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D5000 GENERAL ELECTRICAL REQUIREMENTS

This mandatory functional series document is available online at http://engstandards.lanl.gov.

It derives from P342, Engineering Standards, which is issued under the authority of the Associate Director of Nuclear and High Hazard Operations (ADNHHO) as part of the Conduct of Engineering program implementation at the Laboratory.

Please contact the ESM Electrical POC for interpretation, variance, and upkeep issues.

RECORD OF REVISIONS

Rev	Date	Description	POC	OIC
0	11/18/02	General revision and addition of endnotes; added nuclear requirements. Replaces Subsections 201-202, 218, 219, 295.	David W. Powell, *FWO-SEM*	Kurt Beckman, *FWO-SEM*
1	6/9/04	Added programmatic requirements, new NECA and NETA installation and testing standards, requirement for electrical demolition drawings; clarified requirements for nuclear and hazardous facilities.	David W. Powell, *FWO-DECS*	Gurinder Grewal, *FWO-DO*
2	10/27/06	Administrative changes only. Organization and contract reference updates from LANS transition; 420.1A became 420.1B; NEC edition update; deleted NM Elec Code based on 9/18/06 variance IMP and ISD number changes based on new Conduct of Engineering IMP 341. Master Spec number/title updates. Other administrative changes.	David Powell, *FM&E-DES*	Kirk Christensen, *CENG*
3	06/06/08	References to codes and standards updated. Updated LANS contract references to state laws and regulations. Added reference to Section Z10 for design output requirements. Added references to ESM Chapters 14 and 16. Requirements for coordination studies for special electrical systems expanded. Added requirement for documented analysis to support decisions to modify (vs. replace) existing major electrical equipment. Added UPS and engine-generator load summaries on one-line diagram sheets. Provisions for future expansion of electrical systems clarified. Aligned arc-flash warning label requirements with LANL ISD 101-13 and NFPA 70E. Requirements for marking working spaces modified. Added graded approach to determine the extent of formal electrical acceptance testing.	David Powell, *ES-DE*	Kirk Christensen, *CENG*
4	12/15/09	Updated codes and standards and names of LANL organizations, deleted calc requirements addressed in Z10, clarified and updated electrical drawings requirements, added requirement to address solar heat gain, added requirement for electrical rooms to be lockable and have a sign on the door prohibiting storage, added requirement that on renovation projects arc-flash warning labels be installed on existing equipment where lock-out/tag-out is required for the renovation work, revised supports and anchors article to align with seismic requirements of the IBC and ASCE-7, in demolition article added reference to LMS Section 02 4115 - Electrical Demolition	David Powell, *ES-DE*	Larry Goen, *CENG-OFF*
5	8/23/10	Added requirements for electrical load analysis to address non-coincident loads, contingency	David Powell, *ES-DE*	Larry Goen, *CENG-OFF*

		conditions, and parallel paths; clarified cases where coordination studies are required; revised arc flash hazard calculations and warning label requirements to align with LANL P101-13; changed criteria for designed anchors for individual conduit from “2-1/2 inches” to “weighs more than 5 lb/ft”; modified demolition paragraphs to leave conductors if their removal might damage conductors remaining in service; updated requirements for emergency communications system to align with NFPA 72-2010.		
6	11/8/11	For NFPA 70E & arc flash: defined extent of calculations; required use of approved software for analysis and documentation of power systems; aligned analysis and labeling requirements with LANL P101-13.1 and Section 26 0553; added requirement for labeling equipment with maximum available fault current; changed voltage indication on equipment nameplates to IEEE system voltage notation.	David Powell, *ES-DE*	Larry Goen, *CENG-OFF*
7	9/29/14	NEC adoption follows state (2.2). Added Subsection 5.10, Overcurrent Protection to clarify the used of circuit breaker versus fuses. Revised Subsection 12 to incorporate DOE O 420.1C. Other minor technical and admin updates.	Duane Nizio *ES-EPD*	Mel Burnett, *ES-DO*

D5000 GENERAL ELECTRICAL REQUIREMENTS

1.0 APPLICATION OF THIS CHAPTER

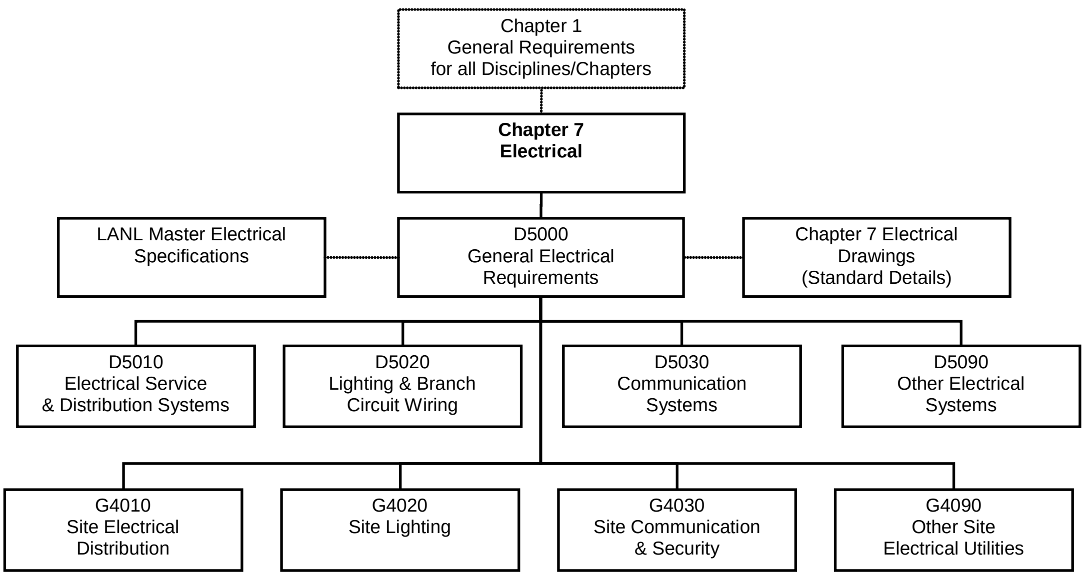
1.1 General Requirements

A. The *National Electrical Code*® (and similarly other codes and standards) contains provisions considered necessary to safety. Compliance with the applicable codes and proper maintenance of systems will result in installations that are essentially free from hazard, but NOT necessarily efficient, convenient, or adequate for good service or future expansion of electrical use.[1] The purpose of this chapter of the LANL Engineering Standards Manual (ESM) is to provide electrical systems that are free from hazard AND are efficient, convenient, and adequate for good service, maintainable, standardized, and adequate for future expansion of electrical use.

B. Electrical design, material, equipment, and installations shall comply with site-specific requirements in this Chapter and Chapter 1 of the ESM. Where appropriate, guidance is provided to aid the cost-effective implementation of site-specific requirements and the requirements in the applicable codes. Code requirements are minimum requirements that are augmented by the site-specific requirements in this chapter.

C. Figure D5000-1 illustrates the relationship of ESM Chapter 7 to Chapter 1 as well as the organization of the parts of Chapter 7.

Figure D5000-1, ESM Chapter 7 Organization



D. Within this chapter, other than for titles of documents, *italicized* text indicates provisions considered desirable but not mandatory. Recommendations are based on good business and engineering practice and lessons-learned at LANL. All other text in regular type indicates **mandatory** requirements unless noted otherwise.

[1] National Electrical Code® Article 90.1 describes the purpose of the code.

E. In addition to new electrical installations, this Chapter applies to all renovation, replacement, modification, maintenance, or rehabilitation projects for which the LANL Electrical Authority Having Jurisdiction[2] (AHJ) requires a design.[3] The LANL Electrical AHJ requires a design for all projects that include any of the following elements:

1. new or modified branch circuit exceeding 100 amps,
2. branch circuit of any size when the grounding system integrity or existing or proposed panelboard loads is unknown,
3. new or modified feeder circuit, including installation of transformer, or
4. new or modified service.

F. For repairs, alterations, or additions to existing systems, follow the LANL Existing Building/System Code (IEBC) described in Section IBC-GEN of ESM Chapter 16-IBC Program.

1.2 Definitions

A. Definitions of terms in Chapter 7 are the same as those in the *National Electrical Code*®.[4]

B. Refer to ESM Chapter 1 Section Z10 for definitions of terms and acronyms used throughout the ESM.

C. The following are definitions of terms and acronyms peculiar to ESM Chapter 7:

1. Low voltage: a class of nominal system voltages less than 1000 V.[5]
2. Medium voltage – a class of nominal system voltages equal to or greater than 1,000 V but less than 100,000 V.[5]
3. High voltage: a class of nominal system voltages from 100,000 V to 230,000 V.[5]

D. This chapter shall be applied to R&D and programmatic systems and components as follows:

1. Headings in this chapter followed by "R&D, Programmatic, and Facility" or similar wording indicate that all of LANL, including R&D and programs, must comply. Comply with all other sections applicable.[6]
2. *Guidance: R&D/programmatic personnel should review all topics in the chapter for relevant material when initiating any design task.*
3. *Guidance: All R&D/programmatic electrical installations should be constructed with materials and components meeting either national standards (e.g., NEMA, ANSI, etc) or be Nationally Recognized Testing Laboratory (NRTL) listed equipment and material that is used in accordance with its listing for the intended purpose. In the case of departure from equipment listing parameters or when equipment is not available as NRTL listed, then the situation should be reviewed for the purpose by the*

[2] LANL P101-13, "Electrical Safety Program," establishes the LANL Electrical Safety Committee as the site-wide electrical authority having jurisdiction (AHJ). The Electrical Safety Committee delegates the day-to-day AHJ duties to the LANL Chief Electrical Safety Officer.

[3] E-mail from Terry Fogle (LANL Chief Electrical Safety Officer) dated 13 October 1999 established criteria for when the LANL electrical AHJ requires an electrical design for LANL projects. (EMref 26) *(Note: EMref refers to an ESM team system for managing hard-to-find reference materials.)*

[4] Refer to *NEC*® Article 100.

[5] Refer to IEEE Std 141, Chapter 3.

[6] Except where otherwise stated by P370 series documents

LANL Electrical AHJ and the using organization's Electrical Safety Officer. Exception: Equipment set-up and used for less than 180 days or that is intentionally destroyed during the experiment, and is constructed and operated by qualified technicians using approved procedures described in formal procedures or Hazard Control Plans.

2.0 CODES AND STANDARDS

2.1 General Requirements

A. Design, material, equipment, and installation shall comply with the applicable portions of the latest edition of each code and standard listed below or referenced elsewhere in this Chapter.

B. Refer to Chapter 1 Section Z10 for description of "Code of Record" concept.

C. In many instances, recommendations or "best practices" in DOE orders, building codes, electrical codes, and industry standards have been adopted as requirements in this Chapter.

D. If there is a conflict between codes, standards, and LANL requirements in this chapter, contact the ESM Discipline POC for assistance in resolving the conflict. If a requirement in the ESM exceeds a minimum code or standard requirement, it is not considered a conflict, but a difference; see also Chapter 1 Section Z10.

E. Where the *NEC*® uses terms similar to "by special permission," obtain written permission from the LANL Electrical AHJ[7].

2.2 LANS Contract (R&D, Programmatic, and Facility)

A. Comply with the State of New Mexico Electrical Code that typically adopts the NEC with local amendments effective on or about July 1 of the edition year; see the New Mexico Administrative Code (NMAC) 14.10.4. [8]

B. Required DOE Orders are contained in Appendix G of the LANS Contract. http://www.doeal.gov/laso/NewContract.aspx

C. Comply with the edition and addenda in effect on the effective date noted in Appendix G, unless otherwise specified. Exception: Comply with the latest edition of applicable CFRs.

D. Title 10 CFR 851, *Worker Safety and Health Program*, requires compliance with certain safety and health standards including NFPA 70 *National Electrical Code* and *NFPA* 70E *Standard for Electrical Safety in the Workplace*.

2.3 LANL Documents

A. LANL Engineering Standards Manual (ESM) (STD-342-100)

1. The ESM, arranged by discipline-specific chapters, provides site-specific engineering requirements and guidance for LANL facilities and systems.

2. Chapters are divided into sections for convenient revision control of the information. Section numbering follows the UNIFORMAT II 1998 system described in

[7] LANL P101-13, "Electrical Safety Program," paragraph 2.2.2 indicates that the Chief Electrical Safety Officer will issue clarifications and interpretations and approve alternate methods to the *NEC*®, NESC, and the LANL Electrical Safety Program.
[8] LANS Contract in Section I, page 45, clause I-123 (a) requires that work at LANL be performed in compliance with applicable State laws and regulations.

