U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR mPOWER™ iPWR DESIGN

14.3.6 ELECTRICAL SYSTEMS - INSPECTIONS, TESTS, ANALYSES, AND ACCEPTANCE CRITERIA

REVIEW RESPONSIBILITIES

Primary - The organization responsible for electrical engineering review

Secondary - None

I. AREAS OF REVIEW

This Design Specific Review Standard (DSRS) section addresses inspections, tests, analyses, and acceptance criteria (ITAAC) related to the station electrical systems. ITAAC information is contained in the final safety analysis report (FSAR) of a combined license (COL) application or Tier 1 information from the design control document (DCD) of a design certification (DC) application. This DSRS section primarily involves the station electrical system, including Class 1E portions of the system, equipment qualification (EQ), major portions of the non-Class 1E system, and portions of the plant lightning protection, grounding, and lighting systems. The development of ITAAC for evolutionary plants typically involve a significant amount of reliance on alternating current (AC) electrical systems for accomplishing safety functions, but it may be much different for passive plant designs that involve much less reliance on AC electrical systems for accomplishing safety functions.

The specific areas of review are as follows:

1. The organization responsible for electrical engineering reviews the Tier 1 portion of the DCD submitted by the applicant. The organization responsible for electrical engineering has primary review responsibility for the station electrical systems in Tier 1. Review guidance for implementing the ITAACs is contained in Appendix A, “Information on Prior Design Certification Reviews,” to Standard Review Plan (SRP) Section 14.3. The scope of the electrical review includes the entire Class 1E portion of the electrical system, equipment qualification (EQ), as well as a major portion of the non-Class 1E electrical system. It also includes portions of the plant lightning protection, grounding, and lighting systems.

   The onsite power supply system for “passive plant” designs and other advanced reactor designs, including small modular reactor plants, are mostly non-safety-related with some portions classified as risk-significant. Thus, they are classified as “non-safety-related risk-significant.” For these passive plant designs, the onsite power supply may be subject to special regulatory treatment of non-safety-related systems (RTNSS) considerations. The criteria for classifying non-safety-related systems that perform risk-significant or important functions (defense-in-depth) as RTNSS are provided by

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Standard Review Plan SRP Section 19.3, "Regulatory Treatment of Non-Safety Systems (Passive Advanced Light Water Reactors)," as well as the general regulatory requirements for RTNSS SSCs. The current passive plant designs (e.g., AP1000, ESBWR, and mPower™) include the following onsite AC power supplies:

A. Ancillary Diesel Generators (ADGs) – classified as RTNSS Criterion B and designed for seismic events and other natural phenomena. ADGs may not be included in the mPower™ design.

B. Standby Diesel Generators (SDGs) – classified as RTNSS Criterion C. RTNSS Criterion B may apply to mPower™ SDGs.

2. The organization responsible for electrical engineering has the lead responsibility for the review of Tier 1 information regarding qualification of equipment to withstand harsh environments.

3. The organization responsible for electrical engineering has responsibility for the review of selected definitions, interface requirements of the standard design within the site, and site-specific portions of the design, that pertain to electrical equipment.

4. The organization responsible for electrical engineering performs related reviews and coordination activities, as requested by other organizations, for Tier 1 systems using Class 1E power.

5. For a DC application:

   A. The staff reviews the proposed ITAACs that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the Atomic Energy Act, and the NRC's regulations.

   B. The staff reviews the justification that compliance with the interface requirements is identified through ITAAC. The staff also reviews the method that is to be used for verification of the interface requirements.

6. For a COL application:

   A. The staff reviews the proposed ITAACs that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the combined license, the Atomic Energy Act, and the NRC's regulations.

   B. If the application references a standard design certification, the staff verifies that the ITAAC contained in the certified design apply to those portions of the facility design that are approved in the design certification as well as site-specific information.

7. <u>COL Action Items and Certification Requirements and Restrictions</u>. For a DC application, the review will also address COL action items and requirements and restrictions (e.g., interface requirements).

For a COL application referencing a DC, a COL applicant must address COL action items (referred to as COL information items in certain DCs) included in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface and site-specific requirements) included in the referenced DC.

Review Interfaces

Other listed DSRS sections interface with this section as follows:

1. SRP Section 14.3 provides general guidance on ITAAC information and review interfaces.

2. Acceptability of ITAAC information regarding qualification of equipment for seismic environments is reviewed under DSRS Section 14.3.2.

3. Review of ITAAC information regarding EQ of electrical and mechanical equipment is reviewed under DSRS Section 3.11. The specific acceptance criteria and review procedures are contained in the referenced DSRS sections.

