EFCOG Best Practice #121

Title: Electrical Safety Assessment Criteria Document

Facility: DOE Complex

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Brief Description of Best Practice:
This best practice provides assessment criteria for electrical safety program and electrical safety practices and can be used for both independent and self-assessment programs.

Why the best practice was used:
This document provides consistent criteria for assessing electrical safety programs against the NFPA and DOE requirements.

What are the benefits of the best practice:
Use of this best practice provides a consistent method for assessing and improving electrical safety programs and electrical safe practice field implementation to help reduce electrical safety events and injuries across the complex.

What problems/issues were associated with the best practice:
No comprehensive set of electrical safety assessment criteria are currently available for complex use.

How the success of the Best Practice was measured:
These criteria have been used in numerous field and HQ assessments across the DOE complex.

Description of process experience using the Best Practice:
N/A

ELECTRICAL SAFETY ASSESSMENT DOCUMENT

October 2017
REV. 1

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ACKNOWLEDGEMENT

This document was developed under the Electrical Safety Improvement Project (ESIP) initiated in 2005 through the Energy Facility Contractors Group (EFCOG) Integrated Safety Management Working Group. This intent of this document is to provide a consistent set of performance criteria to determine weaknesses in electrical safety programs and field implementation at DOE sites to reduce events and injuries.

The following subject matter experts consisting of both DOE contractor and DOE personnel participated in the development and/or review of this document:

- Randall Unger — NNSA SC (Team Leader/Champion and Sponsor)
- Bobby Gray — Richland Operations Office, Hanford Site
- Joseph Kilar — Argonne National Laboratory
- Keith Knotts — National Energy Technology Laboratory
- Paul Holik — Oak Ridge National Laboratory
- Jackie McAlhaney — Savannah River Site

This document was revised by the EFCOG Electrical Safety Task Group (ESTG) in September 2017 to update to latest codes and standards.

INTRODUCTION

This Electrical Safety Assessment Document (ESAD) is provided as an adjunct to conducting electrical safety assessments of DOE/NNSA facilities and operations. The ESAD is comprised of seven major Criteria Review Approach Documents (CRADs) for supporting assessments of electrical safety programs (ESP) in four major areas: Programmatic; Operations; Construction; and, Design.

The *Programmatic* CRAD addresses the major program and process elements of an electrical safety program such as management involvement, the Authority Having Jurisdiction (AHJ), trends processes, standards implementation, oversight processes, and so on.

There are four *Operations* CRADs proposed for use in assessing electrical practices and workplace safety of facility operations and maintenance (O&M) activities.

The *Construction* CRAD addresses electrical safety requirements necessary for the practical safeguarding of employees involved in construction work.

The *Design* CRAD is comprised of two parts: Part I addresses the electrical safety design of DOE/NNSA nuclear facilities; Part II focuses on key requirements for implementing National Electrical Code (NEC) design practices for standard commercial and industrial installations.

Each CRAD is formatted with four major fields: 1) 'Objectives' are the major requirements upon which the assessment focuses – these are the targeted issues to be assessed; 2) 'Criteria' are the "performance measures" used for 'grading' or 'measuring' the Objectives; 3) The 'Approach' is the methodology or action means of implementing the Criteria as measures of the Objectives. Criteria and Approach taskings are related through their respective enumeration: For example, Approach taskings 1.0, 1.1 are subsidiary actions for Criterion number 1; Approach taskings 4.0, 4.1 are related to Criterion number 4, and so on (see Operations CRAD , Wiring Design and Protection.) The 'Requirements Basis' identifies the major drivers for the Objectives and Criteria, and are derived directly from the cited consensus standards and statutes, thus providing a 'requirements-based' assessment.

Though the ESAD is necessarily comprehensive, it is anticipated that it will be implemented in accordance with the 'graded approach'. The ESAD is not intended as a *required* approach process, however, most of the CRADs are directly derived from national consensus standards (NEC, IEEE, etc.) and address technical requirements necessary to successful implementation of the safety commitments cited in federal statutes and DOE/NNSA guidance and orders. Therefore, prospective electrical assessment teams should determine which CRADs to employ for the particular assessment, as well as the rigor of application.

I. PROGRAMATIC CRAD FOR MANAGEMENT SYSTEMS

The Programmatic CRAD provides assessment support for those systems employed to administer site Electrical Safety Programs (ESP). The CRAD addresses the following general elements of an ESP: Management involvement (organizational structure, roles and responsibilities, policies and control systems); Problem identification, tracking and trends processes; Requirements for implementation of appropriate standards (NFPA, DOE, OSHA, IEEE, etc.); Inspection programs; Training and worker qualification; and, Oversight of the Electrical Safety Contractor Assurance Systems (CAS) (assessment programs, event reporting processes, worker feedback, issues management processes, lessons learned, performance measures, etc.)

Assessment of the Management Systems for an Electrical Safety Program

Objective:

MS 1.0 Management Involvement: Establishment of an organization having assigned roles and responsibilities, with a clearly defined mission and charter, that supports line management in its responsibilities of administering site electrical safety programs. (DOE-HDBK-1092-1.3, NEC Article 90.2(C), 90.4, Appendix G 80.2, 80.15, NFPA70E Definitions)(ISM Core Functions 1,2,3,4,5: Guiding Principles 2,3,5,6,7)

Criteria:

1. An Authority Having Jurisdiction (AHJ) is identified or established that is responsible for interpreting rules, approving equipment and materials, and granting special permissions regarding implementation of the rules, procedures, and practices of OSHA, NEC, and other standards applicable to site electrical facilities, systems, equipment, and operations.

2. A proactive Electrical Safety Committee (ESC) is established, formally recognized and empowered to assist management and the electrical AHJ in the establishment and implementation of site electrical policies, procedures and practices.

3. An Unlisted Electrical Equipment Approval Program is established and effectively implemented for Facility and R&D operations.

4. A management authority (AHJ, ESC, Subject Matter Experts, etc.) actively audits and assesses the Electrical Safety Program to ensure:

    a. Accountabilities, authorities, interfaces, roles and responsibilities for the Electrical Safety Program are clearly defined and well integrated into site management systems;

b. Establishment and implementation of appropriate policies, standards, procedures, and practices to ensure proper review, approval, work authorization, oversight and documentation for electrical facilities and R&D operations;

c. Establishment of a formal written contractor Electrical Safety Plan that is effectively implemented to include all site personnel and subcontractors;

d. Implementation of adequate control processes to enable identification and classification of hazards, and establishment of effective barriers for the elimination and/or mitigation of potential accidents and related events;

5. Processes are established for assuring effective problem identification, tracking, and trends management.

6. Inspection programs exist to ensure workplace safety for electrical facilities and R&D operations.

7. Management provides oversight of Contractor Assurance Systems (CAS) to ensure effective implementation and administration of the site Electrical Safety Program.

8. Effective training and qualification programs are established to ensure effective implementation of the site Electrical Safety Program.

9. An effective process for Configuration Management is implemented.

Approach:

1.0 Review the Electrical Safety Plan to determine if the Electrical Safety Program has identified in its organizational structure an AHJ empowered to perform the responsibilities associated with this position.

1.1 Interview AHJ personnel with regard to their respective roles and responsibilities, positional authority, job description, and relationship with the Electrical Safety Committee and management.

2.0 Review the Electrical Safety Plan to determine if the Electrical Safety Program has identified in its organizational structure an Electrical Safety Committee (ESC) chartered to perform the responsibilities associated with this position.

2.1 Interview ESC personnel with regard to their respective understanding of ESC mission, roles and responsibilities, positional authority, job description, and relationship with the AHJ and management.

3.0 Review the Electrical Safety Plan and Program documentation to ensure that an Unlisted Electrical Equipment Approval Program is cited, established, and effectively implemented for Facility and R&D operations.

3.1 Interview AHJ and ESC personnel to ensure equipment approval program implementation and compliance with associated standards and procedures.

3.2 Review historical documentation relating to implementation of the site Unlisted Electrical Equipment Approval process, e.g., sample approval forms, equipment labeling practices, etc.

4.0 Review Electrical Safety Program documentation, and conduct interviews to determine management oversight of the Electrical Safety Program: Evaluate the effectiveness of assessment, reporting, and issues-management processes used by management to identify, track, and correct electrical occurrences.

4.1 Assess the clarity and effectiveness of organizational lines of authority, roles and responsibilities, and chain-of-command vis-à-vis, management and electrical operations.

4.2 Review Electrical Safety Program policies, standards, procedures and practices to ensure that effective work and control systems are implemented for electrical oversight of electrical facilities and R&D operations.

4.3 Review the site Electrical Safety Plan for conformance with existing consensus standards and DOE guidance: Assess the Electrical Safety Plan/Program for consistency with standards and referenced guidance.

4.4 Review Electrical Safety Plan/Program procedures and practices, and conduct interviews, to ensure that the Program is integrated with the Integrated Safety Management process, e.g., work planning, identification of hazards, establishment of controls, conduct of work consistent with controls, etc.

5.0 Review occurrence reports, action plans, and related documentation to determine if an effective problem identification, tracking, and trends management process is implemented to assist in electrical occurrence reporting.

6.0 Review Electrical Safety Plan/Program procedures and practices, and conduct interviews, to ensure that an effective electrical inspection and surveillance program is implemented.

6.1 Review operations and maintenance records, reports and related documentation to ensure that qualified personnel perform inspections in accordance with cited standards and procedures.

6.2 Assure that inspections are documented: Verify that inspection records, deficiencies, and corrective actions are consistent with site procedures and DOE requirements.

6.3 Review logs, records, and other maintenance documentation to verify the conduct of periodic inspections and walk downs of electrical O&M work practices.

7.0 Review Electrical Safety Program documentation and interview personnel to verify management implementation of Contractor Assurance System (CAS) processes for electrical and R&D operations, e.g., Assessments, Event Reporting, Worker Feedback, Issues Management, Lessons Learned, and Performance Measures.

8.0 Review training agendas, course descriptions, instructional manuals and schedules; Check training requirements for employees, electrical employees and non-employees; Review documentation of employees and non-employees participation in required training classes.

8.1 Review Training and Qualification Plans to confirm and assess the programs for compliance with standards and DOE requirements.

9.0 Review drawings, specifications, O&M manuals and other related documentation for electrical systems and equipment, to verify implementation of effective processes for change control, recording of modifications, and distribution of updated versions.

9.1 Sample and review electrical documentation (as-builts, specifications, O&M manuals, procedures, etc.) for conformance with existing facilities and equipment physical configuration.

10.0 Review field work audits to verify that training and procedures are appropriately revised when results indicate that principles and procedures of the electrical safety program are not being followed.

Requirements Basis :

NEC Article 90.2(C), 90.4, Appendix G 80.2, 80.15
NFPA70E Definitions and others

References:

DOE-HDBK-1092-1.3

II. OPERATIONS CRAD ARTICLE 100

The Operations CRAD for Article 100, implements electrical safety requirements necessary for the practical safeguarding of employees in the workplace.

ELECTRICAL SAFETY-RELATED WORK PRACTICES

Implementation of: NFPA 70E Chapter 1, Electrical Safety-Related Work Practices (EWP)

Objective:

EWP 1.0 Safety-related work practices and procedures are established and implemented to protect workers from workplace electrical hazards. (NFPA 70E, Article 110; ISM Core Functions-2,3,4 and Guiding Principles-1,3,5,6,7)

Criteria:

1. A process for effectuating Multiemployer Relationships is adequately implemented.

2. Contractor and subcontractor training programs assure use of qualified workers.

3. An Electrical Safety Program (ESP) is implemented that directs activity appropriate for the voltage, energy level, and circuit conditions.

4. Safety-related work practices are implemented to safeguard employees from injury while they are working on or near exposed electric conductors or circuit parts that are or can become energized.

5. A process is implemented for insuring test instruments/equipment, portable electric equipment, and their associated ground fault and overcurrent protection are used in accordance with applicable standards and practices.

Approach:

1.0 Review ESP documentation and interview workers to ensure that processes and procedures are in place such that outside servicing workers (subcontractors, etc.) are apprised of site hazards, PPE requirements, safe work practices, and emergency/evacuation procedures. Verify that the meeting between the host employer and contract employer is documented.

2.0 Review training and qualification plans, and interview workers to verify that contractor and subcontractor electrical workers are qualified in accordance with the site ESP plan and related national and local standards.

2.1 For R&D operations, ensure that the ESP incorporates appropriate R&D training and qualifications requirements.

3.0 Review pertinent documents and conduct interviews and walk downs to ensure that the ESP incorporates processes and procedures for hazards/risk identification, evaluation, and control.

3.1 For R&D operations, review the ESP to ensure policies and procedures for development of safe work practices have been implemented.

4.0 Review the Safety related work practices to ensure that they address the nature and extent of associated electric hazards.

5.0 Review that the ESP safe work practices address the care and use of test instruments/equipment, portable electric equipment, and their associated ground fault and overcurrent protection in accordance with ratings, design, and applicable standards and practices.

5.0 Review documentation to verify that workers exposed to shock hazards have been trained in methods of safe release, first aid, emergency response and resuscitation.

5.0 Review documentation to verify that portable equipment is used in accordance with manufacturer's instructions and safety warnings.

Requirements Basis :

10 CFR 851, Worker Safety and Health Program (Appendix A, Section 10)
NFPA 70E Article 110
NFPA 70E, Annex F, Risk Assessment Procedure

References:

DOE STD-1092 Electrical Safety Handbook

ELECTRICALLY SAFE WORK CONDITIONS

Objective:

EWP 1.1 Processes and practices are in place to establish an electrically safe work condition. (NFPA 70E, Article 120; ISM Core Functions-2,3,4 and Guiding Principles-1,3,5,6,7)

Criteria:

1. Practices and procedures are developed and implemented for working on or near de-energized electrical conductors or circuit parts.

2. Temporary protective grounding equipment is used in accordance with established practices and procedures.

Approach:

1.0 Review pertinent documents, and conduct interviews and walk downs to ensure that the ESP implements adequate practices and procedures for de-energization of voltage sources, lockout/tagout (LOTO), and zero-energy check verification.

1.1 Review pertinent documents and conduct interviews and walk downs to ensure that the ESP has an established hazardous-electrical-energy-control process that adequately implements requirements relating to use and coordination of simple and complex LOTO procedures; ensure that LOTO requirements are coordinated with multiple employers and outside workers and personnel.

1.2 Review pertinent training and qualification documentation, and conduct interviews to verify that an adequate LOTO training and retraining process is in place.

1.3 Review pertinent documents and conduct interviews and walk downs to verify that appropriate and adequate LOTO equipment, electrical circuit interlocks, and other control devices are available for use, and that workers are competently trained in their application.

1.4 Review LOTO procedures to verify that effective *planning requirements* exist to: effectively locate energy sources; identify the LOTO person-in-charge and potentially exposed workers; correctly apply simple and complex LOTO practices.

1.5 Review LOTO procedures to verify that the necessary *elements of control* have been adequately identified, e.g., equipment de-energization, release of stored energy, disconnecting means, equipment verification, test requirements, grounding, procedural responsibilities, coordination and accountability, etc.

2.0 Review equipment and procedures, and/or conduct walk downs, to verify consistent and safe use of temporary protective grounding equipment as required to include: placement and arrangement of equipment; ground systems impedance and fault-current capacities; and equipment approval requirements.

Requirements Basis:

NFPA 70E, Article 120

References:

DOE STD 1092 Handbook for Electrical Safety

WORKING ON OR NEAR LIVE PARTS

Objective:

EWP 1.2 Processes and practices are in place to ensure an electrically safe work environment during work on or near live parts. (NFPA 70E, Article 130; ISM Core Functions-2,3,4 and Guiding Principles-1,3,5,6,7)

Criteria:

1. Practices and procedures are in place to provide justification for work on or near live parts.

2. Electrical hazards identification, classification, and control procedures are developed and implemented.

Approach:

1.0 Review documentation, and interview workers to verify the adequacy of procedures used for justifying work on or near live parts, e.g., employer demonstration that de-energization increases hazards; infeasibility of de-energization due to equipment design or operational limitations; energized work on systems at less than 50 volts-to-ground, etc.

1.1 Review documentation, and interview workers to verify effective implementation of an Energized Electrical Work Permit (EEWP) process: Ensure that the essential elements of the EEWP are consistent with those as identified in NFPA 70E and that the process is well integrated into the electrical O&M program.

2.0 Review documentation, interview workers and conduct walk downs to verify establishment and implementation of a systematic and integrated process for electrical hazards identification, classification, and control:

a. Verify that shock and flash hazard analysis processes exist or have been performed, and that shock and flash protection boundaries are developed and implemented for identified electrical hazards;

b. Ensure that workers are trained and knowledgeable of approach boundary requirements for qualified and unqualified workers;

c. Verify that workers are trained, qualified, and familiar with the general process of hazards identification and classification, establishment of approach boundaries, and the derivation of Personal Protective Equipment (PPE) requirements;

d. Review documentation, interview workers and conduct walk downs to verify that workers have adequate knowledge of, or familiarization with the site processes for determination of PPE requirements for example work activities;

e. Review documentation, interview workers and conduct walk downs to verify that workers are trained and qualified in the use of protective equipment (insulated tools, ropes and handlines, live-line tools, protective shields, guards, barriers, etc.) including the use and application of alerting techniques and requirements (safety signs and tags, barricades, and oversight attendants).

f. Review documentation, interview workers and conduct walk downs to verify that workers and supervision use alerting techniques to identify look-alike equipment where work is performed on equipment that is de-energized in a work area with other energized equipment similar in size, shape, and construction.

g. Review documentation, interview workers and conduct walk downs to verify that workers take necessary steps to identify and mark location of electrical lines and equipment before excavation starts.

h. Review documentation, interview workers and conduct walk downs to verify that a risk assessment is completed before cutting or drilling into equipment, floors, walls or structural elements.

Requirements Basis:

NFPA 70E, Article 130
NFPA 70E, Annex C, Limits of Approach
NFPA 70E, Annex D, Sample Calculation of Flash Protection Boundary

III. OPERATIONS CRAD ARTICLE 200

The Operations CRAD for Article 200, implements practical safety-related maintenance requirements for electrical equipment and installations in the workplace. Additionally, the provisions of NFPA 70B (Electrical Equipment Maintenance) are implemented in support of assessing preventive maintenance practices for electrical systems and equipment used in industrial-type applications.

GENERAL MAINTENANCE REQUIREMENTS

Implementation of: NFPA 70E Chapter 2, Electrical Safety-Related Maintenance Requirements (EMR)

Objective:

EMR 2.0 General maintenance requirements for electrical installations and equipment are complied with. (NFPA 70E, Article 205; ISM Core Functions-2.3 and Guiding Principles-1,3,5,6,7)

Criteria:

1. Employees who perform maintenance and electrical equipment and installations are qualified persons and are properly trained in maintenance procedures.

2. Single line diagrams of the electrical system are maintained.

3. Working spaces and clearances about electrical equipment are maintained.

4. Equipment, raceway, cable tray, and enclosure bonding and grounding are maintained to ensure electrical continuity.

5. Enclosures are maintained to guard against accidental contact with live parts.

6. Locks and interlocks are maintained in proper working condition to accomplish the control purpose.

7. Access to and egress routes from working spaces are kept clear and unobstructed.

8. Posted warning signs, component identification, and safety related instructions are securely attached and maintained in legible condition.

9. Circuit or voltage identification is securely affixed and maintained in updated and legible condition.

10. Electrical cables and single and multiple conductors are maintained free of damage and shorts that would present a hazard to employees.

11. Flexible cords and cables are maintained to avoid strain (using strain relief) and damage that present an electrical hazard to employees.

12. Grade elevation is maintained for overhead power lines to preserve no less than the minimum designed vertical and horizontal clearances.

Review Approach:

1.0 Review training and qualification plans, and interview personnel to verify that employees conducting maintenance work on electrical equipment are qualified.

2.0 Review documentation to verify single-line diagrams exist and are properly maintained under configuration management control.

3.0 During a walk down of one or more areas verify that working spaces and clearances about electrical equipment are clear.

4.0 During a walk down of one or more areas verify that equipment, raceway, cable tray, and enclosure bonding and grounding are ensuring electrical continuity.

5.0 During a walk down of one or more areas verify that enclosures are intact and operational to guard against accidental contact with live parts.

6.0 During a walk down of one or more areas verify that locks and interlocks are in proper working condition to accomplish the control purpose.

7.0 During a walk down of one or more areas verify that access to and egress routes from working spaces are clear and unobstructed.

8.0 During a walk down of one or more areas verify that posted warning signs, component identification, and safety related instructions are securely attached and maintained in legible condition.

9.0 During a walk down of one or more areas verify that circuit or voltage identification is securely affixed, accurate, and in legible condition.

10.0 During a walk down of one or more areas verify that electrical cables and single and multiple conductors are maintained free of damage and shorts that would present a hazard to employees.

11.0 During a walk down of one or more areas verify that flexible cords and cables are maintained to avoid strain (using strain relief) and damage that present an electrical hazard to employees.

11.1 Verify in the documentation of the electrical equipment inspection program that the flexible cords and cables for unlisted equipment are inspected for proper strain relief.

