TABLE OF CONTENTS

This mandatory functional series document is available online at http://engstandards.lanl.gov.
It derives from P342, Engineering Standards, which is issued under the Conduct of Engineering program 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 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 Powell, *FWO-DECS*	Gurinder Grewal, *FWO-DO*
2	10/27/06	Administrative changes only. Organization and contract reference updates for LANS; 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 CoE IMP 341. Spec number/title updates. Other admin 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 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.	David Powell, *ES-DE*	Larry Goen, *CENG-OFF*

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	Added Article 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*
8	07/24/19	Revised applicability; made NECA and NETA reference-only; made NEC edition per Ch 16; revised calculation/software requirements and added new App A on software. Revised future load growth percentage, equipment location, and labeling and marking. Eliminated seismic controls, demolition, and acceptance testing. Streamlined some content where addressed in Ch 1, 19, CAD Manual, NEC, P101-13, or specs.	Eric Stromberg, *ES-EPD*	James Streit, *ES-DO*

D5000 GENERAL ELECTRICAL REQUIREMENTS

1.0 INTRODUCTION

1.1 Chapter Purpose

A. The purpose of this chapter of the LANL Engineering Standards Manual (ESM) is to provide electrical systems that are reasonably free from hazard AND are efficient, convenient, and adequate for good service, maintainable, standardized, and adequate for future expansion.

1.2 Chapter Applicability

A. This Chapter applies to:

1. All new electrical installations.
2. The modified components of renovations, replacements, modifications, or maintenance.[1]

B. This Chapter does not apply to:

1. Existing components of existing installations.

1.3 General Requirements

A. 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.

B. 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 prefaced with wording identifying it as guidance or recommended.

C. Figure D5000-1 illustrates the relationship of ESM Chapter 7 to Chapter 1 and the organization and location of the electrical standards.

[1] Disconnecting a device or piece of equipment from a distribution system and then reconnecting the device or piece of equipment does not constitute modification of the distribution system. Therefore, it doesn't require the distribution system to be updated to the new Codes and Standards.

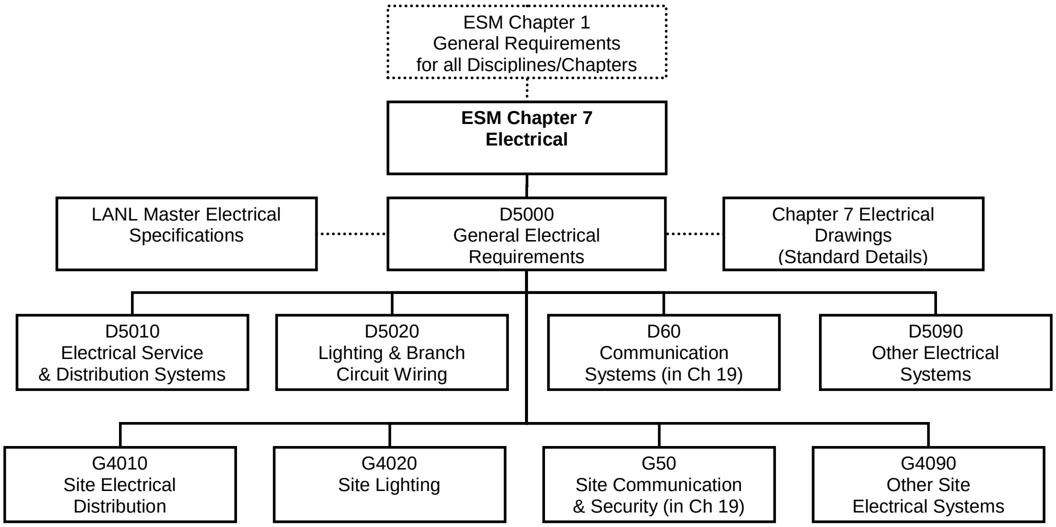

Figure D5000-1, Electrical Standards Organization/Location

1.4 Definitions

A. Definitions of terms in Chapter 7 are the same as those in the *National Electrical Code®*[2].

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

C. The following are definitions of terms, abbreviations, and acronyms that are unique to ESM Chapter 7:

Low voltage	A class of nominal system voltages less than 1000 V.[3]
Medium voltage	A class of nominal system voltages equal to or greater than 1000 V but not exceeding 35,000 V.
High voltage	A class of nominal system voltages greater than 35,000 V, up to 230,000 V.

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

1. Headings in this chapter followed by "Programmatic and Facility" indicate that material shall be complied with by all of LANL, including R&D and programs.
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 consensus standards (e.g., NEMA, ANSI) or be Nationally Recognized Testing Laboratory (NRTL) listed equipment and material that is used in accordance*

[2] Refer to *NEC®* Article 100.
[3] Refer to IEEE Std 1585-2002 and 1623-2004

with its listing. In the case of departure from equipment listing[4] *criteria, or when equipment is not available as NRTL-listed, then the situation should be reviewed for the purpose by the LANL Electrical AHJ and the using organization's Electrical Safety Officer. Exception: Equipment 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[5] of the latest, LANL-adopted, edition of each code and standard listed below or referenced elsewhere in this Chapter. Codes, Standards, or References listed below that are recommended practices are not required or mandatory.

B. 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.

C. Where the *NEC®* uses terms similar to "by special permission," obtain written permission from the LANL Electrical AHJ[6].