ASTM E 1557 (e.g., D5010 Electrical Service and Distribution); *UF2010 adoption is pending*.

3. Standard Detail Drawings (numbered ST-XXXXX-X) referenced in the ESM in regular type are to be considered templates that shall be used in the design drawings for specific projects. The templates shall be edited only to reflect the particular details of the project. If the engineer/designer wishes to take a variance for a portion of an applicable detail, then the ESM POC for that detail shall be contacted for concurrence.

4. Example Drawings (D50XX-X) depict required content and format with potentially mock data and so, unlike Standards Details, are not necessarily valid design templates.

   The above drawings are in the STD-342-400 collection.

B. LANL Master Specification Manual (STD-342-200)

   The LANL Master Specifications Manual provides templates for the preparation of project specific construction specifications at LANL. These LANL Master Specification (LMS) sections are incorporated by reference throughout the ESM Chapter 7 to describe material, equipment, and installation requirements.

C. LANL Drafting (CAD) Manual (STD-342-300)

   The LANL Drafting Manual provides drafting requirements for use when creating or revising construction drawings for LANL construction projects.

D. The above manuals are not intended to cover all requirements necessary to provide a complete operating facility or system. The engineer/designer is responsible for providing a complete design package (drawings and specifications) as required to meet project specific requirements. *Questions concerning the contents in these manuals should be addressed to the applicable LANL discipline POC.*

E. The LANL manuals are available at http://engstandards.lanl.gov/

NOTE: For LANL personnel, most of the following national standards are available at http://www.lanl.gov/library/find/standards/index.php

2.4 ANSI (American National Standards Institute)

A. ANSI Z535.1, *Safety Colors*

B. ANSI Z535.2, *Environmental and Facility Safety Signs*

C. ANSI Z535.3, *Criteria for Safety Symbols*

D. ANSI Z535.4, *Product Safety Signs and Labels*

2.5 ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers)

ASHRAE/IESNA Standard 90.1, *Energy Standards for Buildings Except for Low Rise Residential Buildings*.

2.6 DOE (Department of Energy) (Selected Orders) (Programmatic and Facility)

A. DOE O 420.1C, *Facility Safety*

B. DOE G 420.1-1A, *Nonreactor Nuclear Safety Design Guide for use with DOE O 420.1C, Facility Safety*

C. DOE-STD-1212, *Explosives Safety*

D. Additional DOE Orders and Guides referenced in the LANS Prime Contract.

Note: DOE directives available at http://www.directives.doe.gov/

2.7 ICC (International Code Council)

A. *International Building Code*® (IBC). See LANL amendments in ESM Chapter 16.

B. *International Existing Building Code*® (IEBC). See LANL amendments in ESM Chapter 16.

Note: Refer to ESM Chapters 1, 2, and 16 for life safety requirements.

2.8 IEEE® (Institute of Electrical and Electronics Engineers)

A. IEEE C2™, *National Electrical Safety Code* (NESC)

B. IEEE Std 141™, Recommended Practice for Electric Power Distribution for Industrial Plants (Red Book)

C. IEEE Std 142™, *Recommended Practice for Grounding of Industrial and Commercial Power Systems* (Green Book)

D. IEEE Std 241™, *Recommended Practice for Electric Power Systems in Commercial Buildings* (Gray Book)

E. IEEE Std 242™, *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems* (Buff Book)

F. IEEE Std 315™, *Graphic Symbols for Electrical and Electronics Diagrams*

G. IEEE Std 399™, *Recommended Practice for Power Systems Analysis* (Brown Book)

H. IEEE Std 446™, *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications* (Orange Book)

I. IEEE Std 493™, *Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems* (Gold Book)

J. IEEE Std 519™, *Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*

K. IEEE Std 739™, *Recommended Practice for Energy Management in Industrial and Commercial Facilities* (Bronze Book)

L. IEEE Std 902™, *Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems* (Yellow Book)

M. IEEE Std 1015™, *Recommended Practice Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems* (Blue Book)

N. IEEE Std 1100™, *Recommended Practice for Powering and Grounding Electronic Equipment* (Emerald Book)

O. IEEE Std 1584™, *IEEE Guide for Performing Arc-Flash Hazard Calculations* including Amendments 1584a-2004 and 1584b-2011.

2.9 IESNA (Illuminating Engineering Society of North America)

A. IESNA *Lighting Handbook*

B. IESNA RP-1, *American National Standard Practice for Office Lighting*.

C. IESNA RP-7, *American National Standard Practice for Lighting Industrial Facilities*.

2.10 NECA (National Electrical Contractors Association)[9]

A. NECA 1, *Good Workmanship in Electrical Construction* (ANSI)

B. NECA 90, *Recommended Practice for Commissioning Building Electrical Systems* (ANSI)

C. NECA 100, *Symbols for Electrical Construction Drawings* (ANSI)

D. NECA 101, *Standard for Installing Steel Conduits (Rigid, IMC, EMT)* (ANSI)

E. NECA 104, *Recommended Practice for Installing Aluminum Building Wire and Cable* (ANSI)

F. NECA/NEMA 105, *Recommended Practice for Installing Metal Cable Tray Systems* (ANSI)

G. NECA 111, *Standard for Installing Nonmetallic Raceways (RNC, ENT, LFNC)* (ANSI)

H. NECA/NACNA 120, *Standard for Installing Armored Cable (Type AC) and Metal-Clad Cable (Type MC)* (ANSI)

I. NECA 202, *Recommended Practice for Installing and Maintaining Industrial Heat Tracing Systems* (ANSI)

J. NECA 230, *Standard for Selecting, Installing and Maintaining Electric Motors and Motor Controllers* (ANSI)

K. NECA/FOA 301, *Standard for Installing and Testing Fiber Optic Cables*

L. NECA 331, *Standard for Building and Service Entrance Grounding and Bonding*

M. NECA 400, *Standard for Installing and Maintaining Switchboards* (ANSI)

N. NECA 402, *Standard for Installing and Maintaining Motor Control Centers* (ANSI)

O. NECA/EGSA 404, *Standard for Installing Generator Sets* (ANSI)

P. NECA 407, *Recommended Practice for Installing and Maintaining Panelboards* (ANSI)

Q. NECA 408, *Recommended Practice for Installing and Maintaining Busways* (ANSI)

R. NECA 409, *Recommended Practice for Installing and Maintaining Dry-Type Transformers* (ANSI)

S. NECA 410, *Recommended Practice for Installing and Maintaining Liquid-Filled Transformers* (ANSI)

T. NECA 411, *Recommended Practice for Installing and Maintaining Uninterruptible Power Supplies (UPS)* (ANSI)

U. NECA 420, *Standard for Fuse Applications* (ANSI)

V. NECA 430, *Standard for Installing Medium-Voltage Metal-Clad Switchgear* (ANSI)

[9] The NECA *National Electrical Installation Standards* define a minimum baseline of quality and workmanship for installing electrical products and systems. They referenced in specifications for electrical construction projects.

W. NECA/IESNA 500, *Recommended Practice for Installing Indoor Lighting Systems* (ANSI)

X. NECA/IESNA 501, *Recommended Practice for Installing Exterior Lighting Systems* (ANSI)

Y. NECA/IESNA 502, *Recommended Practice for Installing Industrial Lighting Systems* (ANSI)

Z. NECA/BICSI 568, *Standard for Installing Building Telecommunications Cabling* (ANSI)

AA. NECA/MACSCB 600, *Recommended Practice for Installing and Maintaining Medium-Voltage Cable* (ANSI)

BB. NECA/NEMA 605, *Installing Underground Nonmetallic Utility Duct* (ANSI)

2.11 NETA (InterNational Electrical Testing Association, Inc.)

A. NETA ATS, *Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems*

B. NETA MTS, *Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*

C. NETA ETT, *Standard for Certification of Electrical Testing Technicians* (ANSI)

2.12 NFPA (National Fire Protection Association)

A. NFPA 70™, *National Electrical Code®* (*NEC®*). For electrical design use the edition of the NEC adopted by the State of New Mexico; *see 2.2.A above.*

B. NFPA 70E, *Standard for Electrical Safety in the Workplace*

C. NFPA 101®, Life Safety Code®

Note: Refer to ESM Chapters 1, 2, and 16for life safety requirements.

D. NFPA 110, *Standard for Emergency and Standby Power Systems*

E. NFPA 111, *Standard on Stored Electrical Energy Emergency and Standby Power Systems*

F. NFPA 780, *Standard for the Installation of Lightning Protection Systems*

G. All other NFPA codes and standards except NFPA 5000

Note: Listing of current NFPA codes and standards are available here.

2.13 EIA (Electronic Industries Alliance) and/or TIA (Telecommunications Industry Association)[10]

A. EIA-568-C.1, *Commercial Building Telecommunications Cabling Standard (ANSI)*

B. EIA-568-C.2, *Balanced Twisted-Pair Telecommunications Cabling and Components Standards* (ANSI)

C. EIA-568-C.3, *Optical Fiber Cabling and Components Standard*

D. EIA-569, *Commercial Building Standard for Telecommunications Pathways and Spaces* (ANSI)

[10] The EIA and TIA telecommunications standards provide minimum requirements for wiring, pathways and spaces, grounding, and administration of telecommunications systems in commercial buildings. These standards were invoked for all federal buildings by FIPS PUB 174, 175, and 176. Refer to http://www.itl.nist.gov/fipspubs/ .

E. EIA-606, *Administration Standard for Commercial Telecommunications Infrastructure* (ANSI)

F. EIA-J-STD-607, *Commercial Building Grounding and Bonding Requirements for Telecommunications* (ANSI)

G. EIA-758-A, *Customer-Owned Outside Plant Telecommunications Infrastructure Standard* (ANSI)

3.0 COORDINATION OF DESIGN REQUIREMENTS

3.1 General

Coordinate and clarify electrical design requirements with the LANL project engineer or the ESM Chapter 7 POC. Coordinate and clarify *NEC*® requirements with the LANL Electrical Authority Having Jurisdiction (AHJ).

3.2 Site Utilities

Coordinate and clarify electrical power and telecommunications utility design requirements with the following organizations:

A. Electrical: LANL Utilities & Infrastructure

B. Telecommunications: LANL Network and Infrastructure Engineering

3.3 Special Systems

Coordinate and clarify special systems design requirements with the following organizations:

A. Life Safety: LANL Fire Protection

B. Fire Alarm: LANL Fire Protection; also, see ESM Chapter 2, Fire Protection

C. Telecommunications: LANL Network and Infrastructure Engineering; also see ESM Chapter 18, Secure Communications

D. Security Systems including Badge Reader Systems: LANL Physical Security; also see ESM Chapter 9, Security

4.0 DESIGN DOCUMENTATION

4.1 General

Refer to Section Z10 of LANL ESM Chapter 1 for design output general requirements.

4.2 Calculations

A. Perform the electrical power system calculations, analysis, and documentation described below using the following approved electrical system analysis software[11]:

- SKM Power Tools for Windows® for non-nuclear facility projects[12]

[11] With sufficient compelling justification, the LANL ESM Chapter 7 POC may approve a Variance Request to use other commercial software if the software has been benchmark tested and provides results that are consistent with results from using the IEEE® procedures. Refer to ESM Chapter 1, Section Z10 on design outputs.

[12] *SKM Power Tools for Windows®* has become the default for power system analysis on LANL non-nuclear facility projects.