II. ACCEPTANCE CRITERIA

Requirements

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAACs that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a facility that incorporates the design certification has been constructed and will be operated in conformity with the design certification, the provisions of the Atomic Energy Act, and the NRC's regulations;

2. 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning , that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the combined license, the provisions of the Atomic Energy Act, and the NRC's regulations.

3. GDC 17, in part, requires that an onsite and an offsite electric power system be provided to permit functioning of SSCs important to safety. It further requires that the onsite electric power system have independence and redundancy and the electric power supplied by the offsite system be supplied by two physically independent circuits. Also, GDC 17 requires that provisions be included to minimize the likelihood of losing all electric power as a result of or coincident with, loss of power generated by the nuclear power unit, from the transmission network, or the onsite electric power supplies.

4. 10 CFR 50.49 as it relates to EQ of electrical equipment important to safety for nuclear power plants. Applicants must ensure that safety-related, non-safety-related, and certain post-accident monitoring equipment can perform their intended functions in various anticipated environmental conditions.

5. GDC 5 as it relates to sharing the electrical power systems between units.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are as follows for review described in this DSRS section. The DSRS is not a substitute for the NRC's regulations, and compliance with it is not required. Identifying the differences between this DSRS section and the design features, analytical techniques, and procedural measures proposed for the facility, and discussing how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria, is sufficient to meet the intent of 10 CFR 52.47(a)(9), "Contents of applications; technical information."

The staff's review of the standard plant is conducted to ensure, in part, that Tier 1 contains top level design, fabrication, testing, and performance requirements for SSCs important to safety. Design Descriptions and ITAAC should be established to verify that these top level requirements (or design commitments) are met when the plant is built. IEEE nuclear standards should be used, as appropriate, to further establish top level requirements. IEEE Std. 308, "IEEE Standard Criteria for Class 1E power Systems for Nuclear Power Generating Stations," in conjunction with other related IEEE standards, establish specific design criteria for nuclear power plant electrical systems and equipment.

The standard passive design Class 1E electrical systems may include: (1) the Class 1E electrical power distribution system, (2) the Class 1E direct current (dc) power supply, and (3) the Class 1E vital AC and Class 1E instrument and control power supplies. Using the above regulations, IEEE standards, operating and licensing experience, and PRA as its bases, the applicant should establish top-level design commitments for the Class 1E electrical systems of the standard passive design to be included in the design descriptions and verified by ITAAC. The top-level design commitments for the Class 1E electrical systems include design aspects related to:

1. Equipment qualification for seismic and harsh environment

   To ensure that the seismic design requirements of GDC 2 and the EQ requirements of 10 CFR 50.49 have been adequately addressed, a "basis configuration" standard ITAAC may be established for applicable systems to verify these design aspects of electrical equipment important to safety.

   The Design Description should identify that Class 1E equipment that is seismic Category 1 and located in a harsh environment needs to be qualified. The basic configuration standard ITAAC may be used to verify these areas.

EQ of safe-shutdown equipment may be verified as part of the basic configuration ITAAC for safety-related systems. EQ treatment in the ITAAC would then be discussed in the General Provisions section of Tier 1 (see SRP Section 14.3 Appendix A). Verification may include type tests or a combination of type tests and analyses of Class IE electrical equipment identified in the Design Description or accompanying figures to show that the equipment can withstand the conditions associated with a design basis event (DBE) without loss of safety function for the time that the function is needed.

Qualification of systems and components for seismic and harsh environments should be verified by ITAAC. Electrical equipment located in a "mild" environment should be discussed in the applicable sections of the COL application only. An exception is made for state-of-the-art digital instrumentation and control (I&C) equipment and digital control and protection systems located in an "other than harsh" environment. Operational experience has shown these state-of-the-art equipment and systems to be sensitive to temperature. ITAAC should be also included to verify the qualification of equipment whose performance may be impacted by sensitivity to particular environmental conditions such as electromagnetic or radio-frequency interferences and power surges, not considered by regulations to be harsh.

2. Redundancy and independence

   To ensure that the Class 1E electric systems meet the single failure requirements of GDC 17 (and GDC 5 if any electrical power systems are shared between units), ITAAC may be established to verify the redundancy and independence of the Class 1E portion of the electrical design. For the electrical systems, ITAAC should verify the Class 1E divisional assignments and independence of electric power by both inspections and tests. The independence may be established by both electrical isolation and physical separation. Identification of the Class 1E divisional equipment should be included to aid in demonstrating the separation. (The detailed requirements are specified in Tier 2. For example, separation distances and identification are outlined in Tier 2). These attributes should be verified all the way to the electrically powered loads by a combination of the electrical system ITAAC and the ITAAC of the individual fluid, I&C, and heating, ventilation and air conditioning (HVAC) systems which also cover the electrical independence and divisional power supply requirements.