2.2 Contractual Requirements

A. Title 10 CFR 851, *Worker Safety and Health Program*.

B. The State of New Mexico Electrical Code that is aligned with the currently adopted NEC; see the New Mexico Administrative Code (NMAC), Title 14 Chapter 10. [7]

C. Required DOE Orders and directives contained in the current LANL contract (e.g., Part III – Section J Appendix B).

D. Refer to ESM Ch 1 Section Z10 "Codes and Standards" heading for additional detail and links.

2.3 General Requirements

A. Design, material, equipment, and installation shall comply with the applicable portions[8] of the latest, LANL-adopted, edition of each code and standard listed below or referenced elsewhere in this Chapter. Codes, Standards, or References listed below that are recommended practices are not required or mandatory.

B. 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.

C. Where the *NEC®* uses terms similar to "by special permission," obtain written permission from the LANL Electrical AHJ[9].

---

[4] For UL listed equipment, the UL White Book is to be used as the source for determining compliance with the listing; other NRTLs may follow that or their own listing.
[5] Applicability is determined by the standards POC
[6] 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.
[7] LANL's Contract requires that work at LANL be performed in compliance with applicable State laws and regulations.
[8] Applicability is determined by the standards POC
[9] 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.

2.4 LANL Documents http://engstandards.lanl.gov/

A. LANL Engineering Standards Manual (ESM) (STD-342-100): Includes this document and other applicable chapters and sections.

B. Drawings (STD-342-400)

1. Standard Detail Drawings (numbered ST-XXXXX-X) referenced in the ESM in regular type are to be considered templates that may 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 contact the ESM POC for that detail for concurrence.

2. 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.

C. LANL Master Specifications (STD-342-200): Provides templates for the preparation of project specific construction specifications.

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

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

2.5 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*

2.6 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*.

2.7 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 mandated by the LANL Prime Contract.

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

2.8 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.

2.9 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.

2.10 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*.

2.11 NECA (National Electrical Contractors Association)[10] – The following are not mandatory unless specifically cited elsewhere in LANL Standards.

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

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

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)

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)

2.12 NETA (InterNational Electrical Testing Association, Inc.) – The following are not mandatory unless specifically cited elsewhere in the LANL Standards.

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)

2.13 NFPA (National Fire Protection Association)

A. NFPA 70™, *National Electrical Code®* (*NEC®*)[11]

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

C. NFPA 101®, Life Safety Code®

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

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; email electrical_utilities@lanl.gov.

B. Telecommunications: LANL Network and Infrastructure Engineering (NIE); also see ESM Chapter 18, *Secure Communications* and 19, *Communications*.

3.3 Special Systems

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

A. Fire Alarm, Life Safety: LANL Fire Protection; also, see ESM Chapter 2, *Fire Protection*.

[11] NFPA 70-2017 is incorporated by reference by 10CFR851. A later version may be adopted by LANL if the later version is referenced by PD100, the Worker Safety and Health Plan. PD100 references P101-13 for electrical safety, so adoption of the 2020 or later edition would be through a contractual mandate revision and reference change in PD100, P101-13. For the purposes of design, however, engineering will usually start using a new version before formal adoption by the laboratory. The version used by engineering is reflected in ESM Chapter 16 Section IBC-GEN Attachment A.

B. 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.

1. Use the following electrical system analysis software, approved in accordance with ESM Chapter 21, as follows:
   - ETAP® is allowed for all projects—and required for nuclear system design/analysis.[12]
   - SKM Power Tools for Windows® may only be used for low-voltage, non-nuclear[13] facility projects.
2. Use the approved 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, and
   - Alterations of existing facilities previously analyzed using the approved software. *Guidance: The Facility Operations Director or Facility Design Authority Representative may direct the Project Manager to analyze and document the entire existing electrical system.*
3. Use the approved software to perform the following preliminary calculations and analysis, using catalog data and assumptions, such as conductor length, conduit material, transformer impedance, and so forth:
   - Voltage drop calculations[14] for all services, for all feeders, and for 100 A and greater branch circuits,
   - Fault current calculations as described in paragraph 4.2.C below,
     - *These will be used for the specifying of equipment.*
   - Coordination studies as described in paragraph 4.2.D below,
   - Arc flash boundary and incident energy calculations as described in paragraph 4.2.E below,
     - *These calculations will be used in the design phase in order to determine if there are any locations where the incident energy exceeds 40 cal/cm^2.*
   - Load flow analysis for systems with parallel paths as described in paragraph 4.2-B below, and
   - See Appendix A for other information that is typically included in the model.

---

[12] ETAP® "nuclear version" meets ASME NQA-1 requirements.
[13] SKM may also be used for determining the incident energy of nuclear facilities for the purpose of PPE selection. In this case, the software is not being used to control, or determine the parameters of, a safety system.
[14] Refer to LANL ESM Chapter 7 Section D5010 (*paragraph 2.10*) and Section D5020 (*paragraph 2.0*) for voltage drop criteria.

4. Create a list of all information needed to update the model, once construction is completed. Provide this list as a part of the Post Modification Testing (PMT) or commissioning documents. The requested information shall be returned to engineering in the form of a submittal by the work provider or subcontractor. This information will include, but not be limited to, the following:
   - Conductor lengths
   - Conductor sizes, only if different than on drawings
   - Overcurrent device types (manufacturer and model)
   - Overcurrent device settings (e.g., high range/low range, long time setting, short time setting, instantaneous, ground protection)
   - Transformer impedances and X/R ratios
   - Panel and Overcurrent AIC ratings
5. Update the model with the field verified information. After the model has been updated with the final information, calculate incident energies and use to print the labels needed for application to panels in the field.

