UFC 3-520-01
October 6, 2015

UNIFIED FACILITIES CRITERIA (UFC)

INTERIOR ELECTRICAL SYSTEMS

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

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INTERIOR ELECTRICAL SYSTEMS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

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

This UFC supersedes UFC 3-520-01, dated 3 February 2010, with Change 1.

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 most 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 Center (AFCEC) 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. 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://dod.wbdg.org/.

Refer to UFC 1-200-01, *General Building Requirements*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 3-520-01, *Interior Electrical Systems*

Superseding: UFC 3-520-01, *Interior Electrical Systems*, dated February 3, 2010

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, which may differ from NFPA 70, for interior electrical system design criteria. *Note: if there are conflicts between NFPA 70 and this UFC, apply the criteria provided in this UFC*.

- 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.

Unification Issues

None.

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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 must apply 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.

1-2.1 UFC Scope

Compliance with this UFC is mandatory for the design of interior electrical systems at all facilities and bases. This UFC typically applies up to 5 foot 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.

Refer to UFC 3-550-01 for exterior electrical systems.

1-2.2 Host Nation Standards

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 as defined in UFC 3-510-01 generally applies. Different wiring and grounding conventions usually apply in other host nations; however, follow the design principles provided in this UFC to the extent practical as well as the requirements provided in UFC 1-202-01, *Host Nation Facilities in Support of Military Operations*. 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 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *General Building Requirements*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-4 REFERENCES.

1-5 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.DESIGN STANDARDS.

Comply with the requirements of National Fire Protection Association (NFPA) 70, *National Electrical Code*, and the requirements herein. Electrical safety requirements, including the types of energized work permitted, approval process for energized work, and Personal Protective Equipment (PPE), applicable to the design, installation, and operation of electrical systems are provided in UFC 3-560-01.

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 UFC take precedence over this UFC.

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. The design is intended to use the most current version of a publication, standard or code in effect when the design contract is signed unless written direction is provided to the contrary. If dates are not indicated in the contract or in the absence or other direction, the issue/version of publication in effect at the time the design started is to be used. Designs that have been started and then delayed will need to evaluate which version is applicable, and may have to update to the newer version if considerable time has gone by. This may require some redesign.

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, base the facility system voltage 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. The facility user will normally provide this equipment.

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CHAPTER 3 POWER DISTRIBUTION AND UTILIZATION

3-1 TRANSFORMERS.

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

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:

- Design system such that transformer 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.

- Provide adequate ventilation in transformer spaces 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 Transformer Types.

Do not use unless justified and documented in the design analysis. Refer to Appendix C for additional guidance for applications involving significant harmonic distortion.

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.

Note: Identify when 100 percent rated circuit breakers are included in the design.

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. Do not use fusible overcurrent devices except when necessary to comply with NFPA 70 requirements for selective coordination.

3-2.1 Spare Capacity.

Provide a minimum of 15% empty space and spare capacity (ampacity) for all switchgear, switchboards, and panelboards. For flush-mounted equipment, provide spare conduits extending up above the ceiling and down below raised floors when applicable. For panelboards, provide one spare conduit, minimum of ¾-inch (18 mm), for every three empty spaces.

Note: Do not use spare capacity as part of the demand calculations specified in UFC 3-501-01. The overall calculations already account for this spare capacity with the 15% allowance for future load growth specified in UFC 3-501-01 load analysis calculations for the service entrance.

3-2.2 Selection.

Select equipment as follows:

- 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.

- 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.
- Specify panelboards for service entrance equipment when the service is less than 1200A and feeder circuits can be accommodated in one panelboard.

For all circuit breakers where the continuous current trip setting for the actual overcurrent device in the circuit breaker is rated for or can be adjusted is 1,200 amperes or higher, select the method used to reduce the clearing time for arc energy reduction:

- Zone-selective interlocking, or
- Differential relaying, or
- Energy-reducing maintenance switching with local status indicator, or
- Energy-reducing active arc flash mitigation system or
- An approved equivalent means.

3-2.3 Switchgear.

Design switchgear per IEEE C37.20.1 and UL 1558. Provide electrically operated circuit breakers. The switchgear and circuit breakers must be the product of the same manufacturer.