   ITAAC should be included to verify adequate separation, required inter-ties (if any), required identification (e.g., color coding), proper routing/termination (i.e., location), separation of non-Class 1E loads from 1E buses. Post-fire safe shutdown separation of electrical circuits should be addressed in the fire protection system ITAAC.

3. Capacity and Capability

   To ensure that the electrical systems have adequate capacity and capability to supply the safety-related electrical loads for design basis events, ITAAC should be established to verify the adequate sizing of the electrical system equipment and its ability to respond (e.g., automatically in the times needed to support the accident analyses) to postulated events. This includes the Class 1E portion and the non-Class 1E portion to the extent that it is involved in supporting the Class 1E system functions.

ITAAC should be included to analyze the as-built electrical system and installed equipment (diesel generators, transformers, switchgear, batteries, etc.) to verify its ability to power the loads. In addition, the ITAAC should also include tests to demonstrate the operation of the equipment. Testing should be included in ITAAC to verify SDG and ADG capacity and capability. In some cases regulatory guidance specifies the need for margin in capacity to allow for future load growth.

ITAAC should be developed to verify the initiation of the Class 1E equipment necessary to mitigate postulated events for which the equipment is credited (e.g., loss of coolant accident (LOCA), loss of offsite power (LOOP), and degraded voltage conditions).

ITAAC should be included to analyze the as-built electrical power system for its response to a LOCA, LOOP, combinations of LOCA and LOOP, degraded voltage, and recent operating experience that involved the loss of one of the three phases of the offsite power circuit (Reference 13) including tests to demonstrate the actuation of the electrical equipment in response to postulated events.

Analyses to demonstrate the acceptability of a voltage drop calculation should be included in ITAAC to verify adequacy for supporting the accomplishment of a direct safety function. The applicable section of the COL application should include an inspection of the voltage calculated and voltage measured, i.e., with reference to the BTP 8-6. Testing should be included in ITAAC to verify the adequacy of DGs (i.e., size, and voltage and frequency response) is acceptable.

4. Electrical protection features

   To ensure that the electrical power system is protected against potential electrical faults, ITAAC should be established to verify the adequacy of the electrical circuit protection included in the design. Operating experience and NRC Electrical Distribution System Functional Inspections (EDSFIs) have indicated some problems with the short circuit rating of some electrical equipment and breaker and protective device coordination. Inclusion in ITAAC should be based on the potential for preventing safety functions and the operating experience.

   ITAAC should be included to analyze the as-built electrical system equipment for its ability to withstand and clear electrical faults. ITAAC should also be included to analyze the protection feature coordination to verify its ability to limit the loss of equipment due to postulated faults. Equipment short circuit capability and breaker coordination should be verified by specifying ITAAC for analyses. The description of the analyses should be included in the applicable section of the application. Similarly, SDG and ADG diesel generator protective trips (and bypasses if applicable) should be considered.

5. Displays/controls/alarms

   To help ensure that the electrical power system is available when required, ITAAC should be included to verify the existence of monitoring and controls for the electrical equipment. The minimum set of displays, alarms, and controls is based on the emergency procedure guidelines. In some cases, additional displays, alarms, and

controls may be specified based on special considerations in the design and/or operating experience.

ITAAC should be included to inspect for the ability to retrieve the information (displays and alarms), and to control the electrical power system in the main control room and/or at locations provided for remote shutdown. Detection of undervoltage conditions along with the starting and loading of SDG should be included in ITAAC. This is a direct safety function in response to design basis event of loss of power. Problems with loading of SDG equipment should be evaluated in this requirement.

Other Electrical Equipment Important to Safety

In addition to the Class 1E systems addressed above, other aspects of the electrical design that are deemed to be important to safety and the top-level design commitments are included in Tier 1.

1. Interface (Offsite Power)

   To ensure that the requirements of GDC 17 for the adequacy and independence of the preferred offsite power sources within the standard design scope were met, ITAAC should verify the capacity and capability of the offsite sources to feed the Class 1E divisions, and the independence of those sources.

   ITAAC should be included to inspect the direct connection of the offsite sources to the Class 1E divisions and to inspect for the independence/separation of the offsite sources.