   Typically, the labels will be applied by the subcontractor that is responsible for the electrical installation.
6. The single-line diagram generated using the approved electrical system analysis software does not replace the construction design "contract documents" single-line diagram described in paragraph 4.3-F below.
   - 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 CAD Standards Manual.*
     - *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-F below to the extent practical.*
     - *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-F and the LANL CAD Standards Manual.*

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

1. Use diversity factors only as specifically permitted by the NEC®, other recognized national standards, or with approval from the Electrical Standards POC.
2. In the load calculation, address non-coincident loads in accordance with Section 220.60 of the *NEC®*. *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).*[15]

[15] Incorporates VAR-2010-13 on coincident load calculation.

3. Address all contingency conditions (e.g., operating a double-ended service/system from either, or both, of the sources) to ensure adequacy of equipment.
4. 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.
5. Include the effects of harmonics, if applicable, when selecting service and/or feeder components.
6. Include in feeders, services, and associated distribution equipment the capability for future load growth as described in article 5.1 below.

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

1. For low and medium voltage systems, obtain fault duty information from the LANL electrical utility distribution engineer by sending an email to faultcurrent@lanl.gov.[16]
2. Include in the calculations the effects of motors and on-site sources such as engine-generator systems.
3. Address all contingency conditions (e.g., operating a double-ended service/system from either, or both, of the sources) to ensure adequate bracing and interrupting rating of components.
Note: In some cases, a Tiebreaker closed transfer might result in incident energies that exceed the level of the equipment. This might be acceptable, with the approval of the electrical standards POC, if the switching times are short and the switching is possible by remote operation.

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 construction, update the coordination study to show the actual equipment; determine final trip unit settings.

1. Perform coordination studies for any of the following special systems[17]:
   - ML-1, ML-2, and other vital safety system electrical power systems
   - Emergency power systems[18]
   - Legally-required standby power systems[19]
   - Critical operations power systems (COPS).[20]

   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.
2. Address all contingency conditions (e.g., operating a double-ended service/system from either of the sources) to ensure selective coordination.

---

[16] Change to actual fault current rather than infinite bus incorporates and supersedes VAR-10149.
[17] Coordination study is warranted for the systems enumerated 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 NEC Section 700.28.
[19] Refer to NEC Section 701.27.
[20] Refer to NEC Article 708.

3. If possible, use the selective coordination time interval guidelines in Table D5000-B1 of Appendix B of this document.

4. 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)
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.)	

E. Perform arc-flash hazard analysis using procedures outlined in IEEE Std 1584™.[21]

Note: *An arc flash hazard analysis is not required for equipment operating at 208Y/120V volts if it is fed by a transformer that is smaller than 125 kVA.*[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.

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 1.2 cal/cm^2.

4. Refer to Article 7.2 of this document for arc-flash warning label requirements.

5. In the incident energy calculations, tabulate the following calculated information for each location:

Equipment ID Code	Special conditions (e.g., circuit breaker in an energy-reducing maintenance mode)
System voltage (e.g., 480Y/277 V, 208Y/120 V, 120/240 V)	Arc flash boundary in inches
Maximum available bolted-fault current[23]	Incident energy in cal/cm^2
Arcing current	Working distance[24] selected from IEEE Std 1584™ based on the equipment type

[21] 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.
[22] Refer to IEEE Std 1584a §4.2.
[23] 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.
[24] 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.

Overcurrent protective device clearing time at the arcing current	Hazard/risk category number from NFPA 70E for operations with doors closed and covers on[25]

4.3 Drawings

A. Provide a construction design-drawing package as required to meet project-specific requirements.

B. Demolition: Provide drawings indicating electrical demolition required for the project. Clearly indicate what is to be removed, what is to remain, 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.[26]

C. Use Electrical Drawing D5000-1 for electrical symbols. Delete the general notes on projects that have construction specifications if the information in the general notes is covered in the specifications.

D. 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, receptacles, equipment connections, 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.

E. Electrical Single-line Diagrams ("One-lines"):

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

2. Use Electrical Example Drawing D5000-2 as a template for the single-line diagram. 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. Appendix A is a list of information that shall be included in single-line diagrams, as applicable.

LANL Electrical Example Drawing templates are here.

F. Other templates: Use and edit the following LANL Electrical Example Drawing templates to meet project specific requirements.

[25] 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.
[26] Lessons learned from LANL SM-1321/287 Syllac Building demolition 13.2 kV near miss (ALO-LA-LANL-WASTEMGT-2003-0006).

Template	Project Usage
D5000	circuit designations and electrical equipment identification
D5010	grounding diagram
D5010-2	isolated ground system diagram(s) (if present)
D5010-3, -4, and -5 as applicable	electrical metering
D5020	motor control diagrams (one control diagram may be used to represent more than one identical motor control connection)

4.4 Construction Specifications

A. Provide a specification package, if necessary, to meet project specific requirements. The need for a specification set as well as composition, organization, and editing requirements is addressed by ESM Chapter 1 Section Z10 Att. F – Specifications.

Guidance: Specification packages are often not necessary when the salient information can be included on the drawings, and the project is such that adherence to national codes and standards is sufficient.

B. Utilize the LANL Master Specifications (STD-342-200) where applicable.

C. 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*®.

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 20 percent of the initial design. With the approval of the Electrical Standards POC, facilities may be built with no provision for future growth.