Evaluate the following options as part of the switchgear design:

- Arc-resistant switchgear tested and certified to IEEE C37.20.7 to provide added protection for internal arcing faults.
- Infrared viewing windows to allow the use of an infrared camera or thermal imager direct line of site to inspect electrical connections without requiring the opening of panels and doors.
- A remote racking mechanism to allow an operator to rack a circuit breaker in or out at least 20 feet from the front of the equipment.
- Drawout compartment shutters to protect operators from accidental contact with breaker stabs when a circuit breaker is withdrawn from its cubicle.

3-2.4 Switchboards.

Design switchboards per NEMA PB2 and UL 891. 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 for electrical safety.

3-2.5 Panelboards.

3-2.5.1 Configuration.

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 unless where specifically indicated otherwise for load center type panelboards. Limit each panelboard to a maximum of 42 poles. Do not use dual section panelboards.

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.

3-2.5.2 Location and Design.

Place panelboards as close as possible to the center of the loads to be served. Provide panelboards with hinged fronts to allow safer maintenance access for electrical safety. 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 design for more than one 3-phase circuit; or 3 single-phase conductors, three neutral conductors 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.

Note: If shared neutrals are used on multi-wire branch circuits, ensure the use of multi-phase handle ties at the associated circuit breakers in accordance with NFPA 70.

3-2.5.3 BEQ/BOQ Facilities and Housing

Use panelboards for service entrance equipment and electrical distribution in BEQ/BOQ facilities. Load center style panelboards, 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).

3-2.5.4 Arc-Fault Circuit Interrupters

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.

3-2.6 Motor Control Centers (MCCs).

Comply with UL 845 and NEMA ICS 2.

3-2.7 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.

3-2.8 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.

3-2.9 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.

3-2.10 Signage

Place a safety sign on any cubicles containing more than one voltage source. Refer to ANSI Z535.4 for safety sign criteria.

3-2.11 Interrupting Ratings

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.

3-3 MOTORS AND MOTOR CONTROL CIRCUITS.

3-3.1 Basic Motor Criteria.

3-3.1.1 Efficiency

Apply premium efficiency ratings per the Energy Policy Act of 2005 (EPACT 2005) to all motors.

3-3.1.2 Application

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 larger than 0.5 horsepower (373 watts) at phase-to-phase voltage rather than phase-to-neutral voltage. Motors 0.5 horsepower (373 watts) and smaller 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.

3-3.2.1 Motor Controllers

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.

3-3.2.2 Motor Starting

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.

3-3.2.3 Manual Control

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.

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.

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

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

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

Wire SPDs at grounded service entrances in a line-to-ground (L–G) or line-to-neutral (L–N) configuration. For services without a neutral, connect the SPD elements line-to-ground (L–G).

e. MCOV for L-N and L-G modes of operation: 120% of nominal voltage for 240 volts and below; 115% 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

Wire SPDs at grounded service entrances in a line-to-ground (L–G) or line-to-neutral (L–N) configuration. For services without a neutral, connect SPD elements line-to-ground (L–G).

e. MCOV for L-N, L-G, and N-G modes of operation: 120% of nominal voltage for 240 volts and below; 115% 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.

3-4.2.1 Systems Requiring Protection

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.

3-4.2.2 Protection Levels

Provide surge protection equipment used for communications and related systems as follows:

- If surge protection is required as part of a lightning protection system, comply with the more stringent voltage protection ratings specified in NFPA 780.

- If surge protection is not required as part of a lightning protection system, provide the following protection UL Listed and tested to UL 497A, or third party verified and tested to UL 497A:
    - Telephone communication interface circuit protection – provide a minimum surge current rating of 9,000A.
    - Central office telephone line protection – provide multi-stage protection with a minimum surge current rating of 4,000A.
    - Intercom circuit protection – provide 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, UL Listed or third-party verified and tested to UL 497B, with a minimum of 9,000A surge current rating.
- 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.
- 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 advanced 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, system components, and meter locations 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.

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. Identify locations where split receptacles will be used with one receptacle controlled by a separate toggle switch. Provide GFI and AFCI protection in accordance with NFPA 70.