   In addition, ITAAC should be included to analyze and inspect the main generator rated power factor that permits plant output to the transmission system via the main step-up transformer, and to provide power to the station auxiliary loads via unit auxiliary transformer (UAT) and switchyard. ITAAC should also be included to verify that the main generator circuit breaker is designed to supply power to the plant loads if the unit trips, however, this feature may not be included in the mPower^{TM} design.

2. Containment Electrical Penetrations

   To ensure the containment electrical penetrations (both those containing Class 1E circuits and those containing Non Class 1E circuits) do not fail due to electrical faults and potentially breach the containment, ITAAC should verify that all electrical containment penetrations are protected against postulated currents greater than their continuous current rating.

3. Site-specific information

   To ensure the site-specific information pertaining to particular site or unique system (e.g., supplemental heat sink system, or diesel generators to provide long term battery charging), ITAAC should be developed to verify, through analyses, inspection and testing.

4. Lighting, Grounding, and Lightning Protection

   ITAAC should be included to verify the continuity of power sources for plant lighting, systems to ensure that portions of the plant lighting remain available during accident scenarios, and power failures. The basis for inclusion may be more related to defense-in-depth, support function, licensing and operating experience, or PRA rather than "accomplishing a direct safety function."

   ITAAC should be developed to inspect for appropriate grounding and lightning protection features.

5. Electrical Power for Non-Safety Plant Systems

To ensure that electrical power is provided to support the non-safety plant systems, Design Descriptions cover portions of the non-Class 1E electrical systems. ITAAC should be included to verify the functional arrangement of electrical power systems (i.e., ADGs and SDGs) provided to support non-safety plant systems to the extent that those systems perform a significant safety function. ADGs may not be applicable to the mPower^{TM} design.

Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this DSRS section is discussed in the following paragraphs:

1. Compliance with GDC 17, in part, requires that an onsite and offsite electric power systems be provided to permit functioning of structures, systems and components important to safety. It further requires that the onsite electric power system have independence and redundancy and the electric power supplied by the offsite system be supplied by two physically independent circuits. This provides a reasonable assurance that the facility will function reliably in the event of a fault in an area of the electrical design.

2. Compliance with 10 CFR 50.49 requires that certain electrical equipment located in harsh environments be qualified for DBE. This provides a reasonable assurance that the equipment needed in the event of an accident will perform its intended function.

3. IEEE Std. 308, "IEEE Standard Criteria for Class 1E power Systems for Nuclear Power Generating Stations," in conjunction with other related IEEE standards, establishes specific design criteria for nuclear power plant electrical systems and equipment. This provides a reasonable assurance that the electrical systems will perform their intended function in the anticipated operational environment.

III. REVIEW PROCEDURES

The reviewer will select material from the procedures described below, as may be appropriate for a particular case.

These review procedures are based on the identified DSRS acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II.

1. In establishing the top level requirements for the electrical design, the reviewer should use the Code of Federal Regulations (CFR) including the General Design Criteria (GDC) of Appendix A and Parts 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants." In addition, the Institute of Electrical and Electronics Engineers (IEEE) nuclear standards should be used, as appropriate, to further establish top level requirements. The reviewer should use the electrical review checklists provided in Appendix C, "Detailed Review Guidance," to SRP Section 14.3 as an aid for establishing consistency and comprehensiveness in the review of the systems. Also, the reviewer should consider significant lessons learned from operating and licensing experience problems and insights gained from the probabilistic risk assessment (PRA) for the standard design.

2. Follow the general procedures for review of Tier 1 contained in the Review Procedures section of SRP Section 14.3. Ensure that the DCD is consistent with Appendix A, "Review Branch Responsibility for the Evolutionary designs," to SRP Section 14.3.

3. Ensure that all Tier 1 information is consistent with Tier 2 information. Figures and diagrams should be reviewed to ensure that they accurately depict the functional arrangement and requirements of the systems. Reviewers should use the electrical systems review checklist shown in Appendix C to SRP Section 14.3 as an aid in establishing consistent and comprehensive treatment of issues.

4. Ensure that the electrical systems are clearly described in Tier 1, including the key performance characteristics and safety functions of SSCs based on their safety significance.

5. The reviewer should ensure that appropriate guidance is provided to other technical branches such that electrical issues including RTNSS diesel generators, in Tier 1 are treated in a consistent manner..

6. Ensure that the standard ITAAC EQ entries related to electrical systems are included in the appropriate systems of the design. In particular, the reviewer should review the basic configuration ITAAC for verification of EQ. The reviewer should coordinate with the organization responsible for the review of DSRS Section 3.2.1 for the review of seismic qualification of electrical components in the basic configuration ITAAC. The reviewer should ensure consistent application and treatment of the standard ITAAC entries for divisional power supply, physical separation, and independence for electrical and I&C systems in Tier 1.