5.2 For service renovations to existing facilities, work with the facility owner to establish how much future capacity is practical and should be provided for in the new equipment.

5.3 Sustainable Design and Energy Conservation

Refer to ESM Chapter 14, *Sustainable Design.*

5.4 Lightning

Refer to ESM Chapter 7 Section D5090 for lightning protection system requirements.

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.[27] *The reduced air density at this elevation impedes equipment cooling and reduces the electrical insulation properties of air.*[28]
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., if in direct sunlight.

5.7 Power Quality

A. Use the highest practical service, distribution, and utilization voltages.

B. Large electrical loads such as HVAC equipment, elevators, and process loads should be segregated on separate feeders from sensitive loads.

C. Step-down transformers and associated panelboards should be located physically close to the loads that they supply.

5.8 Power System Harmonic Limits

A. Limit harmonic currents at the point of service for each building to comply with IEEE Std 519™.[29]

5.9 Power System Availability

A. 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.[30]

5.10 Overcurrent Protection

A. Circuit breakers are preferred due to the ability to quickly restore service without spare parts.

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

C. Use fuses where required by manufacturer.
Note: Many manufacturers of electronic devices, such as VFDs, require the upstream overcurrent protection to be fuses instead of circuit breakers. Likewise, if the nameplate on the equipment states "Fuse Size," fuses must be used. If the nameplate indicates "MOP," for maximum overcurrent protection, either fuses or circuit breakers may be used.

---

[27] 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.

[28] 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.

[29] 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.

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

D. Consider fuses for the following:

1. Temporary installations
2. Replacements for no longer available circuit breakers in existing facilities
3. Fused disconnects for small items like lighting transformers
4. Cost effectiveness of fuses instead of circuit breakers; this includes the ongoing cost of the required periodic maintenance of circuit breakers.

5.11 Selective Coordination

A. Provide selectively coordinated overcurrent protection for:

1. Electrical systems that have been designated as Safety Class or Safety Significant
2. Emergency Systems
3. Legally required standby systems
4. Systems greater than 800 amperes.

B. Ground Fault Protection of Equipment (GFPE) must be set higher than the largest downstream overcurrent device in order to maintain selective coordination. Include GFPE settings on, or reference their location from, the system one-line.

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.[31] Acceptable Nationally Recognized Testing Laboratories include[32]:

1. Underwriters Laboratories, Inc. (UL)[33]
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/
Note: equipment that does not contain a voltage greater than 50 volts AC or 100 volts DC does not need to be listed by a NRTL unless otherwise required by the NEC.

C. Where electrical equipment is not labeled, listed, or recognized by any NRTL, equipment must be approved in accordance with the LANL AHJ.

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.

---

[31] 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.

[32] 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.

[33] UL listing information has historically been complied in the UL White book (over 1100 pages). That same information and more is also available in the real-time, online UL Product Spec. The UL White Book or Product Spec is also a good resource in determining "listing violations." If it is not a violation of the listing information in the White Book, it should not be considered a "listing violation." Note: UL White Book is not the IEEE White Book (aka IEEE STD 602).

5.13 Personnel Safety

A. Design systems with the goal of having the incident energy, at any given point, 40 cal/cm^2 or less. If energy levels exceed this value, contact the Electrical Standards POC for guidance as to how to proceed.

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. Note: Arc-resistant equipment does not mitigate the hazards associated with zero voltage checks*
2. *NFPA 70E compliant permanently mounted electrical safety devices for zero voltage checks*
3. *Remote racking (insertion or removal) of circuit breakers*
4. *Remote opening and closing of switching devices*
5. *Current limitation obtained with current-limiting reactors*
6. *Insulated or isolated bus in switchboards and switchgear assemblies.*
7. *Compartmentalized main breakers*
8. *Transformers with internal differential relaying for fault mitigation*
9. *Use of multiple transformers to keep the incident energy manageable. Note: Transformers above 500 kVA, at 480 volts, typically exceed 40 cal/cm^2.*

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.[34]

B. Locate generators such that exhaust does not enter occupied spaces through outside air intakes.
Note: generator exhaust can contain burning carbon, especially when under load after a period of non-loaded use. This, along with prevailing winds, should be considered when determining location of generator.

C. *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 supplied from existing equipment.[35] Each electrical room shall have lockable door(s).

B. 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.

---

[34] *NEC®* Article 110 establishes minimum working clearances and dedicated spaces for electrical equipment

[35] Dedicated electrical rooms make it more likely that LANL will remain in compliance with *NEC®* Article 110.

C. *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, production buildings, or warehouses.*

D. *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.*

E. *In existing buildings where no other suitable location is available, and with the consent of the LANL Electrical Authority Having Jurisdiction, panelboards may be recess mounted in corridors.*

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

G. 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.[36]

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

1. As close as practical to the center of the loads such that voltage drop to loads can be minimized[37]
2. Electric rooms or spaces vertically aligned in multi-story buildings.[38]
3. Branch circuit panelboards on the same floor as the loads they serve.[39]

I. For indoor installations in new equipment rooms, 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.[40] For indoor installations, in new equipment rooms, 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.[41]

J. 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)[42], and 3'-0″ at ends of switchgear lineups after providing space for future expansion.[43] For indoor installations of low-voltage, switchgear, provide access aisles at least 4'-6″ in front[44], 3′-6″ in rear[45], and 3'-0″ at ends of low-voltage equipment after providing space for

---

36 Refer to Clause 1.15 in IEEE Std 241-1990™ for additional building access and loading information.
37 Voltage drop criteria are mandatory provisions in ASHRAE/IESNA Standard 90.1-1999. Reworded to incorporate variance on this topic.
38 Vertical alignment facilitates installing economical feeders, sharing grounding electrode bars, transformers, etc.
39 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.
40 A 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.
41 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.
42 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.
43 Based on medium-voltage switchgear manufacturers’ recommendations.
44 Based on switchgear manufacturer’s recommendations based on removal/insertion of draw-out circuit breakers using a top-mounted breaker hoist.
45 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.

future expansion. Provide greater access space if recommended by the manufacturer or if required to fully open access doors.

