U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR mPOWER™ iPWR DESIGN

8.3.2 DC POWER SYSTEMS (ONSITE)

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of onsite dc power systems

Secondary - None

I. AREAS OF REVIEW

The review addresses the descriptive information, analyses, and referenced documents, including electrical single-line diagrams, electrical control and schematic, functional piping and instrumentation diagrams (P&IDs), logic diagrams, tables, and physical arrangement drawings for the direct current (dc) onsite power system. The intent of the review is to determine whether the dc onsite power system satisfies the requirements of General Design Criteria (GDCs) 2, 4, 5, 17, 18, and 50 and will perform its intended functions during all plant operating, accident, and station blackout (SBO) conditions.

The mPower™ onsite dc power system includes the following classifications of equipment:

- Safety-related risk-significant (Class 1E) equipment
- Safety-related nonrisk-significant (Class 1E) equipment
- Nonsafety-related risk-significant Regulatory Treatment of Nonsafety Systems (RTNSS) equipment
- Nonsafety-related nonrisk-significant equipment.

The mPower™ application will include the classification of structures, systems, and components (SSCs), a list of risk-significant SSCs, and a list of RTNSS equipment. Based on this information, the staff will review according to Design-Specific Review Standard (DSRS) Section 3.2, Standard Review Plan (SRP) Sections 17.4 and 19.3 to confirm the determination of the safety-related and risk-significant SSCs.

Emphasis is placed on confirming the functional adequacy of the safety-related risk-significant portions of the onsite dc power system and ensuring that these systems have adequate redundancy, independence, and testability in conformance with the current regulatory criteria.

The specific areas of review are as follows:

1. System Redundancy Requirements. The staff will review the onsite dc power system to determine whether the required redundancy of components and subsystems is provided such that the system safety function can be accomplished, assuming a single failure. This requires an examination of the dc power system configuration regarding both power sources and their associated distribution systems, including the batteries, battery

chargers, power supply feeders, panel arrangements, loads supplied from each battery, and power connections to the inverters and connections to the instrumentation and control devices of the system.

2. Conformance with the Single-Failure Criterion. In determining the adequacy of this system to meet the single-failure criterion, the reviewer will examine the electrical and physical separation of redundant dc power sources and associated distribution systems to assess the independence between redundant portions of the system. This will include a review of any interconnections between redundant buses, buses and loads, and buses and power supplies; ensuring there is no sharing of the dc power system between units; design criteria and bases governing the installation of electrical cable for redundant portions of the systems; and physical arrangement of redundant switchgear and power supplies.

3. Power Supplies. The staff will review design information and analyses demonstrating the suitability of batteries and battery chargers as dc power supplies and of inverters that convert dc to alternate current (ac) for instrumentation and control power to ensure that they have sufficient capacity and capability to perform their intended functions, including the ability to cope with an SBO event. This will require an examination of (1) the characteristics and design requirements of each load (such as motor horsepower, volt-amp rating, in-rush current, starting volt-amps, and torque), (2) the length of time each load is required, (3) the combined load demand connected to each dc supply during the worst operating conditions, (4) the voltage recovering characteristics of batteries, and (5) the performance characteristic curves (e.g., voltage profile curves, discharge rate curves, and temperature effect curves) that illustrate the response of the batteries to the most severe loading conditions at the plant. The reviewer should ensure that the capacity of the battery charger is based on an evaluation of the largest combined demands of the various continuous steady-state loads plus charging capacity to restore the battery from the design minimum charge state to the fully charged state within the time stated in the design basis, regardless of the status of the plant when these demands occur.

   If the proposed design provides for the connection of nonsafety-related loads to the dc power system, the reviewer should particularly emphasize ensuring against marginal capacity and degradation of reliability that may result from implementing such design provisions.

   Regulatory Position C.1 of Regulatory Guide (RG) 1.81 states that dc systems in multiunit sites should not be shared. For mPower^{TM}, the review should ensure that units do not share safety-related dc power systems (batteries, chargers, or inverters). In addition, the mPower^{TM} design relies on portions of the onsite dc power system to cope with an SBO event; therefore, the staff will review the capacity and capability of the dc power system to withstand and recover from an SBO of specified duration to ensure conformance to Title of the *Code of Federal Regulations* (CFR), Section 50.63. For passive designs such as mPower^{TM}, the staff has required a minimum of 72 hours of battery capacity.