12 During a walk down of one of more areas verify that grade elevation for overhead power lines is maintained.

Requirements Basis:

10 CFR 851, Worker Safety and Health Program (Appendix A, Section 10)
NFPA 70E Article 205
48CFR970.5223
NFPA 70B, Recommended Practice for Electrical Equipment Maintenance

References:

DOE STD-1092 Electrical Safety Handbook

SUBSTATIONS AND OTHER EQUIPMENT

Objective:

EMR 2.1 Maintenance requirements for substations, switchgear assemblies, switchboards, panelboards, motor control centers, and disconnect switches are complied with. (NFPA 70E, Article 210; ISM Core Functions-2,3 and Guiding Principles- 1,3,5,6,7)

Criteria:

1. Enclosures are kept free of material that would create a hazard.

2. Area enclosures such as fences are provided and maintained as required to guard against unauthorized access or accidental contact with exposed live parts.

3. Current carrying conductors are maintained to conduct rated current without overheating and to withstand the available fault current.

4. Insulation integrity is maintained to support the voltage present.

5. Protective devices are maintained to adequately withstand or interrupt available fault current.

Review Approach:

1.0 During a walk down of one or more areas containing substations, switchgear assemblies, switchboards, panelboards, motor control centers, and/or disconnect switches:

   a. Verify that enclosures are kept free of material that would create a hazard;

   b. Verify area enclosures such as fences are provided and maintained as required to guard against unauthorized access or accidental contact with exposed live parts;

   c. Verify current carrying conductors are maintained to conduct rated current without overheating and to withstand the available fault current;

   d. Verify insulation integrity is maintained to support the voltage present;

   e. Verify protective devices are maintained to adequately withstand or interrupt available fault current;

Requirements Basis:

10 CFR 851, Worker Safety and Health Program (Appendix A, Section 10)
NFPA 70E Article 210
48CFR970.5223

References:

DOE STD-1092 Electrical Safety Handbook

PREMISES WIRING

Objective:

EMR 2.2 Maintenance requirements for premise wiring are complied with. (NFPA 70E, Article 215; ISM Core Functions- 2,3 and Guiding Principles- 1,5,6,7)

Criteria:

1. Covers for wiring system components are in place and there are no unprotected openings.

2. Protection from open wiring protection, such as barriers, are maintained to prevent accidental contact.

3. Raceways and cable trays are maintained to provide physical protection and support for conductors.

Review Approach:

1.0 During a walk down of one or more areas, verify that covers for wiring system components are in place and there are no unprotected openings.

2.0 During a walk down of one or more areas, verify the barriers or other protection from opening wiring are in good repair and prevent accidental contact with live wiring.

3.0 During a walk down of one or more areas, verify that raceways and cable trays are maintained to provide physical protection and support for conductors.

Requirements Basis:

10 CFR 851, Worker Safety and Health Program (Appendix A, Section 10)
NFPA 70E Article 215
48CFR970.5223

References:

DOE STD-1092 Electrical Safety Handbook

CONTROLLER EQUIPMENT

Objective:

EMR 2.3 General maintenance requirements for controller equipment are complied with. (NFPA 70E, Article 220; ISM Core Functions-2,3 and Guiding Principles- 1,5,6,7)

Criteria:

1. Protection and control circuitry to prevent employees from accidental contact with live parts is maintained.

Review Approach:

1.0 During one or more walk downs of areas containing controller equipment, verify that protection and control circuitry to prevent employees from accidental contact with live parts is intact and operational.

Requirements Basis:

10 CFR 851, Worker Safety and Health Program (Appendix A, Section 10)
NFPA 70E Article 220
48CFR970.5223

References:

DOE STD-1092 Electrical Safety Handbook

FUSES AND CIRCUIT BREAKERS

Objective:

EMR 2.4 General maintenance requirements for fuses and circuit breakers are complied with. (NFPA 70E, Article 225; ISM Core Functions-2,3 and Guiding Principles-1,3,5,6,7)

Criteria:

1. Fuses are maintained to be free of breaks and cracks.

2. Fuse clips are maintained to provide adequate contact with fuses.

3. Molded-case circuit breakers are maintained to be free of cracks and breaks in cases and operating handles.

4. Circuit breakers that interrupt faults approaching their ratings are inspected and tested in accordance with the manufacturer's instructions.

Review Approach:

1.0 During a walk down of one or more areas, verify that fuses are free of breaks and cracks.

2.0 During a walk down of one or more areas, verify that fuse clips provide adequate contact with fuses.

3.0 During a walk down of one or more areas, verify that molded-case circuit breakers are maintained to be free of cracks and breaks in cases and operating handles.

4.0 Review documentation to verify that circuit breakers with interrupt faults approaching their ratings are inspected and tested in accordance with the manufacturer's instructions.

Requirements Basis:

10 CFR 851, Worker Safety and Health Program (Appendix A, Section 10)
NFPA 70E Article 225
48CFR970.5223

References:

DOE STD-1092 Electrical Safety Handbook

ROTATING EQUIPMENT

Objective:

EMR 2.5 Maintenance requirements for rotating equipment are complied with. (NFPA 70E, Article 230; ISM Core Functions-2,3 and Guiding Principles-1,3,5,6,7)

Criteria:

1. Terminal boxes and enclosures are maintained to prevent accidental contact with live parts and other electrical hazards.

2. Guards, barriers, and access plates are maintained to prevent accidental contact with moving or energized parts.

Review Approach:

1.0 During a walk down of one or more areas with rotating equipment, verify that terminal boxes and enclosures are maintained to prevent accidental contact with live parts.

2.0 During a walk down of one or more areas with rotating equipment, verify that guards, barriers and access plates are maintained to prevent accidental contact with moving or energized parts.

Requirements Basis:

10 CFR 851, Worker Safety and Health Program (Appendix A, Section 10)
NFPA 70E Article 230
48CFR970.5223

References:

DOE STD-1092 Electrical Safety Handbook

HAZARDOUS (CLASSIFIED) LOCATIONS

Objective:

EMR 2.6 General maintenance requirements for hazardous (classified) locations are complied with. (NFPA 70E, Article 235; ISM Core Functions-2,3 and Guiding Principles-1,3,5,6,7)

Criteria:

1. No energized parts are exposed (except for intrinsically safe and nonincendive circuits.)

2. There are no breaks in conduit systems or enclosures.

3. All bonding jumpers are securely fastened and intact.

4. Bolts in all fittings, boxes, and enclosures are all installed and tight.

5. All threaded conduit is wrench tight and enclosure covers are tightened in accordance with manufacturer instructions.

6. There are no open entries into fittings, boxes, or other enclosures that would compromise the protection.

7. All close-up lugs, breathers, seals, and drains are securely in place.

8. Marking of lighting fixtures for maximum lamp wattage and temperature rating is legible and not exceeded.

9. Required markings are secure and legible.

Review Approach:

1.0 Verify during a walk down of one or more hazardous locations that no energized parts are exposed (except for intrinsically safe and nonincendive circuits).

2.0 Verify during a walk down of one or more hazardous locations that there are no breaks in conduit systems or enclosures.

3.0 Verify during a walk down of one or more hazardous locations that bonding jumpers are securely fastened and intact.

4.0 Verify during a walk down of one or more hazardous locations that bolts in fittings. boxes, and enclosures are installed and tight.

5.0 Verify during a walk down of one or more hazardous locations that threaded conduit is tight and enclosures covers are tight.

6.0 Verify during a walk down of one or more hazardous locations that are no open entries into enclosures that compromise protection.

7.0 Verify during a walk down of one or more hazardous locations that close-up lugs, breathers, seals, and drains are securely in place.

8.0 Verify during a walk down of one or more hazardous locations that markings of lighting fixtures for maximum lamp wattage and temperature rating are legible and not exceeded.

9.0 Verify during a walk down of one or more hazardous locations that required markings are secure and legible.

Requirements Basis:

10 CFR 851, Worker Safety and Health Program (Appendix A, Section 10)
NFPA 70E Article 235
48CFR970.5223

References:

DOE STD-1092 Electrical Safety Handbook

BATTERIES AND BATTERY ROOM

Objective:

EMR 2.7 General maintenance requirements for batteries and battery rooms are complied with. (NFPA 70E, Article 240; ISM Core Functions-2,3 and Guiding Principles-1,3,5,6,7)

Criteria:

1. Ventilation systems are maintained to prevent buildup of explosive mixtures including functional test of any detection and alarm systems.

2. Eye and body wash apparatus is maintained in operable condition.

3. Battery cell ventilation openings are unobstructed and cell flame arresters are maintained.

Review Approach:

1.0 Review documentation and verify during a walk down that ventilation systems in one or more battery rooms are operational and a periodic functional test is conducted of any detection and alarm systems.

2.0 Verify during a walk down of one or more random batteries or battery rooms that inspection tags confirm proper periodic inspection of eyewashes and emergency showers.

3.0 Verify during a walk down of one or more random batteries or battery rooms that battery cell ventilation openings are unobstructed and cell flame arresters are maintained.

Requirements Basis:

10 CFR 851, Worker Safety and Health Program (Appendix A, Section 10)
NFPA 70E Article 240
48CFR970.5223

References:

DOE STD-1092 Electrical Safety Handbook

PORTABLE ELECTRIC TOOLS AND EQUIPMENT

Objective:

EMR 2.8 General maintenance requirements for portable electric tools and equipment are complied with. (NFPA 70E, Article 245; ISM Core Functions-2,3 and Guiding Principles-1,3,5,6,7)

Criteria:

1. Attachment plugs, receptacles, cover plates, and cord connectors are maintained such that:

    a. There are no breaks, damage, or cracks exposing live parts;

    b. There are no missing cover plates;

    c. Terminations have no stray strands or loose terminals;

    d. There are no missing, loose, altered, or damaged blades, pins, or contacts;

    e. Polarity is correct;

Review Approach:

1.0 Review ESP and/or other documentation that a program for periodic inspection of portable electric tools is conducted checking for the above items and/or using an electric tool tester.

1.1 During a walk down of one or more random areas, verify that sample tools in use have been inspected and do not exhibit any of the deficiencies identified above.

Requirements Basis:

10 CFR 851, Worker Safety and Health Program (Appendix A, Section 10)
NFPA 70E Article 245
48CFR970.5223

References:

DOE STD-1092 Electrical Safety Handbook

ELECTRICAL PERSONAL SAFETY AND PROTECTIVE EQUIPMENT

Objective:

EMR 2.9 General maintenance requirements for electrical personal safety and protective equipment are complied with. (NFPA 70E, Article 250; ISM Core Functions-2,3 and Guiding Principles-1,3,5,6,7)

Criteria:

1. For grounding equipment; hot sticks; rubber gloves, sleeves and leather protectors; voltage test instruments, blankets and similar insulating equipment, protective barriers, external circuit breaker rack-out devices; portable lighting units, temporary protective grounding equipment; dielectric footwear; and protective clothing:

    a. Visual inspection is conducted before initial use and at intervals thereafter as service conditions require with a maximum interval of a year.

    b. Testing of the insulation of by appropriate test and visual inspection before initial use and at intervals thereafter as service conditions require with a maximum interval of 3 years.

    c. For safety grounding equipment, personal protective ground cable sets are inspected for cuts in the protective sheath and damage to conductors. Clamps and strain relief devices are checked for tightness. These inspections are conducted at intervals as service conditions require, at least every year.

    d. For temporary protective grounding equipment, after safety grounds are repaired or modified, they are tested that the maximum voltage drop values are not exceeded for the rating of the ground set. These inspections are also conducted at an interval in accordance with applicable standards and manufacturer instructions and at least every 3 years.

Review Approach:

For grounding equipment; hot sticks; rubber gloves, sleeves and leather protectors; voltage test indicators, blankets and similar insulating equipment, protective barriers, external circuit breaker rack-out devices; portable lighting units, temporary protective grounding equipment; dielectric footwear; and protective clothing:

1.0 The ESP states that a visual inspection is conducted before initial use and at intervals thereafter with a maximum interval of a year.

1.1 Interview employees to confirm that the initial and periodic inspections are conducted.

2.0 The ESP states that the insulation is tested and/or inspected before initial use and periodically at least every 3 years.

2.1 Interview employees to confirm that the initial and periodic inspections are conducted.

3.0 The ESP states that for temporary protective grounding equipment, personal protective ground cable sets are inspected for cuts and damage and clamps and strain relief devices are checked for tightness at least every year.

3.1 Interview employees to confirm that the periodic inspections are conducted.

4.0 The ESP states that for temporary protective grounding equipment, after safety grounds are repaired or modified, they are tested that the maximum voltage drop values are not exceeded for the rating of the ground set and that these inspections are also conducted at an interval in accordance with applicable standards and manufacturer instructions and at least every 3 years.

4.1 Interview employees to confirm that the periodic inspections are conducted.

Requirements Basis:

10 CFR 851, Worker Safety and Health Program (Appendix A, Section 10)
NFPA 70E Article 250
48CFR970.5223

References:

DOE STD-1092 Electrical Safety Handbook

IV. OPERATIONS CRAD ARTICLE 300

The Operations CRAD for Article 300, implements electrical safety installation requirements and safety-related work practices and procedures for employees working in special electrical equipment environments.

Implementation of: NFPA 70E Chapter 3, Safety Requirements for Special Equipment (SRE)

WORK PRACTICES FOR ELECTROLYTIC CELLS

Objective:

SRE 3.1 Safety-related work practices for Electrolytic Cells are established and implemented to protect workers from workplace electrical hazards. (NFPA 70E, Article 310; ISM Core Functions-2,3,4 and Guiding Principles-1,3,5,6,7)

Criteria:

1. Safety training is provided to ensure that workers are knowledgeable of the specific hazards associated with electrical energy in cell line environments.

2. Safeguards are used to protect employees from injury while working in cell line environments and work zones.

3. Flash hazard analyses or processes exist for determining the risk of flash hazard injury.

4. Unique portable tools and equipment requirements are identified and implemented.

Approach:

1.0 Review training plans and procedures, and interview personnel, to ensure that safety-related work practices and procedural requirements are established and implemented to provide protection from the identified electrical hazards for associated job and task assignments.

1.1 Review training plans and procedures, and interview personnel, to ensure that qualified persons are trained and knowledgeable in the operation of cell line working zone equipment, specific work methods, and are capable of recognizing and avoiding existing electrical hazards.

1.2 Review training plans and procedures, and interview personnel, to ensure that unqualified persons are trained to recognize electrical hazards and avoidance methods.

2.0 Interview personnel, and observe work activities to ensure that adequate work place safeguards are implemented, to include: establishment and implementation of safety-related work procedures and practices; inspection of conductor insulation; availability and use of proper PPE; placement of barriers for prevention of energized or grounded surfaces; implementation of voltage equalization practices; hazardous equipment isolation;

appropriate tool and device selection for cell zone characteristics; and periodic assurance testing of equipment safeguards.

3.0 Review procedures, interview personnel, and observe work activities to ensure that cell line work zones have been analyzed for risk of flash hazard injury. If risk of personnel injury exists, ensure that appropriate measures are taken to protect personnel from flash hazards, e.g., ensure that appropriate PPE is available and implemented; identify work procedures that eliminate or mitigate flash hazard risk; determine whether work practices encourage task scheduling to be performed when the cell line is in a de-energized state.

4.0 Observe cell line operations, equipment and facility conditions to ensure that portable tools, equipment, power supplies, etc., meet the requirements for cell line operations as cited in NFPA 70E, Article 310.6.

Requirements Basis:

10 CFR 851, Worker Safety and Health Program (Appendix A, Section 10)
NFPA 70E Article 310, NFPA 70E Appendix L, IEEE Std. 463-1993

BATTERIES AND BATTERY ROOMS

Objective:

SRE 3.2 Safety-related requirements are established and implemented for batteries and battery rooms exceeding 50 volts or more. (NFPA 70E, Article 320; ISM Core Functions – 2,3,4 and Guiding Principles – 1,5,6,7)

Criteria:

1. Battery connections comply with associated standards and practices.

2. Battery installations comply with associated standards and practices.

3. Battery room requirements comply with associated standards and practices.

4. Battery enclosures comply with associated standards and practices.

5. Battery protection systems comply with associated standards and practices.

6. Battery PPE is available and implemented in accordance with associated standards and practices.

7. Tools and equipment used in battery operations comply with associated standards and practices.

Approach:

1.0 Conduct walk downs and observe work activities in battery-room environments to ensure battery configurations, short-circuit currents, terminals and connectors comply with associated standards and practices.

1.1 Conduct walk downs and observe work activities in battery-room environments to ensure that interconnecting switches and battery cables, busbars, and busways, are rated to withstand prospective short-circuit currents; ensure that DC switching equipment is compliant with the NEC.

1.2 Conduct walk downs and observe work activities in battery-room environments to ensure that DC grounding and ground-fault detection systems comply with associated standards and practices.

1.3 Conduct walk downs and observe work activities in battery-room environments to ensure that DC circuits protection, alarm and warning-signal systems, comply with associated standards and practices.

2.0 Conduct walk downs and observe work activities in battery-room environments to ensure that battery installation location and cell arrangement requirements comply with associated standards and practices.

2.1 Conduct walk downs and observe work activities in battery-room environments to ensure that ventilation requirements for vented-type, VRLA-type, and sealed gel electrolyte systems comply with associated standards and practices.

3.0 Conduct walk downs and observe work activities in battery-room environments to ensure that the following battery room requirements are assessed:

a. Accessibility of battery rooms is limited to only authorized personnel.

b. Battery enclosure accessibility is ensured for surveillance purposes – electrolyte levels, refilling, cleaning, removal, etc.

c. Battery room floor construction and finish is suitable for battery-room operations - floor grading to drains, drip trays and sumps, floor character (concrete, electrolyte resistant, durable, antistatic, slip-resistant), etc.

d. Battery layout and floor area requirements are in compliance with standards and practices.

e. Takeoff battery terminals and outgoing busbars and cables comply with standards and practices.

f. Intertier and interrow connections comply with standards and practices.

g. Barrier requirements comply with standards and practices.

h. Ilumination, location of luminaires, and general-purpose battery room requirements comply with standards and practices.

4.0 Conduct walk downs and observe work activities in battery-room environments to ensure that battery enclosures comply with cited requirements for ventilation, circuits, terminals, busbars, and cables.

5.0 Conduct walk downs and observe work activities in battery-room environments to ensure that battery protection requirements are in compliance with associated standards and practices:

a. Marking and suitable warning notices;

b. Overcurrent protection and protective equipment;

c. Switching and control equipment;

d. Ground-fault protection;

e. Main-isolation switch location;

f. Section-isolating equipment for battery systems exceeding 120 volts;

6.0 Conduct walk downs and observe work activities in battery-room environments to ensure that battery-room PPE, tools and equipment comply with associated standards and practices.

Requirements Basis:

NFPA 70, National Electrical Code, Article 480, Storage Batteries
IEEE Std. 484-2002, Recommended Practice for...Vented Lead-Acid Batteries for Stationary Applications
IEEE Std. 987-1987 (R1993), Recommended Practice for...Lead-Acid Batteries for Photovoltaic Systems
IEEE Std. 1187-1996, Recommended Practice for...Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications
OSHA 1926.403, Battery Rooms and Battery Charging
OSHA 1910.178(g), Changing and Charging Batteries
OSHA 1910.305(j)(7), Storage Batteries

WORK PRACTICES FOR LASER OPERATIONS

Objective:

SRE 3.3 Safety-related work practices for laser operations are established and implemented. (NFPA 70E, Article 330; ISM Core Functions – 2,3,4 and Guiding Principles – 1,5,6,7)

Criteria:

1. A Laser safety program for laser system operations is established and implemented.

2. Laser safety training is in compliance with established standards and procedures.

Approach:

1.0 Interview personnel, conduct walk downs and observations of procedures and practices relating to Laser Controlled and Laser Hazard areas, laser radiation and systems, and design-and-use of fail-safe practices and fail-safe safety interlock systems: Ensure that laser equipment, operations, and practices are in compliance with identified standards and procedures.

1.1 Interview personnel, review training and qualifications documentation, and conduct walk downs to assess laser operations personnel training and qualifications in laser safety, employee safeguarding and employee responsibilities.