K. 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, unless allowed by the *NEC®* and approved by the electrical standards point of contact. For work in existing structures, follow Article 110 in the *NEC®*.

L. Provide at least 30 footcandles[46] general illumination on the vertical surfaces of the electrical equipment. Provide similar illumination at the rear of freestanding equipment. Provide battery-backed-up illumination to avoid safety problems and to facilitate trouble-shooting during a power outage.[47]

M. Provide at least one general-purpose receptacle in each electric room or space for power tools and supplemental lighting.[48]

N. 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).[49] If possible, locate electrical service equipment in above-grade areas not subject to flooding. If electrical service equipment must be installed below grade, provide redundant sump pumps supplied from a reliable standby power system.[50] *Events that could cause flooding include the rupture of fire sprinkler pipe, HVAC pipe, and so forth.*

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

P. Do not install electrical distribution equipment (e.g., panelboards, switchboards, transformers), in corridors, stairways, or janitor closets without written permission from the LANL Electrical AHJ.

1. Provide a prominent sign on electrical room doors with the following message:[51]

NOTICE
ELECTRICAL ROOM
NO STORAGE PERMITTED

Approximate size: 2” x 5”

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, unless otherwise amended in a project-specific Specification.

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

---

[46] Lighting Design Guide in Chapter 10 of the Ninth Edition of the IESNA Lighting Handbook recommends 30 footcandles illuminance for industrial maintenance operations.
[47] Refer to maintenance illumination recommendations in clause 9.2.3 of IEEE Std 902-1996
[48] *NEC®* Article 210.50(B).
[49] Electrical room temperature limits from IEEE C57.12.00, IEEE C57.12.01, IEEE C37.20.1, and IEEE C37.20.3.
[50] Recommended practice from Chapter 3 of NECA 400-1998, adapted to medium-voltage equipment.
[51] Based on tendency to use as storage spaces.

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

1. Shock hazard warning labels
2. Component identification tags
3. Equipment nameplates

D. Provide the following, after as-built information has been received:

1. Incident energy values for arc-flash labels

7.2 Arc-Flash and Shock Hazard Warning Labels

A. Arc-flash and shock hazard-warning labels shall comply with ANSI Z535.4 and be installed on switchgear, switchboards, transformers, motor control centers, panelboards, and industrial control panels.[52]

B. Use the appropriate label design from LMS Section 26 0553. Provide the following information on each label, as applicable:

1. Arc-Flash Boundary (inches) calculated in accordance with IEEE Std 1584™.
2. Incident energy (cal/sq cm) calculated in accordance with IEEE Std 1584™.
3. Working distance (inches) selected from IEEE Std 1584™ 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.*

4. Limited approach boundary as determined from NFPA 70E.
5. Restricted approach boundary as determined from NFPA 70E.
6. Equipment ID code based on Drawings and including TA number, building number, and system identifier (e.g., 03410-EP-PP-A).
7. Maximum available fault current (e.g., 21,650 A).
8. Date that the arc-flash hazard analysis and short-circuit current calculation was performed.

C. Refer to LMS Section 26 0553 for additional requirements for shock hazard and arc flash labelling.

7.3 Component Identification

Identify electrical equipment on drawings and tags in accordance with ESM Chapter 1, Section 200, *Equipment Numbering and Labeling*.[53]

7.4 Component Identification Tags

Install electrical component identification tags to identify electrical equipment using the System Designation, Equipment Identification, the Tech Area Number, and the Building Number.[54]

7.5 Emergency System Identification

Note: In this context, the word "Emergency" is according to the definition in the NFPA. Most back-up systems at LANL are "Optional Standby" systems and not "Emergency."

[52] Refer to Section 130.5(H) of NFPA 70E
[53] Ref. *NEC®* Articles 110.21 and 110.22.
[54] The component identification tag uniquely identifies the equipment item.

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.[55]

7.6 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 supplied, or being supplied from; location of equipment supplied or being supplied from; and the nominal system voltage (e.g., 480Y/277 V, 208Y/120V).[56].
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.[57]
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.

7.7 Receptacle and Light Switch Labels

Install labels on receptacles and light switches indicating circuit number and panelboard.[58] *Note: it is acceptable to label the cover plate of the receptacles and/or switches.*

7.8 Voltage Markers

Install voltage markers on electrical equipment (e.g., switchgear, transformers, motor control centers, panelboards, starters, safety switches, and cabinets).[59]

7.9 Warning Signs

Install warning signs that conform to ANSI Z535 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, and cabinets).[60]

7.10 Wire Markers

Install wire markers on power, control, instrumentation, fire alarm, and communications circuit wires.[61]

7.11 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, and motor control centers. 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.[62]

---

[55] NEC® Section 700.9(A) requires identification of components of an emergency power system.
[56] Category I nameplates are essential to the efficient implementation of the LANL lock-out/tag-out program.
[57] NFPA 70E Section 205.8 requires safety-related operating or maintenance instructions be posted on equipment.
[58] Labeling of outlets and switches to indicate circuit is a long-standing practice at LANL to facilitate maintenance and lock-out/tag-out.
[59] Voltage identification requirement in the New Mexico State Electrical Code for 480-volt equipment is extended to 208 and 240-volt equipment.
[60] NEC Section 110.27 requirement for warning signs on entrances to rooms or other guarded locations is extended to include electrical equipment enclosures.
[61] Labeling of conductors is a long-standing practice at LANL to facilitate trouble-shooting of systems.