- ETAP® for nuclear facility projects[13]

1. Use the approved electrical system analysis software to document the electrical power system (both new and existing electrical distribution system and equipment) and perform calculations and analysis as described below for:
   - New facilities,
   - Additions to existing facilities,
   - IEBC Change of Occupancy of existing facilities,
   - IEBC Level 3 Alterations of existing facilities,
   - IEBC Level 2 and Level 1 Alterations of existing facilities previously analyzed using the approved software. *Guidance: The FOD or Project Manager may find it cost effective for reasons outside the Project to have the entire electrical system in an existing facility documented and analyzed, even for relatively small modifications.*
2. Use the approved electrical system analysis software to perform the following calculations and analysis:
   - Voltage drop calculations[14] for all services, for all feeders, and for 100 A and greater branch circuits,
   - Fault current calculations as described below (*paragraph 4.2.C*),
   - Coordination studies as described below (*paragraph 4.2.D*),
   - Arc flash boundary and incident energy calculations as described below (*paragraph 4.2.E*),
   - Load flow analysis for systems with parallel paths as described below (paragraph 4.2.B). *If cost-effective compared to other methods, perform the load analysis using the approved electrical system analysis software.*
3. Document the electrical system and the results of the analysis described above using one or more single-line diagrams[15] generated using the approved electrical system analysis software. Format the single-line diagram(s) to provide the following information[16] as applicable:
   - **Utility source(s):** Utility circuit voltage, circuit number(s), available three-phase and single line-to-ground fault currents and associated X/R ratios
   - **Utility power transformer(s)**: Ratings (kVA, primary voltage, secondary voltage, and percent impedance), cooling methods (e.g. OA/FA)
   - **Supply characteristics:** Service point nominal system voltage (e.g. 480Y/277 V, 208Y/120V, 120/240 V), system configurations (wye or delta, grounded or ungrounded), frequency (if other than 60 Hz), short-circuit current (3-phase,

[13] ETAP® "nuclear version" meets ASME NQA-1 requirements; was used on the CMRR Nuclear Facility.
[14] Refer to LANL ESM Chapter 7 Section D5010 (para. 2.10) and Section D5020 (para 2.0) for voltage drop criteria.
[15] Some FODs will use the software one-line diagrams to meet the requirement in NFPA 70E-2012 Section 205.2 to keep single-line diagrams current and in a legible condition.
[16] The information indicated for the single-line diagram is necessary to document the electrical power system for operations, maintenance, and design of future modifications.

RMS symmetrical amperes), arc flash incident energy (cal/cm^2) and working distance (inches).

- **Major distribution equipment (e.g. unit substations, switchgear, switchboards, panelboards, motor control centers):** Equipment identification code, location (room number), ratings (system voltage, frequency if other than 60 Hz, bus rated amperes, connection type), fault current (3- phase, RMS symmetrical amperes), interrupting rating, arc flash incident energy (cal/cm^2) and working distance (inches), types of loads served, electrical and/or mechanical interlocks between devices.
- **Service and feeder switching and overcurrent protective devices:** Circuit number, number of poles (if other than three poles), switch or circuit breaker frame size in amperes, circuit breaker long-time trip amperes, circuit breaker ground-fault trip amperes, fuse rating and type, short-circuit interrupting rating. Provide the same information for any branch circuits shown on the one-line diagram.
- **Discrete protective relays:** Function, use, type, and number. Use device function numbers from IEEE C37.2™.
- **Service(s) and feeders:** Raceway size, length, and material (Magnetic or Non-magnetic); quantity, size, type (if other than copper), and insulation type for phase, grounded, and grounding conductors. Provide the same information any for branch circuits shown on the one-line diagram
- **Surge protective devices:** Indicate surge protective devices for medium-voltage equipment, and low-voltage equipment.
- **Metering:** Voltmeters, ammeters, kW/kWh meters, test blocks, electronic metering packages.
- **Potential transformers**: Number, ratio (e.g., 4:1), and overcurrent protection
- **Current transformers:** Number, class, and ratio (e.g., 2000:5).
- **Generator system(s):** Equipment identification code, location (room number), ratings (voltage, sub-transient reactance, kW/kVA at sea level and at 7500 ft), connection, fuel type, NFPA 110 class, type, and level, fault current (3- phase, RMS symmetrical amperes), arc flash incident energy (cal/cm^2) and working distance (inches).
- **Transfer switch(es):** Equipment code, location (room number), ratings (voltage, rated current, and number of poles), fault current (3- phase, RMS symmetrical amperes), short-circuit withstand rating, arc flash incident energy (cal/cm^2) and working distance (inches).
- **Dry-type transformers:** Equipment identification code, location (room number), ratings (kVA, K-factor, primary voltage, secondary voltage, and percent impedance), cooling methods (e.g. OA/FA), temperature rise, winding connections, fault current (3- phase, RMS symmetrical amperes), arc flash incident energy (cal/cm^2) and working distance (inches).
- **Uninterruptible Power Supply (UPS) Systems:** Equipment identification code, location (room number), ratings (kW/kVA at sea level and at 7500 ft, input and output voltage, frequency if other than 60 Hz, amperes, connection type), static

and manual bypass arrangements, energy storage run-time, types of loads served, fault current (3- phase, RMS symmetrical amperes), arc flash incident energy (cal/cm^2) and working distance (inches).

- **Battery systems:** Equipment identification code, location (room number), battery and charger ratings (input and output voltage, amperes, connection type), bypass arrangements, battery run-time, types of loads served, DC short-circuit current, arc flash incident energy (cal/cm^2) and working distance (inches).
- **Major loads** (branch circuit loads rated 100 amperes and greater and all loads connected to switchboards or switchgear assemblies)**:** Equipment identification code, location (room number), ratings (kW or kVA), fault current (3-phase, RMS symmetrical amperes), arc flash incident energy (cal/cm^2) and working distance (inches).
- **Motor Loads:** Equipment identification code, location (room number), voltage, horsepower, or kVA rating; starting method if other than across the line; interlocks between controllers; and location of all motors connected to switchgear, switchboards, and motor control centers.
- **Critical systems:**
  - Indicate nuclear facility critical loads (e.g. safety class or safety significant).
  - Indicate emergency power systems, legally required standby power systems.

4. The single-line diagram generated using the approved electrical system analysis software does not replace the construction design “contract documents” single-line diagram described below (*paragraph 4.3.G*).
   - The single-line diagram described above must be sufficiently legible to meet the requirements of NFPA 70E Article 205 and be useable for documenting modifications made to the electrical system during the life cycle of the facility.
   - *Guidance: The single-line diagram described above is not required to meet the requirements of the LANL Drafting Standards Manual.*
   - *Guidance: To promote consistency in content and arrangement from facility to facility, the single-line diagram described above should match the arrangement of the single-line diagram described in paragraph 4.3.G below to the extent practical.*
   - *Guidance: It is possible to export basic single line diagrams from either of the approved electrical system analysis software into AutoCAD®; some editing will be necessary to meet requirements of paragraph 4.3.G and the LANL Drafting Standards Manual*.
5. Update the above calculations and single-line diagram based upon approved electrical equipment submittals, as-built construction documents, and approved electrical test and inspection reports. Submit calculations and single-line diagram in electronic format as part of the Project Closeout documentation.

B. Calculate electrical power system design loads for sizing systems and equipment in accordance with Article 220 of the *NEC*®.

1. For load densities/demand use the greater of the values in the *NEC*®, this design standard, or the actual connected loads or measured loads.

2. Use diversity factors only as specifically permitted by NEC® or other recognized national standards.

3. In the load calculation, address non-coincident loads in accordance with Section 220.60 of the *NEC*®. Document the logic used to identify and include the non-coincident loads. *Guidance: Typically, the non-coincidence of loads is based on either the nature of the loads (e.g. heating vs. cooling) or the nature of the operation (e.g. number and type of machine shop tools vs. number of operator personnel).*

4. Address all contingency conditions (e.g. operating a double-ended service from either of the sources) to assure adequacy of service and feeder components.

5. For power system networks having parallel paths, perform a load flow analysis in accordance with Chapter 6 of IEEE Std 399, using a static (positive sequence) model.

6. Include the effects of harmonics when selecting service and feeder components.

7. Include in feeders, services, and associated distribution equipment the capability for future load growth as described below (Para 5.1, "Adequacy and Future Expansion").

C. Perform fault current calculations using procedures outlined in IEEE Std 141™ and IEEE Std 242™.

1. For medium voltage systems, obtain fault duty information from the LANL electrical utility distribution engineer.

2. For low voltage systems:

   - For low-voltage equipment selections, base fault current calculations on an infinite bus medium-voltage utility source.
   - For coordination studies and arc flash hazard calculations, base fault current calculations on actual utility system fault duty information obtained from the LANL electrical utility distribution engineer.

3. Extend calculations to points in the distribution system until fault duty is less than 14,000 amps RMS symmetrical on 480Y/277V systems and less than 10,000 amps RMS symmetrical on 208Y/120V or 240/120V systems. Continue calculations down to the branch circuit level as required for coordination studies. Coordinate with the power system studies required in LMS Section 26 0813, Electrical Acceptance Testing.

4. Include in the calculations the effects of motors and on-site sources such as engine-generator systems, battery banks, and UPS systems.

5. Address all contingency conditions (e.g. operating a double-ended service from either of the sources) to assure adequate bracing and interrupting rating of components.

D. Perform coordination studies using procedures outlined in IEEE Std 141™ and IEEE Std 242™. During design demonstrate that selective coordination can be achieved; determine preliminary settings for circuit breaker trip units. After switchgear construction submittals are approved, update the coordination study to show the actual equipment;

determine final trip unit settings. Coordinate with the power system studies required in LMS Section 26 0813, Electrical Acceptance Testing.

1. Perform coordination studies for all projects that include or modify a low voltage service or feeder with size larger than 800 amperes.
2. Perform coordination studies for all projects that include or modify any of the following special systems[17]:
   - safety class electrical power systems[18]
   - safety significant electrical power systems[18]
   - vital safety systems[18]
   - emergency power systems[19]
   - legally required standby power systems[20], or
   - critical operations power systems (COPS).[21]
3. Include in the coordination study all voltage classes of equipment from the utility's incoming line protective device down to, and including, each low voltage load protective device rated as follows:
   - 100 amperes and larger in normal power systems
   - 15 amperes and larger in any of the special systems listed above.
4. Include in the coordination study special equipment such as engine-generator systems, DC power systems 50 volts and higher, and three-phase UPS systems.
5. Address all contingency conditions (e.g. operating a double-ended service from either of the sources) to assure selective coordination.
6. Use the selective coordination time interval guidelines in Table D5000-1. Where these guidelines must be compromised, include in the study a narrative discussion of the assumptions and logic leading to the proposed compromise of selective coordination.
7. Provide tabulated circuit breaker electronic trip unit settings based on the results of the fault current study and the coordination study; include the following information for each circuit breaker electronic trip unit:
   - Circuit number
   - Load name
   - Sensor rating (amperes) "S"
   - Rating plug (amperes) "P"
   - Long time pickup setting (times P)
   - Long time delay setting (seconds)
   - Short time pickup setting, if used (times P)
   - Short time delay setting, if used (seconds)

[17] Coordination study is warranted for safety class, safety significant, vital safety system, emergency system, and standby power system branch circuits since an orderly shutdown of each of these systems is required to minimize hazards to equipment, personnel, and the environment; refer to *NEC*® Section 240.12.
[18] Refer to §3.1.2 and §5.2.3 in DOE G 420.1-1.
[19] Refer to NEC Section 700.28.
[20] Refer to NEC Section 701.27.
[21] Refer to NEC Article 708.

- Instantaneous pickup setting (times P)
- Ground fault pickup setting, if used (times P)
- Ground fault delay setting, if used (seconds)
- Trip unit manufacturer and model
- Remarks (e.g., i^2t setting, residual, zero sequence.)

TABLE D5000-1, SELECTIVE COORDINATION TIME INTERVAL GUIDELINES

		INDUCTION RELAYS	SOLID-STATE RELAYS
1.	RELAY-TO-DOWNSTREAM RELAY: CB opening time (5 cycles) Relay over-travel Safety Margin Minimum time interval (seconds)*	 0.083 0.100 0.200 0.383	 0.083 0.000 0.200 0.283
2.	RELAY-TO-DOWNSTREAM RELAY WITH INSTANTANEOUS UNIT: CB opening time (5 cycles) Relay over-travel Safety Margin Minimum time interval (seconds)*	 0.083 0.100 0.100 0.283	 0.083 0.000 0.100 0.183
3.	RELAY-TO-DOWNSTREAM LOW VOLTAGE CIRCUIT BREAKER: Relay over-travel Safety Margin Minimum time interval (seconds)*	 0.100 0.100 0.200	 0.000 0.100 0.100
4.	RELAY-TO-DOWNSTREAM MEDIUM VOLTAGE FUSE: Relay over-travel Safety Margin Minimum time interval (seconds*) (To total clearing time curve)	 0.100 0.100 0.200	 0.000 0.100 0.100
5.	RELAY-TO-DOWNSTREAM LOW VOLTAGE FUSE Relay over-travel Safety Margin Minimum time interval (seconds)* (To total clearing time curve)	 0.100 0.100 0.200	 0.000 0.100 0.100
6.	MEDIUM VOLTAGE FUSE-TO-DOWNSTREAM PROTECTIVE DEVICE: For times greater than 0.01 second, the total clearing time of the downstream protective device should be below and to the left of the adjusted minimum-melting curve of the upstream fuse. The minimum melting curve of the upstream fuse should be adjusted to 75% (current basis) to compensate for pre-fault loading. AND For times less than 0.01 second, the total clearing energy of the downstream fuse should be less than the minimum melting energy of the upstream fuse.		
7.	LOW VOLTAGE CIRCUIT BREAKER-TO-DOWNSTREAM CIRCUIT BREAKER: Time-current characteristic bands should not cross or overlap. OR The maximum available fault current at the downstream circuit breaker is less than the instantaneous trip setting of the upstream circuit breaker.		
8.	LOW VOLTAGE FUSE-TO-DOWNSTREAM LOW VOLTAGE FUSE: The total clearing time of the downstream fuse should be below and to the left of the minimum-melting curve of the upstream fuse.		
9.	NOTES: * Time intervals may be decreased if field tests indicate that the system still selectively coordinates using the decreased time interval. When protecting a delta-wye substation or pad-mounted transformer, add an additional 16% current margin between the primary and secondary protective device curves. Refer to IEEE Std 242™ for additional system protection and selective coordination guidelines.		