2.0 Review the laser safety training and qualifications program to ensure that the minimum scope of laser safety training includes:

   a. System operating procedures;

   b. Hazard control procedures;

   c. PPE requirements;

   d. Accident reporting process;

   e. Laser biological effects on eye and skin;

   f. Electrical and other hazards associated with laser equipment;

   g. 'Proof-of-qualification' documentation for laser operations personnel;

Requirements Basis:

NFPA 70E, Article 330

WORK PRACTICES FOR POWER ELECTRONIC EQUIPMENT

Objective:

SRE 3.4 Safety-related work practices for power electronic equipment are established and implemented. . (NFPA 70E, Article 320; ISM Core Functions – 2,3,4 and Guiding Principles – 1,5,6,7)

Criteria:

1. Employers and employees are aware of the hazards associated with power electronic equipment.

2. Employers and employees are aware of respective responsibilities for personal safety.

Approach:

1.0 Review personnel safety documentation and interview personnel to ensure employer and employee awareness of, or training and qualification in hazards associated with power electronic equipment to include as a minimum:

   a. Results of: Power Frequency Current; DC perceptibility and thresholds; voltage considerations; shortness-of-time contact considerations; AC frequency thresholds above 100 Hz; effects of waveshape and capacitive discharge;

   b. High voltage power supplies;

   c. RF energy-induced high voltages;

   d. Effects of RF, and vicinity field effects of antennas and antenna transmission lines;

   e. Ionizing (X-ray) and non-ionizing RF hazards;

   f. Industrial scientific and medical equipment;

   g. RF induction and dielectric heating;

   h. Industrial microwave heaters and diathermy radiators;

2.0 Review personnel safety documentation and interview personnel (employers and employees) to assess personnel knowledge of specific personnel safety measures:

2.1 Employer responsibilities to include:

   a. Training and supervision by qualified personnel;

   b. Properly installed equipment;

c. Equipment Access;

d. Availability for O&M tools;

e. Identification and guarding of dangerous equipment;

f. Provisioning of complete and accurate circuit diagrams;

g. Maintenance of equipment work areas;

h. Provisioning of work area illumination;

2.2 Employee responsibilities to include:

a. Alertness and awareness of hazards;

b. Proper tools and procedures use;

c. Informing employer of malfunctioning protective measures;

d. Examination of ALL documents provided by the employer, relevant to work;

e. Maintenance of good housekeeping in equipment work space;

f. Hazardous incident reporting;

Requirements Basis:

NFPA 70E, Article 340
International Electrotechnical Commission (IEC) 60476.1-3, Effects of current passing through the human body.

V. OPERATIONS CRAD NFPA 70

The Operations CRAD for NFPA 70, implements electrical safety requirements for electrical installations, based on the provisions of NFPA 70, National Electrical Code.

Implementation of: NFPA 70 Article 110, General NEC Requirements for Electrical Installations (REI)

GENERAL REQUIREMENTS FOR ELECTRICAL INSTALLATIONS

Objective:

REI 4.0 General requirements for electrical installations are established and implemented in accordance with the provisions of NFPA 70, National Electrical Code. (NFPA 70, Article 110; ISM Core Functions – 2,3,4 and Guiding Principles – 1,5,6,7)

Criteria:

1. Processes are established and implemented to ensure effective examination, identification, installation, and use of electric equipment.

2. Equipment and protection devices have adequate interrupt ratings sufficient for the nominal circuit voltages and currents available at the equipment line terminals.

3. Overcurrent protective devices and circuit impedance characteristics are effectively designed to ensure circuit selectivity and coordination to provide system protection in the event of faults and short-circuits.

4. Conductors and equipment are located in appropriate environmental conditions.

5. Work practices are performed to ensure that electric equipment is installed in a neat and workmanlike manner.

6. Work practices are performed to ensure that electric equipment is securely mounted and effectively installed to facilitate cooling requirements.

7. Electrical connections, terminals and splices are effected in accordance with standards and good work practices.

8. Energized electrical equipment requiring examination, adjustment, servicing or maintenance, is field marked for arc flash hazards in accordance with standards and good work practices.

9. Electric equipment and/or parts prone to producing arcs, sparks, flames, or molten metal, are enclosed, separated and isolated from combustible materials.

10. Equipment is marked in accordance with standards and good work practices.

11. Electric circuit and systems disconnecting means are appropriately identified in accordance with standards and good work practices.

12. For systems of 600 volts nominal or less, ensure that:

    a. Electric equipment has adequate operating space in accordance with standards and good work practices;

    b. Processes and procedures are in place for guarding of live parts.

13. For systems over 600 volts, ensure that:

    a. Enclosures and work space for electrical installations are in accordance with standards and good work practices;

    b. Processes and procedures are in place for assuring work space and guarding requirements in accordance with standards and good work practices.

Approach:

1.0 Conduct walk downs and observations to assess equipment suitability for installation and use in conformity with standards and good work practices, e.g., observe equipment markings, listings, and labels to ensure that the equipment is utilized for its intended purpose and application, and in the appropriate environment.

1.1 Observe and assess mechanical strength and durability of electric equipment enclosures to ensure that enclosures afford the intended protection.

1.2 Observe and assess factors that may contribute to the practical safeguarding of personnel using or likely to come into contact with electrical installations to include:

    a. Adequacy of wire-bends and connection space;

    b. Insulation ratings and integrity;

    c. Potential heating and arcing effects likely to arise during electrical operations;

    d. Equipment classifications by type, size, voltage, current capacity, specific use, etc.

2.0 Review engineering or maintenance documentation, interview personnel, and sample electrical systems to ensure that equipment and protection devices have adequate interrupt ratings sufficient for the nominal circuit voltages and currents available at the equipment line terminals.

3.0 Perform spot checks and conduct sample calculations of electric installations to determine short-circuit and fault current values.

3.1 Review time-current curves and peak let-through charts to assess circuit and equipment coordination and selectivity for adequacy of protection for the electrical installation.

4.0 Inspect electrical installations to ensure that conductors and equipment (unless identified for use in those environments) are not located in damp or wet locations, nor exposed to gases, fumes, liquids, excessive temperatures or radiation environments, or other deteriorating agents.

4.1 Inspect equipment to verify that Type 1 equipment is only employed for indoor use.

5.0 Inspect electrical installations or observe work practices to verify that electric equipment is installed in a neat and workmanlike manner:

a. Ensure that openings in raceways, gutters, cabinets, cutout boxes, enclosures, equipment cases and housings are finished and effectively closed for protective purposes;

b. Ensure that where metallic plugs or plates are used with nonmetallic enclosures, they are recessed at least ¼ inch from the outer enclosure surface;

c. Ensure that conductors in subsurface enclosures are properly racked to afford safe access to installation and maintenance personnel;

d. Ensure that internal parts of electric equipment, busbars, wiring terminals, insulators, and such, are not damaged or contaminated by foreign materials (paints, plaster, cleaners, residues, etc.)

e. Inspect equipment and installations to ensure there are no damaged, broken, bent, corroded parts that may impact safe operation or mechanical equipment strength;

6.0 Inspect electrical installations or observe work practices to verify that electric equipment is securely mounted and effectively installed. Verify that wooden plugs are not used in masonry, concrete, or plaster materials to facilitate mounting of electric equipment.

6.1 Inspect electrical installations or observe work practices to verify that installed equipment has adequate spacing and clearance to facilitate natural circulation, affording necessary cooling of equipment; ensure that equipment and installations are free of obstructions that may interfere with ventilation and free circulation of cooling air.

7.0 Inspect electrical installations or observe work practices to verify that connection of conductors to terminal parts are sound and non-damaging, using pressure connectors, solder lugs, or splices to flexible leads.

7.1 Inspect electrical installations or observe work practices to verify proper mechanical conductor splices.

7.2 Inspect electrical installations or observe work practices to verify soundness of splices using brazing, welding, or soldering techniques: Ensure that splices are mechanically and

electrically secure; check free ends of conductor splices and joints to ensure they are covered with proper insulation to prevent shorting or faulting to conductive parts.

7.3 Inspect electrical installations or observe work practices to verify that conductors and splicing means intended for direct burial are listed for that use.

8.0 Inspect electrical installations or observe work practices to verify that energized electrical equipment that may require examination, adjustment, servicing or maintenance, is field marked and clearly visible in warning for arc flash hazards in accordance with standards and good work practices.

9.0 Inspect electrical installations or observe work practices to verify that electric equipment and/or parts prone to producing arcs, sparks, flames, or molten metal, are enclosed, separated and isolated from combustible materials.

10.0 Inspect electrical installations or observe work practices to verify that equipment is marked in accordance with standards and good work practices, to include manufacturer's name, trademarks, system characteristics (voltage, current, wattage, etc.) and other ratings as necessary for equipment identification and/or warnings.

11.0 Inspect electrical installations or observe work practices to verify electric circuit and systems disconnecting means are legibly and durably marked to indicate its purpose.

11.1 Inspect electrical installations or observe work practices to verify that where series-rated equipment is used, the equipment is legibly marked and properly rated for its intended use: For facilities implementing series-rated configurations, conduct a sampling of equipment installations to ensure that each of the affected nodes/equipment locations is clearly marked with the necessary warnings and cautions.

11.2 For those facilities implementing series-rated circuit configurations, inspect electrical installations or observe work practices to ensure that distinct circuits are not using different manufacturer's circuit breakers to establish the series-rated circuit configurations, e.g., specific series-rated feeder and branch circuits must use the same manufacturer's breakers for that particular circuit.

11.3 For those facilities implementing series-rated circuit configurations, inspect electrical installations or observe work practices to ensure that equipment is NRTL recognized as being suitable for series-rated implementation, and that series-rated panelboards are legibly marked for that use identifying ampere ratings and catalog numbers of circuit breakers suitable for use with the equipment.

12.0 For systems of 600 volts nominal or less, ensure that:

a. Electric equipment has adequate operating space in accordance with standards and good work practices;

b. Processes and procedures are in place for guarding of live parts;

13.0 For systems over 600 volts, ensure that:

a. Enclosures and work space for electrical installations are in accordance with standards and good work practices;

b. Processes and procedures are in place for assuring work space and guarding requirements in accordance with standards and good work practices;

Requirements Basis :

NFPA 70, National Electrical Code

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WIRING DESIGN AND PROTECTION

Objective:

REI 4.1 Requirements and practices for Wiring Design and Protection are established and implemented. (NFPA 70, Chapter 2; ISM Core Functions – 2,3,4 and Guiding Principles – 1,5,6,7)

Criteria:

1. Grounded and grounding conductors are identified and used in accordance with standards and good practices.

2. Branch circuits and components are identified and implemented in accordance with standards and good practices.

3. Ungrounded conductors are identified and implemented in accordance with standards and good practices.

4. GFCI protection for personnel is identified and implemented in accordance with standards and good practices.

5. Outlet devices are identified and implemented in accordance with standards and good practices.

6. Cord connections are identified and implemented in accordance with standards and good practices.

7. Outside branch circuit, feeder, and service conductors of 600 volts-or-less, are identified and implemented in accordance with standards and good practices.

8. Services are identified and implemented in accordance with standards and good practices.

9. Overcurrent protection of systems rated at 600 volts-or-less are identified and implemented in accordance with standards and good practices.

10. Overcurrent protection of systems rated at over 600 volts are identified and implemented in accordance with standards and good practices.

11. Grounding requirements are established and implemented in accordance with standards and good practices.

Approach:

1.0 Conduct walk downs of electrical installations and observe electrical work activities to ensure that grounded and grounding conductors are identifiable and distinguishable from each other.

1.1 Conduct walk downs of electrical installations and observe electrical work activities to ensure that proper polarity of connections is maintained.

2.0 Conduct walk downs of electrical installations and observe electrical work activities to ensure that facilities having multiple nominal voltage systems, establish procedures and implement practices requiring phase and system identification for ungrounded conductors of multiwire branch circuits.

2.1 Conduct walk downs of electrical installations and observe electrical work activities to ensure that receptacles and cord connectors are rated and connected in compliance with standards and good practices.

3.0 Conduct walk downs of electrical installations and observe electrical work activities to ensure that facilities having multiple nominal voltage systems, establish procedures and implement practices requiring identification of ungrounded conductors: Sample systems for appropriate color coding, marking, tagging or other approved means of identification.

3.1 Conduct walk downs of electrical installations and observe electrical work activities to ensure that facilities having multiple nominal voltage systems, establish procedures and implement practices requiring that multiple system branch-circuit identification is permanently posted at each branch-circuit panelboard.

4.0 Conduct walk downs of electrical installations and observe electrical work activities to ensure that bathrooms, kitchens, and rooftops have appropriate GFCI protection implemented in accordance with standards and good practices.

4.1 Conduct walk downs of electrical installations and observe electrical work activities to ensure that facilities having temporary wiring installations establish procedures and implement practices requiring GFCI protection in accordance with standards and good practices as noted in NFPA 70.

5.0 Conduct walk downs of electrical installations and observe electrical work activities to ensure that Outlet device ratings, connections, and configurations are identified and implemented in accordance with standards and good practices.

6.0 Conduct walk downs of electrical installations and observe electrical work activities to ensure that Cord connections, ratings, and loads are identified and implemented in accordance with standards and good practices .

7.0 Conduct walk downs of electrical installations and observe electrical work activities to ensure that outside branch circuit, feeder, and service conductors of 600 volts-or-less, are identified and implemented in accordance with NEC standards and good practices : Inspect conductor separation and spacing on poles; Inspect overhead conductor spans and service-drop conductors to ensure compliance with clearance from ground; Inspect conductors for clearances from building openings, windows. platforms, projections, and other surfaces from which they might be reached.

8.0 Conduct walk downs, inspect electrical installations, and observe electrical work activities, to ensure that Services are identified and implemented in accordance with standards and good practices: Inspect services and equipment to ensure that all facility conductors are provided a means of disconnection from the service-entrance conductors; Ensure that service disconnection means are in compliance with requirements for location and accessibility, marking and identification, and for designed use.

8.1 Conduct walk downs, inspect electrical installations, and observe electrical work activities, to ensure that services in excess of 600 volts are in compliance with enclosure, accessibility, and warning-sign requirements.

9.0 Conduct walk downs, inspect electrical installations, and observe electrical work activities, to verify that overcurrent protection of systems rated at 600 volts-or-less are identified and implemented in accordance with standards and good practices: Sample and inspect protective devices and conductors for short-circuit current values and interrupt ratings; Inspect installations for compliance with standards and good practices for grounded conductors, fused disconnects, arcing or suddenly moving equipment, and circuit breakers.

10.0 Conduct walk downs, inspect electrical installations, and observe electrical work activities, to verify that overcurrent protection of systems rated at over 600 volts are identified and implemented in accordance with standards and good practices: Inspect feeder and branch-circuit conductors to ensure appropriate location and overcurrent protection of ungrounded conductors; Inspect overcurrent relays, current transformers, and fuses for appropriate ratings, capacities, and configuration; Inspect protective devices for capability to detect and interrupt the anticipated short-circuit currents; Verify that protective devices and conductors are adequately coordinated to protect systems from the anticipated short-circuit currents.

10.1 Conduct walk downs, inspect electrical installations, and observe electrical work activities, to ensure that overcurrent protective device ratings and settings for feeders are compliant with standards and good practices: Verify that continuous amperage rating of fuses do not exceed three times the ampacity of the feeder conductors; Determine that circuit breaker long-time trip element settings or the minimum trip settings of electronically actuated fuses are not in excess of six times the feeder conductor ampacities.

11.0 Inspect electrical installations, and/or take impedance measurements to verify electrical continuity of grounding paths, jumpers and bonds: Ensure paths to ground from circuits, equipment, and enclosures are permanent, continuous and effective; Validate that bonds and jumpers have capacity and capability to safely conduct anticipated fault and short-circuit currents.

11.1 Inspect electrical installations to verify that systems are grounded in accordance with standards and good practices .

11.2 Inspect electrical installations to verify that grounded and ungrounded systems – bonds, jumpers, connections to grounding electrodes, – are in compliance with standards and good practices .

11.3 Inspect electrical installations to verify that enclosures, raceways, frames, equipment, and service cable grounding is compliant with standards and good work practices .

Requirements Basis:

NFPA 70, National Electrical Code

WIRING METHODS, COMPONENTS

Objective:

REI 4.2 Requirements and practices for wiring methods, components, and equipment for general use are established and implemented.[1] (NFPA 70 Chapters 3 and 4)

Criteria:

1. Wiring methods are established and implemented in accordance with standards and good work practices.

2. Cabinets, cutout boxes, and enclosures are installed and protected in accordance with standards and good practices.

3. Positioning and connection of switches are in accordance with standards and good work practices.

4. Switchboards and panelboards are located, protected, and maintained in accordance with standards and good work practices.

5. Enclosures for damp and wet locations are in accordance with standards and good work practices.

6. Flexible cords and cables are in accordance with standards and good work practices.

7. Portable cables over 600 volts are in accordance with standards and good work practices.

8. Fixture wires are in accordance with standards and good work practices.

9. General use equipment is in accordance with standards and good work practices.

Approach:

1.0 Conduct walk downs and inspect electrical installations to verify the following:

   a. Metal raceways, cable trays, cable armor, cable sheath, enclosures, frames, fittings, and other metal non-current carrying parts designed to serve as equipment grounding conductors are adequately bonded and have electrical continuity to carry the anticipated fault currents;

   b. Nonconductive paints, enamels, or similar coatings are removed at threads, contact points, and contact surfaces, or such contact points and surfaces are connected by means enabling electrical continuity.

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[1] Note: These provisions do not apply to the conductors that form an integral part of equipment, such as motors, controllers, motor control centers, factory-assembled control equipment, or listed utilization equipment.

1.1 Inspect electrical installations to ensure that isolated grounding circuits, where required for electrical noise reduction, comply with standard provisions and that those circuits are supplemented by internal insulated equipment grounding conductors installed to ground the equipment enclosures.

1.2 Inspect electrical installations to ensure that no wiring systems of any type are installed in ducts used to transport dust, loose stock, flammable vapors or other such environments.

1.3 Inspect electrical installations to ensure that temporary wiring is in compliance with standards and good work practices:

a. Ensure that temporary wiring installations meet the time constraints of NFPA 70;

b. Inspect temporary wiring electrical installations to verify that feeders and branch circuits, cable trays, and open wiring, comply with the provisions in NFPA 70.

2.0 Inspect electrical installations to ensure that conductors entering cabinets, cutout boxes, and enclosures, are protected from abrasion and that openings are adequately closed in accordance with standards and good work practices.

2.1 Inspect electrical installations to ensure that cables are secured to cabinets, cutout boxes, and enclosures in accordance with standards and good work practices.

2.2 Inspect electrical installations to ensure that for completed installations, all boxes and other such enclosures have covers, faceplates, or other such fixture canopies in accordance with standards and good work practices.

2.3 Inspect electrical installations to ensure that pull and junction boxes for use on systems over 600 volts provide complete enclosure for the associated conductors and cables, and that these boxes are closed with suitable covers having permanent markings and warnings in accordance with standards and good work practices .

3.0 Inspect electrical installations to ensure appropriate installation, configuration, and connection of switches :

a. Single-throw switches are to be positioned so that gravity will not tend to close them; single-throw switches approved for use in the inverted position are to be provided with locking devices to ensure that blades remain in the open position when so set;

b. Double-throw switches mounted in the vertical position must have locking devices to hold the blades in the open position when so set;

3.1 Inspect electrical installations to ensure appropriate connection of switches:

a. Single-throw knife switches and switches with butt contacts are connected so that blades are de-energized when the switch is in the open position;

b. Bolted pressure contact switches must have barriers that prevent inadvertent contact with energized blades;

c. Switches and circuit breakers, used as switches, are to be connected such that terminals supplying the load are de-energized when the switches are in the open position ;

4.0 Inspect switchboards and panelboards to verify that they are located, protected, and maintained in accordance with standards and good work practices:

a. Switchboards having exposed live parts operating at 50 volts or more are to be located in permanently dry locations, must be under competent supervision and accessible only to qualified personnel;

b. Switchboards are to be located such that probability of damage from equipment or processes is minimized;

c. Panelboards are to be dead front and mounted in cabinets, cutout boxes or other such enclosures designed for the purpose. (Note: Panelboards other than dead front, externally operable type, are permitted where accessible only to qualified personnel);

5.0 Inspect electrical installations to verify that enclosures for damp and wet locations are in accordance with standards and good work practices:

a. Surface-type metal enclosures located in damp or wet locations are placed or equipped to prevent moisture or water from entering the enclosure, and ¼ inch minimum air space is maintained between the enclosure and the mounting surface;

b. Enclosures installed in wet locations are to be weatherproof;

c. Switchboards and panelboards located outside or in damp or wet locations, are to be enclosed in weatherproof enclosures;

6.0 Inspect electrical installations to verify that flexible cords and cables are in accordance with standards and good work practices:

a. Flexible cords and cables are suitable for the conditions of use and location, e.g., used as luminaire wiring, portable lamps, crane and hoist wiring, connection of moving parts, etc.;

b. Flexible cords and cables are NOT to be used as a substitute for fixed wiring, where run through holes in walls, ceilings or floors, doorways or similar openings;

c. Flexible cords and cables must adhere to requirements for marking, splices, pull at joints and terminals, etc. ;

7.0 Inspect electrical installations to verify that portable cables over 600 volts comply with construction standards and good work practices:

a. Conductors are to be #8 AWG copper or larger and have flexible stranding ;

b. Cables operating over 2000 volts are to be shielded to confine voltage stresses to the insulation;

c. Equipment grounding conductors are to be provided with appropriate size and capacity requirements;

7.1 Inspect electrical installations to verify that portable cables over 600 volts have shields that are grounded.

7.2 Inspect electrical installations to verify that portable cables over 600 volts have grounding conductors connected in accordance with construction standards and good work practices:

a. Minimum bending radii for cabling during installation and handling are adequate to prevent damage to the cabling;

b. Fittings and connectors are to be of the type that lock firmly together to prevent opening or closing of cable lengths during energization; Tension at connectors and terminations is to be eliminated;

c. Only permanent molded, vulcanized splices are allowed for cables over 600 volts;

d. Terminations on portable cables rated over 600 volts are to be accessible only to authorized and qualified personnel;

8.0 Inspect electrical installations to verify that fixture wires are in accordance with standards and good work practices:

a. Fixture wires are be the type approved for the voltage, temperature, and location of use;

b. Fixture wires to be used as grounded conductors are to be so identified, e.g., marked, colored, etc.

c. Fixture wires are to be used only as permitted ;

9.0 Inspect electrical installations to verify that fixtures, lamps, and lampholder live parts, receptacles, cord connectors, and plugs are in accordance with standards and good work practices:

a. Ensure that fixtures, lamps, and lampholder live parts operating at 50 volts or more, are not exposed to contact;

b. Ensure that portable handlamps comply with provisions of NFPA 70E, 420.10(A)(1);

c. Sample lampholders and ensure that where supplied by a circuit having a grounded conductor, the grounded conductor is connected to the screw shell of the lampholder;

d. Ensure that lampholders installed in wet or damp locations are rated as weatherproof;

e. For double-pole switched lampholders, ensure that when the device is switched, that both conductors are disconnected from the circuit;

f. Ensure that receptacles, cord connectors, and attachment plugs are in compliance with the provisions of NFPA 70;

9.1 Inspect appliances for electrical installations to ensure that no live parts operating at 50 volts or greater are exposed to contact; ensure that appliances have means of disconnecting from all ungrounded conductors, and that nameplate markings indicate an identifying name, and ratings in volts, amperes, or watts.