4 Identification of Cables, Raceways, and Terminal Equipment. The staff will review the proposed means for identifying the plant's dc power system components, including cables, raceways, and terminal equipment. The reviewer should also evaluate the identification scheme used to distinguish among redundant Class 1E systems,

associated circuits assigned to redundant Class 1E divisions, non-Class 1E systems, and their associated cables and raceways without the necessity for consulting reference materials.

5. Vital Supporting Systems. The staff will review the instrumentation, control circuits, and power connections of vital supporting systems to determine whether they are designed to the same criteria as those for the safety-related loads and the power systems that they support. This will include an examination of the vital supporting system component redundancy; power feed assignment to instrumentation, controls, and loads; initiating circuits; load characteristics; equipment identification scheme; and design criteria and bases for the installation of redundant cables.

6. System Testing and Surveillance. The staff will review the proposed means for monitoring the status of the dc power system and vital supporting system operability to ensure that these systems perform their intended functions. In addition, the staff will review the onsite testing capability to ensure conformance to the requirements of GDC 18.

7. Other Review Areas. The reviewer will determine whether the dc system and vital supporting systems meet the following:

   A. The systems and their components have the appropriate seismic design classification.

   B. The systems and their components are housed in a seismic Category I classified structures.

   C. The systems and their components are designed to withstand environmental conditions associated with normal operation, natural phenomena, and postulated accidents.

   D. The safety-related systems and their components have a Class 1E quality assurance classification.

8. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC). For design certification (DC) and combined license (COL) reviews, the staff reviews the applicant's proposed ITAAC associated with the structures, systems, and components (SSCs) related to this DSRS section in accordance with SRP Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria." The staff recognizes that the review of ITAAC cannot be completed until after the rest of this portion of the application has been reviewed against acceptance criteria contained in this DSRS section. Furthermore, the staff reviews the ITAAC to ensure that all SSCs in this area of review are identified and addressed as appropriate in accordance with SRP Section 14.3.

9. COL Action Items and Certification Requirements and Restrictions. For a DC application, the review will also address COL action items and requirements and restrictions (e.g., interface requirements and site parameters).

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

Review Interfaces

Other SRP and DSRS sections interface with this section as follows:

1. The organization responsible for onsite dc power systems reviews the adequacy of the offsite and onsite ac power system, including ac power sources, ac distribution systems, and ac instrumentation and control power systems, as part of its primary review responsibility for DSRS Sections 8.2 and 8.3.1.

2. In accordance with DSRS Section 8.4, the organization responsible for onsite dc power systems reviews overall compliance with 10 CFR 50.63 requirements, including the adequacy of the SBO analysis; the length of time that the plant can either withstand or cope with, and recover from, an SBO event; and the adequacy of any dc system power supplies that are not a part of the onsite dc power system reviewed under this DSRS section regarding the specified SBO event/duration.

3. The organization responsible for onsite dc power systems reviews the adequacy of the environmental qualification of safety-related electrical equipment, as part of its primary review responsibility for DSRS Section 3.11. This includes a review of the capability of safety-related electrical equipment to perform its intended safety functions when subjected to the effects of (a) accident environments such as loss-of-coolant accidents (LOCAs) and/or steamline breaks, (b) abnormal environments that may temporarily exceed equipment continuous-duty design parameters such as temperature and humidity, (c) abnormal environments caused by degradation or loss of heating, ventilation, and/or air conditioning systems, (d) seismic shaking, and (e) normal design environments on redundant safety-related electrical equipment that does not include design diversity (e.g., redundant components manufactured and designed by the same supplier).

4. The organization responsible for the review of plant ventilation systems evaluates the adequacy of those auxiliary supporting ventilation systems that are vital to the proper operation and/or protection of the dc power system, as part of its primary review responsibility for DSRS Sections 9.4.1 through 9.4.5. This includes systems such as the heating and ventilation systems for load center, battery, battery charger, and inverter rooms. In particular, the organization responsible for the review of plant ventilation systems determines whether the piping, ducting, and valving arrangements of redundant auxiliary supporting systems meet the single-failure criterion.