7. Ensure that design features from the resolutions of selected technical and policy issues are adequately addressed in Tier 1, based on safety significance. Ensure that the appropriate Commission guidance, requirements, bases and resolutions for these items are documented clearly in the SER.

8. Ensure that definitions, legends, interface requirements, and site-specific information that pertain to electrical issues are treated consistently and appropriately in Tier 1.

9. For review of a DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements), set forth in the final safety analysis report (FSAR) meets the acceptance criteria. DCs have referred to the FSAR as the design control document (DCD). The reviewer should also consider the appropriateness of identified COL action items. The reviewer may identify additional COL action items; however, to ensure these COL action items are addressed during a COL application, they should be added to the DC FSAR.

   For review of a COL application, the scope of the review is dependent on whether the COL applicant references a DC with, an early site permit (ESP) or other NRC approvals (e.g., manufacturing license, site suitability report or topical report). The COL application consists of addressing COL action items and site-specific information

10. Implementation of ITAAC will be inspected in accordance with NRC Inspection Manual Chapter IMC-2503, "Construction Inspection Program - ITAAC Inspections."

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable) support conclusions of the following information to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

1. The reviewer verifies that sufficient information has been provided to satisfy DSRS Section 14.3.6, and this DSRS section concludes that the ITAAC is acceptable. A finding similar to that in the Evaluation Findings section of DSRS Section 14.3.6 should be provided in a separate section of the SER.

2. For DC and COL reviews, the findings will also summarize the staff's evaluation of interface and site-specific information) and COL action items relevant to this DSRS section.

V. IMPLEMENTATION

The staff will use this DSRS section in performing safety evaluations of mPower^{TM}-specific design certification (DC), combined license (COL)applications submitted by applicants pursuant to 10 CFR Part 52. The staff will use the method described herein to evaluate conformance with Commission regulations.

Because of the numerous design differences between the mPower^{TM} and large light-water nuclear reactor power plants, and in accordance with the direction given by the Commission in SRM- COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights to Enhance the Safety

Focus of Small Modular Reactor Reviews," dated August 31, 2010 (Agencywide Documents Access and Management System Accession No. ML102510405), to develop risk-informed licensing review plans for each of the small modular reactor (SMR) reviews including the associated pre-application activities, the staff has developed the content of this DSRS section as an alternative method for mPower™ -specific DC, or COL, applications submitted pursuant to 10 CFR Part 52 to comply with 10 CFR 52.47(a)(9), "Contents of applications; technical information."

This regulation states, in part, that the application must contain "an evaluation of the standard plant design against the Standard Review Plan (SRP) revision in effect 6 months before the docket date of the application." The content of this DSRS section has been accepted as an alternative method for complying with 10 CFR 52.47(a)(9) as long as the mPower™ DCD FSAR does not deviate significantly from the design assumptions made by the NRC staff while preparing this DSRS section. The application must identify and describe all differences between the standard plant design and this DSRS section, and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria. If the design assumptions in the DC application deviate significantly from the DSRS, the staff will use the SRP as specified in 10 CFR 52.47 (a)(9). Alternatively, the staff may supplement the DSRS section by adding appropriate criteria in order to address new design assumptions. The same approach may be used to meet the requirements of 10 CFR 52.79 (a)(41), for COL applications.

VI. REFERENCES

1. 10 CFR 52.47, "Contents of Applications."

2. 10 CFR 52.80, "Contents of Applications."

3. 10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants."

4. 10 CFR Part 50, Appendix A, General Design Criterion 5, "Sharing of structures, systems, and components,"

5. 10 CFR Part 50, Appendix A, General Design Criterion 17, "Electric Power Systems."

6. NUREG-1503, "Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor," Volumes 1 and 2, July 1994.

7. NUREG-1462, "Final Safety Evaluation Report Related to the Certification of the System 80+ Design," Volumes 1 and 2, August 1994.

8. IEEE Std. 308-2001, "Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations."

9. NRC Regulatory Guide RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

10. SECY-00-77, Certification of Two Evolutionary Designs, April 15, 1996.

11. NRC Inspection Manual Chapter IMC-2503, “Construction Inspection Program - ITAAC Inspections,” issued April 26, 2006.

12. NUREG – 0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition”

13. NRC Bulletin 2012-01, “Design Vulnerability in Electrical Power System,” issued July 27, 2012.