9.2 Inspect electric motor installations to verify compliance with NFPA 70:

a. Ensure that associated equipment (controllers, starters, etc.) are within sight of motors;

b. Ensure that motors are provided with adequate disconnecting means in accordance with NFPA 70;

c. Ensure that transformer installations comply with NFPA 70, e.g., voltage warnings, indoor/outdoor installation requirements, access to vault doorways, transformer/foreign interfaces (water pipes and accessories), and material storage in transformer vaults.

9.3 Inspect capacitor installations to verify compliance with NFPA 70:

a. Review load current requirements for capacitor switching for compliance with NFPA 70;

b. Ensure that isolation means are installed for all voltage sources of capacitors, banks, and installations – ensure that a visible gap of isolation in the electrical circuit exists for the cited operating voltage;

c. For capacitor isolating or disconnecting means with no interrupt rating, ensure that the means are interlocked with the load interrupting device or that prominently displayed caution signs exist preventing load current switching.

Requirements Basis:

NFPA 70, National Electrical Code

SPECIFIC PURPOSE EQUIPMENT AND INSTALLATIONS

Objective:

REI 4.3 Standards and good work practices for specific purpose equipment and installations are established and implemented. (NFPA 70E, Chapter 6; ISM Core Functions – 2,3,4 and Guiding Principles – 1,5,6,7)

Criteria:

1. Installations of electric signs and lighting systems are in accordance with standards and good work practices.

2. Installations of cranes and hoists are in accordance with standards and good work practices.

3. Installations of elevators, escalators, moving walks and lifts are in accordance with standards and good work practices.

4. Electric welder systems are in accordance with standards and good work practices.

5. Disconnecting means for information technology equipment is in accordance with standards and good work practices.

6. X-ray equipment is installed and operated in accordance with standards and good work practices.

7. Induction and dielectric heating equipment is installed and operated in accordance with standards and good work practices.

Approach:

1.0.1 Inspect installations of electric signs and lighting systems to verify that disconnects are provided, and that when operated, disconnects serve to open all ungrounded circuits.

1.1 Inspect installations of electric signs and lighting systems to verify that when disconnects are out of the line of sight from its controlled equipment, the disconnecting means is capable of being locked in the open position.

1.2 Inspect installations of electric signs and lighting systems to verify that systems operated by externally located electronic or electromechanical controllers are in accordance with the following provisions:

   a. Disconnecting means is located within sight of the controller or in the same enclosure with the controller;

   b. Disconnecting means disconnects both the equipment and the controller from all ungrounded conductors;

c. Disconnecting means is designed such that no pole can be operated independently, and is capable of being locked in the open position.

2.0 Inspect installations of cranes and hoists to verify the following requirements:

a. Runway conductor disconnecting means are: readily accessible; operable from the ground or floor locations; capable of being locked in the open position; designed to open all ungrounded conductors simultaneously when operated; within view of the runway contact conductors;

b. Crane and hoist disconnecting means comply with the provisions of NFPA 70;

2.1 Inspect installations of cranes and hoists to verify that limit switches or other devices are provided to prevent the load block from passing the safe upper limits of travel of the hoisting mechanisms.

2.2 Inspect installations of cranes and hoists to verify clearance requirements (see NFPA 70).

3.0 Inspect installations of elevators, escalators, moving walks and lifts to verify that disconnecting means, equipment operation, and ancillary requirements are in accordance with standards and good work practices .

4.0 Inspect installations for electric welder systems to verify that:

a. Arc welder disconnecting means have ratings not less than that necessary to accommodate overcurrent protection;

b. Ampere ratings of disconnecting means for resistance welders is not less than the supply conductor ampacity;

5.0 Inspect installations for information technology (IT) equipment to verify that a disconnecting means exists to disconnect all power to electronic equipment.

5.1 Inspect IT installations to verify that a disconnecting means exists to disconnect power to all dedicated HVAC systems serving the IT room, and that operation of the disconnect causes all required fire/smoke dampers to close.

5.2 Inspect IT installations to verify that IT room disconnecting means are grouped and identified, and readily accessible at the principal exit doors.

5.3 Inspect IT installations to verify that when pushbuttons are used as the means to disconnect power, that the action of “pushing-in” of the button shall be the initiating means used to disconnect power.

6.0 Inspect X-ray installations to verify that the disconnecting means and operational control of equipment comply with NFPA 70.

6.0 Inspect induction and dielectric heating equipment installations to verify operational, equipment, and control compliance with NFPA 70.

Requirements Basis:

NFPA 70, National Electrical Code

HAZARDOUS (CLASSIFIED) LOCATIONS

Objective:

REI 4.4 Standards and good work practices for hazardous locations and installations are established and implemented. (NFPA 70E, Chapter 5; ISM Core Functions – 2,3,4 and Guiding Principles – 1,5,6,7)

Criteria:

1. Hazardous locations, operational activities, and equipment are identified and properly documented.

2. Requirements for class and zone classification are established and implemented in accordance with standards and good work practices.

3. Electrical equipment used in hazardous locations is suitable and properly listed and marked in accordance with standards and good work practices.

Approach:

1.0 Inspect hazardous location facilities and equipment, review documentation, and interview personnel to verify that operational activities and equipment are identified and properly documented:

   a. Review documentation to ensure that hazardous locations and electrical equipment are identified and that operational procedures and safety practices are readily available to O&M personnel who work in hazardous locations;

   b. Inspect equipment to verify that is identified and rated for use in the established environment (class, zone, location, etc): Ensure that equipment is rated for the class location as well as for the property of use, e.g., operational properties (explosiveness, combustibility, ignitibility) must match the specific gas, vapor, dust, fiber or other materials that will be present;

   c. Inspect conduits, enclosures, and fittings to ensure that threaded conduits and fittings are wrenchtight to prevent sparking and facilitate explosionproof and flameproof integrity;

   d. Inspect equipment to verify that it is adequately marked to show class, group, and operating temperature or temperature class;

2.0 Select hazardous location facilities and equipment to verify that requirements for class and zone classification are established and implemented in accordance with standards and good work practices:

a. Inspect hazardous location facilities to ensure that electrical equipment with threaded conduits and fittings use NPT (National Standard Pipe Taper) or metric threads;

b. Inspect hazardous location facilities to ensure that for electrical equipment interfaces with NPT and metric-threaded connections, the metric entries are identified and listed as NPT-metric adapters;

c. Review documentation and interview personnel to ensure that classification of areas and selection of equipment and wiring methods are under the supervision of a qualified Registered Professional Engineer;

2.1 Inspect hazardous location facilities and electrical equipment to ensure that locknut-bushing and double-locknut types of contacts are NOT depended on for bonding purposes: verify that bonding jumpers with proper fittings or other approved means of bonding are used.

2.2 Inspect hazardous location facilities and electrical equipment to ensure that where flexible metal conduit or liquidtight flexible metal conduit is used and is to be relied on to complete a sole equipment grounding path, that it is installed with internal or external bonding jumpers in parallel with each conduit .

2.3 Inspect hazardous location facilities and perform sample measurements to ensure that electrical equipment operational surface temperatures are less than the cited ignition temperatures of the surrounding gases or vapors.

2.4 Inspect facilities and sample equipment to verify that equipment identified as intrinsically safe is rated, operated and configured in accordance with the cited requirements, e.g., minimized power levels, physically separated from other circuits, use of gas and vapor seals, etc.

2.5 Inspect facilities and sample equipment to verify use of explosion-proof equipment for required environments: Acceptable listings, ratings and markings; use of flat surface or screw thread fittings; appropriate conduit and enclosure seals.

2.6 Inspect hazardous location facilities to verify use of explosion-proof equipment in Class I locations, to include: Conduits, enclosures, seals and fittings; circuit-breaker panelboards; luminaires and fixtures; switches, make-and-break contacts, relays, alarms; motors controllers and starters; plugs, receptacles and couplings.

3.0 Inspect hazardous location facilities to ensure that electrical equipment used in hazardous locations is suitable, properly listed and marked in accordance with standards and good work practices:

a. Inspect electrical equipment to assess suitability for use in the operational environment: Review equipment listings and labeling to verify acceptability of use in the hazardous environment; review evidence and documentation relating to qualified testing laboratory or inspection agency concerned with product

evaluation; review AHJ documentation relating to equipment acceptability based on manufacturer's self-evaluation or owner's engineering judgment;

b. Inspect equipment to verify that equipment marking complies with requirements as cited in the NEC;

Requirements Basis:

NFPA 70, National Electrical Code, 500-series articles

SPECIAL SYSTEMS

Objective:

REI 4.5 Requirements for special systems are established and implemented. (NFPA 70E, Chapter 7; ISM Core Functions – 2,3,4 and Guiding Principles – 1,5,6,7)

Criteria:

1. Requirements for systems over 600 volts are established and implemented in accordance with standards and good work practices.

2. Installation, operation and maintenance of emergency systems are established and implemented in accordance with standards and good work practices.

3. Classes 1, 2, and 3 circuits are installed, and implemented in accordance with standards and good work practices.

4. Fire alarm systems are established and implemented in accordance with standards and good work practices.

5. Communications systems are established and implemented in accordance with standards and good work practices.

6. Solar photovoltaic systems are established and implemented in accordance with standards and good work practices.

Approach:

1.0 Inspect aboveground wiring practices for systems over 600 volts to ensure that conductors are suitably installed, e.g., in rigid metal conduits, intermediate metal conduits, electrical metallic tubing, cable trays, busways, etc.

1.1 Inspect open runs of braid-covered insulated conductors to verify that the braiding is flame-retardant or that a flame-retardant saturant has been applied to the braid covering after installation. Check treated braid coverings to ensure they are stripped back a safe distance at conductor terminals, e.g., not less than one inch per kilovolt of conductor-to-ground voltage.

1.2 Inspect metallic and semiconducting insulation shielding to ensure it is trimmed back an adequate distance dependent on circuit voltage and insulation; ensure that factory-applied shielding terminations employ stress reduction means; check for adequate grounding of metallic shielding components, e.g., tapes, wires, braids, etc.

1.3 Inspect cable conductors that emerge from metal sheath and where protection against moisture or physical damage is required, ensure that the insulation is protected by a cable sheath terminating device.

1.4 Inspect circuit breaker installations:

a. Ensure that indoor installation of circuit breakers are mounted in metal-enclosed units or fire-resistant cell-mounted units (open-mounting is permitted for locations accessible only to qualified personnel);

b. Ensure that circuit breakers used to control oil-filled transformers are either located outside the transformer vault or are capable of operation from outside the vault;

c. Ensure that oil circuit breakers are arranged or located such that combustible materials or structures are adequately safeguarded;

1.5 Inspect power fuses and fuseholders:

a. Ensure that where required, fuses are placed in each ungrounded conductor;

b. Ensure that vented type power fuses are not used indoors, underground, or in metal enclosures, unless identified for that use;

1.6 Inspect distribution cutouts and fuse links (expulsion type):

a. Ensure that cutouts are located and installed to enable efficient and safe operation and re-fusing, and that fuse exhaust does not endanger personnel;

b. Ensure that distribution cutouts are not used indoors, underground, or in metal enclosures;

c. Ensure that approved means are employed to interrupt anticipated loads;

d. Ensure that appropriate signs and warnings are employed for those installations where cutouts are not to be operated under load (unless the fused cutouts are interlocked to prevent opening under load);

1.7 Inspect enclosures for oil-filled cutouts to ensure that suitable barriers are provided to prevent contact with energized parts of the cutout.

1.8 Inspect facilities to ensure that load-interrupter interconnections to load terminals providing alternate connection to different supply conductors, are properly identified for this hazard.

1.9 Inspect facilities to ensure that equipment is provided with an isolation means and that isolating switches that are not interlocked with an approved circuit-interrupting device are provided with a sign warning against opening them under load.

1.10 Inspect facilities to ensure safeguards of accessibility to energized parts:

a. Ensure that potential access to high-voltage equipment by unqualified personnel is guarded against by locked doors;

b. Ensure that low-voltage circuits and equipment are not installed in high-voltage compartments except as allowed ;

1.11 Inspect facilities to ensure that mobile and portable equipment are effectively safeguarded:

a. Ensure that energized switching and control parts are enclosed in effectively grounded metal enclosures, properly marked, and locked so that only authorized and qualified personnel may have access; verify that such enclosures have circuit breakers and protective equipment having the operating means projecting through the metal enclosure so that these units can be reset without opening the locked doors;

b. Ensure that power cable connections to mobile machines comply with standards and good work practices: power cable terminals are enclosed in metallic enclosures; provisions for solid connection of ground terminals for the machine frame; ungrounded conductors attached to insulators or terminated with approved high-voltage couplers; cable terminations use stress/strain reduction to prevent stressing of electrical connections; enclosure has provision for locking and is marked for the appropriate hazards.

1.12 Inspect tunnel installations for compliance with appropriate standards and good work practices, e.g., conductors in conduit, protection against physical damage, grounding and bonding, etc. .

2.0 Inspect emergency systems to ensure that wiring from an emergency source or its distribution overcurrent protection to emergency loads, is kept independent of other wiring and equipment ;

2.1 Inspect emergency systems to verify that emergency lighting is designed and installed such that failure of one segment or component does not result in total darkness in any space.

2.2 Inspect facilities to ensure that a sign is located at the emergency source service entrance equipment that indicates type and location of on-site emergency power sources; When grounding electrodes are located remotely from the emergency source equipment, ensure that a sign is located at the electrode grounding location identifying all emergency and normal sources connected at that location.

3.0 Inspect Class 1, 2, and 3 circuits for compliance with their respective definitions , e.g., ensure that these circuits meet the voltage and power requirements for these Class designations.

3.1 Inspect circuits to verify that remote control, signaling, and power-limited circuits are identified and comply with standards and good work practices.

4.0 Inspect fire alarm systems to ensure that non-power-limited fire alarm circuits are NOT supplied through GFCI equipment.

4.1 Inspect fire alarm systems to ensure that identified power-limited fire alarm circuits comply with provisions cited in NFPA 70.

4.2 Inspect fire alarm systems to ensure fire alarm circuits are separated from electric power and light circuits as required in NFPA 70.

4.3 Inspect fire alarm circuits to verify that they are so identified at terminal and junction locations.

5.0 Inspect communication systems to ensure that each circuit with aerial wire or aerial cable exposure is provided with a primary protective device.

5.1 Inspect communication systems to ensure that primary protectors are provided to circuits (aerial or underground) having potential exposure to electric power and light conductors operating at over 300 volts to ground.

5.2 Inspect communications systems having potential of lightning exposure, to ensure that interbuilding circuits are protected by a listed primary protector at each end of the interbuilding circuit.

5.3 Inspect communications system wiring and cabling to maintain a minimum of 6 feet separation from lightning conductors.

5.4 Inspect communications system wiring and cabling to maintain a minimum of 2 inches from conductors of electric light, power, Class 1, non-power-limited fire alarm, or medium power broadband circuits.

5.5 Inspect communications system grounding for required grounding; ensure that metallic sheath of communications cables entering buildings is grounded as close as practical to the point of entrance.

5.6 Inspect communications system grounding to ensure grounding conductors, electrodes, connections, and bonding methods are in compliance with NFPA 70.

6.0 Inspect solar photovoltaic systems to verify compliance with standards and good work practices, e.g., conductors of different systems, disconnecting means, warning signs for switches and circuit breakers .

Requirements Basis:

NFPA 70, National Electrical Code

VI. CONSTRUCTION CRAD

The Construction CRAD is intended to be applied to those electrical work activities during the construction phase of commercial and industrial work activities. The CRAD implements requirements in four major divisions: Installation safety; Safety-related work practices; Safety-related maintenance and environmental considerations; and, Safety requirements for special equipment. The CRAD is developed from federal statutes and consensus standards, e.g., OSHA, NEC, and NFPA.

Implementation of: Electrical Safety Practices for Construction Activities (CES)

GENERAL REQUIREMENTS

Objective:

CES 5.0 General requirements for construction activities are established and implemented to ensure compliance with the provisions of NFPA 70, National Electrical Code; NFPA 70E, Standard for Electrical Safety in the Workplace; and 29CFR1926, Subpart K. (ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6)

Criteria:

1. Processes are established and implemented to ensure the construction employer has a documented electrical safety program.

2. Processes are established and implemented to ensure applicable electrical safety codes and standards are included in contractual documents for construction subcontractors.

3. Processes are established and implemented to ensure the requirements of NFPA 70E, Section 110.4 regarding multiemployer relationship are met.

4. An inspection program is established that ensures compliance with installation requirements.

5. Processes are established that ensures construction personnel have the qualifications, skills, and training to comply with requirements.

Approach:

1.0 Review construction employer's electrical safety program to ensure key principles, as identified in the DOE Model electrical Safety Program, are included.

1.1 Review construction employer's electrical safety procedures and policies.

1.2 Interview construction personnel to ensure electrical safety policies and procedures are known and understood.

1.3 Conduct interviews to validate implementation of required processes, policies and procedures.

2.0 Review contract documentation, interview personnel to verify requirements are included in work scope for construction employers.

2.1 Interview contract and procurement personnel to ensure electrical safety requirements are established, understood and included in procurement specifications.

3.0 Review meeting minutes of the required meeting to establish multiemployer roles and responsibilities for electrical safety.

4.0 Conduct walk downs and observations of construction areas to assess adequacy of the installation inspection program.

5.0 Review construction employer's electrical safety training and qualification program or policy.

Requirements Basis:

NFPA 70E, Standard for Electrical Safety in the Workplace, Article 110
29CFR1926 Subpart K
29CFR1910 Subpart S

PRACTICES FOR INSTALLATION OF SUBSTATIONS

Objective:

CES 5.1 Requirements and practices for Installation of Substations, Switchboards, Panels, and Major Equipment are established and implemented. (ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,3,5,6)

Criteria:

1. The location (working environment) is adequate.

2. Labels indicate NRTL compliance or equipment contains a manufacturer's declaration of compliance.

3. Equipment is installed according to manufacturer's recommendations.

4. All live parts are covered.

5. Equipment is adequately protected with a barrier or fence.

6. Exposed live parts are accessible to qualified personnel only.

7. Working space around equipment is adequate.

8. Dedicated space requirements are met.

9. No equipment or material is stored in front of panels.

10. Equipment is adequately supported.

11. Adequate illumination is available.

12. Panel(s) and branch circuits are identified.

13. All unused openings in electrical equipment are covered.

14. Cables and conductors are terminated correctly.

Approach:

1.0 Conduct walk downs of electrical installations and observe electrical work activities to ensure that the location (working environment) is adequate.

2.0 Conduct walk downs of electrical installations and observe electrical work activities to ensure that labels indicate NRTL compliance.

3.0 Conduct walk downs of electrical installations and observe electrical work activities to ensure that equipment is installed according to manufacturer's recommendations.

4.0 Conduct walk downs of electrical installations and observe electrical work activities to ensure that all live parts are covered.

5.0 Conduct walk downs of electrical installations and observe electrical work activities to ensure that equipment is adequately protected with a barrier or fence.

6. Conduct walk downs of electrical installations and observe electrical work activities to ensure that exposed live parts are accessible to qualified personnel only.

7. Conduct walk downs of electrical installations and observe electrical work activities to ensure that working space around equipment is adequate.

8. Conduct walk downs, inspect electrical installations, and observe electrical work activities, to ensure that dedicated space requirements are met.

9. Conduct walk downs, inspect electrical installations, and observe electrical work activities, to ensure that no equipment or material is stored in front of panels.

10. Conduct walk downs, inspect electrical installations, and observe electrical work activities, to ensure that equipment is adequately supported.

11. Conduct walk downs, inspect electrical installations, and observe electrical work activities, to ensure that adequate illumination is available.

12. Conduct walk downs, inspect electrical installations, and observe electrical work activities, to ensure that panels and branch circuits are adequately identified.

