surveillance and warning facilities.

- Command and control facilities.
- Weapon systems.
- Security lighting systems.
- Aircraft and aircrew alert facilities.
- Law enforcement and security facilities.
- Emergency operations centers (EOCs).
- Mission, property, and life support facilities at remote and not readily accessible sites, such as split-site aircraft warning and surveillance installations.
- Industrial facilities that have noxious fumes requiring removal—provide power for exhaust system only.
- Readiness facilities relying on electrical power to support tactical or critical missions.
- Photographic laboratories providing critical and essential support to combat and contingency tactical missions.
- Other facilities, including facilities required for emergency response, approved by the AHJ. *Note: Some installations have contingency plans in place that transfer the function to an alternate location in the event something disrupts the operation of a single facility for emergency response*.

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:

- AFI 32-1063—establishes Air Force requirements for the use of emergency generators and related wiring systems when needed to support certain mission-critical functions.
- IEEE Std 446—provides a detailed discussion of how to evaluate the need for backup power.
- UFC 3-540-04N—provides specific guidance related to satisfying backup power needs.

- MIL-HDBK-1190—provides authorization for emergency power for various applications.
- 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.

Refer to TSEWG TP-9, *Automatic Transfer Equipment*, at http://www.wbdg.org/ccb/browse_cat.php?o=29&c=248 for additional information regarding ATS design and application.

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. For the Air Force, refer also to AFPAM 32-1186 for additional information regarding VRLA batteries.

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 UFC 3-520-05.

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.

Refer to TSEWG TP-4, *Stationary Battery and Charger Sizing*, at http://www.wbdg.org/ccb/browse_cat.php?o=29&c=248 for additional information regarding battery sizing principles.

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.

For the Army and Navy, comply with NFPA 70 criteria for grounding and bonding requirements.

For the Air Force, comply with Air Force Instruction (AFI) 32-1065 for grounding and bonding requirements.

For the Army and Navy, comply with NFPA 77 criteria for static protection requirements.

For the Air Force, comply with AFI 32-1065 and NFPA 77 for static protection requirements.

3-12 LIGHTNING PROTECTION SYSTEMS.

Provide lightning protection systems in accordance with NFPA 780, UL96A, and MIL-HDBK-1004/6 criteria. Provide a UL Lightning Protection Inspection Certificate for the facility.

For the Air Force, comply with AFI 32-1065.

For the Navy, provide lightning protection for munitions storage and handling facilities in accordance with NAVSEA OP-5.

3-13 400-HERTZ DISTRIBUTION SYSTEMS.

Design 400 hertz power systems in accordance with UFC 3-555-01N and MIL-HDBK-1028/6A.

3-14 270-VOLT DC DISTRIBUTION SYSTEMS.

System design requirements and specifications for the Joint Strike Fighter are in progress. For the Navy, contact Code CIEE, NAVFAC Atlantic Office at john.peltz@navy.mil

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.

However, if the facility design incorporates large motor applications or other specific loads that may adversely affect the power factor, provide an evaluation that includes the considerations identified in TSEWG TP-2, *Capacitors for Power Factor Correction*, at http://www.wbdg.org/ccb/browse_cat.php?o=29&c=248.

If the evaluation supports the need for power factor correction, contact the AHJ for authorization prior to providing power factor correction equipment.

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. Refer to Appendix C for power quality design criteria.

3-17 **SYSTEMS FURNITURE**.

When systems furniture is utilized, the electrical designer, 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.

GLOSSARY

Abbreviations and Acronyms:

A—Amperes

AC—Alternating Current

AFCESA—Air Force Civil Engineer Support Agency

AFI—Air Force Instruction

AFPAM—Air Force Pamphlet

AHJ—Authority Having Jurisdiction

ANSI—American National Standards Institute

ASD—Adjustable Speed Drive

ATS—Automatic Transfer Switch

AWG—American Wire Gauge

BEQ—Bachelor's Enlisted Quarters

BOQ—Bachelor's Officer Quarters

CCTV—Closed Circuit Television

CATV—Cable Television

CFR—Code of Federal Regulations

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

NAVFAC—Naval Facilities Engineering Command

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

SWD—Switching Duty

TSEWG—Tri-Service Electrical Working Group

TVSS—Transient Voltage Surge Suppressor

UFC—Unified Facilities Criteria

UL—Underwriters Laboratories

UPS—Uninterruptible Power Supply

USACE—U.S. Army Corps of Engineers

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 UFC. 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 transfer 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 enclosing 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.