E. Perform arc-flash hazard analysis using procedures outlined in IEEE Std 1584™.[22]

1. Perform arc-flash hazard calculations for switchgear, switchboards, transformers, motor control centers, panelboards, motor controllers, safety switches, and industrial control panels.

2. Base calculations on the installed equipment and components; coordinate with the power system studies required in LMS Section 26 0813, Electrical Acceptance Testing.

3. Extend arc-flash hazard calculations to points in the distribution system where the calculated incident energy at the assumed working distance is less than 1.0 cal/cm^2.[23]

4. Refer to Para 7.2, "Arc-Flash and Shock Hazard Warning Label" of this document for arc-flash warning label requirements.

5. In the arc-flash hazard calculations, tabulate the following calculated information for each location:

- Equipment ID Code,
- System voltage (e.g. 480Y/277 V, 208Y/120 V, 120/240 V),
- Maximum available bolted-fault current,[24]
- Arcing current,
- Overcurrent protective device clearing time at the arcing current,
- Special conditions (e.g. circuit breaker in an energy-reducing maintenance mode),
- Arc flash boundary in inches,
- Arc flash incident energy in cal/cm^2,
- Working distance[25] selected from IEEE Std 1584™ based on the equipment type,
- Hazard/risk category number from NFPA 70E for operations with doors closed and covers on.[26]

Note: *An arc flash hazard analysis is not required for equipment operating at 208Y/120V volts unless it involves at least one 125 kVA or larger low-impedance transformer in its immediate power supply.*[27]

[22] LANL P101-13, Electrical Safety Program, designates IEEE Std 1584™ as the preferred method for calculating the arc flash boundary and the arc-flash incident energy.
[23] LANL P101-13 requires a 20% margin of safety for arc flash PPE selection; this reduces the threshold incident energy where arc-rated protective clothing and PPE is required from 1.2 to 1.0 cal/cm^2.
[24] Refer to NEC section 110.24. This NEC requirement, added in the 2011 Edition, requires that a label indicating the maximum available fault current be placed on service entrance equipment. The purpose is to facilitate field verification that the equipment has, and continues to have, adequate withstand and interrupting ratings. This purpose is also valid for other electrical equipment in a facility, so the requirement is extended to all equipment that receives an arc-flash and shock hazard-warning label. The calculated maximum available fault current is an input to the arc flash hazard calculation, and both calculations must be reviewed periodically and updated when changed by system modifications.
[25] Working distance is the distance for the head and torso from energized parts; it is a function of the type of equipment and the system voltage.
[26] This requirement recognizes the non-zero possibility of an arc-flash event even with equipment doors closed; refer to NFPA 70E-2012, section 130.7(C)(15), Informational Note No. 2.
[27] Refer to IEEE Std 1584a §4.2.

4.3 Drawings

A. Provide a complete construction design drawings package as required to meet project specific requirements.

B. New drawings for a Design Change Form (or Revision Notice) and all new construction design packages shall meet the requirements below.

C. Comply with the LANL Drafting Manual for composition, organization, and format of drawings in a design package including diagram size, drafting layers, and software.

D. Demolition: Provide drawings indicating electrical demolition required for the project. Clearly indicate what is to be removed, what is to remain in service, locations to disconnect electrical energy sources, and organizations with which the construction/demolition Subcontractor must coordinate demolition work. **CAUTION:** The construction/demolition Subcontractor remains responsible for verifying adequacy/safety of demolition design via hazard analysis/work control (*e.g., IWD)* and lockout/tagout programs.[28]

E. Use Electrical Drawing ST-D5000-1 for electrical symbols. Delete the general notes on projects that have construction specifications.

F. Provide electrical drawings and details that adequately communicate the electrical design.

1. Provide plan view drawings to show the location and identification of electrical service and distribution equipment, luminaires, lighting control devices, receptacle outlets, equipment connections, branch circuiting, telecommunications outlets and distribution, paging system components, lightning protection system, grounding electrode system, and other system components as required by the Project.

2. Provide large-scale drawings of electrical rooms and similar congested spaces; show the NEC-required working spaces for electrical equipment.

3. Provide elevation drawings to show equipment arrangements or installation requirements that are not readily apparent in the plan views.

G. Electrical Single-line Diagrams (“One-lines”):

1. A single-line diagram as described in this section shall be used to represent the electrical power service and distribution system for each facility. The one-line shall show the electrical distribution system from the service point down to the lighting/power panelboard and motor control center level.

2. Use Electrical Example Drawing ST-D5000-2 as a template for the single-line diagram, configured such that upstream to downstream paths are shown from top to bottom or left to right. Edit to meet project specific requirements. Use additional sheets as required for large systems.

3. Symbology: Depict any single-line equipment not reflected in the LANL standard drawings or Drafting Manual in accordance with IEEE Std 315.

4. Single-line diagrams shall include the following information as applicable:

   - **Utility source(s):** Utility circuit voltage, circuit number(s), riser pole number(s), pad-mounted switchgear cubicle number(s), and manhole structure number(s).

[28] Lessons learned from LANL SM-1321/287 Syllac Building demolition 13.2 kV near miss (ALO-LA-LANL-WASTEMGT-2003-0006).

- **Supply characteristics:** Service point nominal system voltages (e.g., 480Y/277V, 208Y/120V, 120/240 V), system configurations (wye or delta, grounded or ungrounded), frequency (if other than 60 Hz), phase rotation, and short-circuit current (3-phase, RMS symmetrical amperes).
- **Power transformers**: Equipment identification code, ratings (kVA, primary voltage, secondary voltage, and percent impedance), cooling methods (e.g. OA/FA), winding connections, grounding electrode conductor size, dielectric type, location.
- **Generator systems:** Equipment identification code, ratings (voltage, subtransient reactance, kW/kVA at sea level and at 7500 ft), connection, fuel type, transfer switch ratings, equipment code, and location.
- **Major distribution equipment (e.g. unit substations, switchgear, switchboards, panelboards):** Equipment identification code, location (room number), ratings (system voltage, frequency if other than 60 Hz, amperes, connection type), short-circuit current (3- phase, RMS symmetrical amperes), short-circuit interrupting rating, types of loads served, electrical and/or mechanical interlocks between devices.
- **Service and feeder switching and overcurrent protective devices:** Circuit number, number of poles (if other than three poles), switch or circuit breaker frame size in amperes, circuit breaker long-time trip amperes, circuit breaker ground-fault trip amperes, fuse rating and type, short-circuit interrupting rating. Provide same information for branch circuits shown on the one-line diagram.
- **Protective relays:** Function, use, type, and number. Use device function numbers from IEEE C37.2™.
- **Services and feeders:** Raceway size and length; quantity, size, type (if other than copper), and insulation type for phase, grounded, and equipment grounding conductors. Provide the same information for branch circuits shown on the one-line diagram.[29]
- **Metering:** Voltmeters, ammeters, kW/kWh meters, test blocks, electronic metering packages.
- **Potential transformers**: Number, ratio, and overcurrent protection
- **Current transformers:** Number and ratio.
- **Dry-type transformers:** Equipment identification code, ratings (kVA, K-factor, primary voltage, secondary voltage, and percent impedance), cooling methods (e.g. OA/FA), temperature rise, winding connections, location, grounding electrode conductor size.
- **Surge protective devices:** Indicate surge protective devices for medium-voltage equipment, low-voltage service equipment, and specialized systems (e.g. isolated ground power systems).
- **Uninterruptible Power Supply (UPS) Systems:** Equipment identification code, location (room number), ratings (input and output voltage, frequency if other than 60 Hz, amperes, connection type), static and manual bypass arrangements, energy storage run-time, types of loads served, short-circuit current (3-phase, RMS symmetrical amperes).

[29] The one-line diagram is generally not intended to show branch circuits; however, information about major loads and large branch circuits increases the usefulness of the diagram

- **Major loads:**[30] Equipment identification code, voltage, kVA rating, and location of branch circuit loads rated 100 amperes and greater and all loads connected to switchboards or switchgear assemblies.
- **Motors:** Equipment identification code, voltage, horsepower, or kVA rating; starting method if other than across the line; interlocks between controllers; and location of all motors connected to switchgear and switchboards. *Motors connected to motor control centers or panelboards are branch circuit loads; they can be shown either on single-line diagrams or included in schedules; consult with the Facility Manager or the User for preference.*
- **Available short-circuit current:** The calculated three-phase bolted short-circuit current at each bus down to points in the distribution system where fault duty is less than 14,000 amps RMS symmetrical on 480Y/277V systems and less than 10,000 amps RMS symmetrical on 208Y/120V or 240/120V systems.
- **Critical systems:**
  - Indicate nuclear facility critical loads (e.g. safety class or safety significant).
  - Indicate emergency power systems, legally required standby power systems.
- **Battery systems:** Equipment identification code, location (room number), battery and charger ratings (input and output voltage, amperes, connection type), bypass arrangements, battery run-time, types of loads served, and short-circuit current.
- **Service Load Summary:** Provide a summary of the calculated or measured load for the service entrance. Refer to Drawing ST-D5000-2 for the required content and format.
- **Engine-Generator Load Summary:** Provide a summary of the calculated or measured loads for the engine-generator system(s). Indicate the NEC 110 level, type and class. Indicate the system configuration (e.g. single unit, N+1).
- **UPS Load Summary:** Provide a summary of the calculated or measured loads for the UPS system(s) Indicate the NFPA 111 Level, Type, and Class. Indicate the system configuration (e.g. single unit, parallel-redundant, N+1 battery).

H. Use Electrical Drawing ST-D5000-3 as a template for the project circuit designations and electrical equipment identification. Edit the template to meet project specific requirements.

I. Use Electrical Drawing ST-D5010-1 as a template for the project grounding diagram. Edit the template to meet project specific requirements.

J. Use Electrical Drawing ST-D5010-2 as a template for the project isolated ground system diagram(s) (if present). Edit the template to meet project specific requirements.

K. Use Electrical Drawings ST-D5010-3, ST-D5010-4, and ST-D5010-5 (as applicable) as templates for the project electrical service metering. Edit the templates to meet project specific requirements.

L. Use Electrical Drawing ST-D5020-1 as a template for the project motor control diagrams. Edit the template to meet project specific requirements. *One control diagram may be used to represent more than one identical motor control connection.*

[30] Ditto.

M. Use Electrical Drawing ST-D5030-1 or ST-D5030-3 (as applicable) as a template for the project telecommunications system riser diagram(s) and telecommunications room plan(s). Edit the template to meet project specific requirements.

4.4 Construction Specifications

A. Follow ESM Chapter 1 Section Z10 Attachment F - Specifications.

B. Provide a complete specification package as required to meet project specific requirements.

C. Edit the applicable LMS sections to meet project specific requirements; refer to paragraph 2.3.B of this document.

D. Generate additional construction specification sections as required to describe project materials or systems not addressed in the LMS sections.

1. *Avoid creating proprietary specifications based on a single manufacturer's example specification.*

2. *Consider using consensus guide specifications such as Unified Facilities Guide Specifications*, *MasterSpec®*, or *SpecText®*.

4.5 Sealing (Stamping) Construction Documents

Refer to ESM Chapter 1 Section Z10.

5.0 SYSTEM REQUIREMENTS

5.1 Adequacy and Future Expansion

A. Provide electrical systems with adequate capacity for the initial known requirements plus provisions for future expansion of the system as follows:

1. For new facilities, provide for load growth of 1 percent of the initial design load per year of expected facility service life[31], but not exceeding 30 percent. For new facilities with less than 20 years expected service life, less than 20 percent future-load-growth capability may be used with written authorization from the Chapter 7 POC.