13. Conduct walk downs, inspect electrical installations, and observe electrical work activities, to ensure that all unused openings in electrical equipment are covered

14. Conduct walk downs, inspect electrical installations, and observe electrical work activities, to ensure that cables and conductors are terminated correctly.

Requirements Basis:

NFPA 70, National Electrical Code
29CFR1926 Subpart K

PRACTICES FOR INSTALLATION OF SINGLE- AND MULTIPLE-CONDUCTOR CABLES

Objective:

CES 5.2 Requirements and practices for Installation of Single- and Multiple-Conductor Cables, Flexible Cords, and Open Wiring. (ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6)

Criteria:

1. The installation is approved for the purpose and environment.

2. The installation is not subject to physical damage.

3. The installation is marked as required.

4. The installation is identified as required.

5. Overcurrent protection is adequate for the ampacity.

6. The installation is supported as required.

7. The installation is terminated as required.

8. Cords that pass through holes are protected from physical damage.

Approach:

1.0 Conduct walk downs and inspect electrical installations to verify the installation is approved for the purpose and environment.

2.0 Conduct walk downs and inspect electrical installations to verify the installation is not subject to physical damage

3.0 Conduct walk downs and inspect electrical installations to verify the installation is marked as required.

4.0 Conduct walk downs and inspect electrical installations to verify the installation is identified as required.

5.0 Conduct walk downs and inspect electrical installations to verify the installation overcurrent protection is adequate for the ampacity.

6.0 Conduct walk downs and inspect electrical installations to verify the installation is supported as required.

7.0 Conduct walk downs and inspect electrical installations to verify the installation is terminated as required.

8.0 Conduct walk downs and inspect electrical installations to verify that cords that pass through holes are protected from physical damage.

Requirements Basis:

NFPA 70, National Electrical Code
29CFR1926 Subpart K

PRACTICES FOR WIRING METHODS

Objective:

CES 5.3 Standards and good work practices for wiring methods are established and implemented. (ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6)

Criteria:

1. Installations of raceways and cable trays are approved for the purpose and environment.
    a. Installations of junction boxes suitable for the purpose and environment;
    b. Installed junction boxes have all openings covered;
    c. Live parts within installed junction boxes are covered;
2. Installations of lighting are suitable for the location and environment.
    a. Installations of lighting include labels indicating NRTL compliance;
    b. Lighting equipment is installed according to manufacturer's recommendations;
    c. All lamps are protected from physical damage;
3. All 15- and 20-amp receptacles are protected by Ground Fault Circuit Interrupters (GFCI).
    a. All receptacles are of the grounding type;
    b. All receptacles are of the required configuration;
    c. Receptacles installed in damp locations are GFCI protected;
4. Any installed temporary service is adequately grounded.
    a. Any service that is supplied from a separately derived source, such as a transformer or generator is properly grounded.
    b. The grounding electrode conductor is connected to both the equipment grounding conductor and the grounded circuit conductor.
    c. The grounding electrode conductor is sized adequately.
    d. All electrical equipment is grounded effectively.
    e. All electrical components are bonded together.

f. Installed bonding conductors are sized adequately.

5. Feeders are supported adequately.

6. All extension cord sets used with portable tools are of the 3-wire and “extra-hard use” type.

7. Electrical equipment installed in hazardous locations is approved for the location:

    a. Installed electrical equipment is marked for the specific occupancy;

    b. Classification of hazardous locations has been determined;

    c. Appropriate wiring methods are used in hazardous locations;

Approach:

1.0 Inspect installations of raceways, cable trays, junction boxes, and other parts of the raceway system meet installation requirements.

1.1 Inspect installations of junction boxes to verify they are suitable for the purpose and environment.

1.2 Inspect installations of junction boxes to verify all openings are covered.

1.3 Inspect installations of junction boxes to verify live parts within installed junction boxes are covered.

2.0 Inspect installations of lighting to verify the following requirements:

    a. Installations of lighting are suitable for the location and environment;

    b. Installations of lighting include labels indicating NRTL compliance;

    c. Lighting equipment is installed according to manufacturer’s recommendations;

    d. All lamps are protected from physical damage;

3.0 Inspect installations of receptacles to ensure the following:

    a. All 15- and 20-amp receptacles are protected by Ground Fault Circuit Interrupters (GFCI);

    b. All receptacles are of the grounding type;

    c. Receptacles installed in damp locations are GFCI protected.

4.0 Inspect installations for proper grounding and bonding.

4.1 Inspect any installed temporary service to ensure it is adequately grounded.

4.2 Inspect any service that is supplied from a separately derived source, such as a transformer or generator to ensure it is properly grounded.

4.3 Inspect all grounding electrode conductors to ensure they are connected to both the equipment grounding conductor and the grounded circuit conductor.

4.4 Inspect the grounding electrode conductors to ensure they are sized adequately.

4.5 Inspect all electrical equipment to ensure it is grounded effectively.

4.6 Inspect all electrical components to ensure they are bonded together to form and electrically continuous path for any fault current that might be imposed.

4.7 Inspect installed bonding conductors to ensure they are sized adequately.

5.0 Inspect feeders to ensure they are supported adequately.

6.0 Inspect extension cord sets to ensure they are of the 3-wire and “extra-hard use” type.

7.0 Inspect wiring in hazardous locations to verify the following:

a. Electrical equipment installed in hazardous locations is approved for the location;

b. Installed electrical equipment is marked for the specific occupancy;

c. Classification of hazardous locations has been determined;

d. Appropriate wiring methods are used in hazardous locations.

Requirements Basis:

NFPA 70, National Electrical Code
29 CFR 1926 Subpart K

DOCUMENTATION FOR GOOD WORK PRACTICES

Objective:

CES 5.4 Standards and good work practices are documented in policies and procedures and executed on the work site. (ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,3,5,6,7)

Criteria:

1. An electrical safety program is documented that includes all key elements identified in the DOE Model Electrical Safety Program.

    a. A written electrical safety program identifies a competent person in charge.

    b. A written electrical safety program requires qualified persons are doing electrical work.

    c. A process is established and implemented that ensures hazards are identified, analyzed, and training provided to control the hazards.

    d. A process is established and implemented that ensures workers are trained to work in confined spaces.

    e. Documentation of required training competition is maintained.

2. A Lockout/Tagout program is documented in a procedure.

    a. All equipment that is locked and tagged is rendered inoperative.

    b. A tag is installed on all locked out equipment.

3. A written procedure describes how to create an electrically safe work condition.

    a. A written procedure describes how to develop work plans.

    b. A written procedure describes how to apply personal protective grounds.

    c. A written procedure describes how to select and use test equipment.

    d. A written procedure describes how to use and care for personal protective equipment.

    e. A written procedure describes how to complete an Energized Electrical Work Permit.

    f. A written procedure describes how to conduct a shock and flash hazard analysis.

g. A written procedure describes how to work on or near exposed energized parts.

h. A written procedure describes how to use mobile equipment near overhead conductors.

i. A written procedure describes how to respond to an electrical accident.

j. A written procedure describes how to correctly apply temporary wiring including lighting and extension cord set use.

Approach:

1.0 Inspect work sites and equipment, review documentation, and interview personnel to verify that programs, policies, and procedures are adequate to ensure a workplace free of electrical hazards.

1.1 Review documentation to ensure that:

a. An electrical safety program is implemented that includes all key elements identified in the DOE Model Electrical Safety Program;

b. A written electrical safety program identifies a competent person in charge;

c. A written electrical safety program requires qualified persons are doing electrical work;

d. A process is established and implemented that ensures hazards are identified, analyzed, and training provided to control the hazards;

e. Documentation of required training competition is maintained.

f. A process is established and implemented that ensures workers are trained to work in confined spaces;

2.0 Inspect work sites and equipment, review documentation, and interview personnel to verify that an adequate lockout/tagout program will effectively protect the worker:

a. A Lockout/Tagout program is documented in a procedure;

b. All equipment that is locked and tagged is rendered inoperative;

c. A tag is installed on all locked out equipment.

3.0 Review documentation and interview personnel to verify that procedures are written and workers are trained on their use for the following activities:

a. How to create an electrically safe work condition;

b. How to develop work plans;

c. How to apply personal protective grounds;

d. How to select and use test equipment;

e. How to use and care for personal protective equipment;

f. How to complete an Energized Electrical Work Permit;

g. How to conduct a shock and flash hazard analysis;

h. How to work on or near exposed energized parts;

i. How to use mobile equipment near overhead conductors;

j. How to respond to an electrical accident; and

k. How to correctly apply temporary wiring including lighting and extension cord set use.

Requirements Basis:

NFPA 70, National Electrical Code
NFPA 70E, Standard for Electrical Safety in the Workplace
29 CFR 1926 Subpart K

VII. DESIGN CRAD

PART I: ELECTRICAL DESIGN FOR VITAL SAFETY SYSTEMS (VSS)

Part I of the Design CRAD is intended for use in assessing electrical safety design of DOE/NNSA Vital Safety Systems. The CRAD addresses the design requirements for safety systems as described in the IEEE Nuclear Power Engineering Standards. DOE/NNSA implements the IEEE standards for non-reactor VSS design in accordance with DOE O 420.1B, and DOE G 420.1-1; therefore, this CRAD should be implemented consistent with the guidance in the DOE documentation.

Implementation of: IEEE Nuclear Power Engineering Standards, Electrical Safety Design Practices for Vital Safety Systems (DES)

ELECTRICAL DESIGN REQUIREMENTS

Objective:

DES 1.0 Electrical design requirements for Vital Safety Systems (VSS) are identified and established in accordance with national consensus standards. (IEEE Standards: 279, 308, 323, 379, 383, 494, 603; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7)

Criteria:

1. The Design Basis is established and implemented for Vital Safety Systems.

2. Electrical safety system Design Basis documentation is available, safety system criteria identified, and requirements are established.

3. Principal and Supplementary design criteria for Class 1E[2] electrical safety systems have been identified and requirements established.

4. Class 1E designated electrical safety systems are designed for qualification of life and condition requirements.

5. Class 1E designated electrical safety systems are designed to meet single-failure criterion.

Approach:

1.0 Review Design Basis documentation (DSA, TSR, etc.) to ensure that ***non-electrical*** VSS descriptions, configuration, drawings, and other related information are available, accurate, and compatible with the designed ***electrical system***.

[2] "Class 1E" electric power systems designated for use in this CRAD, are those electrical systems, equipment and components of VSS, required for powering its safety-related actions, e.g., electric powering of trip systems, engineered safety systems, and auxiliary support.

2.0 Assess ***electrical*** safety system Design Basis documentation for the VSS to ensure that documentation is available, safety system criteria identified, and requirements are established:

a. Review VSS electrical safety system Design Basis documentation to verify that VSS electrical systems documentation is identified as 'nuclear safety related' (494);

b. Review VSS electrical safety system Design Basis documentation to verify that Design Basis documentation provides information relating to system functional adequacy (279, 603).
c. Review VSS electrical safety system Design Basis documentation to verify that Design Basis documentation addresses principal and supplementary design criteria (308).

3.0 Review Class 1E design to ensure that indicators and control systems are in accordance with the Design Basis (308).

3.1 Ensure that Class 1E system documentation (design, O&M, etc.) are marked or labeled in accordance with standards (494).

3.2 Review Class 1E systems to verify that design for Independence has been incorporated into systems design (384).

a. Review Design Basis and related electrical design documentation and ensure that equipment and circuits requiring independence and those 'Associated' non-Class 1E systems have been identified.

b. Review Design Basis and related electrical design documentation and ensure that Specific Separation Criteria have been established for VSS electrical systems, e.g., cables and raceways, standby power supplies, distribution systems, instrumentation cabinets, sensors, actuated equipment, etc.

c. Review Design Basis and related electrical design documentation and ensure that Specific Electrical Isolation Criteria have been established for power, instrumentation and control circuits.

4.0 Review Class 1E systems to verify that design for qualification of life and condition requirements are incorporated into systems design (323 and 383):

a. Review Design Basis and related electrical design documentation to ensure that Class 1E cables and splices to be installed in environmentally 'harsh' areas are identified and requirements established.

b. Review Design Basis and related electrical design documentation to ensure that Class 1E equipment to be installed in environmentally 'harsh' areas are identified and requirements established.

c. Review Design Basis documentation relating to environmental conditions (temperature, humidity, radiation, etc.) to ensure that electrical design requirements are established to assure Class 1E systems (equipment, cables, and splices) safety performance during and following the prospective DBE.

5.0 Review Class 1E electrical design to ensure that the provisions for 'single-failure criterion' are met (379):

a. Verify that system design addresses 'independence and redundancy' to assure that no single failure of a component will interfere with proper operation of the Class 1E system;

b. Verify that system design addresses 'nondetectable' failures identification;

c. Verify that system design incorporates 'cascaded' failures – failures resulting from additional failures that occur due to a single failure from a prospective source;

d. Verify design to assure that Class 1E systems are designed to meet Design Basis Events (DBE);

e. Verify design to assure that Class 1E systems address potential 'common-cause' failures (external environmental effects, design deficiencies, manufacturing errors, maintenance errors, operator errors):

1) Assess the design approach and determine whether qualification and QA program support activities are required to afford protection from external environmental effects, design deficiencies, and manufacturing errors.

2) Identify anticipated personnel training requirements, control-room design, and O&M and surveillance procedures intended to mitigate maintenance and operator errors.

f. Verify 'shared-systems' design to ensure that single failures within one unit will not adversely effect or propagate to other units;

g. Assess design of redundant channel interconnections (device interconnections through data loggers, test circuitry, etc.) to ensure circuit independence such that no single failure will cause loss of the safety function;

h. Sample logic circuits to verify that no single failure in system logic will cause failure in channels or actuation circuits, thereby resulting in loss of the safety function;

1) Review actuation devices and actuators, designed to fail in a preferred mode upon loss of power, to assure that no single failure can cause loss of the safety function;

2) Identify prospective failures that may cause power to be maintained incorrectly on the actuator terminals, or mechanical binding that may prevent movement to a preferred position;

3) For actuators designed to apply power when protective action is energized, assure that no single open circuit, short circuit, or loss of power will result in loss of the safety function;

4) Assure that mechanical actuator failure does not result in electrical failure and vice versa.

Requirements Basis:

IEEE Standards:
279, Criteria for Protection Systems for Nuclear Power Generating Stations;
308, Criteria for Class 1E Power Systems for Nuclear Power Generating Stations;
323, Qualifying Class 1E Equipment for Nuclear Power Generating Stations;
379, Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems;
383-1974, Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations;
383-2003, Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations;
494, Method for Identification of Documents Related to Class 1E Equipment and Systems for Nuclear Power Generating Stations;
603, Criteria for Safety Systems for Nuclear Power Generating Stations.

References:
Systems Design Basis Documentation, e.g., Documented Safety Analysis, Technical Safety Requirements, Hazard Analysis, etc.
DOE Order 420.1B, Facility Safety

ELECTRIC CABLES AND FIELD SPLICES

Objective:

DES 2.0 Electrical design practices for Class 1E equipment, electric cables and field splices of Vital Safety Systems (VSS) are established and implemented in accordance with national consensus standards. (IEEE Standards: 308, 323, 383, 384, 603, 690; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7)

Criteria:

1. Principal and supplementary design criteria are implemented in Class 1E electrical systems design (308).

2. Class 1E electrical systems to be employed in 'harsh' environments, are designed in accordance with established 'qualification' requirements (323, 383).

3. Class 1E electrical systems design implements nuclear safety requirements established in the safety system Design Basis (279, 384, 603, 690).

Approach:

1.0 Review Class 1E electrical systems design to assure that no Design Basis event causes a loss of electric power that may impede performance to engineered safety features, surveillance devices, or protective system devices (308);

1.1 Review Class 1E electrical systems to ensure that as a minimum, the following are included in the Design Basis documentation (279, 603):

   a. Numbers and locations of sensors; operational limits of established variables;

   b. Design margins between operational limits and levels of onset of unsafe conditions;

   c. Ranges for transient and steady-state conditions for equipment and environments during normal, abnormal, and accident circumstances throughout which the system is expected to perform;

   d. Malfunctions, accidents, or other events that could physically damage protective system components or cause environmental changes leading to functional degradation of system performance;

   e. System response times, accuracy requirements, and ranges – magnitudes, rates of change of sensed variables, etc.;

1.2 Ensure that Class 1E power systems are capable of performing their functions when subjected to identified Design Basis events (308);

1.3 Ensure that the Design Basis includes or identifies as a minimum the following (308):

a. Those events requiring Class 1E systems operations;

b. Identification of actuation signals for Class 1E systems operations;

c. Load lists of equipment connected to the Class 1E buses and standby power supplies;

d. Start-up sequences and loading profiles for Class 1E systems;

e. Limits and operational requirements applicable to Class 1E standby generators and their prime movers during Design Basis events, e.g., voltage, speeds, time of operation;

f. Cited malfunctions, accidents, environmental events, and operating modes, that may pose threats (physical damage, degradation, etc.) to Class 1E systems;

g. Acceptable ranges for transient and steady-state conditions for power supplies and the environment during normal, abnormal, and accident events, throughout which the equipment must perform, e.g., voltage, frequency, humidity, temperature, pressure, vibration,;

h. Minimum equipment and system performance criteria, e.g., standby power supply unit start-up time, undervoltage relay accuracy, voltage regulation limits, load limits, battery charge times;

i. Conditions that should be permitted to shut down or disconnect Class 1E power sources, e.g., differential relay actuation, engine overspeed;

1.4 Ensure that principal and supplementary design includes consideration of the following (308):

a. Power quality does not permit safety system load degradation of performance below cited acceptable levels (verify requirements relating to voltage, frequency, waveform, harmonic distortion);

b. Operational and human factors consideration of location for indicators and control;

c. Requirements for equipment identification, independence, and physical separation of Class 1E systems, equipment, and circuits;

d. Single-failure criterion requirements;

e. Non-Class 1E equipment and circuits, intermingling with Class 1E systems is in accordance with standards;

f. Assure that plant physical design permits administrative control of access to Class 1E system areas;

g. Class 1E systems and circuit design are adequate for the established environment, e.g., radiation, temperature, humidity;

h. Protective devices are employed to support Class 1E reliability;

i. AC, DC, and Instrument & Control system requirements are established and implemented in accordance with standards;

j. Execute, and Sense-and-Command signal system requirements are established and implemented in accordance with standards.

2.0 Review documentation for prospective Class 1E equipment, cable and splicing requirements for harsh environments; verify that the documentation demonstrates equipment and cable/splicing adequacy to perform the Class 1E function within the cited environment (383):

a. Review cable and/or field splice specifications or qualification plan;

b. Ensure that documentation demonstrates compliance with the qualification plan;

c. Ensure that electrical design meets established DB inspection and maintenance requirements;

d. Ensure that the documentation contains 'summaries and conclusions' that demonstrates equipment adequacy to perform the safety function(s) with no failure mechanism(s) that could lead to common-cause failures;

2.1 Review Class 1E equipment, cable and splicing qualification documentation (for systems anticipated for use in harsh environments) to ensure that a qualified life is established to allow Class 1E systems to perform the safety function during and following the DBE (383).

2.2 Review harsh-environment Class-1E-systems documentation to verify that qualification was accomplished by using one or more of the following methods (383):

a. Qualification type testing;

b. Qualification with operating experience;

c. Qualification with analysis.

2.3 Review Class 1E protection systems to ensure that electrical safety design is in compliance with Design Basis requirements (279, 603):

a. Identify prospective events that may violate the *single-failure criterion,* e.g., ensure that no single failure within the protection system prevents proper protective action at the system level;

b. Review test data for prospective Class 1E systems to verify that *qualification* requirements are adequate for protection system equipment to satisfy DB performance requirements;

c. Ensure that protection-system *channel integrity* is maintained during cited DB Events, e.g., environmental, energy supply, malfunctions, and accidents;

d. Ensure that protection-system channels for the same protective function are independent and physically separated (*channel independence*) to accomplish decoupling of the effects of unsafe environmental factors, electric transients, and physical accident consequences identified in the DB; ensure that design reduces the likelihood of interactions between channels during maintenance operations or in the event of channel malfunction.

3.0 Review control and protection system interaction to ensure incorporation of the following electrical safety engineering practices (279, 603):

a. Equipment used for both *protective and control functions* is classified as protection system equipment;

b. Protection system *single-failure and single-event-caused multiple-failure events* design are in compliance with consensus standards design requirements;

c. *Derivation of system inputs* – protection system design preference is that inputs shall be derived from signals that are direct measures of the desired variables;

d. *Capability for sensor checks* – Means are provided for checking (with a high degree of confidence) the operational availability of each system input sensor during VSS operations;

e. *Capability for Test and Calibration* – Capability is provided for testing and calibrating channels and devices used to derive the final system output signal from the various channel signals;

f. *Channel Bypass* or Removal from Operation – Protective system is designed to permit any one channel to be maintained, tested, or calibrated during power operation, without initiating a protective action at the systems level[3];

g. *Indication of Bypasses* – Protective action bypass of system components must be continually indicated in the control room;

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[3] See the "***one-out-of-two***" exception, wherein systems are permitted to violate the single-failure criterion during channel bypass if reliability of operation can be demonstrated.

h. Design must permit administrative control of the means for *manually bypassing channels or protective functions;*

i. *Multiple-set-points design* shall provide positive means of assuring that the more restrictive set point is used;

j. Protective system design shall be such that when initiated, a *protective action* at the system level shall go to *completion*; return to operational mode shall require subsequent deliberate operator action;

k. The protective system shall include means for *manual initiation* of each protective action at the system level;

l. Design shall permit *administrative control of access to all set point adjustments*, module calibration adjustments, and test points;

m. Protective actions shall be *indicated and identified down to the channel level*;

n. *Information read-out* shall be clear, unambiguous and designed to incorporate human systems integration;

o. *System repair indication* shall be designed for optimization of recognition, location, replacement, repair, adjustment of malfunctioning components or modules;

p. Protection system equipment and components shall be distinctively *marked and identified* in accordance with consensus standards.