5. The organization responsible for the review of plant structures examines the physical arrangement of the dc power system and its supporting auxiliary system components and associated structures to confirm that single events and accidents will not disable redundant features, as part of its primary review responsibility for DSRS Sections 3.4.1, 3.5.1.1, 3.5.2, and 3.6.1.

6. The organization responsible for the review of engineered safety feature systems identifies those system components that require electric power as a function of time for each mode of reactor operation and accident condition, as part of its primary review responsibility for DSRS Sections 9.1.3, 9.2.1, 9.2.2, 9.2.4, 9.2.5, 9.2.6, 9.3.3, 9.4.1 through 9.4.5, 10.4.5, 10.4.7, and 10.4.9; and SRP Sections 9.1.4, 9.3.1, and 9.5.1.

7. The organization responsible for fire protection examines the fire detection and fire protection systems for the dc power system and its vital supporting systems to ensure that the adverse effects of fire are minimized, as part of its primary review responsibility for SRP Section 9.5.1. This review includes assessing the adequacy of protection provided for redundant safe-shutdown circuits to confirm that a single design-basis fire will not disable both redundant circuits.

8. The organization responsible for the review of reactor coolant and auxiliary process systems identifies those system components that require electric power as a function of time for each mode of reactor operation and accident condition, as part of its primary review responsibility for DSRS Sections 9.2.3, 9.3.2 and 9.3.6, and SRP Section 5.4.8,

9. The organization responsible for the review of containment systems and severe accidents evaluates the adequacy of those containment ventilation systems provided for maintaining a controlled environment for safety-related electrical equipment located inside the containment, as part of its primary review responsibility for DSRS Section 6.2.2. The organization responsible for the review of containment systems and severe accidents identifies those system components that require electric power as a function of time for each mode of reactor operation and accident condition, as part of its primary review responsibility for DSRS Sections 6.2.2, 6.2.4 and 6.2.5.

10. The organization responsible for the review of reactor coolant and reactivity systems identifies those system components that require electric power as a function of time for each mode of reactor operation and accident condition, as part of its primary review responsibility for DSRS Sections 4.6, 5.4.7 and 6.3, and SRP Section 5.4.12.

11. The organization responsible for the review of instrumentation and controls identifies those system components that require electric power as a function of time for each mode of reactor operation and accident condition, as part of its primary review responsibility for DSRS Chapter 7. In addition, the organization responsible for the review of instrumentation and controls verifies, upon request, the adequacy of safety-related display instrumentation, alarms, and other instrumentation systems (including bypass indication, status of batteries, and status of battery chargers required for safety), as part of its review responsibility for DSRS Chapter 7.

12. The organization responsible for the review of quality assurance and maintenance determines the acceptability of the preoperational and initial startup tests and programs, as part of its primary review responsibility for DSRS Section 14.2.

13. The organization responsible for quality assurance coordinates and performs the reviews of design, construction, and operations phase quality assurance programs, including general methods for addressing periodic testing, maintenance, and reliability assurance under SRP Section 17.5. The organization responsible for quality assurance also reviews the RTNSS in passive plant designs, as part of its primary review responsibility for SRP Section 17.5.

14. The organization responsible for mechanical engineering review, as part of its primary review responsibility for DSRS Section 3.10, reviews the criteria for seismic qualification and the test and analysis procedures and methods to ensure the mechanical survivability of Category I instrumentation and electrical equipment (including raceways, switchgear, control room boards, and instrument racks and panels) in the event of a

seismic occurrence.

15. The organization responsible for the review of technical specifications and short-term availability controls (for RTNSS items) coordinates and performs reviews for technical specifications or short-term availability controls as part of its primary review responsibility for DSRS Section 16.0.

16. The organization responsible for human performance, as part of its primary review responsibility for SRP Sections 13.5.1.1 and 13.5.2.1, reviews the adequacy of administrative, maintenance, testing, and operating procedure programs.

II. ACCEPTANCE CRITERIA

Requirements

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

1. GDC 2, as it relates to the ability of dc power system SSCs to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods, as established in Chapter 3 of the safety analysis report (SAR) and reviewed by organizations with primary responsibility for the reviews of plant systems, civil engineering and geosciences, and mechanical engineering.

2. GDC 4, as it relates to the ability of dc power system SSCs to withstand the effects of missiles and environmental conditions associated with normal operation and postulated accidents, as established in Chapter 3 of the SAR and reviewed by the organizations with primary responsibility for the reviews of plant systems, materials, and chemical engineering.