2. For service renovations to existing facilities, provide for 1 percent-per-year load growth based on the expected remaining service life of the renovated facility.

B. Refer to Design Goals (*Article 6.0)* in Section Z10 of ESM Chapter 1 for expected lives of systems and structures.

5.2 Sustainable Design and Energy Conservation

Comply with ESM Chapter 14, Sustainable Design.

5.3 Fault Current Capacity

Provide electrical equipment with bus bracing and device interrupting capacities that exceed the fault current available at the line terminals of the equipment.

[31] Refer to IEEE Std. 141-1993, paragraph 2.4.1.4.

5.4 Lightning

Provide systems protected from the effects of direct or nearby lightning discharges in accordance with NFPA 780, IEEE Std 1100, and the IEEE C62 Surge Protection Standards Collection. *In an average year, Los Alamos experiences 61 thunderstorm days a year, about twice the national average.*[32] *The lightning flash density for parts of LANL is 8 flashes to ground per sq km per year.* [33] Refer to Section D5090.

5.5 Operating Altitude

Provide electrical equipment that is suitable and rated (or properly de-rated) for operation at an elevation of not less than 7500 feet.[34] *The reduced air pressure at this elevation impedes equipment cooling and reduces the electrical insulation properties of air.* [35] NOTE: Some LANL facilities such as TA-16, TA-28, and TA-57 (Fenton Hill) are at elevations higher than 7500 feet; provide equipment suitable for use at the elevation of such sites; see ESM Chapter 1 Section Z10.

5.6 Solar Heat Gain

Provide outdoor electrical equipment that is suitable and rated (or properly de-rated) for operation with a solar heat gain of 110 W/sq ft.

5.7 Power Quality

A. Provide electrical systems that are selected and configured to provide adequate power quality for the satisfactory operation of electrical utilization equipment:

1. *Use the highest practical service, distribution, and utilization voltages.*
2. *High-impact electrical loads such as HVAC equipment, elevators, and process loads should be segregated on separate feeders from sensitive loads.*
3. *Step-down transformers and associated panelboards should be located physically close to the loads that they serve.*
4. *Loads on each feeder should be balanced so the voltage on each phase will be within 1 percent of the average voltage of the three phases.*[36]

B. Follow recommended practice in IEEE Std 1100™ and IEEE Std 141™.

5.8 Power System Harmonic Limits

Limit harmonic currents at the point of service for each building to comply with IEEE Std 519™.[37]

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[32] Climatology information (average temperatures, thunderstorm frequency, etc.) is from “Brief Climatology for Los Alamos, NM” available at http://weather.lanl.gov. (A thunderstorm day is a day on which thunder is heard or a thunderstorm occurs.)
[33] Lightning flash density map for Los Alamos from Global Atmospherics, Inc. for 1/1/2001 to 12/31/2001.
[34] Altitude at LANL ranges from 6250 ft at TA-39 to 7780 ft at TA-16. Elevation information is from USGS 1:24000 quadrant maps: Frijoles, NM and White Rock, NM.
[35] IEEE Std 1015™, “Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems,” the ANSI C37 collection “Circuit Breakers, Switchgear, Substations, and Fuses,” and the ANSI C57 collection “Distribution, Power, and Regulating Transformers” provide information about the de-rating effects of elevation on electrical equipment.
[36] DOE Office of Industrial Technologies Motor Tip Sheet #7, September 2005 available at http://www1.eere.energy.gov/industry/bestpractices/pdfs/eliminate_voltage_unbalanced_motor_systemts7.pdf
[37] IEEE Std. 141-1993™, Chapter 9 points to IEEE Std 519 for limits on the harmonic currents that a user can induce back into the utility power system.

5.9 Power System Availability

Power system availability analysis and design shall comply with IEEE 493™ to ensure continual power supply to systems and equipment designated by project design criteria as "mission critical," "safety significant," or "safety class." Consider the need for multiple transformer-switchgear service equipment to ensure power supply continuity within the facility during scheduled or emergency equipment outages.[38]

5.10 Overcurrent Protection[39]

A. Where possible, use circuit breakers with the required NRTL-listed interrupting ratings.[40]

B. Where circuit breakers with the required NRTL-listed interrupting ratings are not available, current-limiting fuses may be used to obtain the required interrupting rating.

C. Use fuses where required by equipment NRTL listings.

5.11 Selective Coordination

A. Provide selectively coordinated overcurrent protection; refer to the Calculations paragraph in this Section for detailed requirements.

B. When the *NEC*® requires ground-fault protection for service or feeder disconnecting means, provide an additional step of ground fault protection in the next level of feeders as required to provide fully selectively coordinated ground-fault protection.

5.12 Standards for Material and Equipment

A. Use electrical materials and equipment that is constructed and tested in accordance with the standards of NEMA, ANSI, ASTM, or other recognized commercial standard.

B. If material and equipment is labeled, listed, or recognized by any Nationally Recognized Testing Laboratory (NRTL) acceptable to OSHA and the LANL Electrical AHJ, then provide NRTL labeled, listed, or recognized material and equipment.[41] Acceptable Nationally Recognized Testing Laboratories include[42]:

1. Underwriters Laboratories, Inc. (UL)
2. Factory Mutual Research Corp. (FMRC)
3. Intertek Testing Services NA, Inc. (ITSNA, formerly ETL)
4. Canadian Standards Association (CSA)

A complete listing of **acceptable** NRTLs is located at http://www.osha.gov/dts/otpca/nrtl/

C. Where material and equipment is not labeled, listed, or recognized by any NRTL, provide a manufacturer's Certificate of Compliance indicating complete compliance of each item with applicable standards of NEMA, ANSI, ASTM, or other recognized standard.

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[38] IEEE 493™ provides methods for quantitative reliability analysis as it applies to the planning and design of electric power distribution systems.

[39] This has been the philosophy at LANL since 1985 and was previously mandated under the switchboard/panelboard article of D5010.

[40] Circuit breakers can usually be re-set after the fault has been investigated and cleared; no spare parts, such as fuses, are required.

[41] LANL P101-13, "Electrical Safety Program;" OSHA 1910.303(a); OSHA 1926.403(a); and *NEC*® Article 110.2 establish the requirement that electrical system and utilization equipment be acceptable to the AHJ.

[42] LANL P101-13, "Electrical Safety Program" establishes that NRTLs acceptable to the LANL AHJ are those "Organizations Currently Recognized by OSHA as NRTLs" on the OSHA website.

D. Do not install or use electrical material or equipment for any use other than that for which it was designed, labeled, listed, or identified unless formally approved for such use by the LANL Electrical AHJ.[43]

5.13 Personnel Safety

A. Design systems and select equipment to reduce electrocution, arc flash, and arc blast hazards to maintenance and operations personnel.[44]

B. Equipment *and design practices are available to minimize energy levels and the number of at-risk procedures that require an employee to be exposed to high energy level sources. Proven designs to reduce the hazards of electrical systems include*:

1. *Arc-resistant switchgear, motor control centers, etc.*
2. *Remote racking (insertion or removal) of circuit breakers,*
3. *Remote opening and closing of switching devices,*
4. *Current limitation obtained with higher impedance transformers or current-limiting reactors, and*
5. *Insulated or isolated bus in switchboards and switchgear assemblies.*

6.0 EQUIPMENT LOCATION

6.1 General

A. Locate electrical equipment so it will be accessible for inspection, service, repair, and replacement without removing permanent construction, with working clearance and dedicated space as required by the *NEC*® and as recommended by the manufacturer.[45]

B. Locate equipment so generator exhaust, etc. does not enter occupied spaces through outside air intakes.

C. See ESM Chapter 1 Section Z10 for other requirements.

D. *Where possible, locate major electrical equipment outside of areas with unusual security restrictions (e.g. SCIFs) or personnel hazards (e.g. radiation or toxic chemicals).*

6.2 Equipment Rooms and Spaces

A. Provide one or more dedicated electrical equipment rooms on each floor in every building except for modifications where loads can be served from existing equipment.[46] Each electrical room shall have lockable door(s).

1. Provide electrical equipment rooms to house switchgear, switchboards, power panelboards, transformers, transfer switches, lighting control relay panels, and similar distribution equipment in office buildings or light laboratory buildings.
2. In existing buildings where no other suitable location is available, and with the consent of the ESM Chapter 7 POC, panelboards may be recess-mounted in corridors.

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[43] This *National Electrical Code*® requirement repeated for emphasis.
[44] Refer to NFPA 70E, Article 130.1.
[45] *NEC*® Article 110 establishes minimum working clearances and dedicated spaces for electrical equipment
[46] Dedicated electrical rooms make it more likely that LANL will remain in compliance with *NEC*® Article 110.

3. Dedicated electrical equipment spaces may be used in lieu of equipment rooms for switchgear, panelboards, transformers, transfer switches, lighting control relay panels, and similar distribution equipment in industrial, process, or production buildings.
4. In laboratory buildings, one or more panelboards dedicated to each laboratory may be located in the corridor outside the lab entrance door. Recess lab panelboards in public corridors. Lab panelboards may be surface mounted in non-public service corridors.

B. Design electrical equipment rooms or spaces to facilitate equipment installation/removal and to provide adequate access for operation and maintenance of the equipment.

C. Provide for the removal of the largest component from each electrical room or space for off-site servicing. Provide adequate floor loading capability on the access routes and in the electric rooms or spaces for the electrical equipment and material handling equipment.[47]

D. Locate electrical rooms or spaces in the building to satisfy the following criteria:

1. Branch circuit panelboards on the same floor as the loads they serve.[48]
2. Electric rooms or spaces vertically aligned in multi-story buildings.[49]
3. Maximum feeder voltage drop: 2 percent[50]
4. Maximum branch circuit voltage drop: 3 percent[50]. *Guidance: To achieve this, consider perform voltage drop calculations when:*
   - *a 208Y/120V system branch circuit's length is greater than 100 ft.* [51]
   - *a 480Y/277V system branch circuit's length is greater than 230 ft.* [52]

E. For indoor installations, provide at least 60 inches of clear height to the underside of the building structure above medium-voltage switchgear to allow for vertical conduit elbows above the equipment.[53] For indoor installations, provide at least 48 inches of clear height to the underside of the building structure above low-voltage switchgear and switchboards to allow for busway transitions and conduit bends above the equipment.[54]

F. For indoor installations of medium-voltage switchgear, provide access aisles at least 5'-0" in front, 5'-0" in rear (if rear access is required)[55], and 3'-0" at ends of switchgear lineups after providing space for future expansion.[56] For indoor installations of low-voltage,

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[47] Refer to Clause 1.15 in IEEE Std 241-1990™ for additional building access and loading information.
[48] Having the panelboard on the same floor as the load reduces the number of customers disturbed when a panel must be de-energized for maintenance or modification.
[49] Vertical alignment facilitates installing economical feeders, sharing grounding electrode bars, transformers, etc.
[50] Mandatory provisions in ASHRAE/IESNA Standard 90.1 (8.4.1 in 2013 edition).
[51] 100 ft is the approximate maximum circuit length serving a 120V 16-ampere, 0.95 pf line-neutral load through a magnetic conduit with 12 AWG conductors in a balanced multi-wire circuit or with 10 AWG conductors in a 2-wire circuit with 3% voltage drop.
[52] 230 ft is the approximate maximum circuit length serving a 277V 16-ampere, 0.95 pf line-neutral load through a magnetic conduit with 12 AWG conductors in a balanced multi-wire circuit or with 10 AWG conductors in a 2-wire circuit with 3% voltage drop.
[53] 60" vertical clearance above medium-voltage switchgear allows for the 51" offset of a 6" conduit elbow with 36" radius plus space for conduit hangers.
[54] The 48-inch clearance is calculated as follows: 5000A busway switchgear flanged end 10", transition elbow 21", edgewise busway centerline to top 13", busway hanger and support rod 4". This guidance is from lessons learned from several LANL installations that were very difficult due to inadequate vertical clearance above switchgear.
[55] Minimum clear distance based on *NEC*® Table 110.34(A) using 7960 volts to ground (13,800 / 1.732) and Condition 2. Working space to allow thermographic examination with equipment energized.
[56] Based on medium-voltage switchgear manufacturers' recommendations.

switchgear, provide access aisles at least 4'-6" in front[57], 3'-6" in rear[58], and 3'-0" at ends of low-voltage equipment after providing space for future expansion. Provide greater access space if recommended by the manufacturer or if required to fully open access doors.