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. LANL is in a Seismic Design Category D area.[63]

B. Electrical Equipment this is in, or attached to, a building must be installed with seismic design considerations, unless the structural point of contact has deemed otherwise.

C. At time of writing[64], the following exemptions existed:

Equipment exemptions, for equipment that is positively attached to the structure:

- Equipment that satisfies all of the following:
  - 400 pounds or less
  - has a center of gravity not more than 4 feet above the floor
  - has in importance factor equal to 1.0
- Positively attached equipment that weighs 20 pounds or less

Raceway exemptions:

- Raceways that are Trade Size 2 or less
- Raceways that are positively attached and are supported within 12 inches of the structure
  - Except for rod type hangers or trapeze systems

Other raceway considerations:

- Rod-type hangers
  - Where rod is less than or equal to 12 inches in length, a swivel must be used to provide flexibility
  - Where rod is greater than 12 inches, a seismic design is required
- Trapeze installations
  - Where trapeze, of any length, supports systems that are more than 10 pounds per foot, a seismic design is required.
  - Where trapeze, of any length, supports systems that are 10 pounds per foot or less, the trapeze is exempt from seismic considerations.

D. Clearly identify electrical components that must remain in position, must contain internal parts, or remain operable following a design seismic event.

E. Refer to the following documents for additional requirements:

- LANL ESM Chapter 5, *Structural*
- LANL Seismic Spec-Editing Flowchart and Guides (linked from Master Specs page, directly here).
- LMS Section 26 0529, *Hangers and Supports for Electrical Systems*
- LMS Section 26 0548.16, *Seismic Controls for Electrical Systems*
- The heading "Additional Requirements for Safety-Related Electrical Systems" in this document for special requirements and guidance.

---

62 Marking of the *NEC®* required clear space at electrical equipment helps keep facility users from using these areas for storage.

63 Refer to ASCE 7 Chapter 15 and LANL ESM Chapter 5 for latest applicable seismic design criteria. The need for programmatic equipment restraint is currently addressed in ESM Ch 16 IBC-GEN, Table IBC-GEN-1.

64 Per ASCE 7-2010, Ch 13.

9.0 RODENT-PROOFING

A. Specify and install outdoor low-voltage and medium-voltage equipment to be rodent-proof with maximum 1/4 inch[65] 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.*[66]

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.[66]

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. Where indicated on drawings, 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.**[67]**
Guidance: Abandoned wiring and raceways can result from actions that include the following:

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

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

- *The system is in a radiological contaminated area and ALARA precludes the removal. 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.*
- *The building, or structure, is slated for demolition and it does not make economic sense to remove abandoned equipment*
- *Removal is not feasible due to hazards, construction methods, or restricted access*
- *Removal of abandoned conductors may damage conductors that must remain operational*

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

C. Restore the original fire rating of floors, walls, and ceilings after electrical demolition.[68]

D. Refer to LMS Section 02 4115, *Electrical Demolition*, and ESM Chapter 16 IBC-GEN.

---

[65] 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.
[66] Refer to "Rodent Exclusion Techniques" pamphlet published by the National Park Service in 1997.
[67] 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.
[68] The logic in *NEC®* Section 300.21 for preventing the spread of fire and products of combustion is extended from new construction to demolition.

11.0 ACCEPTANCE TESTING

A. Perform acceptance testing, inspections, function tests, and calibration to ensure 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 D5000-1 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.[69]

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.[70]
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 inspections in accordance with LMS Section 26 0813, Electrical Acceptance Testing[71] using the current edition of NETA ATS, *Acceptance Testing Specification*.[72]
3. *For ML-3 systems, the design may invoke formal electrical acceptance testing for selected electrical systems at lower thresholds than indicated in Table D5000-1.*
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.*

---

[69] This graded approach for electrical acceptance testing is based on the safety design criteria (using ML) 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 referenced as a code for both Safety-Class and Safety-Significant (ML-1 and ML-2) electrical systems in DOE G 420.1-1, 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.

[70] Refer to the issued specifications on the project.

[71] LANL Master Specifications Section 26 0813–*Electrical Acceptance Testing* indicates minimum qualifications for Electrical Testing Agencies and test technicians using an ML-based graded approach.

[72] *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.

Table D5000-1 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
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	

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
	Low-Voltage Motor Control Centers	> 200 HP Connected	Any	
	Medium-Voltage Motor Control Centers	Any	Any	
7.17	**Adjustable Speed Drive Systems**	> 100 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**			
	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)**			
	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 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 may invoke formal electrical acceptance testing for selected electrical systems at lower thresholds than indicated in this table.