APPENDIX A REFERENCES

Note: *The most recent edition of referenced publications applies, unless otherwise specified.* [1]

Military Publications

AFI 32-1063, *Electric Power Systems.*
AFI 32-1065, *Grounding Systems.*
AFPAM 32-1186, *Valve-Regulated Lead-Acid Batteries for Stationary Applications.*
MIL-HDBK-1004/6, *Lightning Protection*.
MIL-HDBK-1028/6A, *Aircraft Fixed Point Utility Systems.*
MIL-HDBK-1190, *Facility Planning and Design Guide*.
NAVSEA OP-5, *Ammunition and Explosives Safety Ashore.*
UFC 3-501-01, *Electrical Engineering.*
UFC 3-510-01, *Foreign Voltages and Frequencies Guides.*
UFC 3-520-05, *Stationary Battery Areas.*
UFC 3-530-01, *Design: Interior and Exterior Lighting and Controls.*
UFC 3-540-04N, *Diesel Electric Generating Plants.*
UFC 3-550-01, *Exterior Electrical Power Distribution.*
UFC 3-555-01N, *400 Hertz Medium Voltage Conversion/Distribution and Low Voltage Utilization Systems.*
UFC 3-560-01, *Electrical Safety, O & M.*

American National Standards Institute

Note: Many ANSI documents are sponsored or co-sponsored by other organizations, such as NEMA or IEEE.

ANSI C84.1, *Electric Power Systems and Equipment—Voltage Ratings (60 Hz).*
ANSI Z535.4-2007, *Product Safety Signs and Labels.*

IEEE (formerly Institute of Electrical and Electronics Engineers)

IEEE C2-2007, *National Electrical Safety Code.*
IEEE C57.110, *IEEE Recommended Practice for Establishing Transformer Capability When Supplying Nonsinusoidal Load Currents.*
IEEE C62.41, *IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.*

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[1] Addresses for standards:

1. American National Standards Institute, 25 West 43rd Street, New York, NY 10036
2. Institute of Electrical and Electronics Engineers, 3 Park Avenue, 17th Floor, New York, NY 10016
3. International Electrical Testing Association,
4. National Electrical Manufacturers' Association, 1300 North 17th Street, Suite 1752, Rosslyn, VA 22209
5. National Fire Protection Association, One Batterymarch Park, P.O. Box 9101, Quincy, MA 02269
6. Underwriters Laboratories, Inc., 333 Pfingston Road, Northbrook, IL 60062

IEEE C62.45, *IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits.*
IEEE Std 100, *IEEE Standards Dictionary: Glossary of Terms & Definitions.*
IEEE Std 446, *IEEE Emergency and Standby Power Systems for Industrial and Commercial Applications* (IEEE Orange Book).
IEEE Std 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.*
IEEE Std 484, *IEEE Recommended Practice for Installation Design and Implementation of Vented Lead-Acid Batteries for Stationary Applications.*
IEEE Std 485, *IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications.*
IEEE Std 519, *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.*
IEEE Std 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications.*
IEEE Std 1115, *IEEE Recommended Practice for Sizing Nickel-Cadmium Batteries for Stationary Applications.*
IEEE Std 1159, *IEEE Recommended Practice for Monitoring Electric Power Quality.*
IEEE Std 1184, *IEEE Guide for Batteries for Uninterruptible Power Systems.*
IEEE Std 1187, *IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications.*
IEEE Std 1188, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve Regulated Lead-Acid Storage Batteries for Stationary Applications.*
IEEE Std 1189, *Guide for Selection of Valve Regulated Lead-Acid Batteries for Stationary Applications.*
IEEE Std 1375, *Guide for the Protection of Stationary Battery Systems.*

National Electrical Manufacturers Association

NEMA ICS 1, *Industrial Control and Systems: General Requirements.*
NEMA ICS 2, *Industrial Control and Systems: Controllers, Contactors and Overload Relays Rated 600 Volts.*
NEMA ICS 7, *Adjustable-Speed Drives.*
NEMA LS 1, *Low Voltage Surge Protective Devices.*
NEMA PB 2, *Deadfront Distribution Switchboards.*
NEMA ST 20, *Dry Type Transformers for General Applications.*

National Fire Protection Association

NFPA 70, *National Electrical Code.*
NFPA 70E-2004, *Electrical Safety in the Workplace. Note: Criteria have been coordinated with the 2004 edition. The 2009 edition has been published and is under review by the Tri-Services Electrical Working Group. Relevant changes in the 2009 edition will be incorporated into applicable criteria in the next revision.*
NFPA 75, *Standard for the Protection of Information Technology Equipment.*
NFPA 77, *Static Electricity.*

NFPA 99, *Health Care Facilities*.
NFPA 110, *Emergency and Standby Power Systems.*
NFPA 111, *Stored Electrical Energy Emergency and Standby Power Systems.*
NFPA 780, *Installation of Lightning Protection Systems.*

Occupational Safety and Health Administration

Note: OSHA regulations can be downloaded from www.osha.gov.