3.2 Assess electrical system design to verify Class 1E equipment and circuit independence (384):

a. Review Class 1E equipment and circuit design to ensure that requirements for independence (physical separation and electrical isolation) are established and in compliance with consensus standards:

1) Review the use of safety class structures, separation distances, and barriers as a means of achieving physical separation;

2) Review the use of separation distances, isolation devices, shielding and wiring techniques, as a means of achieving electrical isolation.

b. Review Class 1E equipment and circuit design to identify 'associated'[4] circuits to ensure their compliance with consensus standards;

[4] 'Associated' circuits are non-Class 1E power, control, and instrumentation circuits that become associated with Class 1E systems in view of the means of their proximity, physical separation, or connection to Class 1E systems;

c. Identify NON-Class 1E circuits, and verify their independence (physical separation, electrical isolation) from Class 1E or associated circuits.

3.3 Review Class 1E and associated electrical systems to ensure that design is in compliance with requirements for specific separation criteria (384):

a. Ensure that Class 1E and associated electrical system areas are classified in accordance with consensus standards, e.g., nonhazard areas, limited-hazard areas, and hazard areas;

b. Review Class 1E and associated electrical systems to ensure their compliance with minimum separation distances for their respective classified areas, e.g., cables and raceways, standby power supplies, DC systems, distribution systems, control switchboards, instrumentation cabinets, sensors, actuated equipment;

c. Review Class 1E and associated electrical systems (cables and raceways, standby power supplies, DC systems, distribution systems, control switchboards, instrumentation cabinets, sensors, actuated equipment, etc.) to ensure their compliance with consensus standards requirements relating to redundancy, routing, physical location, and associated environmental hazards.

3.4 Review Class 1E and associated electrical systems to ensure that power circuits, and instrumentation and control (I&C) circuits comply with specific electrical isolation criteria (384):

a. Ensure that power and I&C circuits are properly identified as *Class 1E*, *non-Class 1E*, or *associated*, in accordance with their interconnections and relative configurations;

b. Review and assess power and I&C circuit interconnections and configurations to identify those devices which qualify as '*isolation devices*', in accordance with consensus standards;

c. For power circuit isolation devices, ensure that the device meets the following qualifying criteria:

1) For circuit breakers actuated by fault current to be considered as qualified 'isolation devices', the breaker must be properly coordinated with the upstream breaker, and the power source for the breaker must be able to supply the necessary fault current for a sufficient time to ensure the proper coordination without loss of Class 1E load function[5];

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therefore, associated circuits are generally required to meet the same standards for independence as Class 1E systems.

[5] The power source – standby generator, UPS, etc.—must have capacity to provide the transient load during the fault.

2) For circuit breakers actuated by accident signals (generated within the same division as that to which the breaker/isolation device is applied) to be considered as qualified 'isolation devices', the breaker total-time delay (sum of accident-signal generation and interrupt times) must not cause unacceptable degradation of the Class 1E power system;

3) Input-current limiting devices that limit the fault currents to an acceptable value under faulted conditions at their output, are considered isolation devices (inverters, regulating transformers, battery chargers with current limiting characteristics, etc.);

4) Fuses may be considered as power isolation devices if the following criteria are met:

a. The fuse provides design overcurrent protection capability for the life of the fuse;

b. Fuse time-overcurrent trip characteristics for all circuit faults, cause the fuse to open prior to the initiation of an opening of any upstream interrupting device;

c. The power source has capacity to supply the necessary fault current to ensure the proper coordination without loss of the Class 1E load function.

d. For I&C isolation devices, ensure that the device meets the following qualifying criteria:

1) Maximum credible voltage or current transient applied to the device's non-Class 1E side does NOT degrade the operation of the circuit connected to the device Class 1E or associated side, below an acceptable level;

2) Shorts, grounds, or open circuits occurring in the non-Class 1E side do not degrade the circuit connected to the device Class 1E or associated side, below an acceptable level;

3) The highest voltage to which the isolation device non-Class 1E side is exposed shall determine the minimum voltage level that the device shall withstand across the non-Class 1E side terminals, and between the non-Class 1E side terminals and ground;

4) The capability of the device to perform its isolation function shall be demonstrated by qualification testing;

5) Acceptable I&C isolation devices include the following: amplifiers, control switches, current transformers, fiber optic and photo-optical couplers, relays, transducers, power packs, and circuit breakers;

6) For fuses that are used as I&C isolation devices, ensure that:
   a. The fuse provides design overcurrent protection capability for the life of the fuse;

   b. Fuse time-overcurrent trip characteristics for circuit faults are adequately coordinated with upstream interrupting devices;

   c. Power sources must have adequate capacity to supply the anticipated fault current to ensure proper coordination without loss of the Class 1E load functions.

3.5 Review Class 1E and associated electrical systems to ensure that capability for testing and calibrating of safety system equipment is provided whilst retaining the capability of the safety systems to accomplish their safety functions (603).

3.6 Review Class 1E and associated electrical systems to ensure that information displays minimize the possibility of ambiguous indications that may confuse the operator: Display instrumentation shall provide accurate, complete, timely information pertinent to safety system status to include indication and identification of protective actions of the sense-and-command, and execute features (603).

3.7 Review Class 1E and associated electrical systems to ensure that design permits the administrative control of access to safety system equipment (603).

3.8 Review Class 1E and associated electrical systems to ensure that for those systems for which reliability goals have been established, design analysis shall be performed to confirm achievement of those goals (603).

3.9 Review Class 1E and associated electrical systems to ensure that sense-and-command features comply with consensus standards including (603):

   a. Automatic and manual control of sense-and-command features;

   b. Capability of testing and calibrating of sense-and-command features to include:

      1) Checking and assuring operational availability;

      2) Automatic prevention of operating-bypass activation;

      3) Capability of the safety system to accomplish its safety function whilst the sense-and-command features equipment is in maintenance bypass mode;

4) Ensuring that when multiple setpoints are necessary for adequate protection, the design provides positive means of assuring that the more restrictive setpoint is used when required.

3.10 Review Class 1E and associated electrical systems to ensure that execute features comply with consensus standards including (603):

a. Automatic and manual control of sense-and-command features;

b. Assure that when execute features are initiated, the protective actions of the execute features shall go to completion;

c. Automatic prevention of operating-bypass activation, and capability of the safety system to accomplish its safety function whilst the execute features equipment is in maintenance bypass mode.

3.11 Review Class 1E and associated electrical systems to ensure that power and I&C conductors are in compliance with consensus standards (690):

a. Ensure that conductor sizing meets consensus standards requirements, e.g., ampacity, environmental ratings and qualification for temperature and radiation, voltage regulation, shield circulating current;

c. Review design to ensure that cables and circuits are properly segregated: Cables installed in stacked cable trays should be arranged by descending voltage levels with higher voltage at the top;

d. Verify that cable systems are properly classified, e.g., low-voltage, medium-voltage, control, instrumentation;

e. Review cable system design to ensure:

1) Medium-voltage systems cannot be impressed on lower voltage systems through failure of cable insulation or shielding;

2) Medium-voltage system electric and magnetic fields will not be impressed on lower voltage systems and mutual inductive coupling will be minimized;

3) Instrument cable installation design minimizes noise interference.

1. Review medium-voltage power cable design to ensure (690):

a. Cables rated 5 kV and above shall be shielded (except as noted for special application designs);

b. Cable shield terminations shall include voltage stress relief devices to facilitate cable shield and insulation integrity;

c. Shield grounding requirements:

1) Cable shields and metallic sheaths shall be grounded for operation at or near ground potential;

2) Shields and sheaths with multiple ground points that carry induced and circulation currents should be compensated for heating effects;

3.13 Review instrument cable design to ensure (690):

a. Cable shields shall be electrically continuous (except for special design requirements); when two lengths of shielded cable are connected to a terminal block, an insulated point of the terminal block shall be used for connecting the shields;

b. The shield for each cable shall be isolated to prevent stray and multiple grounds from occurring;

c. Shields designed to reduce electrostatic or electromagnetic coupling shall not be used as an electrical conductor for phase or grounding purposes;

d. Shielding criteria shall be in accordance with design requirements and manufacturer instructions;

e. Grounding of instrumentation cable shields should comply with consensus standards.

3.14 Cable-penetration fire stops, fire breaks, and system enclosures shall incorporate requirements as cited in consensus standards (690).

Requirements Basis:

IEEE Standards:
279, Criteria for Protection for Nuclear Power Generating Stations;
308, Criteria for Class 1E Power Systems for Nuclear Power Generating Stations;
323, Qualifying Class 1E Equipment for Nuclear Power Generating Stations;
383-1974, Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations;
383-2003, Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations;
384, Criteria for Independence of Class 1E Equipment and Circuits;
603, Criteria for Safety Systems for Nuclear Power Generating Stations;
690, Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Stations.

EMERGENCY, STANDBY, AND BACKUP

Objective:

DES 3.0 Electrical design practices for emergency, standby, and backup power supplies supporting VSS are established and implemented in accordance with consensus standards. (IEEE Standards: 387, 446, 650, 944; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7)

Criteria:

1. Emergency and standby (E&S) power supplies (Motor/Diesel-Generators) supporting Class 1E electrical systems are designed in accordance with national consensus standards (387, 446).

2. UPS systems supporting Class 1E electrical systems are designed in accordance with national consensus standards (944).

3. Static battery chargers and inverters supporting Class 1E electrical systems are designed in accordance with national consensus standards (650).

Approach:

1.0 Review Design Basis documentation and electrical design for emergency and standby power supplies supporting Class 1E electrical systems; verify that design includes consideration of the following (387):

f. Operational cycles (4000 starts over a period of 40 years);

g. Operating hours (6000 hours over a period of 40 years);

h. Environmental conditions (temperature, humidity, etc.);

i. Seismic response spectra, if applicable;

j. Radiation (10,000 rad gamma integrated dose over a 40 year period, unless otherwise specified);

k. Load profile with allowable voltage and frequency variations;

l. Effect of fire protection actuation.

1.1 Review Design Basis documentation and electrical design for emergency and standby (E&S) power supplies supporting Class 1E electrical systems to ensure that the following design requirements are consistent with the DB (387):

a. Operational modes: Starting and loading; Light-load or no-load operation;

b. Design load: Ensure the unit(s) is capable of carrying the design load for the time required by the DB and equipment specification;

c. Ensure the unit(s) is capable of meeting 'quality power' requirements, e.g., the unit is capable of maintaining voltage and frequency within DB limits for the identified loads and durations cited;

1.2 Verify that the (E&S) power supply independence between units is not compromised (387): Ensure that the mechanical and electric system interactions between a particular E&S unit and other units, and the Class 1E electric system are coordinated in such a way that the E&S design function and capability requirements are realized for any DBE, except failure of that particular E&S unit.

1.3 Review design and application requirements to ensure that the considerations of Table 1, IEEE Std 387-1995, are included, e.g., avoidance of common failure modes, single-failure criterion, control/protection/surveillance systems, equipment design life;

1.4 Review design and application requirements to ensure that E&S design addresses (387):

a Mechanical and electrical features for vibration;

b Voltage regulator operation for parallel and nonparallel operations;

c Control modes;

d Surveillance systems, modes, and instrumentation;

e E&S protection – engine overspeed, generator differential overcurrent;

1.5 Ensure that E&S motor/diesel-generator supplies comply with the grounding arrangements for E&S systems as described in IEEE Std 446-1995:

a Review E&S grounding configuration to ensure that no parallel current paths or stray neutral currents arise due to improper neutral grounding or transfer switching operations;

b For E&S systems without grounded circuit conductors, or for those systems employing high-resistance grounded systems, ensure that design considers:

1) E&S generator case grounding;

2) Use of Ground-Fault Indicators and alarms for high resistance grounded systems;

3) Provision is made for emergency or critical loads requiring grounded neutrals, for non-grounded or high-resistance grounded E&S systems.

2.0 Review Design Basis documentation and UPS electrical design to ensure that Class 1E system design includes (944):

a. Load identification:

1) Loads that cannot withstand sustained loss of voltage;

2) Loads that cannot withstand frequency or voltage fluctuations;

3) Loads that cannot withstand harmonic distortion.

b. UPS sizing considerations:

1) Total steady-state load;

2) Load power factor;

3) Continuous or short-duration load;

4) Inrush current requirements of the load.

c. Nonlinear loads and potential impact on the UPS inverter;

d. UPS configuration:

1) Single UPS with rectifier/charger, inverter, and battery;

2) Single UPS with separate battery charger;

3) Single UPS with alternate source and static transfer switch;

4) Standby redundant UPS units;

5) UPS with bypass/maintenance source and transfer switch.

2.1 Review UPS requirements for special considerations (944):

a. UPS system reactions, e.g., wave shape, fault clearing times, etc.;

b. Availability figures-of-merit, MTBF, MTTR, etc.

c. Source requirements for the UPS, e.g., AC or DC;

d. Output requirements: capacity, voltage, frequency, grounding, output waveform, transient and short-circuit responses, overload rating, synchronizing requirements;

e. Controls, instruments, and alarms.

3.0 Review Design Basis documentation and electrical design for static battery chargers and inverters supporting Class 1E electrical systems to ensure the following (650):

a. Class 1E performance characteristics:
    1) Input conditions (voltage, frequency, phase);

    2) Output requirements (voltage, current, frequency, load power factor, ripple voltage, harmonic distortion, etc.);

    3) Surge withstand capacity;

    4) Reverse DC current flow prevention;

    5) Auxiliary equipment characteristics (transfer switches, isolating devices, etc.);

b. Qualified Life Objectives (if applicable);

c. Environmental conditions:

    1) Operational vibration;

    2) Nuclear radiation type;

    3) Prospective Radio Frequency or Electromagnetic Interference (RFI/EMI);

d. Equipment specifications, e.g., total number of operating cycles or operating time period for electromechanical devices, electrical and mechanical interfaces, etc.

Requirements Basis:

IEEE Standards:
387-1995, Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations;
446, (Orange Book) Emergency and Standby Power Systems for Industrial and Commercial Applications;
650, Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations;
944, Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations.

CLASS 1E RACEWAY SYSTEM

Objective:

DES 4.0 Electrical design practices for Class 1E raceway systems supporting VSS are established and implemented in accordance with consensus standards. (IEEE Standards: 628-2001; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7)

Criteria:

1. Class 1E electrical raceways comply with requirements for separation, grounding, identification, and materials.

2. Class 1E electrical system design complies with raceway system requirements.

3. Class 1E raceway systems design incorporates structural design criteria.

Approach:

1.0 Review DB documentation and Class 1E electrical design to ensure:

   a. Raceway design requirements for physical independence and separation are in compliance with IEEE Std 384-1992;

   b. Raceways shall be separated according to voltage classification of their electrical cables (IEEE Std 690-1984);

   c. Metallic raceways shall be electrically continuous and electrically connected to the station ground grid in accordance with IEEE Std 665-1995;

   d. Raceways shall be identified in accordance with IEEE Std 384-1992;

   e. Raceway materials and finishes shall be in accordance with the standards cited in IEEE Std 628-2001.

2.0 Review DB documentation and Class 1E electrical design to ensure that raceway system requirements include consideration of the following:

   a. Conduit system requirements (IEEE Std 690-1984);

   b. Cable tray system requirements (IEEE 628-2001);

   c. Wireway system requirements (IEEE 628-2001);

   d. Underground duct system requirements (IEEE 628-2001).

3.0 Review DB documentation and Class 1E electrical design to ensure that raceway design includes the following structural design criteria (IEEE 628-2001):

a. Dead, live, and thermal load requirements;

b. Seismic loading considerations;

c. Methods used for qualifying raceway systems, e.g., analysis, testing, seismic similarity screening, etc.

Requirements Basis:

IEEE Standards:
628, Criteria for Design, Installation, and Qualification of Raceway Systems for Class 1E Circuits for Nuclear Power Generating Stations;
384, Criteria for Independence of Class 1E Equipment and Circuits;
665, Generating Station Grounding;
690, Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Stations.

CLASS 1E CONTROL BOARDS, RACKS, AND PANELS

Objective:

DES 5.0 Electrical design practices for Class 1E control boards, panels, and racks supporting VSS are established and implemented in accordance with consensus standards (IEEE Standard: 420-2001; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. Electrical design practices for Class 1E control boards, panels, and racks supporting nuclear VSS are in compliance with consensus standards.

2. Specifications and QA requirements for Class 1E control boards, panels, and racks supporting nuclear VSS are in compliance with consensus standards.

Approach:

1.1 Review design and layout of Class 1E control board, panel, or rack systems to verify that design has incorporated human factors engineering principles (IEEE Std 1023-1988).

1.2 Review Class 1E control board, panel, or rack systems structure to verify that seismic analysis has been incorporated into design to enable equipment to meet its essential performance requirements during and after the postulated DB earthquake (IEEE Std 344-1987).

1.3 Review electrical design for Class 1E control board, panel, or rack systems to verify that the general requirements for achieving electrical independence of redundant Class 1E equipment and circuits are in compliance with consensus standards (IEEE Std 384-1992):

a. Preferred design for achieving physical separation is to locate redundant Class 1E equipment and circuits on separate control boards, panels, or rack systems that are physically separated from each other; where operational or human factors considerations preclude this configuration, redundant Class 1E equipment may be located on the same panels, provided specified separation criteria are established (IEEE Std 384-1992);

b. Ensure that circuitry physical separation requirements are in compliance with consensus standards (420):

1) Termination areas and cable entrance areas for external (field) cables shall be designed and located to comply with cable entrance separation requirements;

2) Equipment and components installed in Class 1E equipment shall comply with physical separation requirements;

3) Internal wiring (of control boards, panels, or rack systems) shall be routed and supported such that the designed physical separation is maintained throughout enclosure life.

c. If minimum separation distances cannot be maintained, ensure that barriers are installed between equipment and wires requiring separation (420):

1) Acceptable barriers for use within Class 1E control boards, panels, or rack systems, include metallic conduits that are not in contact with each other and sheets of fire-retardant material with cable touching only one side of the respective barrier;

2) Barrier attachments shall be mechanically secured to control boards, panels, or rack systems, by welding, bolting, or other suitable means to maintain separation and structural and mechanical integrity.

d. Preferential design consideration should be given to control of combustibles (420):

1) Use of flame-retardant materials;

2) Treatment of materials that are not flame-retardant;

3) Use of fire-protective paints and coatings;

4) Avoid use of materials that release toxic or corrosive gases when burning;

5) Materials that cannot be considered flame-retardant should be encased in a material that is flame-retardant;

6) Consideration should be given to use of fire-detection devices internal to control boards, panels, or rack systems.

e. Wiring practices shall include (420):

1) Wire bundles to be supported at intervals not exceeding 45 cm (18 inches);

2) Control board, panel, or rack mounted components (switches, indicators, modules, etc.) shall permit removal of the devices for maintenance;

3) Control boards, panels, and racks shall be connected to the station ground;

2.0 Review electrical design of Class 1E control boards, panels, and racks to verify compliance with consensus standards (420):

a. Ensure that Class 1E control boards, panels, and racks include specifications to include the elements as cited in IEEE Standard 420-2001, section 4.10.3;

b. Ensure that Class 1E control boards, panels, and racks meet ASME NQA 1-2001 QA requirements as cited in IEEE Standard 420-2001, section 4.10.4.

Requirements Basis:

IEEE Standards:
344-1987, Seismic Qualification of Class 1E Equipment for Nuclear Power Stations;
384-1992, Criteria for Independence of Class 1E Equipment and Circuits;
420, Design and Qualification of Class 1E Control Boards, Panels, and Racks;
1023-2004, Human Factors engineering to Systems, Equipment, and Facilities;
ASME NQA-1

CLASS 1E SUPPORT SYSTEMS FOR ACCIDENT MONITORING INSTRUMENTATION

Objective:

DES 6.0 Electrical design practices for Class 1E systems in support of accident monitoring instrumentation are established and implemented in accordance with consensus standards (IEEE Standard: 497-2002; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. Design basis documentation identifies selection and performance criteria for electrical safety design of accident monitoring instrumentation.

2. Electrical design requirements for Class 1E systems in support of accident monitoring instrumentation are in compliance with consensus standards.