3. GDC 5, as it relates to sharing dc power system SSCs between reactor modules.

4. GDC 17, as it relates to (1) the capacity and capability of the onsite dc power system to enable the functioning of SSCs important to safety and (2) the independence and redundancy of the onsite dc power system in performing its safety function, assuming a single failure.

5. GDC 18, as it relates to the testability of the onsite dc power system.

6. GDCs 33, 34, 35, 38, 41, and 44, as they relate to the operation of the onsite dc power system, encompassed in GDC 17 to ensure that the safety functions described in GDCs 33, 34, 35, 38, 41, and 44 are accomplished appropriately for the mPower™ design.

7. GDC 50, as it relates to the design of containment electrical penetrations containing circuits of safety-related and nonsafety-related dc power systems.

8. 10 CFR 50.55a(h), as it relates to the incorporation of Institute for Electrical and Electronics Engineers (IEEE) Standard (Std.) 603-1991 (including the correction sheet dated January 30, 1995).

9. 10 CFR 50.65(a)(4), as it relates to the assessment and management, before the performance of maintenance activities, of the increase in risk that may result from proposed maintenance activities. These activities include, but are not limited to, surveillances, post maintenance testing, and corrective and preventive maintenance. Compliance with the maintenance rule, including verification that appropriate maintenance activities are covered therein, is reviewed under SRP Chapter 17.

10. 10 CFR 52.47(b)(1), requires that the mPower™ DC application contain the proposed ITAAC 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 DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act (AEA), and the U.S. Nuclear Regulatory Commission's (NRC's) regulations;

11. 10 CFR 52.80(a), requires that COL applications 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 COL, the provisions of the AEA, and the NRC's regulations.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are set forth below. 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 requirements in 10 CFR 52.47(a)(9), "Contents of applications; technical information." The same approach may be used to meet the requirements of 10 CFR 52.79(a)(41) for COL applications.

Branch technical positions and RGs that provide information, recommendations, and guidance and in general describe a basis acceptable to the staff that may be used to implement the requirements of GDCs 2, 4, 5, 17, 18, and 50 are identified in DSRS Section 8.1, Table 8-1.

1. RG 1.6, Positions D.1, D.3 and D.4, as they relate to the independence between redundant onsite dc power sources and between their distribution systems.

2. RG 1.32, as it relates to the design, operation, and testing of the safety-related portions of the onsite dc power system.

3. RG 1.75, as it relates to the physical and electrical independence of the circuits and electrical equipment that comprise or are associated with the onsite dc power system.

4. RG 1.81, as it relates to the sharing of SSCs of the dc power system. Regulatory Position C.1 states that multi-unit sites should not share dc systems.

5. RG 1.128, as it relates to the installation of vented lead-acid storage batteries in the onsite dc power system.

6. RG 1.129, as it relates to maintenance, testing, and replacement of vented lead-acid storage batteries in the onsite dc power system.

7. RG 1.118, as it relates to the capability to periodically test the onsite dc power system.

8. RG 1.153, as it relates to the design, reliability, qualification, and testability of the power, instrumentation, and control portions of safety systems of nuclear plants, including the application of the single failure criterion in the onsite dc power system. As endorsed by RG 1.153, IEEE Std. 603 provides a method acceptable to the staff to evaluate all aspects of the electrical portions of the safety-related systems, including basic criteria for addressing single failures.

9. RG 1.53, as it relates to the application of the single-failure criterion.

10. RG 1.63, as it relates to the capability of electric penetration assemblies in containment structures to withstand a LOCA without loss of mechanical integrity and the external circuit protection for such penetrations.

11. The guidelines of RG 1.160, as they relate to the effectiveness of maintenance activities for dc power systems. Compliance with the maintenance rule, including verification that appropriate maintenance activities are covered therein, is reviewed under DSRS Chapter 17.

12. The guidelines of RG 1.182, as they relate to conformance to the requirements of 10 CFR 50.65(a)(4) for assessing and managing risk when performing maintenance.

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 2 requires that nuclear power plant SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquake, tornado, hurricane, flood, tsunami, or seiche without losing the capability to perform their intended safety functions.