29 CFR 1910.305, *Wiring Methods, Components and Equipment for General Use — Design Safety Standards for Electrical Systems.*

Underwriter's Laboratories

UL 96A, *Standard for Installation Requirements for Lightning Protection Systems*.
UL 497A, *Standard for Secondary Protectors for Communication Circuits*.
UL 497B, *Standard for Protectors for Data Communication and Fire Alarm Circuits*.
UL 891*, Switchboards.*
UL 845, *Motor Control Centers*.
UL 1008, *Standard for Transfer Switch Equipment*.
UL 1283, *Standard for Electromagnetic Interference Filters*.
UL 1449, *Standard for Surge Protective Devices*.

Miscellaneous Documents

EGSA 100S, *Performance Standard for Transfer Switches for Use with Engine Generator Sets.*
NETA ATS, *Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.*
Electric Current Abroad, U.S. Department of Commerce.

APPENDIX B ADJUSTABLE SPEED DRIVES

ASDs are also referred to as variable frequency drives, variable speed drives, and adjustable frequency drives.

The following provides additional criteria relating to the design and installation of ASDs.

At the rated full load of the driven equipment, the output voltage and frequency of the ASD should be the same as the motor's rating. Note that this design requirement places limits on the motor design; the motor should not have a significantly higher full load horsepower or speed rating than the driven load. Mismatches can easily cause operational problems, including efficiency losses and increased ASD input current. In extreme cases, a mismatch can cause the ASD to trip on overcurrent during motor starting or cause the ASD input current to be substantially higher than the design without the ASD.

The ASD short term current rating should be adequate to produce the required motor starting torque, including loads with high starting torque.

Specify a motor with a minimum 1.15 service factor or ensure the motor is rated well above the actual load it will carry. Verify with the manufacturer that the motor is capable of acceptable operation with an ASD. Standard motors can often operate down to 50% of rated speed, high efficiency motors can often operate down to 20% of rated speed, and "inverter duty" motors can operate below 20% of rated speed without problems in a variable load application.

Ensure that the final installation does not create voltage or current harmonic distortion beyond acceptable limits. Take power quality field measurements after installation to confirm that the system total harmonic distortion is not degraded beyond acceptable levels. If the ASD can be provided power from a standby generator upon loss of normal commercial power, the harmonic distortion evaluation must include the system effects when powered from the standby generator.

Voltage sags can cause nuisance tripping. Ensure that the ASD either has a minimum of 3-cycle ride-through capability or automatic reset circuitry.

Nearby capacitor switching can cause transient overvoltages, resulting in nuisance tripping. In this case, ensure the ASD either has input filtering to reduce the overvoltage or automatic reset circuitry.

Important applications should include bypass operation capability to allow motor operation independent of the ASD.

APPENDIX C POWER QUALITY

C-1 **INTRODUCTION**.

Unlike other electrical design requirements, power quality design solutions are very dependent on the types of transients and disturbances that can and will occur in power systems. In many cases, it will be easier to provide protection and power quality design features to specific equipment rather than generically throughout the facility.

C-2 **UNBALANCED VOLTAGES**.

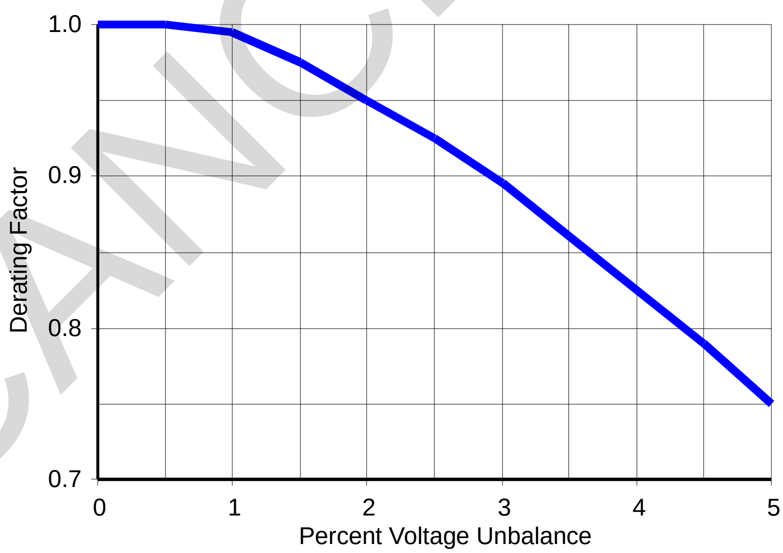
Evaluate the loading on each phase and balance the loads as well as possible. As part of acceptance testing, monitor the degree of unbalance and make corrections if necessary.