Approach:

1.0 Review Design Basis documentation and electrical design to verify that identified accident monitoring variables (Types A, B, C, D, E) are consistent with their respective selection criteria (IEEE Std 497, Table 1);

1.1 Review electrical safety design to verify that accident monitoring performance criteria are consistent with Design Basis requirements (IEEE Std 497):

a. Ensure that channel monitoring range is established to cover identified transients;

b. Ensure that the accuracy of accident monitoring instrument channels is established and based on the assigned function (IEEE Std 497, Annex A);

c. Ensure that response times for accident monitoring equipment is designed to provide real time, or timely information;

d. Ensure that post-event operating time (operational duration) of each accident monitoring variable is defined and addressed in accordance with the Standard (497, Section 5.4);

e. Ensure that reliability goals have been established in accordance with DB documentation;

f. Ensure that performance assessment documentation includes considerations of:

1) Allowances for calibration uncertainties, loop errors, and drift;

2) The magnitude and direction of errors imposed on the accident monitoring instrumentation by environmental or seismic conditions during and after the DBE.

2.0 Review electrical safety design criteria and verify that accident monitoring instrumentation is in compliance with DB documentation:

a. Ensure that instrumentation using microprocessor based sensors, data acquisition, or display equipment for Type A, B, and C variables shall address concerns over the use of computer software that could result in common-cause failures (497, Section 6.2);

b. If identical software is designed to be used in redundant instrumentation channels, ensure that (IEEE Std 7-4.3.2-1993):

1) Channel diversity exists using components not subject to a software common mode failure, or;

2) An analysis exists demonstrating that defense-in-depth exists against the consequences of a software common failure.

c. Ensure that accident monitoring instrument channels for Types A, B, and C variables, are independent and physically separated;

d. Ensure that transmission of signals between accident monitoring instrumentation and systems NOT meeting design requirements, is accomplished via 'isolation' devices;

e. Ensure that Type A, B, and C variables provide unambiguous information during any accident monitoring instrument channel failure event, e.g. redundant displays disagree and the operator cannot readily deduce which channel has failed;

g. Ensure that electric power supplies for accident monitoring equipment instrumentation of Type A, B, and C variables, are designed in accordance with Class 1E requirements for independence, physical separation, and redundancy;

h. Ensure that accident monitoring instrument channels have the capability to be calibrated during normal and abnormal operations;

i. Ensure that accident monitoring instrument channels have test capability to periodically verify operability requirements;

j. Ensure that portable instruments supporting accident monitoring channels meet Class 1E requirements for independence, physical separation, and redundancy;

k. Ensure that design criteria for accident monitoring instrumentation are documented and maintained.

2.1 Review accident monitoring instruments to verify qualification for seismic and environmental conditions.

2.2 Review accident monitoring instruments to ensure that display criteria are in accordance with consensus standards (IEEE Std 497-2002).

2.3 Review accident monitoring instrumentation for Types A, B, and C variables to ensure that design, manufacture, inspection, operation, and maintenance requirements comply with ASME NQA-1-2001.

Requirements Basis:

IEEE Standards:
497-2002, Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations;
7-4.3.2-1993, Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Systems;
ASMD NQA-1-2001

CLASS 1E MOTOR CONTROL CENTERS

Objective:

DES 7.0 Electrical design practices for Class 1E Motor Control Centers (MCC) are established and implemented in accordance with consensus standards (IEEE Standard 649-1991(R2004) ; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. Class 1E MCC electrical design implements qualification requirements as cited in consensus standards.

2. Class 1E MCC equipment specification requirements are implemented in accordance with consensus standards.

Approach:

1.0 Review DB documentation, electrical design, and the MCC Qualification Program Plan to verify that qualification requirements have been integrated into MCC electrical design (649, Sections 6, 7, and 8):

   a. Assess qualification documentation showing that MCC equipment is capable of performing its required safety functions before, during, and after the postulated DBE;

   b. Identify and list from the qualification documentation which set of equipment operational and environmental conditions are established as the pertinent qualification objectives, e.g., significant aging mechanisms, specified DBEs, seismic requirements, etc.;

   c. Review MCC devices and components and verify that significant aging mechanisms (operational cycling, temperature, radiation, etc.) have been identified for associated materials, design, and operational environmental conditions;

   d. Identify which qualification alternative(s) (testing, analysis, or operating experience) is employed for the qualification process, and ensure that its approach is consistent with the consensus standards (649, Section 10), and that the results of the qualification process assure MCC component and device qualification;

2.0 Review the equipment specification for the Class 1E MCC to ensure that as a minimum, the following requirements are included:

   a. Equipment description: MCC physical and electrical configuration;

b. Equipment safety functions: Performance requirements and specific safety functions of MCC equipment (required operating times, DBE functional sequence, etc.);

c. Interfaces and loadings via physical attachments to the equipment at equipment boundaries – mounting requirements, cable, raceway and bus connections;

d. Pertinent design standards;

e. Service conditions: Supply and control voltages and frequencies; design and environmental requirements (temperature, humidity, seismic, etc.); radiation; vibration, etc.

f. Normal and abnormal service conditions and effects resulting from the DBE;

g. Identification of established *qualification* margins;

h. Operational aging parameters (649, Table 1);

Requirements Basis:

IEEE Standard 649-1991, Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations.

DIGITAL COMPUTERS FOR VITAL SAFETY SYSTEMS (VSS)

Objective:

DES 8.0 Electrical safety design requirements for digital computers supporting Vital Safety Systems are established and implemented in accordance with consensus standards (IEEE Standards 7-4.3.2-2003, and 603-1998; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. Design Basis documentation or electrical safety design identifies qualification requirements for digital computers supporting Vital Safety Systems (VSS).

2. Digital computer design for VSS complies with consensus standards.

Approach:

1.0 Review DB documentation and, computer hardware and software requirements, to ensure that safety system design requirements are identified and established to include as a minimum (603-1998):

   a. Verify that applicable DB events are identified and defined for digital computer operations;

   b. Verify that digital computer safety functions and corresponding protective actions of the digital computer-generated execute features for each DBE, are identified and defined;

   c. Verify that safety variables to be monitored and acted upon by digital computers are identified and defined;

   d. Verify that digital computer controlled ancillary equipment (Programmable Logic Controllers, actuating devices, etc.) responsible for sense-and-command and execute operations, are identified and qualified in accordance with consensus standards;

   e. Ensure that the range of transient and steady-state conditions for digital computer operations is identified and defined for normal, abnormal, and accident conditions, during the period through which the safety system is intended to perform;

   f. Verify that conditions having the potential for functional degradation of safety system performance of digital computer operations (e.g., missiles, pipe breaks, fires, loss of ventilation, spurious operation of fire suppression systems, operator error, failure in non-safety-related systems) are identified and that mitigating provisions are incorporated to retain the safety system function;

g. Verify digital computer system reliability as cited in the DB or other safety system documentation (see 7-4.3.2-2003, Annex F).

1.1 Review digital computer safety system design criteria to ensure compliance with consensus standards for single-failure criterion, completion of protective action and quality (603-1998).

1.2 Review digital computer safety system design to verify that digital computers used in safety systems are qualified in accordance with consensus standards (7-4.3.2-2003, Section 5.4):

a. Ensure that computer system qualification testing includes that software and diagnostics that are representative of those used in actual operations;

b. Ensure that all portions of the computer necessary to accomplish the safety function, or those parts whose operation or failure could impair safety, shall be exercised during qualification testing, e.g., memory, the CPU, inputs and outputs, display functions, diagnostics, communications paths, interfaces, etc.

2.0 Review DB documentation to identify requirements for digital computer diversity; verify that digital computer safety system qualification (testing) has addressed prospective common-mode failure threats by incorporating necessary diversity requirements (7-4.3.2-2003, Annex B).

2.1 Review DB documentation to identify requirements for digital computer independence (7-4.3.2-2003, Annex E):

a. Verify that independence of electrical and communications of the safety computer from non-safety equipment is assured through use of proper isolation devices;

b. Review communication configuration between computers in different safety channels to ensure proper electrical and communications isolation (7-4.3.2-2003, Annex E, Section E.2.1);

c. Review communication configuration between safety and non-safety computers to ensure proper electrical and communications isolation (7-4.3.2-2003, Annex E, Section E.2.2).

Requirements Basis:

IEEE Standards:
603-1998, Criteria for Safety Systems for Nuclear Power Generating Stations;
7-4.3.2, Criteria for Digital Computers in Safety Systems for Nuclear Power Generating Stations.

PROTECTION SYSTEMS FOR VSS

Objective:

DES 9.0 Electrical safety design requirements of protection systems for Vital Safety Systems are established and implemented in accordance with consensus standards (IEEE Standards 741-1997(R2002), and 833-1998; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. Protection of Class 1E power systems and equipment complies with consensus standards (741).

2. Class 1E electric equipment is protected from water hazards in accordance with consensus standards (833).

Approach:

1.0 Review electrical design of AC power distribution systems:

   a. Ensure that protection systems for the AC distribution systems are coordinated in accordance with IEEE Std 242-1986;

   b. Ensure that, where required, interlocks or administrative controls are provided during operations involving paralleled transfers; verify that consideration has been given to selection of protective devices and the potential for higher fault currents that may result during paralleled operations;

   c. Verify that coordination and protection planning are considered for bus voltage monitoring schemes (bus voltage transfers, monitoring, detection, control, test and calibration);

1.1 Review electrical design protection for standby power supply considerations including control modes, synchronizing interlocks, and paralleled operations;

1.2 Ensure that load shedding and sequential loading operations are consistent with cited DB requirements and consensus standards;

1.3 Ensure that surge protection of equipment and systems is in accordance with DB requirements and consensus standards;

1.4 Ensure that coordination for DC power system circuits includes protective devices for the main bus and branch circuits;

1.5 Ensure that for instrumentation and control power systems:

a. That when rectifier-type power supplies are used as inverter sources, they are provided with reverse current protection, current-limiting features or overload protection, and output undervoltage/overvoltage protection;

b. The instrumentation and control power distribution system is provided with coordinated protection;

c. That ground-detection monitoring is provided for ungrounded systems;

d. That instrumentation and control power systems are provided with under/over voltage, and underfrequency protection.

1.6 Ensure that for valve actuator motors:

1) That time-current characteristics of the protective device are coordinated with the time-current characteristics of the motor, and that coordination ensures that the allowable duty cycle of the valve is completed without compromising the motor thermal withstand capability;

2) Short-circuit protection device setpoints for valve actuator motors are coordinated for: accuracy of the protective device; ambient temperature effects; effects of motor terminal operating voltage ranges.

2.0 Verify that practices for protecting electric equipment from identified water hazards, are in accordance with consensus standards (833), e.g., ensure that electric equipment protection includes considerations for equipment location, design, sealing and shielding requirements.

Requirements Basis:

IEEE Standards:
741-1997(R2002), Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations;
833-1988, Recommended Practice for the Protection of Electric Equipment in Nuclear Power Generating Stations from Water Hazards.

PREFERRED POWER SUPPLY CONSIDERATIONS

Objective:

DES 10.0 Electrical safety design considerations for Preferred Power Supplies (PPS) supporting Vital Safety Systems are established and implemented in accordance with consensus standards (IEEE Std 765-2002; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. General electrical design criteria for PPS are in compliance with consensus standards.

2. Specific electrical design criteria for PPS are in compliance with consensus standards.

Approach:

1.0 Verify that PPS (transmission and distribution facilities) circuits are designed to provide sufficient capacity and capability to support DB-identified Vital Safety Systems.

1.1 Ensure that PPS circuits and equipment are adequately sized to supply the maximum expected coincident Class 1E and non-Class 1E loads, during normal operations.

1.2 Verify that a minimum of two circuits from the transmission system to the Class 1E/VSS power system, are available during start-up and normal operation to meet accident, post-accident, and safe shutdown requirements, in accordance with consensus standards (765-2002, Section 4.5 a-e).

1.3 Verify that PPS circuits to the Class 1E/VSS power system are physically independent, designed, and located to minimize the likelihood of simultaneous failure of both PPS circuits under operating and accident conditions.

1.4 Ensure that the Design Basis for the PPS includes as a minimum the following considerations:

a. Environmental conditions to which the PPS may be subjected to during operations;

b. Potential DB events and operating incidents inducing PPS degradation;

c. Identification of transmission system, steady-state, and transient conditions to which the PPS may be required to respond;

d. Required PPS performance and operating characteristics;

e. Required levels of independence and redundance within the PPS;

f. PPS interface descriptions with switchyard, transmission system, Class 1E/VSS power systems;

g. PPS capability for periodic testing;

h. Prospective use of PPS circuits for applications other than safe shutdown, accident, and post-accident conditions;
i. Restoration methodology for realignment of the PPS following the loss of off-site power.

2.0 Ensure that transmission system and switchyard interfaces are designed to meet DB-established requirements for reliability and independence.

2.1 Verify that a minimum of two PPS circuits are provided to the Class 1E/VSS power system.

2.2 Ensure that connection between the PPS and the Class 1E/VSS power system is made at the input terminals of the Class 1E/VSS circuit breaker.

Requirements Basis:
IEEE Standard 765-2002, Preferred Power Supply (PPS) for Nuclear Power Generating Stations.

EQUIPMENT GROUNDING OF INSTRUMENTATION AND CONTROL FOR VSS

Objective:

DES 11.0 Electrical design practices for equipment grounding of Instrumentation and Control (I&C) VSS are established and implemented in accordance with consensus standards (IEEE Std 1050-1996; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. Electrical design considerations for electrical noise minimization are established and implemented in accordance with consensus standards.

2. I&C system grounding complies with consensus standards.

3. Signal cable and shield grounding requirements are established and implemented in accordance with consensus standards.

Approach:

1.0 Review I&C electrical safety design to verify that noise sources are identified and their potential problem characteristics are considered in the design, e.g., natural sources and incidental sources – lightning, transmission and substation facilities, computer systems, etc. (1050, Section 4.1).

1.1 Review I&C electrical safety design to verify that potential noise-coupling methods have been identified, e.g., conductive, capacitive, inductive, radiative (1050, Section 4.2).

1.2 Ensure that I&C electrical safety design has established mitigating measures for electrical noise minimization, e.g., source suppression, control cable positioning and isolation, shielding, grounding, filtering, other suppression techniques, etc. (1050, Section 4.3).

2.0 Review I&C electrical safety design to verify that I&C equipment grounding methodologies are established and implemented to meet two major objectives:

   a. Provide for protection of personnel and equipment;

   b. Provide noise immunity for signal ground references.

2.1 Review I&C electrical safety design to verify that I&C signal grounding approaches (single-point, multi-point, and floating ground systems) comply with consensus standards (1050, Sections 5.3, 5.4, 5.5):

   a. Ensure that single-point grounds are implemented only for circuit frequencies below 300 kHz (1050, Section 5.3.1);

b. Ensure that multi-point grounds are implemented for grounding equipment operating at frequencies greater than 300 kHz, or when long ground cables are required (1050, Section 5.3.2);

c. Ensure that floating grounds are implemented when electrical equipment necessitates circuit isolation from common ground plane noise, or when the possibility of induced circulating currents from other circuits may impede equipment operation (1050, Section 5.3.3);

d. For those systems and equipment that may be potentially exposed to the hazards of static charge, ensure that floating ground systems are connected to bleed-off resistors to avoid the development of static charge (1050, Section 5.3.3);

3.0 Review I&C electrical safety design to verify that I&C signal cable shield grounding requirements are consistent with consensus standards (1050, Section 6).

Requirements Basis:

IEEE Standards:
142-1991, Grounding of Industrial and Commercial Power Systems;
1050-1996, Instrumentation and Control Equipment Grounding in Generating Stations;
1100-1999, Powering and Grounding Electronic Equipment.

CLASS 1E MOTOR OPERATED VALVE APPLICATION FOR VSS

Objective:

DES 12.0 Electrical safety design requirements for VSS/Class 1E, Motor Operated Valve (MOV) applications, are established and implemented in accordance with consensus standards (IEEE Standard 1290-1996; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. Electrical safety design of MOV motor applications are consistent with consensus design standards.

2. Protection of MOV motor applications are consistent with consensus design standards.

3. Control requirements for MOV motor applications are consistent with consensus design standards.

Approach:

1.0 Review electrical Design Basis requirements and electrical safety design documentation to ensure that MOV motor application electrical design includes consideration of thermal, voltage, and motor torque requirements.

2.0 Review electrical Design Basis requirements and electrical safety design documentation to ensure that MOV motor application electrical protection includes consideration of:

   a. Thermal overload relays (TOLs);

   b. Fuses;

   c. Thermal contacts;

   d. Resistance Temperature Detector (RTD) devices (resistors);

   e. Molded case circuit breakers;

   f. DC Valve Actuator Motors (VAM) surge protection;

3.0 Review electrical Design Basis requirements and electrical safety design documentation to ensure that MOV motor application control philosophy includes consideration of:

   a. TOLs;

   b. Limit/Torque switches;

   c. Valve control;

d. Valve position indication;

e. Alarms;

f. Motor contactors

g. Interlocks;

h. Hardware and material;

i. Valve anti-hammering;

Requirements Basis:

IEEE Standard 1290-1996, Motor Operated Valve Motor Application, Protection, Control, and Testing in Nuclear Power Generating Stations.

PART II: NATIONAL ELECTRICAL CODE (NEC) INSTALLATIONS DESIGN

Part II of the Design CRAD, addresses some of the key electrical design requirements for standard commercial and industrial installations. CRAD requirements are developed from the NEC.

Implementation of: National Electrical Code, (NEC) Electrical Installation Design Practices (NID)

PRACTICES FOR WIRING AND PROTECTION

Objective:

NID 1.0 Electrical design practices for wiring and protection are established in accordance with consensus standards (NEC, Ch. 2; ISM Core Functions – 1,2,3,4 and Guiding Principles 1,5,6,7).

Criteria:

1. All premises wiring systems, other than those exempted and prohibited by the NEC, shall have a grounded conductor that is identified in accordance with Article 200.6 of the NEC.

2. Branch circuits, others than those that supply only motor loads, shall comply with the requirements of Article 210 of the NEC.

3. Feeders supplying branch circuits shall comply with the requirements of Article 215 of the NEC

4. Overcurrent protection, overcurrent protection devices, grounding and bonding shall comply with the general requirements of Articles 240 and 250 respectively of the NEC.

5. If surge arrestors are installed in premises wiring it shall be installed in manner that complies with the Article 280 of the NEC.

Approach:

Review electrical design documentation and electrical installation requirements to:

1.0 Ensure that grounded conductors or premises wiring is connected to the supply system grounded conductor to ensure a common, continuous grounded system unless it is a separately derived system.

1.1 Ensure that grounded conductors are identified via color coding or other acceptable means as described in Articles 200.6 and 200.7 of the NEC.

1.2 Ensure that grounded conductor terminals are identified and the conductors are connected in accordance with Articles 200.9, 200.10, and 200.11 of the NEC.

2.0 Verify that branch circuits comply with Article 210 or with the Articles and Sections identified in Table 210.2 “Specific-Purpose Branch Circuits”

2.1 Verify that branch circuits are rated in accordance with the maximum permitted amperage rating or setting of the overcurrent device.

2.2 Verify that all conductors in multiwire branch circuits originate from the same panelboard or similar distribution equipment.

2.3 Verify that multiwire branch circuits supplying more than one device or equipment are provided with a means to disconnect simultaneously all ungrounded conductors supplying those devices or equipment at the point where the circuit originates.

2.4 Verify that multiwire branch circuits supply only line-to-neutral loads.

2.5 Verify that equipment grounding conductors are identified in accordance with 250.119 of the NEC.

2.6 Verify that where the premises wiring system has branch circuits supplied from more than one nominal voltage system, each ungrounded conductor of a branch circuit shall be identified by system, where accessible.

2.7 Verify that branch circuits that are derived from autotransformers have a grounded conductor that is electrically connected to a grounded conductor of the system supplying the autotransformer.

2.8 Verify that branch circuit conductors and equipment are protected by overcurrent protective devices that have a rating or setting that complies with 21.20(A) through (D) of the NEC.

2.9 Verify that load on branch circuits do not exceed the ampere rating of the circuit and the devices on the circuit are rated for load to be served by the circuit.

2.10 Verify that a 125 volt receptacle has been installed at an accessible location for the servicing of heating, air-conditioning, and refrigeration equipment.

3.0 Verify that feeder conductors have an ampacity not less than required to supply the calculated load.

3.1 Verify that the ampacity of feeder circuits are sized to comply with Article 215.2 of the NEC.

3.2 Verify that feeder circuits are protected against overcurrent in accordance with Part I of Article 240 of the NEC and where feeders supply continuous, or any combination of continuous and non-continuous load the overcurrent device shall not be less than the non-continuous load plus 125 percent of the continuous load.

3.3 Verify that when installed in a common raceway or other metal enclosure, all feeders using a common neutral are enclosed within the same raceway or enclosure.

3.4 Verify that if required by the Authority Having Jurisdiction, a diagram showing feeder details as specified by Article 215.5 of the NEC is provided prior to the installation of the feeders.

3.5 Verify that where a feeder supplies a branch circuit which requires equipment grounding conductors the feeder circuit includes or provides a grounding means.

3.6 Verify that calculations for branch circuits, feeders, and service loads are performed following the requirements specified in Article 220 of the NEC.

3.7 Verify that outdoor branch circuits and feeders run on or between buildings, structures or poles on the premises; and electric equipment and wiring for the supply of utilization equipment that is located on or attached to the outside of buildings, structures, or poles comply with the requirements of Article 225 of the NEC.