   With regard to the dc power system, this criterion requires that the capability for the onsite dc power system to perform its functions must be retained during the most severe natural phenomena that historically have been reported for the site and surrounding area. Therefore, the dc power system and its components must normally be located in seismic Category I structures that provide protection from the effects of tornadoes, tornado missiles, and floods. Equipment and components composing the onsite dc power system must also generally be seismically designed and/or qualified to perform their functions in the event of an earthquake. Meeting this requirement will provide assurance that equipment and structures will be designed to withstand the effects associated with natural phenomena, thus decreasing the probability that seismically and/or climatologically related natural phenomena could initiate accidents or prevent equipment from performing its safety function during an accident.

2. Compliance with GDC 4 requires that SSCs important to safety (1) be designed to accommodate the effects of, and be compatible with, the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents and (2) be appropriately protected against dynamic effects that may result from equipment failures, including missiles.

   The dc power system must provide power to systems important to safety during normal, abnormal, accident, and post-accident conditions. As applied to mPower™ plants, GDC 4 requires SSCs of the safety-related portions of the onsite ac power system (e.g., ac power supplied from safety-related batteries and inverters), to be capable of accommodating environmental conditions associated with normal operation, maintenance, testing, and postulated accidents and be protected against dynamic effects, including the effects of missiles, that may result from equipment failures. The environmental qualification of electrical equipment is evaluated in DSRS Section 3.11.

   Meeting these requirements will provide assurance that the dc power system will supply the electric power required for the operation of systems important to safety, even if or when they are subject to adverse environmental conditions and/or dynamic effects.

3. General compliance with GDC 5 requires that SSCs important to safety shall not be shared among nuclear power units unless such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units. Regulatory Position C.1 of RG 1.81 recommends that dc systems in multiunit nuclear power plants should not be shared. Meeting this requirement will negate the potential for common cause failure between the dc power systems of multiple units.

4. Compliance with GDC 17 requires the provision of onsite and offsite electrical power systems to facilitate the functioning of SSCs important to safety. Each electric power system, assuming that the other system is not functioning, must provide sufficient capacity and capability to ensure that (1) specified acceptable fuel design limits and the design conditions of the reactor coolant pressure boundary are not exceeded as a result of anticipated operational occurrences (AOOs) and (2) the core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents.

   Provisions must also be included to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit, the loss of power from the transmission network, or the loss of power from the onsite electric power supplies.

   GDC 17 also requires that the onsite power supplies and the onsite electrical distribution system have sufficient independence and redundancy to perform their safety functions, assuming a single failure. Therefore, no single failure will prevent the onsite power system from supplying electric power, thereby enabling safety functions and other vital functions that require electric power to be performed after any single failure in the power system.

   This DSRS section cites RGs 1.6, 1.32, 1.53, 1.75, 1.128, and 1.153 as establishing acceptable guidance for meeting the requirements of GDC 17. DSRS Sections 8.1, 8.2, 8.3.1, and 8.4 include additional information related to the review of compliance with

GDC 17.

Meeting the requirements of GDC 17 provides assurance that a reliable onsite dc power supply will be provided for all facility operating modes, including AOOs and design-basis accidents (DBAs), to permit the performance of safety functions and other vital functions, even in the event of a single failure.

5. Compliance with GDC 18 requires that electric power systems important to safety be designed to permit appropriate periodic inspection and testing of key areas and features to assess their continuity and the condition of their components. These systems shall be designed to test periodically (1) the operability and functional performance of the components of the systems, such as onsite dc power sources, relays, switches, and buses, and (2) the operability of the systems as a whole and, under conditions as close to design as practical, the full operation sequence that brings the systems into operation, including operation of applicable portions of the protection system and the transfer of power among the nuclear power unit, the offsite power system, and the onsite power system.

   This criterion requires that the dc power system provide the capability to perform integral periodic testing of Class 1E systems. This DSRS section cites RG 1.32, 1.47, 1.118, 1.129, and 1.153, and DSRS 7.2.15, as establishing acceptable guidance for meeting the requirements of this criterion.

   Meeting the requirements of GDC 18 provides assurance that, when required, onsite dc power systems can be appropriately and unobtrusively accessed for required periodic inspection and testing, enabling verification of important system parameters, performance characteristics, and features, as well as detection of degradation and/or impending failure under controlled conditions.