C. Perform formal electrical acceptance testing and inspection using the services of the LANL Startup Group (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.[73]

E. Refer to ESM Chapter 15, *Commissioning*.

12.0 ADDITIONAL REQUIREMENTS FOR ML-1 AND ML-2 ELECTRICAL SYSTEMS

A. Design electrical SSCs to perform safety functions with the reliability required by the safety analysis:

1. Design **safety-class (SC) and other ML-1** electrical SSCs against single-point failure in accordance with the criteria, requirements, and design analysis identified in IEEE 379™, *Standard Application of the Single-Failure Criterion to Nuclear Power Generating Safety Systems*.[74]
2. For **safety significant (SS) 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.*[75]

B. For facilities subject to DOE O 420.1C *Facility Safety*, comply with its requirements for the design of nuclear safety related electrical structures, systems, and components (SSCs) for Hazard Category 1, 2, and 3 facilities.

- *Use the additional guidance provided in DOE G 420.1-1A Nonreactor Nuclear Safety Design for use with DOE O 420.1C Facility Safety.*[76]
- *DOE-STD-1027 defines Hazard Category 1 facilities as "Category A" reactors, which are not anticipated at LANL.*
- *Instrumentation, control, and alarm systems are in LANL ESM Chapter 8.*

C. Use environmental qualification to ensure that safety-class and safety-significant electrical SSCs can perform all safety functions, as determined by the safety analysis, 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.[77] 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.

D. Use this article along with Chapter 1–General Section Z10, Chapter 10–Hazardous Processes, and Chapter 12–Nuclear and other ESM chapters as applicable.

E. Meet the quality assurance requirements of 10 CFR 830 Subpart A for safety-related electrical SSCs for nuclear facilities. The procurement of components will in most cases be 'off-the-shelf' and should follow the procurement process specified in the quality assurance program. For facilities that are required to meet the requirements of NQA-1, this should include the Commercial Grade Dedication (CGD) process requirements specified in NQA-1. *A CGD*

[73] Refer to LANL P101-13 Electrical Safety Program (Chapter 2)
[74] IEEE 379 is invoked by DOE O 420.1C Chg 2 for new/major mods; otherwise per DOE-STD-1189 process.
[75] From DOE G 420.1-1A Section 5.4.14 *Design of Electrical Systems*.
[76] DOE G 420.1-1A *Nonreactor Nuclear Safety Design for use with DOE O 420.1C Facility Safety,* provides an acceptable approach for satisfying the requirements of DOE O 420.1C.
[77] IEEE is invoked by DOE O 420.1C Chg 2 for new/major mods; otherwise per DOE-STD-1189 process.

process takes time to develop and implement; therefore, at the earliest possible stage, project personnel should establish a qualified CGD process if it will be used for the project.[78]

F. For safety-related electrical SSCs, follow as applicable the IEEE® standards listed in Table D5000-2.

- *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.*[79]

G. 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.[80]

H. The following guidance is provided to assist in the interpretation and application of the IEEE® nuclear standards listed in Table D5000-2 to LANL non-reactor nuclear facilities:

- 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."

I. *Other IEEE® standards referenced in Table D5000-2, but not indicated as required, should be considered as guidance in the design of moderate and high hazard, and non-reactor nuclear, facilities.*

Table D5000-2 IEEE Standards for Safety Systems[81]

List of Standards	ML-2	ML-1
This table lists standards that may not have been invoked elsewhere in Chapter 7. These additional standards shall be considered for ML-2, safety-significant, ML-1, and safety-class electrical SSCs, keeping in perspective the applicable use of IEEE standards for the specific application. **R = Treat as requirements; all others consider as guidance.** NOTE: For LANL, IEEE standards are available at http://int.lanl.gov/library/find/standards/index.shtml or https://ieeexplore.ieee.org/browse/standards/collection/ieee		
Hardware		
Applicable NFPA codes and standards	R	R
IES HB-10, *IES Lighting Handbook*	R	R
IEEE C2, *National Electrical Safety Code*	R	R

[78] From DOE G 420.1-1A Section 5.1.5 *Quality Assurance*.
[79] Follows DOE O 420.1C Att 3, 3.b (5).
[80] Requirement based on experience from interactions with the Defense Nuclear Facilities Safety Board (DNFSB) and perception of their expectations.
[81] From 420.1C Chg 2 Att 3, 3.b (5) tables 5 and 6. For facilities not subject to this order, LANL may grant variance to this article so long as consistent with SD330.

List of Standards	ML-2	ML-1
IEEE C37™, *Standards Collection: Power Switchgears, Substations, and Relays,* Standards on switchgear as applicable	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 (IEEE Buff Book)*	R	R
IEEE 279™, *IEEE Standard: Criteria for Protection Systems for Nuclear Power Generating Stations, 1971*	withdrawn[82]	
IEEE 308™, *IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations*	—	R
IEEE 338™, *Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems*	—	R
IEEE 379™, *Standard Application of the Single-Failure Criterion to Nuclear Power Generating Safety Systems*	—	R
IEEE 384™, *IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits*[83]	—	R
IEEE 399™, *IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis (IEEE Brown Book)*	R	R
IEEE 446™, *IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications*	R	—
IEEE 493™, *IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems*	R	R
IEEE 577™, *IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Power Generating Stations*	R	R
Guidance Standards for use as applicable for specific hardware		
IEEE 279™, *IEEE Standard: Criteria for Protection Systems for Nuclear Power Generating Stations*	withdrawn	
IEEE 323™, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*	R	R
IEEE 334™, *IEEE Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations*	R	R
IEEE 336™, *IEEE Recommended Practice for Installation, Inspection and Testing for Class 1E Power, Instrumentation, and Control Equipment at Nuclear Facilities*	R	R
ANSI/IEEE 344™, *IEEE Standard for Seismic Qualification of 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 381™, *Standard Criteria for Type Tests of Class 1E Modules Used in Nuclear Power Generating Stations*	withdrawn	
IEEE 382™, *Standard for Qualification of Safety-Related Actuators for Nuclear Power Generating Stations*	—	—
IEEE 383™, *Standard for Qualifying Electric Cables and Splices for Nuclear Power Generating Stations*	R	R
IEEE 387™, *IEEE Standard Criteria for Diesel Generator Units Applied as Standby Power Supplies for Nuclear Power Generation Stations*	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