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: Two duplex receptacles, one double duplex, or one quadraplex 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.

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.

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 Cable and Raceway Criteria.

3-6.2.1 Installation

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.

The above minimum conduit size does not apply to conduit that is part of a factory installed assembly, such as lighting fixtures.

3-6.2.2 Approved Cable and Raceway Types

Specify cables and raceway in accordance with NFPA 70 as follows:

- The Uses Permitted are as modified by Table 2-1.
- The Uses Not Permitted are:
    - As specified in NFPA 70.
    - When restricted by other UFCs for specific types of buildings such as medical facilities.

For instances where NFPA 70 does not allow an installation based on “subject to physical damage” or “subject to severe physical damage”, select an alternate design approach. Locations that are subject to physical damage or severe physical damage include:

- Exposed interior raceways installed less than 6 ft above finished floor elevation where personnel are operating mechanized equipment on a recurring basis. Mechanized equipment that might be operated on a recurring basis include vehicles, carts, forklifts, and pallet-handling units.

- Exposed exterior raceways installed less than 8 ft above finished grade or 8 ft above floor elevation for raceways on elevated platforms, loading docks, or stairwells.

Table 2-1 Authorized Cable and Raceway Types

NFPA 70 Article	Raceway/Cable Type	Authorization
320	AC – Armored Cable	Prohibited for feeder circuits. Prohibited for embedded locations. Allowed for branch circuits only in the following dry locations: • New construction and renovations in exposed locations. • Concealed in renovations in existing areas where walls and ceilings are not disturbed. • Cable trays.
322	FC – Flat Cable Assemblies	Authorized.
324	FCC – Flat Conductor Cable	Authorized.
326	IGS – Integrated Gas Spacer Cable	Prohibited.
328	MV – Medium Voltage Cable	Authorized. For interior applications, MV cable must be installed in raceway or a fully enclosed cable tray. Refer to UFC 3-550-01 for additional applications.

NFPA 70 Article	Raceway/Cable Type	Authorization
330	MC – Metal-Clad Cable	Prohibited for feeder circuits other than feeder circuits for aerial messengers between buildings. Prohibited for embedded or direct buried locations. Prohibited for concealed locations, except as allowed below. Allowed for branch circuits only in the following dry locations: • New construction and renovations in exposed locations. • Concealed in renovations in existing areas where walls and ceilings are not disturbed. • Cable trays.
332	MI – Mineral-Insulated, Metal-Sheathed Cable	Authorized.
334	NM, NMC, NMS – Nonmetallic-Sheathed Cable	Allowed only in one- and two-family dwellings and their attached or detached garages, and their storage buildings.
336	TC – Power and Control Tray Cable	Authorized.
338	SE, USE – Service-Entrance Cable	Authorized.
340	UF – Underground Feeder and Branch-Circuit Cable	Prohibited.
342	IMC – Intermediate Metal Conduit	Authorized.
344	RMC – Rigid Metal Conduit	Authorized. Only threaded-type fittings are allowed for wet and damp locations.
348	FMC – Flexible Metal Conduit	Flexible metal conduit can be used, limited to 6 ft 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.

NFPA 70 Article	Raceway/Cable Type	Authorization
350	LFMC – Liquidtight Flexible Metal Conduit	Use LFMC where authorized for FMC in damp and wet locations and for pumps.
352	PVC – Rigid Polyvinyl Chloride Conduit	Authorized. Minimum allowed size is PVC Schedule 40. For exterior use, comply with UFC 3-550-01.
353	HDPE – High Density Polyethylene Conduit	For exterior use only. Comply with UFC 3-550-01.
354	NUCC – Nonmetallic Underground Conduit with Conductors	Authorized only for exterior branch circuits and for feeder circuits between buildings.
355	RTRC – Reinforced Thermosetting Resin Conduit	Authorized.
356	LFNC – Liquidtight Flexible Nonmetallic Conduit	Prohibited.
358	EMT – Electrical Metallic Tubing	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.
360	FMT – Flexible Metallic Tubing	Prohibited.
362	ENT – Electrical Nonmetallic Tubing	Prohibited.
366	Auxiliary Gutters	Authorized and must be listed for the application.
368	Busways	Authorized. For low voltage busway, provide UL 857 listed busway. For medium voltage busway, comply with IEEE C37.23.
370	Cablebus	Authorized.