6. GDCs 33, 34, 35, 38, 41, and 44 set requirements for the safety functions for which access to both offsite and onsite power sources must be provided. Compliance with these criteria requires provision of this capability for reactor coolant makeup during small breaks, residual heat removal, emergency core cooling, containment heat removal, containment atmosphere cleanup, and cooling water for SSCs important to safety. These functions must be available during normal and accident conditions, as provided by the specific mPower™ systems.

   GDCs 33, 34, 35, 38, 41, and 44 require safety system redundancy such that, for onsite power system operation (assuming offsite power is unavailable); the safety function can be accomplished, assuming a single failure. Redundancy must be reflected in the standby power system with regard to both power sources and associated distribution systems. In addition, redundant safety loads must be distributed between redundant distribution systems, and associated redundant distribution systems must supply the instrumentation and control devices for the Class 1E loads and power system

   Meeting the requirements of these criteria, as encompassed by GDC 17, provides assurance that required dc power will be provided for all facility operating modes, including transients and DBAs, so that the safety functions required in these criteria may be performed, even in the event of any single failure.

7. Compliance with GDC 50 requires that the reactor containment structure—including access openings, penetrations, and containment heat removal systems—be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from any LOCA. Containment electric penetrations must therefore be designed to accommodate, without exceeding their design leakage rate, the calculated pressure and temperature conditions resulting from a LOCA.

   This criterion, as it applies to this DSRS section, relates specifically to ensuring the integrity of containment electrical penetrations in the event of design-basis LOCA conditions. This DSRS section cites RG 1.63 as guidance acceptable to the staff for meeting the requirements of this criterion.

   Meeting the requirements of GDC 50 provides assurance that a LOCA will not cause a containment structure, including its electrical penetrations, to exceed the design leakage rate, thus limiting the consequences of a LOCA.

III. <u>REVIEW PROCEDURES</u>

The primary objective in the review of the dc power system is to determine whether this system satisfies the acceptance criteria in Subsection II and will perform its design functions during normal plant operations, AOOs, accident conditions, and SBO events. To ensure that the acceptance criteria in Subsection II are satisfied, the review is performed as detailed below.

The primary reviewer will coordinate this review with the other branch areas of review, as stated in Subsection I. The primary reviewer obtains and uses such input as required to ensure that this review procedure is complete.

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.

Although IEEE Std. 946, IEEE Std. 1375, and IEEE Std. 1184 furnish additional technical supporting information related to the design of onsite dc power systems, an RG has not formally endorsed these standards. Therefore, they are included here as additional sources of information only.

1. In accordance with 10 CFR 52.47(a)(8),(21), and (22), for new reactor license applications submitted under Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues and medium- and high-priority generic safety issues that are identified in the version of NUREG-0933 current on the date 6 months before application and that are technically relevant to the design; (2) demonstrate how the operating experience insights have been incorporated into the plant design; and, (3) provide information necessary to demonstrate compliance with any technically relevant portions of the Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v). These cross-cutting review areas should be addressed by the reviewer for each technical subsection and relevant conclusions documented in the corresponding safety evaluation report (SER) section.

2. System Redundancy Requirements. GDCs 33, 34, 35, 38, 41, and 44 set requirements regarding safety-related systems that must be supplied by the onsite ac and dc power systems. In addition, these criteria state that safety-related system redundancy shall be such that, for onsite power system operation (assuming offsite power is not available), the system safety function can be accomplished, assuming a single failure. The acceptability of the onsite dc power system with regard to redundancy is based on conformance to the same degree of redundancy as that needed for safety-related components and systems required by these criteria. As endorsed by RG 1.153, IEEE Std. 603 provides a method acceptable to the staff to evaluate all aspects of the electrical portions of safety-related systems and the onsite power system, including criteria addressing redundancy. The staff will review the descriptive information—including electrical single-line diagrams, functional P&IDs, and electrical control and schematics—to verify that the dc power system reflects this redundancy, both in power sources and in associated distribution systems. The reviewer will also coordinate with other branches, as necessary, to verify that (1) redundant safety-related loads are distributed between redundant distribution systems and (2) the instrumentation and control devices for the safety-related loads and power system are supplied from the related redundant distribution systems. The review verifies that reactor core cooling is maintained after the loss of any one dc power supply or bus or a single independent active failure in any other system required for shutdown cooling.