G. For new construction, provide dedicated electrical space equal to width and depth of the equipment extending from floor to a height of 25 ft or to the bottom of the floor slab or roof slab above; allow no piping, ducts, or equipment foreign to the electrical installation in this zone. For work in existing structures, follow Article 110 in the *NEC*®. [59]

H. Provide at least 30 footcandles[60] general illumination on the vertical surfaces of the electrical equipment. Provide similar illumination at the rear of freestanding equipment. Provide emergency illumination to avoid safety problems and to facilitate trouble-shooting during a power outage.[61]

I. Provide at least one general-purpose receptacle in each electric room or space for power tools and supplemental lighting.[62]

J. Provide HVAC for electrical distribution equipment spaces with 30 percent air filtration and heating/cooling as required to maintain an average ambient temperature not to exceed 86ºF (30ºC). The average ambient temperature shall cover 24 hours, and the maximum temperature during the 24-hour period shall not exceed 104ºF (40ºC).[63]

K. If possible, locate electrical service equipment in above-grade areas not subject to flooding. If service switchgear must be installed below grade, provide redundant sump pumps supplied from a reliable standby power system.[64] *Events that could cause flooding include the rupture of fire sprinkler pipe, HVAC pipe, etc.*

L. Locate electrical service entrance equipment as close as practical to the building water service entrance and to major electrical loads.

M. Do not install electrical distribution equipment (e.g., panelboards, switchboards, transformers) in stairways or janitor closets.[65]

N. Provide a prominent sign on electrical room doors with the following message:[66]

NOTICE
ELECTRICAL ROOM
NO STORAGE PERMITTED

Approximate size: 2" x 5"

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[57] Based on switchgear manufacturer's recommendations based on removal/insertion of draw-out circuit breakers using a top-mounted breaker hoist.
[58] Working space to allow thermographic examination with equipment energized. Minimum clear distance based on *NEC*® Table 110.26(A)(1) using 151-600 volts to ground and Condition 2.
[59] To enhance flexibility and expandability, the pre-1999 *NEC*® dedicated space requirements for electrical equipment are retained for new LANL facilities. In existing facilities being renovated, the minimum current *NEC*® dedicated space requirements are allowed.
[60] Lighting Design Guide in Chapter 10 of the Ninth Edition of the IESNA Lighting Handbook recommends 30 footcandles illuminance for industrial maintenance operations.
[61] Refer to maintenance illumination recommendations in IEEE Std 902 (clause 9.2.3 in 1996).
[62] *NEC*® Article 210.50(B).
[63] Electrical room temperature limits from IEEE C57.12.00, IEEE C57.12.01, IEEE C37.20.1, and IEEE C37.20.3.
[64] Recommended practice from Chapter 3 of NECA 400-1998, adapted to medium-voltage equipment.
[65] Cooling problems, hard to maintain, IRC practice.
[66] Requirement is based on LANL experience that electrical equipment rooms are used as storage spaces.

7.0 ELECTRICAL IDENTIFICATION

7.1 General

A. Comply with LMS Section 26 0553, Identification for Electrical Systems, for electrical identification products, materials, and installation.

B. Refer to Electrical Drawing ST-D5000-3 for preferred locations of electrical identification.

C. Provide schedules in Construction Documents indicating all required information for the following:

1. Arc-flash and shock hazard-warning labels
2. Component identification tags
3. Equipment nameplates

7.2 Arc-Flash and Shock Hazard Warning Labels

A. Install arc-flash and shock hazard-warning labels that comply with ANSI Z535.4 on switchgear, switchboards, transformers, motor control centers, panelboards, motor controllers, safety switches, and industrial control panels.[67] On renovation projects, install arc-flash warning labels on existing equipment where lock-out/tag-out will be required for the renovation work.[68]

B. Use the appropriate label design from LMS Section 26 0553 as follows:

1. Label Design #1 for equipment where a calculation is required, and the calculated arc flash incident energy does not exceed 33.3 cal/cm^2. [69]
2. Label Design #2 for equipment operating at a nominal system voltage of 208Y/120 V and served by a single transformer with a rating less than 125 kVA.

Note: *An arc flash hazard analysis is not required for equipment operating at 208Y/120V volts unless it involves at least one 125 kVA or larger low-impedance transformer in its immediate power supply.*[70]

3. Label Design #3 for equipment where the calculated arc-flash incident energy is greater than 33.3 cal/cm^2.

C. Provide the following information on each label; for design projects include the information in a schedule on the Drawings or specify that arc flash warning label information will be provided as one of the power system studies required in LMS Section 26 0813, Electrical Acceptance Testing:

1. Arc-Flash Boundary[71] (inches) calculated in accordance with IEEE Std 1584a™.
2. Indication of any special condition assumed in the arc-flash hazard analysis *(e.g. circuit breaker in an energy-reducing maintenance mode or zone-selective interlocking engaged).*

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67 Refer to Section 110.16 in the *NEC*®.
68 Refer to NFPA 70-E, Articles 120 and 130.
69 LANL P101-13 requires a 20% margin of safety for arc flash PPE selection; this reduces the maximum incident energy where arc-rated protective clothing and PPE can provide practical protection from 40 to 33.3 cal/cm^2
70 Refer to IEEE Std 1584a §4.2.
71 LANL P101-13, Electrical Safety Program, paragraph 4.4.3 identifies IEEE Std 1584a™ as the preferred method arc flash incident energy calculations.

3. Arc-flash incident energy (cal/sq cm) calculated in accordance with IEEE Std 1584a™.
4. Working distance[72] (inches) selected from IEEE Std 1584a™ or NFPA 70E based on the type of equipment.

***Note:** LANL P101-13, Electrical Safety Program, provides on-line tools to select arc-rated protective clothing and PPE based on the calculated incident energy.*

5. NFPA 70E Hazard/Risk Category number or the appropriate PPE for operations with doors closed and covers on.[73]
   - *Typical operations include operating circuit breakers, fused switches, and meter selector switches.*
   - If the calculated incident energy with doors open or covers off is less than[74] 1.0 cal/cm^2, the minimum PPE for operations with doors closed and covers on is safety glasses and leather gloves.

   ***Note:** The incident energy may be assumed to be less than 1.0 cal/cm^2 for equipment operating at 208Y/120 V and fed by a 112.5 kVA or smaller transformer.*

   - If the calculated incident energy with doors open or covers off is above 1.0 cal/cm^2, indicate on the label the Hazard/Risk Category number from NFPA 70E Table 137(C)(9) for operations with doors closed and covers on.
   - If the short-circuit current or clearing time exceeds the limits noted in NFPA 70E Table 137(C)(9) for the class of equipment, indicate on the label the Hazard/Risk Category number as 4 for operations with doors closed and covers on.
6. System phase-to-phase voltage
7. Condition(s) when a shock hazard exists (e.g., with cover off)
8. Limited approach boundary as determined from NFPA 70E
9. Restricted approach boundary as determined from NFPA 70E
10. Prohibited approach boundary as determined from NFPA 70E
11. Class for insulating gloves based on system voltage (e.g., Class 00 for up to 500 volts)
12. Voltage rating for insulated or insulating tools based on system voltage (e.g., 1,000 volts)
13. Equipment ID code based on Drawings and including TA number, building number, and system identifier (e.g. 03410-EP-PP-A)
14. Maximum available fault current[75] (e.g., 21,650 A)

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[72] Working distance is the distance for the head and torso from energized parts; it is a function of the type of equipment and the system voltage.

[73] This requirement recognizes the non-zero possibility of an arc-flash event even with equipment doors closed; refer to NFPA 70E-2012, section 130.7(C)(15) Informational Note No. 2.

[74] LANL P101-13 requires a 20% margin of safety for arc flash PPE selection; this reduces the threshold incident energy where arc-rated protective clothing and PPE is required from 1.2 to 1.0 cal/cm^2.

[75] Refer to NEC section 110.24. This NEC requirement, added in the 2011 Edition, requires that a label indicating the maximum available fault current be placed on service entrance equipment. The purpose is to facilitate field verification that the equipment has, and continues to have, adequate withstand and interrupting ratings. This purpose is also valid for other electrical equipment in a facility, so the requirement is extended to all equipment that receives an arc-flash and shock hazard-warning label. The calculated maximum available fault current is an input to the arc flash hazard calculation, and both calculations must be reviewed periodically and updated when changed by system modifications.

15. Date that the arc-flash hazard analysis[76] and short-circuit current calculation[75] was performed

D. Refer to LMS Section 26 0553 for additional requirements.

7.3 Component Identification

Identify electrical equipment on drawings and tags in accordance with ESM Chapter 1, Section 200 – Equipment & Component Numbering and Labeling.[77]

7.4 Component Identification Tags

Install electrical component identification tags (formerly called code tags) to identify electrical equipment using the System Designation, Equipment Identification, the Tech Area Number, and the Building Number.[78]

7.5 Diagrams and Operating Instructions

Post and maintain diagrams, operating instructions and emergency procedures for electrical systems and major equipment. *They should consist of simplified instructions and diagrams of equipment, controls and operation of systems, including selector switches, main-tie-main transfers, ATS-bypass, UPS-bypass etc*. Post and maintain an up-to-date one-line diagram of the electrical system adjacent to the service entrance equipment.[79]

7.6 Emergency System Identification

Install markers to identify emergency system transfer switches, generators, switchgear, transformers, motor control centers, panelboards, starters, safety switches, pull boxes, and cabinets as components of the emergency system.[80]

7.7 Equipment Nameplates

A. Install electrical equipment nameplates of the following three categories:

1. Category I - Circuit Directory Information: Nameplates shall contain circuit number, piece of equipment being served or being served from, location of equipment served or being served from, and the nominal system voltage (e.g., 480Y/277V, 208Y/120V).[81]
2. Category II - General or Operational Information: Nameplates shall contain or refer to posted basic instructions or specific operating procedures such as special switching procedures for a load transfer scheme.[82]
3. Category III - Emergency Operations: Nameplate shall contain or refer to posted information concerning emergency shutdown procedures for room, equipment, and building isolation in event of fire or other emergency.

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[76] Refer to NFPA 70E-2012 section 130.5.
[77] P101-19, Safety Signs, Labels, and Tags; *NEC*® Articles 110.21 and 110. 22.
[78] The component identification tag uniquely identifies the equipment item.
[79] NFPA 70B-1994, paragraph 4-2.3, Recommended Practice for Electrical Equipment Maintenance, strongly recommends having system diagrams, operating instructions, and emergency procedures readily available.
[80] NEC® Section 700.9(A) requires identification of components of an emergency power system.
[81] Category I nameplates are essential to the efficient implementation of the LANL lock-out/tag-out program.
[82] NFPA 70E Section 205.8 requires safety-related operating or maintenance instructions be posted on equipment.

7.8 Receptacle and Light Switch Labels

Install labels on receptacle outlets and light switches indicating circuit number, panelboard, and voltage.[83]

7.9 Voltage Markers

Install voltage markers on electrical equipment (e.g., switchgear, transformers, motor control centers, panelboards, starters, safety switches, pull boxes, cabinets).[84]

7.10 Warning Signs

Install warning signs that conform to ANSI Z535.2 and meet the intent of the OSHA and *NEC*® danger and caution specifications on electrical equipment containing hazardous voltages (e.g. switchgear, switchboards, transformers, motor control centers, panelboards, starters, safety switches, busways, pull boxes, and cabinets).[85]

7.11 Wire Markers

Install wire markers on power, control, instrumentation, fire alarm, and communications circuit wires.[86]

7.12 Working Space Markers

A. In electrical rooms and electrical spaces, permanently mark the floor with the *NEC*® required clear space in front of and behind switchgear, transformers, motor control centers, panelboards, starters, and safety switches. Install marking on the floor using color schemes conforming to ANSI Z535.1: black and white striped border.

1. Rear clear working space is required for maintenance activities such as thermographic inspection of energized switchgear.[87]
2. *Floor marking may be omitted in carpeted areas and similar areas where floor marking is not practical.*

B. Install working space labels on all equipment likely to require examination, adjustment, servicing, or maintenance while energized where marking the floor is not practical.

8.0 ELECTRICAL SUPPORTS AND SEISMIC CONTROLS

A. Specify, and as necessary design, hangers and supports for electrical equipment in accordance with the *NEC*®, manufacturer's instructions, ESM Chapter 5 – Structural, the *IBC*, and ASCE 7.