[82] Required by 420.1C Chg 1; not required when LANL adopts Chg 2.
[83] IEEE 384 is invoked by 420.1C Chg 2 for new/major mods; otherwise per DOE-STD-1189 process.

List of Standards	ML-2	ML-1
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 Vented Lead Acid Storage Batteries 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™, *IEEE Standard Criteria for the Design, Installation, and Qualification of Raceway Systems for Class 1E Circuits for Nuclear Power Generating Stations*	R	R
IEEE 649™, *IEEE Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations*	R	R
IEEE 650™, *IEEE Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations*	R	R
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 749™, *IEEE Standard Periodic Testing of Diesel- Generator Units Applied as Standby Power Supplies in Nuclear Power Generating Stations*	withdrawn	
IEEE 833™, *IEEE 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*	withdrawn	
IEEE 944™, *Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations*	withdrawn	
IEEE 946™, *Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations*	R	R

J. 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.[84]

1. Emergency communications system must meet NFPA 72 Chapter 24 requirements for materials, installation, and performance.[85]
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 existing facilities. See also ESM Chapter 19* Communications, *Section D60.*

[84] Refer to DOE G 420.1-1 §4.7.
[85] Refer to DOE G 420.1-1 §4.7.3 and NFPA 72 Chapter 24.

13.0 APPENDIX A – SUPPLEMENTARY INFORMATION FOR MODELING AND SINGLE-LINES

Relating to calculations using electrical analysis modelling software (SKM or ETAP) per above Article 4.2 and content of single-lines per Article 4.3 on Drawings.

The following are examples of what might be included in the model used for calculating short circuit values and incident energies:

1. **Utility source(s):** Utility circuit voltage, circuit number(s), available three-phase and single line-to-ground fault currents and associated X/R ratios
2. **Utility power transformer(s)**: Ratings (kVA, primary voltage, secondary voltage, X/R, and percent impedance), cooling methods (e.g., OA/FA)
3. **Supply characteristics:** Service point nominal system voltage (e.g., 480Y/277 V, 208Y/120V, 120/240V), system configurations (wye or delta, grounded or ungrounded), frequency (if other than 60 Hz), short-circuit current (3-phase, RMS symmetrical amperes), arc flash incident energy (cal/cm^2) and working distance (inches).
4. **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.
5. **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.
6. **Discrete protective relays:** Function, use, type, and number. Use device function numbers from IEEE C37.2™.
7. **Service(s) and feeders:** Raceway size, length, and material (Magnetic/ferrous or Non-magnetic/non-ferrous); 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
8. **Surge protective devices:** Indicate surge protective devices for medium-voltage equipment, and low-voltage equipment.
9. **Metering:** Voltmeters, ammeters, kW/kWh meters, test blocks, electronic metering packages.
10. **Potential transformers**: Number, ratio (e.g., 4:1), and overcurrent protection.
11. **Current transformers:** Number, class, and ratio (e.g., 2000:5).
12. **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).
13. **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).
14. **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).

15. **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).
16. **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).
17. **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).
18. **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.
19. **Critical systems:**
    - Indicate nuclear facility critical loads (e.g., safety class or safety significant).
    - Indicate emergency power systems, legally required standby power systems.

14.0 APPENDIX B SELECTIVE COORDINATION TIME INTERVAL GUIDELINES

TABLE D5000-B1, SELECTIVE COORDINATION TIME INTERVAL GUIDELINES

Upstream/Downstream Overcurrent Device Coordination	INDUCTION RELAYS	SOLID-STATE RELAYS
1. RELAY-TO-DOWNSTREAM RELAY		
CB opening time (5 cycles)	0.083	0.083
Relay over-travel	0.100	0.000
Safety Margin	0.200	0.200
Minimum time interval (seconds)*	0.383	0.283
2. RELAY-TO-DOWNSTREAM RELAY WITH INSTANTANEOUS UNIT		
CB opening time (5 cycles)	0.083	0.083
Relay over-travel	0.100	0.000
Safety Margin	0.100	0.100
Minimum time interval (seconds)*	0.283	0.183
3. RELAY-TO-DOWNSTREAM LOW VOLTAGE CIRCUIT BREAKER		
Relay over-travel	0.100	0.000
Safety Margin	0.100	0.100
Minimum time interval (seconds)*	0.200	0.100
4. RELAY-TO-DOWNSTREAM MEDIUM VOLTAGE FUSE		
Relay over-travel	0.100	0.000
Safety Margin	0.100	0.100
Minimum time interval (seconds*) (to total clearing time curve)	0.200	0.100
5. RELAY-TO-DOWNSTREAM LOW VOLTAGE FUSE		
Relay over-travel	0.100	0.000
Safety Margin	0.100	0.100
Minimum time interval (seconds)* (to total clearing time curve)	0.200	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.		
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.		