3.8 Verify that service conductors and equipment for the control and protection of services and their installation comply with the requirements of Article 230 of the NEC.

4.0 Verify that conductors, other than flexible cords, flexible cables, and fixture wires are protected against overcurrent as required by Article 240 of the NEC unless the interruption of the circuit would create a hazard, such as in material-handling magnets or fire pump circuits. However, short circuit protection shall be provided.

4.1 Verify that a fuse or overcurrent trip unit of a circuit breaker is connected in series with each ungrounded conductor and located at the point where the conductor receive it supply except as specified in Article 240.21 (A) through (G).

4.2 Verify that overcurrent devices are protected from physical damage by a method complying with the requirements of Article 240.30 of the NEC.

4.3 Verify that a disconnecting means of overcurrent devices and guarding of overcurrent devices against personnel injury are provided as specified in Part IV of Article 240 of the NEC.

4.4 Verify that fuses, fuseholder, adapters and circuit breakers meet the requirements of and are utilized according to the requirements of Parts V through VII of Article 240 of the NEC.

4.5 Verify that electrical installations meet the requirements for grounding and bonding of grounded and ungrounded systems as specified in Article 250 of the NEC.

4.6 Verify that electrical systems are installed in a manner that will prevent objectionable current over the grounding conductors or grounding path.

4.7 Verify that connection of grounding or boding equipment is accomplished in a manner acceptable with Articles 250.8 through 250.12 of the NEC.

4.8 Verify that system grounding is accomplished in a manner that complies with Part II of Article 250 of the NEC.

4.9 Verify that grounding electrode systems and grounding electrode conductors are installed, sized, and configured in a manner to comply with the requirements of Part III of Article 250 of the NEC.

4.10 Verify that enclosures and raceways for service conductors are grounded in a manner that meets the requirements of Part IV of Article 250 of the NEC.

4.11 Verify that bonding is provided where necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed.

4.12 Verify that equipment grounding and equipment grounding conductors are installed, sized, and configured in a manner to comply with the requirements of Part VI of Article 250 of the NEC.

4.13 Verify that methods of equipment grounding are performed in a manner that complies with Part VII of Article 250 of the NEC.

5.0 Verify that surge arrestors are installed in accordance with NEC Articles 280 and 285.

Requirements Basis:

National Electrical Code, Ch. 2

WIRING INSTALLATION

Objective:

NID 2.0 Wiring installations are established in accordance with consensus standards (NEC, Ch. 3; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. Conductors shall be installed in a manner consistent with the requirements of the National Electric Code.

2. Raceways, cable trays, wiring enclosures, conduits, cabinets, cutout boxes, meter sockets, boxes, conduit bodies, fittings, and handhole enclosures constructed and installed in accordance with the NEC.

Approach:

Review electrical design documentation and electrical installation requirements to:

1.0 Verify that conductors used in wiring systems shall be of the type, size, and installed utilizing methods approved my Article 300 of the NEC.

1.1 Verify that conductors of 600 volts, nominal, or less are do not occupy equipment wiring enclosures, and cable, or raceways with conductors of circuits rated over 600 volts, nominal.

1.2 Verify that conductors are protected against physical damage, corrosion and deterioration.

2.0 Verify that raceways or cable trays only contain electrical conductors and do not contain other items such as pipe or tubing for uses such as steam, water, air, or drains.

2.1 Verify that raceways, cable trays, junctions, switch points, boxes and conduit are installed in a manner to comply with the requirements of Article 300 of the NEC.

2.2 Verify that conductors utilized in electrical installations meet the requirements of Article 310 for their type designation, insulations, markings, mechanical strengths, ampacity ratings and uses.

2.3 Verify that cabinets, cutout boxes, and meter socket enclosures are installed and meet the construction specifications for their use.

2.4 Verify that outlet, device, pull, and junction boxes; conduit bodies, fitting; and handhole enclosures are installed and used in a manner consistent with the requirements of Article 314 of the NEC.

Requirements Basis:

National Electrical Code, Chapter 3.

GENERAL USE EQUIPMENT

Objective:

NID 3.0 Electrical design practices for general use equipment are established in accordance with consensus standards (NEC, Ch. 4).

Criteria:

1. Design configuration and installation requirements for motors, motor circuits, and controllers, is consistent with NEC, Article 430, and Figure 430.1.

2. Design configuration and installation requirements for air-conditioning and refrigeration equipment are consistent with NEC, Article 440.

3. Design configuration and installation requirements for generators are consistent with NEC, Article 445.

4. Design configuration and installation requirements for transformers and transformer vaults are consistent with NEC, Article 450.

5. Design configuration and installation requirements for phase converters are consistent with NEC, Article 455.

6. Design configuration and installation requirements for capacitors are consistent with NEC, Article 460.

7. Design configuration and installation requirements for resistors and reactors are consistent with NEC, Article 470.

8. Design configuration and installation requirements for storage batteries are consistent with NEC, Article 480.

9. Design configuration and installation requirements for equipment rated over 600 volts, nominal, are consistent with NEC, Article 490.

Approach:

1.0 Review electrical design documentation and Motor Control Center (MCC) installation requirements to ensure that MCC installations and interfaces with the supply, comply with the general configuration and system components identified in NEC Figure 430.1:

   a. Ensure that MCC configuration is consistent with Figure 430.1, e.g., feeder supply interface includes motor-feeder short-circuit and ground-fault protection followed by a motor disconnecting means that interfaces with the branch-circuit and ground-fault protection devices;.

a. Ensure that MCC design includes or addresses the particular system components, equipment, and devices as cited in NEC Figure 430.1, e.g., interfaces, disconnecting means, protective devices, controllers and control circuits, overload protection;

1.1 Review electrical design documentation and electrical installation requirements to ensure that MCC installations are designed in accordance with NEC Article 430:

a. Motor circuit conductors;

b. Motor and branch-circuit overload protection;

c. Motor and branch-circuit short-circuit and ground-fault protection;

d. Motor feeder short-circuit and ground-fault protection;

e. Motor control circuits;

f. Motor controllers;

g. Motor Control Centers;

h. Disconnecting means;

i. Adjustable speed drive systems;

j. MCC installations rated over 600 volts, nominal;

k. Protection of live parts;

l. Grounding for MCC installations;

2.0 Review electrical design documentation and electrical installation requirements to ensure that air-conditioning and refrigeration equipment installations are designed in accordance with NEC Article 440:

a. Disconnecting means;

b. Branch-circuit short-circuit and ground-fault protection;

c. Branch-circuit conductors;

d. Controllers for motor compressors;

e. Motor-compressor and branch-circuit overload protection;

f. Provisions for room air conditioners, including grounding, branch-circuit requirements, disconnecting means, leakage current detection and interruption, and arc-fault circuit interrupters;

3.0 Review electrical design documentation and electrical installation requirements to ensure that generator installations are designed in accordance with NEC Article 445:

a. Overcurrent protection;

b. Conductor ampacity;

c. Protection of live parts;

d. Guards for attendants;

e. Bushings;

f. Generator terminal housings;

b. Disconnecting means.

4.0 Review electrical design documentation and electrical installation requirements to ensure that transformers and transformer vault installations are designed in accordance with NEC Article 450:

a. Overcurrent protection;

b. Autotransformers and grounding;

c. Secondary ties;

d. Design for parallel operation of transformers;

e. Specific provisions applicable to different types of transformers;

f. Transformer vaults: locations, construction, ventilation, drainage;

5.0 Review electrical design documentation and electrical installation requirements to ensure that phase converter equipment installations are designed in accordance with NEC Article 455:

a. Rotary and static-phase converters;

b. Equipment grounding connections;

c. Conductors;

d. Overcurrent protection;

e. Disconnecting means;

f. Connection to single-phase loads;

g. Terminal housings;

h. Special provisions for: disconnecting means; start-up; power interruption; and capacitors.

6.0 Review electrical design documentation and electrical installation requirements to ensure that capacitor installations are designed in accordance with NEC Article 460:

a. Enclosing and guarding of capacitor installations;

b. Capacitors rated at 600 volts and under;

c. Capacitors rated at over 600 volts.

7.0 Review electrical design documentation and electrical installation requirements to ensure that resistors and reactor equipment installations are designed in accordance with NEC Article 470:

a. Installations rated at 600 volts and under;

b. Installations rated at over 600 volts.

8.0 Review electrical design documentation and electrical installation requirements to ensure that storage battery installations are designed in accordance with NEC Article 480.

9.0 Review electrical design documentation and electrical installation requirements to ensure that over-600 volts equipment installations are designed in accordance with NEC Article 490:

a. Circuit-interrupting devices;

b. Isolating means;

c. Voltage regulators;

d. Minimum spacing and separation;

e. Metal-enclosed power switchgear and industrial control assemblies;

f. Mobile and portable equipment;

g. Electrode-type boilers.

Requirements Basis:

National Electrical Code, Chapter 4.

DESIGN FOR HAZARDOUS (CLASSIFIED) LOCATIONS

Objective:

NID 4.0 Electrical design practices for hazardous (classified) locations are established in accordance with consensus standards (NEC, Ch. 5; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. Areas containing flammable or combustible materials shall be properly classified as defined in the NEC.

2. Equipment installed in hazardous locations shall meet the requirements of Chapter 5 of the NEC.

Approach:

Review electrical design documentation and electrical installation requirements to:

1.0 Verify that areas containing flammable gases or vapors, flammable liquids, combustible dust or ignitable fibers or flyings are properly classified in accordance with Article 500.5 of the NEC.

2.0 Verify that appropriate protection techniques are utilized for electrical and electronic equipment in hazardous locations corresponding with the requirements of Article 500.7(A) through (L) of the NEC.

2.1 Verify that the equipment utilized in hazardous locations is suitable for the environment in which it will be installed.

2.2 Verify that equipment installed in hazardous locations in a manner that complies with the requirements of Articles 501 through 503 of the NEC.

2.3 Verify that intrinsically safe apparatus, wiring and systems that are utilized in Class I, II, or III areas comply with the requirements of Article 504 of the NEC.

Requirements Basis:

National Electrical Code, Chapter 5.

DESIGN PRACTICES FOR SPECIAL EQUIPMENT

Objective:

NID 5.0 Electrical design practices for special equipment are established in accordance with consensus standards (NEC, Ch.6; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. Cranes, monorail hoists, hoists, and all runways shall be installed to meet the requirements of Article 610 of the NEC.

2. Elevators shall be installed in accordance with the requirements of Article 620 of the NEC.

3. Arc welders, resistance welders, plasma cutters and other similar welding and cutting process equipment shall meet the requirements Article 630 of the NEC.

4. Information Technology Rooms shall comply with the requirements of Article 645 of the NEC.

5. Solar Photovoltaic Systems shall comply with the requirements of Article 690 of the NEC.

6. Fuel cells that are stand-alone or interactive with other electrical power production sources shall comply with the requirements of Article 692 of the NEC.

7. Electric power sources, interconnecting circuits, switching and control equipment dedicated to fire pump drivers shall comply with the requirements of Article 695 of the NEC.

Approach:

Review electrical design documentation and electrical installation requirements to:

1.0 Verify that all equipment operates in a hazardous location conforms to the requirements of Article 500 of the NEC.

1.1 Verify that conductors comply with Article 610, and Table 310.13 of the NEC unless otherwise permitted by Article 610.

1.2 Verify that the disconnecting means comply with Part IV of Article 610.

1.3 Verify that overcurrent protection complies with the requirements of Part V of Article 610.

1.4 Verify that the controls meet the requirements of Part VI of Article 610.

1.5 Verify that grounding of cranes, monorail hoists, hoists, and accessories are grounded in accordance with the requirements of Article 610.61 of the NEC.

2.0 Verify that unless otherwise permitted by 620.3(A) through 620.3(C) of the NEC the supply voltage of elevators is limited to 300 volts.

2.1 Verify that live parts are enclosed as specified in 620.4 of the NEC.

2.2 Verify that working clearance is provided about controllers, disconnecting means, and other electrical equipment as specified in 620.5 of the NEC.

2.3 Verify that conductors are insulated, sized, and rated to comply with the requirements of Part II of Article 620 of the NEC.

2.4 Verify that appropriate wiring methods were utilized for the branch circuits, and the branch circuits for car lighting, receptacles, ventilation, heating, air conditioning, hoistway pit lighting and other utilization equipment comply with the requirements of Part III of Article 620.

2.5 Verify that conductors are installed to comply with the requirements of Part IV of Article 620 of the NEC.

2.6 Verify that traveling cables are suspended, installed, protected, and properly rated for the location in which they are utilized as specified in Part V of Article 620.

2.7 Verify that the disconnecting means car(s), car lights, receptacle(s), ventilation, heating, and air condition and other utilization equipment have been properly installed and provided with warning signs and labels as specified by Part VI of Article 620.

2.8 Verify that overcurrent protection is provided in accordance with the requirements of Part VII of Article 620.

2.9 Verify that elevator driving machinery; motor-generator sets; motor controllers; and disconnecting means are installed in a room or space set aside for that purpose unless permitted by 620.71(A) or 620.71(B) of the NEC.

2.10 Verify that grounding of elevators systems complies with the requirements of Part IX of Article 620 of the NEC.

2.11 Verify that elevators with emergency and/of standby power systems comply with the requirements of Part X of Article 620 of the NEC.

3.0 Verify that the ampacity of conductors for arc welders complies with the requirements of 630.11(A) and (B) of the NEC.

3.1 Verify that overcurrent protection of arc welders complies with the requirements of 630.12(A) and (B) of the NEC.

3.2 Verify that the disconnecting means for each arc welder complies with the requirements of 630.13 of the NEC.

3.3 Verify that a rating plate is provided for each arc welder and it contains the information specified by 630.14 of the NEC.

3.4 Verify that the ampacity of conductors for resistance welders complies with the requirements of 630.11(A) and (B) of the NEC.

3.5 Verify that overcurrent protection of resistance welders complies with the requirements of 630.12(A) and (B) of the NEC.

3.6 Verify that the disconnecting means for each resistance welder complies with the requirements of 630.13 of the NEC.

3.7 Verify that a rating plate is provided for each resistance welder and it contains the information specified by 630.14 of the NEC

3.8 Verify that welding cable meets the requirements of Part IV of Article 60 of the NEC.

4.0 Verify that Information Technology Rooms comply with the requirements of 645.4 of the NEC. ***NOTE: If the IT room does not comply with 645.4 of the NEC then the requirements of NFPA 75 must be followed which are not included in this document.***

4.1 Verify that the supply circuits and interconnecting cables comply with the requirements of 645.5 of the NEC.

4.2 Verify the penetrations of the fire-resistant boundary of the IT room are in accordance with 300.21 of the NEC.

4.3 Verify that disconnecting means are provided for all electrical equipment, including HVAC equipment, and that they comply with 645.10 of the NEC.

4.4 Verify that Uninterruptible power supplies comply with 645.11 of the NEC.

4.5 Verify that all non-current carrying metal parts of on information technology system comply with 645.15 of the NEC.

4.6 Verify that power distribution units used for information technology equipment comply with the requirements of 645.17 of the NEC.

5.0 Verify that the installation, ground-fault protection, and alternating current modules of photovoltaic systems comply with the requirements of Part I of Article 690.

5.1 Verify that the requirements of appropriate articles are applied to the photovoltaic systems as specified in 690.3 of the NEC.

5.2 Verify that requirements for photovoltaic systems comply with Part II of Article 690.

5.3 Verify that the disconnecting means, fuses, and switch or circuit breakers meet the requirements of Part III of Article 690.

5.4 Verify that the wiring methods and connectors comply with Part IV of Article 690.

5.5 Verify that grounding of photovoltaic systems meet the requirements of Part V of Article 690.

5.6 Verify that marking of modules, power sources, interconnections, and energy storage comply with the requirements of Part VI of Article 690.

5.7 Verify that photovoltaic systems connected to other sources meet the requirements of Part VII of Article 690.

5.8 Verify that storage batteries are utilized in accordance with Part VIII of Article 690.

5.9 Verify that photovoltaic systems over 600 volts comply with the requirements of Part XI of Article 690.

6.0 Verify that the installation and listing requirements are met for the fuel cell system as specified in Part I of Article 692 of the NEC.

6.1 Verify that the requirements of appropriate articles are applied to the photovoltaic systems as specified in 692.3 of the NEC.

6.2 Verify that the requirements for circuit sizing and current, overcurrent protection, and stand-alone system circuits comply with the requirements of Part II of Article 692 of the NEC.

6.3 Verify that the disconnecting means for the fuel cell comply with the requirements of Part III of Article 692.

6.4 Verify that the wiring methods are in accordance with 692.31 of the NEC.

6.5 Verify that grounding of the fuel cell system is in accordance with Part V of Article 692.

6.6 Verify that the fuel cell system is properly marked and labeled as required in Part VI of Article 692.

6.7 Verify that connections to other circuits by the fuel cell system comply with the requirements of Part VII of Article 692.

6.8 Verify that fuel cells with a maximum output voltage over 600 volts ac comply with the requirements of other articles of the NEC applicable to such installations.

7.0 Verify that the power source(s) for electric motor-driven fire pumps comply with 695.3 of the NEC.

7.1 Verify that circuits that supply electric motor-driven fire pumps are supervised from inadvertent disconnection as specified in 695.4(a) or 695.4(B).

7.2 Verify that a transformer(s) installed between the system and the fire pump controller meets the requirements of 695.5.

7.3 Verify that power circuits and wiring method comply with the requirements of 695.6(A) through (H) except as noted in 696.6 of the NEC.

7.4 Verify that voltage drop at the controller line terminal and at the motor terminal do not occur beyond those allowed by 695.7 of the NEC.

7.5 Verify that equipment is listed for fire pump service as required by 695.10 of the NEC.

7.6 Verify that equipment locations comply with the requirements of 695.12 of the NEC.

7.7 Verify that control wiring complies with the requirements of 695.14 of the NEC.

Requirements Basis:

National Electrical Code, Chapter 6.

DESIGN PRACTICES FOR EMERGENCY, STANDBY, AND FIRE-ALARM SYSTEMS

Objective:

NID 6.0 Electrical design requirements for emergency, standby, and fire-alarm systems are established in accordance with consensus standards (NEC, Ch. 7; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. Design configuration and installation requirements emergency systems are consistent with NEC, Article 700.

2. Design configuration and installation requirements for standby systems are consistent with NEC, Article 701.

3. Design configuration and installation requirements fire alarms are consistent with NEC, Article 760.

Approach:

1.0 Review electrical design documentation and electrical installation requirements to ensure that emergency systems are designed in accordance with NEC Article 700:

   a. Capacities, ratings, load pickup and shedding;

   b. Transfer equipment shall be automatic, identified for emergency use, and AHJ-approved;

   c. Signals, ground-fault indication, signs for emergency sources and grounding;

   d. Circuit wiring;

   e. A source of power – generators, batteries, UPS, etc.

   f. Emergency system circuits for lighting and power – circuit loads and emergency lighting, circuits for emergency power;

   g. Control of emergency lighting circuits – switch requirements and location;

   h. Overcurrent protection – accessibility, ground-fault protection of equipment (GFE), and coordination;

2.0 Review electrical design documentation and electrical installation requirements to ensure that standby systems are designed in accordance with NEC Article 701:

   a. Capacities, ratings, transfer equipment, signals and sign requirements;

b. Circuit wiring;

c. Sources of power – batteries, generators, UPS, etc.

d. Overcurrent protection – accessibility, GFE, and device coordination;

3.0 Review electrical design documentation and electrical installation requirements to ensure that fire alarm (FA) systems are designed in accordance with NEC Article 760:

a. FA circuit and equipment grounding, and circuit identification;

b. Non-Power Limited Fire Alarm (NPLFA) circuits – overcurrent protection and device location;

c. Circuit wiring methods, enclosures and raceways, conductors (size, use, and insulation), conductor numbers in trays, raceways, and derating;

d. Power-limited FA (PLFA) circuits – wiring methods on supply and load sides; separation requirements from other circuits (use of barriers and enclosures);

Requirements Basis:

National Electrical Code, Chapter 7.

DESIGN PRACTICES FOR COMMUNICATION SYSTEMS

Objective:

NID 7.0 Electrical design practices for communications systems are established in accordance with consensus standards (NEC, Ch. 8; ISM Core Functions – 1,2,3,4 and Guiding Principles – 1,5,6,7).

Criteria:

1. Communication equipment shall comply with Article 800 of the NEC.

Approach:

1.0 Verify that the general requirements as specified in Part I of Article 800 are complied with when inspecting the communication equipment.

1.1 Verify that the applicable articles as specified in 800.3 of the NEC are adhered to as related to communication equipment.

1.2 Verify that wires and cables outside and entering building comply with the requirements of Part II of Article 800.

1.3 Verify that protective devices and grounding methods comply with Parts III and IV of Article 800.

1.4 Verify that communications wires, raceways, equipment, and cable within buildings are installed and marked in a manner that complies with Part V of Article 800.

1.5 Verify that communications wires, raceways, cables, and equipment are listed as required by Part VI of Article 800.

Requirements Basis:

National Electrical Code, Chapter 8.