B. Using the services of a qualified structural engineer, provide documented designs (calculations, plan views, details) for electrical nonstructural components requiring seismic bracing and/or anchorage in accordance with LANL ESM Chapter 5 - Structural, the *IBC*,

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[83] Labeling of outlets and switches to indicate circuit is a long-standing practice at LANL to facilitate maintenance and lock-out/tag-out.
[84] Voltage identification requirement in the New Mexico State Electrical Code for 480-volt equipment is extended to 208- and 240-volt equipment.
[85] NEC Section 110.27 requirement for warning signs on entrances to rooms or other guarded locations is extended to include electrical equipment enclosures.
[86] Labeling of conductors is required in NEC 210.5 and 215.12. Additionally wire marking facilitates trouble-shooting of systems.
[87] Marking of the *NEC*® required clear space at electrical equipment helps keep facility users from using these areas for storage.

and ASCE 7. Clearly identify and detail the seismic bracing and/or anchorage on the Drawings. Based on their seismic Performance Category (PC) or Importance Factor (I_p), electrical components that require designed seismic bracing and/or anchorage include the following[88]:

1. Systems, equipment, and components categorized as PC-2 or PC-3, plus all that are PC-1 in any of the following cases:
   - I_p equals 1.5 (e.g., emergency related)
   - Equipment is:
     - mounted above designated exit pathways
     - weighs more than 400 lb mounted 4 ft or less above a floor level
     - weighs more than 20 lb mounted more than 4 ft above a floor level
     - without flexible connections to associated raceway systems
   - Supports that are cantilevered up from the floor, include bracing to limit deflection, or are constructed as rigid welded frames
   - Attachments into concrete using nonexpanding inserts, power-actuated fasteners, or cast iron embedments
   - Attachments using spot welds, plug welds, or minimum size welds as defined by AISC

   Guidance: The above will generally result in designed anchorage for, as a minimum, battery racks and battery cabinets, cable trays, enclosed bus assemblies, engine-generators, motor control centers, switchboards, switchgear, uninterruptible power supplies, unit substations, and wireways.

2. For conduit, whenever PC-3, plus PC-1 and PC-2 where conduits are either (a) individually supported and weigh more than 5 lb/ft, or (b) trapeze supported with an aggregate weight exceeding 10 lb/ft.

C. Clearly identify electrical components that must maintain containment of hazardous content or remain operable following a design seismic event.

D. Refer to the following documents for additional requirements:

1. LANL ESM Chapter 5, Structural
2. LMS Section 13 4800, Sound, Vibration, and Seismic Control[89]
3. LMS Section 26 0529, Hangers and Supports for Electrical Systems
4. LMS Section 26 0548, Vibration and Seismic Controls for Electrical Systems
5. In nuclear facilities, the heading “Additional Requirements for Safety-Related Electrical Systems” in this document for special requirements and guidance

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[88] The list of electrical components that require seismic bracing and/or anchorage is based on Chapter 13 of ASCE 7 and information about component characteristics, installation, and use.

[89] DOE-STD-1020 requires seismic protection based on the assigned PC level. LANL Master Specification 13 4800 provides seismic protection measures for mechanical and electrical equipment.

9.0 RODENT-PROOFING

A. Specify and install outdoor low-voltage and medium-voltage equipment to be rodent-proof with maximum 1/4 inch[90] unprotected openings in enclosures.

B. Seal all cable entries and plug unused conduits entering outdoor equipment with material that rodents will not be able to gnaw through, squeeze through, or push aside. *Suitable materials include 24-gauge or heavier galvanized sheet steel, 19-gauge galvanized woven/welded 1/4” mesh hardware cloth, 16 to 19-gauge stainless steel 1/4” mesh hardware cloth, and galvanized lath screen.*[91]

C. When penetrating an exterior wall, roof, or floor with conduit, wireway, enclosed busway, etc., seal openings and provide a metal collar securely fastened to the structure.[91]

D. Seal all cable entries and plug unused conduits entering indoor equipment from outdoors with material that rodents will not be able to gnaw through, squeeze through, or push aside. *Suitable materials include 24-gauge or heavier galvanized sheet steel, 19-gauge galvanized woven/welded 1/4” mesh hardware cloth, 16-19-gauge stainless steel 1/4” mesh hardware cloth, and galvanized lath screen.*

10.0 DEMOLITION

A. Remove abandoned electrical distribution equipment, utilization equipment, outlets, and the accessible portions of wiring, raceway systems, and cables back to the source panelboard, switchboard, switchgear, communications closet, or cabinet.[92] *Abandoned wiring and raceways can result from actions that include the following:*

1. *Equipment is removed or relocated*
2. *Fixtures are removed or relocated*
3. *System is no longer used*
4. *There is no demonstrable near term use for the existing circuit or raceway system.*

B. Leave abandoned electrical equipment, conductors, and material in place only if one or more of the following conditions exist:

1. *The system is in a radiological contaminated area and ALARA precludes the removal.*
2. *The removal requires the demolition of other structures, finishes, or equipment that is still in use. An example is abandoned conduit above an existing plaster ceiling.*
3. *Removal is not feasible due to hazards, construction methods, or restricted access.*
4. *Removal of abandoned conductors may damage conductors that must remain operational.*

C. Remove conduits, including those above accessible ceilings, to the point that building construction, earth, or paving covers them. Cut conduit beneath or flush with building

[90] By gnawing, mice can gain entry through openings larger than 1/4 inch. Refer to “Rodent Exclusion Techniques” pamphlet published by the National Park Service in 1997.
[91] Refer to “Rodent Exclusion Techniques” pamphlet published by the National Park Service in 1997.
[92] LANL institutional policy developed through observation and experience. Removal of abandoned equipment, outlets, wiring, and raceways will have positive safety benefit for maintenance and operations personnel; in addition it will reduce the clutter and obstructions in LANL facilities.

construction or paving. Plug, cap, or seal the remaining unused conduits. Install blank covers for abandoned boxes and enclosures not removed.[93]

D. Extend existing equipment connections using materials and methods compatible with the existing electrical installation and this Chapter 7.

E. Restore the original fire rating of floors, walls, and ceilings after electrical demolition.[94]

F. Use approved lock-out/tag-out procedures to control hazardous energy sources. Assure that an electrically safe work condition exists in the demolition area before beginning demolition.[95] Where possible, disconnect the building from all sources of electrical power before beginning demolition; if this is not possible, contact the LANL Electrical AHJ for planning and operational support of electrical safety during demolition.[96]

G. Refer to ESM Chapter 16 IBC-GEN and LMS Section 02 4115, Electrical Demolition (*becoming 26 0505 Selective Demolition for Electrical).*

11.0 ACCEPTANCE TESTING

A. Perform acceptance testing, inspections, function tests, and calibration to assure that installed electrical systems and components, both Subcontractor and user supplied, are:

1. Installed in accordance with design documents and manufacturer's instructions,
2. Tested and inspected in accordance with applicable codes and standards (e.g., NFPA 110 and NFPA 111),
3. Ready to be energized, and
4. Operational and within industry and manufacturer's tolerances.

B. Use the graded approach outlined in Table D5000-2 to determine the degree or formality of acceptance testing that is consistent with the institutional risk of a failure of the particular electrical system or component type balanced against the safety risks associated with performing the acceptance testing, inspection, and calibration.[97]

1. If the indicated threshold is not exceeded for a particular system or equipment type, then only the Subcontractor-performed inspections and tests described in the specification section for that particular system or equipment type are required.[98]
2. If the indicated threshold is exceeded for a particular system or equipment type, then that system or equipment type must receive formal electrical acceptance testing and

[93] LANL institutional policy developed through observation and experience. Describe extent and limits of demolition work.

[94] The logic in *NEC*® Section 300.21 for preventing the spread of fire and products of combustion is extended from new construction to demolition.

[95] P101-13, "Electrical Safety Program," applies to D&D work.

[96] Refer to LANL AHJ memo February 13, 1995, Subject: Electrical Safety in Demolition Work and Remodeling Projects.

[97] This graded approach for electrical acceptance testing is based on the safety design criteria (using Management Level) and/or operational impact (using component ratings) of electrical system failures, balanced against the cost of performing the tests and the hazards involved. The validity of this graded approach is broadly indicated by comparing IEEE Std 141 to IEEE Std 241: the industrial electric power distribution standard has extensive discussions about electrical acceptance testing in §5.9, but the commercial building power systems standard has no similar discussion. IEEE Std 141 is mandated for both Safety-Class and Safety-Significant (ML-1 and ML-2) electrical systems in DOE O 420.1C, so all ML-1 and ML-2 systems are indicated to receive formal electrical acceptance testing. Project experience indicates that 800 amperes is an appropriate demarcation between the typical small GPP office buildings and small laboratory facilities (such as CINT) that have significantly greater operational impact. It is appropriate for electrical systems in larger commercial-type office buildings (such as NSSB) to receive formal acceptance testing due to the mission impact of the great number of workers that would be affected by an electrical system failure. Medium-voltage electrical systems are indicated to receive formal acceptance testing due to the fact that a system failure would affect a large number of programs and workers.

[98] Refer to LANL Master Specifications.

inspections in accordance with LMS Section 26 0813, Electrical Acceptance Testing[99] using the current edition of NETA ATS, *Acceptance Testing Specification.*[100]

3. *For ML-3 systems, the Design Authority may invoke formal electrical acceptance testing for selected electrical systems at lower thresholds than indicated in Table D5000-2.*

4. *If formal electrical acceptance inspection and testing is required for one or more systems or equipment types, then it may be cost-effective to use the Electrical Testing Agency to perform acceptance inspection and testing on all applicable electrical systems.*

Table D5000-2 Thresholds for Formal Electrical Acceptance Inspection and Testing

NETA ATS Clause	System or Component Type (Note 1)	Threshold for ML-4 or ML-3 SSC (Note 4)	Threshold for ML-2 or ML-1 SSC	Notes
7.1	**Switchgear and Switchboards**			
	Medium-Voltage Switchgear	Any	Any	2
	Low-Voltage ANSI Switchgear	Any	Any	
	Low-Voltage NEMA Switchboards	> 800 A Main Bus	Any	
7.2	**Transformers**			
	Low-Voltage, Dry-Type	>225 kVA Rating	Any	
	Medium-Voltage, Dry-Type	Any	Any	2
	Liquid-Filled	Any	Any	2
7.3	**Cables**			
	Low-Voltage	> 800 A Circuit	Any	
	Medium- and High-Voltage	Any	Any	2
7.4	**Metal-Enclosed Busways**	> 800 A Rating	Any	
7.5	**Switches**			
	Low-Voltage	> 800 A Rating	Any	
	Medium- or High-Voltage	Any	Any	2
7.6	**Circuit Breakers**			
	Low-Voltage Molded Case	> 800 A Frame	Any	
	Low-Voltage Insulated Case	Any	Any	
	Low-Voltage Power	Any	Any	
	Medium- or High-Voltage	Any	Any	2
7.7	**Circuit Switchers (Medium-Voltage)**	Any	Any	2

[99] LANL Master Specifications Section 26 0813–*Electrical Acceptance Testing* indicates minimum qualifications for Electrical Testing Agencies and test technicians using a Management Level based graded approach.

[100] *The NETA Acceptance Testing Specifications* (ATS) is a document to assist in specifying required tests on newly installed electrical power systems and apparatus, before energizing, to ensure that the installation and equipment comply with specifications and intended use as well as with regulatory and safety requirements. *The Acceptance Specifications* include topics such as Applicable Codes, Standards, and Reference; Qualifications of the Testing Agency; Division of Responsibility; General Information concerning Testing Equipment; Short-Circuit Analysis and Coordinating Studies, System Function Tests; and Thermographic Surveys. The ATS includes tests to be performed on Switchgear and Switchboard Assemblies, Transformers, Cables, Metal-Enclosed Busways, Switches, Circuit Breakers, Network Protectors, Protective Relays, Instrument Transformers, Metering and Instrumentation, Grounding Systems, Ground Fault Systems, Rotating Machinery, Motor Control, Direct-Current Systems, Surge Arresters, Capacitors, Outdoor Bus Structures, Emergency Systems, Automatic Circuit Reclosers and Line Sectionalizers, Fiber-Optic Cables, and Electrical Safety Equipment.