NFPA 70 Article	Raceway/Cable Type	Authorization
372	Cellular Concrete Floor Raceways	Authorized. Requires a unique Unified Facilities Guide Specification to be developed as part of any design.
374	Cellular Metal Floor Raceways	Authorized. Requires a unique Unified Facilities Guide Specification to be developed as part of any design.
376	Metal Wireways	Authorized and must be listed for the application.
378	Nonmetallic Wireways	Authorized. *Note: The UFC definition of "subject to physical damage" prohibits the use of nonmetallic wireways for exterior applications installed less than 8 ft above finished grade or 8 ft above floor elevation for raceways on elevated platforms, loading docks, or stairwells.*
380	Multioutlet Assembly	Authorized 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. Authorized for Sensitive Compartmented Information Facilities (SCIF) to limit the number of electrical penetrations through the SCIF boundary.
382	Nonmetallic Extensions	Prohibited.
384	Strut-Type Channel Raceway	Authorized.
386	Surface Metal Raceways	Authorized for use 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. Authorized for Sensitive Compartmented Information Facilities (SCIF) to limit the number of electrical penetrations through the SCIF boundary.

NFPA 70 Article	Raceway/Cable Type	Authorization
388	Surface Nonmetallic Raceways	Prohibited.
390	Underfloor Raceways	Authorized for listed underfloor raceways.
392	Cable Trays	Authorized.
393	Low-Voltage Suspended Ceiling Power Distribution Systems	Authorized.
394	Concealed Knob-and-Tube Wiring	Prohibited.
396	Messenger-Supported Wiring	Authorized only for exterior applications.
398	Open Wiring on Insulators	Prohibited.
399	Outdoor Overhead Conductors over 1000 Volts	Authorized.

3-6.2.3 Enclosures and Hazardous Locations

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. Provide branch circuit breakers rated for 20 amperes minimum, except where lesser ratings are required for specific applications, such as fractional horsepower motor circuits.

3-7 LIGHTING.

Design lighting, including ASHRAE 90.1 criteria, in accordance with UFC 3-530-01.

3-8 EMERGENCY GENERATORS.

Comply with UFC 3-540-01, *Engine Generators for Backup Power Applications*.

Coordinate with the Activity to establish marking requirements for receptacles and panelboards served by backup power systems.

3-9 AUTOMATIC TRANSFER EQUIPMENT.

Comply with UFC 3-540-01. Refer to NFPA 99 for any transfer switch applications involving medical facilities.

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.

3-10.1.1 Vented Lead Acid Batteries

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.

3-10.1.2 Valve-Regulated Lead Acid Batteries

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.

3-10.1.2.1 Allowed Applications

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.

3-10.1.2.2 Prohibited Applications

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.

3-10.1.3 Nickel-Cadmium Batteries

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.

3-10.1.4 Lithium Batteries

Do not use lithium-ion, lithium metal polymer, or other lithium-based batteries for stationary applications.

3-10.1.5 Battery Life for Life-Cycle Cost Analyses

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.

Note: the above industry standards apply to lead acid and nickel cadmium batteries. There are no industry standards available yet for the selection, specification, sizing, design, installation, maintenance, and testing of lithium-ion, lithium metal polymer, or other lithium-based batteries for stationary applications.

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.

3-10.3.4 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.

3-10.3.5 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.

3-11.1.1 Design

For ground rod composition, minimum spacing requirements and connections, conform to requirements of NFPA 70 Article 250 except that minimum ground rod dimensions are 10 feet (3.0 m) in length and ¾ inch (19 mm) diameter. Provide copper-clad steel, solid copper, or stainless steel ground rods.

3-11.1.2 Connections

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.

3-11.1.3 Spacing and Location

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. If another UFC requires the installation of one or more ground rods inside a facility, follow the requirements specified in that UFC.

3-11.2 Ground Rings.

Coordinate requirements for the ground ring of a lightning protection system with UFC 3-575-01. Provide a ground ring (counterpoise) for facilities with sensitive electronic equipment or other applications when identified by project requirements.