Calculate voltage unbalance as follows:

$$\textit{Percent Unbalance} = \frac{\textit{Maximum Phase Deviation from Average Voltage}}{\textit{Average Voltage}} \times 100\%$$

The rated load capability of three-phase equipment is reduced by voltage unbalance. Figure C-1 shows a typical derating factor for three-phase induction motors as a function of voltage unbalance.

Figure C-1 Typical Derating Factor for Three-Phase Induction Motors



C-3 **HARMONIC DISTORTION EVALUATION**.

If a significant number of nonlinear loads are installed in the facility, perform a harmonic distortion evaluation during the facility design phase. If the effect of nonlinear loads is expected to be minor, a detailed harmonic distortion evaluation is not required. IEEE Std 519 provides the industry-accepted method of evaluating harmonic voltages and currents. IEEE Std 519 provides *system level* guidance, not equipment specific guidance; harmonic distortion limits are established for the facility and the installation of any equipment should not degrade the system to beyond acceptable levels.

C-4 **HARMONIC CURRENT EFFECTS ON TRANSFORMERS**.

Whenever significant nonlinear loads are expected in a facility, evaluate the system in accordance with IEEE C57.110 to determine if transformer derating will be required. For transformers without a k-factor rating, derating must be used to determine the maximum fundamental load current that the transformer can maintain with the additional harmonic currents

> *Note: Derating applies to the full-load capability of the transformer when applied in an environment containing significant harmonic distortion. If the transformer is not fully loaded, the derating process might have little or no practical significance unless it is expected that the transformer will eventually be fully loaded. Nationwide surveys indicate average loading levels for dry-type transformers of between 35% for commercial facilities and 50% for industrial facilities. Military facilities are commonly loaded to less than 25% of the service entrance transformer full-load capability during periods of peak demand.*

If it is determined that a transformer will require derating because of harmonic distortion, perform the following additional reviews:

- Verify the expected transformer loading assumptions for a new design or actual metering data for an existing design to confirm that the transformer is fully loaded; most transformers are never fully loaded.

- Determine if the harmonic distortion environment can be improved by design changes for the most offending loads.

- If the transformer requires more than 10% derating, evaluate the feasibility of installing a new transformer designed for a harmonic distortion environment (often referred to as a k-factor transformer). Include delivery and replacement time scheduling as well as cost in the evaluation.

- If transformer derating is the selected option, annotate the percent derating on the applicable design drawings and install a label near the transformer nameplate indicating that the transformer has been derated. The purpose of these actions is to prevent inadvertent overloading of the transformer in the future.

C-5 **NONLINEAR LOAD DESIGN CONSIDERATIONS**.

Analyze planned electrical loads on new projects to determine whether or not they are considered potential nonlinear loads with high harmonic content. The following guidelines are provided if nonlinear loads are a significant portion of the total load.

- Derate transformer, motor, and generator outputs if necessary to prevent overheating or burnout. Ensure that design documents and equipment nameplates reflect the derated capability.

- If standby generators represent the only power source upon loss of normal power, the generator design must account for nonlinear loads.

- Use a single three-phase transformer with common core, delta connected primary and wye connected secondary instead of three single-phase transformers connected for three-phase service. Evaluate the use of a k-factor transformer if a standard transformer has to be derated by more than 10%. Compare the cost of a k-factor transformer to an equivalent standard transformer. Even if derating of a standard transformer is not required, select the k-factor transformer if the cost of the two types is within 5%, provided that the lead time of a k-factor transformer satisfies facility schedule requirements.

- Specify harmonic filters as necessary to minimize the localized effects of harmonics. If separate harmonic filters are installed specifically to protect against offending loads, locate each filter as close to each load as practical.

- Specify true RMS sensing meters, relays, and circuit breaker trip elements.

Analysis alone will not always adequately predict power quality problems. Refer to IEEE Std 1159 for additional information regarding power quality monitoring.

C-6 **NEUTRAL CIRCUIT SIZING FOR NONLINEAR LOAD CONDITIONS**.

Minimize neutral circuit overheating by specifying separate neutral conductors for line-to-neutral connected nonlinear loads with high harmonic content. Treat the neutral conductors as current carrying conductors in the design analysis. When a shared neutral conductor must be used for three-phase, four-wire systems, size the neutral conductor to have an ampacity equal to at least 1.73 times the ampacity of the phase conductors.

Two paralleled, full size neutral conductors can be used to obtain the required neutral ampacity for conductors sized #1/0 AWG and larger. Size the neutral conductor between the transformer and the panelboard to be a minimum of 1.73 times the ampacity of the phase conductors. Select panelboards that have been rated for nonlinear loads.