NETA ATS Clause	System or Component Type (Note 1)	Threshold for ML-4 or ML-3 SSC (Note 4)	Threshold for ML-2 or ML-1 SSC	Notes
7.8	**Network Protectors (Low-Voltage)**	Any	Any	
7.9	**Protective Relays**	Any	Any	2
7.10	**Instrument Transformers**	> 800 A Circuit	Any	3
7.11	**Metering Devices**	> 800 A Circuit	Any	3
7.12	**Regulating Apparatus**	Any	Any	2
7.13	**Grounding Systems**			
	Main Grounding Electrode	> 800 A Service	Any	
	System Grounding	> 800 A Service	Any	
	Equipment Bonding	> 800 A Circuit	Any	
7.14	**Ground Fault Protection Systems**	> 800 A Circuit	Any	
7.15	**Rotating Machinery**			
	AC Induction Motors and Generators			
	Low-Voltage	> 100 HP or 100 kW	Any	
	Medium-Voltage	Any	Any	
	Synchronous Motors and Generators			
	Low-Voltage	Any	Any	
	Medium-Voltage	Any	Any	
	DC Motors and Generators	Any	Any	
7.16	**Motor Control**			
	Low-Voltage Motor Starters	> 100 HP Motor	Any	
	Medium-Voltage Motor Starters	Any	Any	
	Low-Voltage Motor Control Centers	> 200 HP Connected	Any	
	Medium-Voltage Motor Control Centers	Any	Any	
7.17	**Adjustable Speed Drive Systems**	> 50 HP Rating	Any	
7.18	**Direct-Current Systems**			
	Flooded Cell Lead-Acid Batteries	>100 V or 1 kWh storage	Any	
	Valve-Regulated Lead-Acid Batteries	>100 V or 1 kWh storage	Any	
	Battery Chargers	>100 V or 1 kW output	Any	
7.19	**Surge Arresters**			
	Low-Voltage	> 800 A Circuit	Any	
	Medium- and High-Voltage	Any	Any	2
7.20	**Capacitors and Reactors**			
	Low-Voltage	>50 kVAR Rating	Any	
	Medium- and High-Voltage	Any	Any	2
7.21	**Outdoor Bus Structures**	Any	Any	
7.22a	**Emergency Systems (Level 1)**			
	Engine-Generator and Transfer Switch(es)	Any	Any	
	Uninterruptible Power Systems	Any	Any	
7.22b	**Standby Systems (Level 2)**			

NETA ATS Clause	System or Component Type (Note 1)	Threshold for ML-4 or ML-3 SSC (Note 4)	Threshold for ML-2 or ML-1 SSC	Notes
	Engine-Generator and Transfer Switch(es)	>150 kW Generator	Any	
	Uninterruptible Power Systems	>150 kW Rating	Any	
7.23	**Communications Systems (Reserved)**			
7.24	**Automatic Circuit Reclosers and Line Sectionalizers**			
	Vacuum (Medium-Voltage)	Any	Any	2
	Oil (Medium-Voltage)	Any	Any	2
7.25	**Fiber Optic Cables (Used for Power Systems)**	Any	Any	

Notes:

1 Thresholds for formal electrical acceptance inspection and testing apply on a system-by-system basis.

2 LANL Utilities & Infrastructure will inspect and test medium- and high-voltage utility equipment . Other medium-voltage systems serving large motors or other utilization equipment that are part of the facility shall be inspected and tested by the Electrical Testing Agency.

3 Building service revenue-type metering apparatus and associated instrument transformers are inspected and tested by LANL Utilities & Infrastructure. Other metering apparatus or instrument transformers that are part of the facility shall be inspected and tested by the Electrical Testing Agency if the threshold is exceeded.

4 For ML-3 systems, the Design Authority may invoke formal electrical acceptance testing for selected electrical systems at lower thresholds than indicated in this table.

C. Perform formal electrical acceptance testing, inspection, and calibration using the services of the LANL Construction Management Division (if qualified) or a qualified independent electrical testing firm.

D. Energize electrical systems only after they have been inspected and tested in accordance with this article and have been inspected and approved by the LANL electrical AHJ.[101]

E. Refer to ESM Chapter 15, Commissioning.

12.0 ADDITIONAL REQUIREMENTS FOR NUCLEAR SAFETY RELATED ML-1 AND 2 ELECTRICAL SYSTEMS (PROGRAMMATIC AND FACILITY)

Note: This Subsection 12.0 applies to new facilities and major modifications (see ESM Chapter 1 Section Z10 definition) – and shall be considered for other modifications. Also, refer to Z10 on Code of Record for implementation schedule and for alternative implementation process (e.g., Variances, etc.)

A. Comply with requirements in DOE O 420.1C *Facility Safety* in the design of nuclear safety related ML-1 and ML-2 electrical structures, systems, and components (SSCs) in Hazard Category 1, 2, and 3 facilities ("safety related" in this subsection).

- *Use the additional guidance provided in DOE G 420.1-1A Nonreactor Nuclear Safety Design for use with DOE O 420.1C Facility Safety (esp. 5.4.14).*[102]
- *Instrumentation, control, and alarm systems are in LANL ESM Chapter 8.*

[101] Refer to LANL P101-13 – *Electrical Safety Program*.(*§2.2.5*)
[102] DOE G 420.1-1A provides an acceptable approach for satisfying the requirements of DOE O 420.1C.

B. For safety-related electrical SSCs, apply as appropriate the IEEE® standards listed in Table D5000-3.[103]

- *NOTE: For LANL personnel, IEEE standards are available here.*
- *Note: Many of the ANSI/IEEE standards, below define requirements for the manufacturing, installation, and testing of commercial reactor Safety-Class 1E electrical systems and components. While these requirements for commercial reactor Safety-Class 1E SSCs may not be directly applicable to nonreactor nuclear facilities, these standards contain useful and significant information that should be considered. Before using these standards, their applicability to the design(s) being considered should be reviewed.[104]*

C. Document the consideration process and the decisions made about the applicability each of the listed IEEE standards and the approach for applying the applicable standards. Submit documentation to ESM Chapter 7 POC for review and approval.[105]

D. The following paragraphs interpret the DOE G 420.1-1A guidance for application at LANL.

E. Use this article along with Chapter 1-General Section Z10, Chapter 10-Hazardous Process, Chapter 12-Nuclear, and other ESM chapters as applicable.

F. Design electrical SSCs to perform safety functions with the reliability required by the DSA:

1. Design **safety-class and other ML-1** electrical SSCs against single-point failure in accordance with the criteria, requirements, and design analysis identified in ANSI/IEEE 379™ *Standard Application of the Single-Failure Criterion to Nuclear Power Generating Safety Systems*.
2. For **safety significant and other ML-2** electrical SSCs, analyze the need for redundant power sources (normal or alternative) on a case-by-case basis. *Redundancy may not be needed for safety-significant electrical power systems if it can be shown that there is sufficient response time to provide an alternative source of electrical power.[106]*

G. Use environmental qualification to ensure that safety-class and safety-significant electrical SSCs can perform all safety functions, as determined by the DSA, with no failure mechanism that could lead to common cause failures under postulated service conditions. Use the requirements for “mild environmental qualification” from IEEE 323™ unless the environment in which the SSC is located changes significantly because of the design basis accident conditions. Qualification for mild environments shall consist of two elements:

1. Ensuring that electrical equipment is selected for application to the specific service conditions based on sound engineering practices and manufacturers’ recommendations.
2. Ensuring that the system documentation includes controls that will preserve the relationship between electrical equipment application and service conditions.

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[103] DOE O 420.1C

[104] Ibid.

[105] Requirement is based on experience from interactions with the Defense Nuclear Facilities Safety Board (DNFSB) and NNSA and perception of their expectations. This can be done with a statement in the Functional and Requirements Document (FRD) indicating that only the IEEE that are listed are those from 420.1C that are applicable and those not listed were considered and are not applicable.

[106] DOE G 420.1-1A *Nonreactor Nuclear Safety Design for use with DOE O 420.1C Facility Safety* Section 5.4.14 *Design of Electrical Systems*.

H. Meet the quality assurance requirements of 10 CFR 830 Subpart A for safety-related electrical SSCs for nuclear facilities.[107] See ESM Chapter 1 Section Z10.

I. Interpret the IEEE® nuclear standards at LANL as follows:

- Substitute “safety class or ML-1 electrical” for “Class 1E.”
- Substitute “facility” for “unit” and/or “station.”
- Substitute “non-reactor nuclear or high hazard facility” for “nuclear power generating station.”
- Substitute “normal power” for “preferred power”.
- Substitute “safety systems” for “reactor trip system.”
- Ignore nuclear-reactor-specific terms such as “reactor transient”, “fuel cladding”, “reactor coolant”,
- Substitute “confinement” for “containment.”

J. IEEE® standards referenced Table D5000-3 but not indicated as required should be considered as guidance in the design of moderate and high hazard SSCs -- and for modifications in existing nuclear facilities that are not “major modification” level.

Table D5000-3 IEEE Standards for Safety Systems

R = Treat as requirement; all others consider as guidance.

List of Standards	**ML-2 and Safety-Significant Systems**	**ML-1 and Safety-Class Systems**
IEEE C37™, *Standards Collection: Circuit Breakers, Switchgear, Substations, and Fuses*	R	R
IEEE 80™, *Guide for Safety in AC Substation Grounding*	R	R
IEEE 141™, *IEEE Recommended Practice for Electric Power Distribution for Industrial Plants*	R	R
IEEE 142™, *IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems*	R	R
IEEE 242™, *IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems*	R	R
IEEE 279™, *IEEE Standard: Criteria for Protection Systems for Nuclear Power Generating Stations*	R	R
IEEE 308™, *Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations*	—	R
IEEE 323™, *Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*	R	R
IEEE 334™, *Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations*	R	R
IEEE 336™, *Standard Installation, Inspection and Testing Requirements for Power, Instrumentation, and Control Equipment at Nuclear Facilities*	R	R
IEEE 338™, *Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems*	—	R

[107] DOE G 420.1-1A, *Nonreactor Nuclear Safety Design for use with DOE O 420.1C Facility Safety* Section 5.1.5 *Quality Assurance*.

List of Standards	ML-2 and Safety-Significant Systems	ML-1 and Safety-Class Systems
ANSI/IEEE 344™, *Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations*	R	R
IEEE 352™, *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems*	R	R
IEEE 379™, *Standard Application of the Single-Failure Criterion to Nuclear Power Generating Safety Systems*	—	R
IEEE 381™, *Standard Criteria for Type Tests of Class 1E Modules Used in Nuclear Power Generating Stations*	—	—
IEEE 382™, *Standard for Qualification of Actuators for Power-Operated Valve Assemblies with Safety-Related Functions for Nuclear Power Plants*	R	R
IEEE 383™, *Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations*	R	R
IEEE 384™, *Standard Criteria for Independence of Class 1E Equipment and Circuits*	—	R
IEEE 387™, *IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations*	R	R
IEEE 399™, *IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis*	R	R
IEEE 420™, *Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations*	R	R
IEEE 446™, *IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications*	R	—
IEEE 450™, *Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*	R	R
IEEE 484™, *Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*	R	R
IEEE 493™, *IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems*	R	R
IEEE 535™, *Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations*	R	R
IEEE 577™, *Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Power Generating Stations*	R	R
IEEE 603™, *Standard Criteria for Safety Systems for Nuclear Power Generating Stations*	R	R
IEEE 627™, *IEEE Standard for Qualification of Equipment Used in Nuclear Facilities*	R	R
IEEE 628™, *Standard Criteria for the Design, Installation, and Qualification of Raceway Systems for Class 1E Circuits for Nuclear Power Generating Stations*	R	R
IEEE 649™, *Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations*	R	R
IEEE 650™, *Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations*	R	R

List of Standards	ML-2 and Safety-Significant Systems	ML-1 and Safety-Class Systems
IEEE 690™, *Standard for the Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Systems*	—	—
IEEE 741™, *Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations*	—	—
IEEE 833™, *Recommended Practice for the Protection of Electric Equipment in Nuclear Power Generating Stations from Water Hazards*	R	R
IEEE 934™, *Standard Requirements for Replacement Parts for Class 1E Equipment in Nuclear Power Generating Stations*	—	—
IEEE 944™, *Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations*	—	—
IEEE 946™, *Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations*	R	R

K. Provide an emergency communications system for any facility that must respond to internal or external emergency events to control acute exposures to radiation in excess of the annual exposure limits or to hazardous materials in excess of Permissible Exposure Limits, or to preclude multiple fatalities.[108]

1. Emergency communications system must meet NFPA 72 Chapter 24 requirements for materials, installation, and performance.[109]
2. Follow the recommendations in Appendix A of NFPA 72.
3. *Guidance: The building fire alarm system may be used as the emergency evacuation annunciation system for new and existing facilities. See also Section D5030, Communications*.

[108] DOE G 420.1-1A §5.4.8
[109] DOE O 420.1C and NFPA 72 Chapter 24