Provide a ground ring with 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 MIL-HDBK 419A when identified by project requirements.

3-11.4 Static Electricity Protection.

Comply with UFC 3-575-01 for static protection requirements.

3-11.5 Aircraft Hangars.

Refer to UFC 3-575-01 for grounding criteria for power systems and static electricity protection for aircraft hangars.

3-12 LIGHTNING PROTECTION SYSTEMS.

Provide lightning protection systems in accordance with UFC 3-575-01.

3-13 400-HERTZ DISTRIBUTION SYSTEMS.

Design 400 hertz power systems in accordance with UFC 4-121-10N.

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 william.phelps@navy.mil.
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.

3-15 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.

3-16 SYSTEMS FURNITURE.

3-16.1 Planning

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.

3-16.2 Design

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.

3-17 ASHRAE COMPLIANCE.

Provide automatic receptacle control in accordance with ASHRAE 90.1-2013.

The detailed electrical energy monitoring requirements of ASHRAE 90.1-2013 are permissible on projects when authorized in writing by the activity in order to coordinate with their existing industrial controls program.

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APPENDIX A REFERENCES

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

www.ansi.org

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*.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

http://www.ashrae.org/

ANSI/ASHRAE/IESNA Standard 90.1-2010 (ASHRAE 90.1), Energy Standard for Buildings Except Low Rise Residential Buildings, 2010

DEPARTMENT OF THE AIR FORCE

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

AFI 32-1063, *Electric Power Systems*.

AFPAM 32-1186, *Valve-Regulated Lead-Acid Batteries for Stationary Applications*.

DEPARTMENT OF THE NAVY

NAVSEA OP-5, *Ammunition and Explosives Safety Ashore*.

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION

www.netaworld.org

ANSI/NETA ATS, *Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*.

IEEE

www.ieee.org

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*.

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 MANUFACTURER'S ASSOCIATION

www.nema.org

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 PB 2, *Deadfront Distribution Switchboards*.

NEMA ST 20, *Dry Type Transformers for General Applications*.

NATIONAL FIRE PROTECTION ASSOCIATION

www.nfpa.org

NFPA 70, *National Electrical Code* (NEC). Note: *Apply the latest edition of the NEC for new design projects awarded after January 1 of the year following the issuance of a revised edition unless specifically identified otherwise in contract documents*.

NFPA 70E, *Electrical Safety in the Workplace*.

NFPA 75, *Standard for the Protection of Information Technology Equipment*.

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

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 497A, *Standard for Secondary Protectors for Communication Circuits*.

UL 497B, *Standard for Protectors for Data Communication and Fire Alarm Circuits*.

UL 845, *Motor Control Centers*.

UL 891, *Switchboards*.

UL 1008, *Standard for Transfer Switch Equipment*.

UL 1283, *Standard for Electromagnetic Interference Filters*.

UL 1449, *Standard for Surge Protective Devices*.

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-202-01, *Host Nation Facilities in Support of Military Operations.*

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, *Interior and Exterior Lighting Systems and Controls*.

UFC 3-540-01, *Engine Generators for Backup Power Applications* .

UFC 3-550-01, *Exterior Electrical Power Distribution*.

UFC 3-560-01, *Electrical Safety, O & M*.

UFC 3-575-01, *Lightning and Static Electricity Protection Systems*.

UFC 4-121-10N, *Design, Aircraft Fixed Point Utility System*.

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.

B-1.1 ASD Sizing

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.

B-1.2 Motor Considerations

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.

B-1.3 Power Quality

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.

B-1.4 Capacitor Switching Effects

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.

B-1.5 Bypass Capability

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.

C-2.1 Calculation

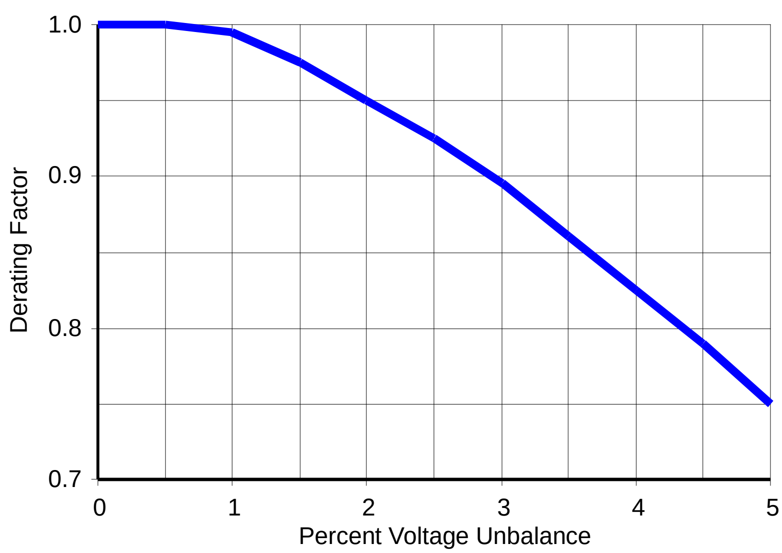
Calculate voltage unbalance as follows:

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

C-2.2 Effect on Motors

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 DERATING TRANSFORMERS FOR HARMONIC CURRENT EFFECTS.

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 (harmonic mitigating 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 harmonic mitigating transformer if a standard transformer has to be derated by more than 10%.

  Note: 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 harmonic mitigating transformers.
- 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.

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APPENDIX D GLOSSARY

D-1 ACRONYMS

A	Amperes
AC	Alternating Current
AC	Armored Cable
AFCEC	Air Force Civil Engineer Center
AFCI	Arc Fault Current Interrupter
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
COPS	Critical Operations Power System
dc	Direct Current
DCOA	Designated Critical Operations Area
EGSA	Electrical Generating Systems Association
EMT	Electrical Metallic Tubing
ENT	Electrical Non-Metallic Tubing
FC	Flat Cable Assemblies

FCC	Flat Conductor Cable
FMC	Flexible Metal Conduit
FMT	Flexible Metallic Tubing
ft	Feet
GFI	Ground Fault Circuit Interrupter
GRS	Galvanized Rigid Steel
HDPE	High Density Polyethylene Conduit
HID	High Intensity Discharge
Hz	Hertz
IEEE	formerly Institute of Electrical and Electronics Engineers
IMC	Intermediate Metal Conduit
kA	Kilo-Amperes
kVA	Kilo-Volt-Amperes
kW	Kilowatt
LFMC	Liquidtight Flexible Metal Conduit
LFNC	Liquidtight Flexible Nonmetallic Conduit
m	Meter
MCC	Motor Control Center
MCOV	Maximum Continuous Overvoltage Rating
mm	Millimeter
MC	Metal-Clad Cable
MI	Mineral-Insulated, Metal-Sheathed Cable
MV	Medium Voltage Cable
NAVFAC	Naval Facilities Engineering Command
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association

NETA	International Electrical Testing Association
NFPA	National Fire Protection Association
NM, NMC, NMS	Nonmetallic-Sheathed Cable
NUCC	Nonmetallic Underground Conduit with Conductors
OSHA	Occupational Safety and Health Administration
PVC	Rigid Polyvinyl Chloride Conduit
RMC	Rigid Metal Conduit
RMS	Root-Mean-Square
RTRC	Reinforced Thermosetting Resin Conduit
SCIF	Sensitive Compartmented Information Facilities
SE, USE	Service-Entrance Cable
SPD	Surge Protective Devices
SWD	Switching Duty
TC	Power and Control Tray Cable
TSEWG	Tri-Service Electrical Working Group
TVSS	Transient Voltage Surge Suppressor
UF	Underground Feeder and Branch-Circuit Cable
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

D-2 DEFINITION OF 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.

Subject to Physical Damage (or Subject to Severe Physical Damage): Locations that are subject to physical damage or severe physical damage include:

- Exposed interior raceways installed less than 6 ft above finished floor elevation where personnel are operating mechanized equipment on a recurring basis. Mechanized equipment that might be operated on a recurring basis includes vehicles, carts, forklifts, and pallet-handling units.

- Exposed exterior raceways installed less than 8 ft above finished grade or 8 ft above floor elevation for raceways on elevated platforms, loading docks, or stairwells.

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.