3. Conformance with the Single-Failure Criterion. As required by GDC 17, the dc power system must be capable of performing its safety function, assuming a single failure. In evaluating the adequacy of this system to meet the single-failure criterion, the staff will review both electrical and physical separation of redundant power sources and distribution systems, including their connected loads, to assess the independence between redundant portions of the system.

   To ensure electrical independence, the staff will review the design criteria, analyses, description, and implementation—as depicted on functional logic diagrams, electrical single-line diagrams, and electrical control and schematics—to determine whether the design meets the positions of RGs 1.153, 1.53, 1.32, and 1.6. As endorsed by RG 1.153, IEEE Std. 603 provides a method acceptable to the staff for evaluating all aspects of the electrical portions of safety-related systems and the onsite power system. For guidance related to the application of the single-failure criterion, IEEE Std. 603 references IEEE Std. 379. In addition, as endorsed by RG 1.53, IEEE Std. 379 provides an acceptable methodology for satisfying the Commission's regulations for the application of the single-failure criterion to onsite dc power systems. The following aspects of the design need special review attention to confirm that the electrical independence and physical separation have not been compromised:

   A. With respect to the electrical independence of the onsite Class 1E power system from the offsite power system, as well as from any nonsafety portion of the onsite power system, electrical isolation is normally provided by Class 1E circuit breakers. However, in the special case of a passive design, the isolation is most likely provided by the Class 1E battery chargers. In this case, the battery chargers have a dual mission with respect to isolation. The battery chargers must protect the dc system from any degraded conditions or transients that may originate from the offsite or onsite ac systems, as well as during a loss of offsite power and SBO they must prevent the dc system from trying to power any upstream ac loads. The reviewer must assure that the battery chargers have these capabilities as isolation devices as described in IEEE Std. 384 and RG 1.75 and documented as part of their Class 1E qualification.

B. The reviewer will examine any proposed interconnections between redundant load centers through bus tie breakers and multi-feeder breakers used to connect extra redundant loads to either of the redundant distribution systems to ensure that no single failure in the interconnections or inadvertent closure of interconnecting devices will compromise division independence in a manner that will cause the paralleling of the dc power supplies. To ensure this, the control circuits of the bus tie breakers or multi-feeder breakers must preclude automatic transferring of load centers or loads from the designated supply to the redundant counterpart upon loss of the designated supply (Regulatory Position 4 of RG 1.6). Regarding the interconnections through bus tie breakers, an acceptable design will provide for two tie breakers connected in series and physically separated from each other in accordance with the acceptance criteria for separation of safety-related systems, as discussed below. Furthermore, the interconnection of redundant load centers must be accomplished only manually.

C. To ensure physical independence, the staff will review the criteria governing the physical separation of redundant equipment, including cables and cable trays and their implementation as depicted on preliminary or final physical arrangement drawings, to confirm that the design arrangement satisfies the requirements of IEEE Std. 384 and the positions of RG 1.75. These guides and standards set acceptance criteria for the separation of circuits and electrical equipment contained in, or associated with, the safety-related dc power system. To determine whether the independence of the redundant cable installation is consistent with the requirements in IEEE Std. 384 and the positions in RG 1.75, the staff will review the proposed design criteria governing the separation of safety-related cables and raceways, including criteria such as those for cable derating; raceway filling; cable routing in containment penetration areas, cable spreading rooms, control rooms, and other congested areas; sharing raceways with nonsafety-related cables or with cables of the same system or other systems; prohibiting cable splices in raceways; spacing power and control wiring and components associated with safety-related electric systems in control boards, panels, and relay racks; and fire barriers and separation between redundant raceways.

4. <u>Power Supplies and Distribution Systems</u>. To ensure that the requirements of GDC 17 have been met regarding the dc power system having sufficient capacity and capability to supply the required distribution system loads, the staff will review the design bases, design criteria, analyses, description, and implementation (as depicted on electrical drawings and performance characteristic curves). As endorsed by RG 1.32, IEEE Std. 308 describes a method acceptable to the NRC staff for complying with the NRC's regulations for the design, operation, and testing of dc power systems in nuclear power plants.

To establish that the capacity of the dc supply is adequate to power the prescribed loads, reviewer checks the nameplate capacity claimed in the design bases against the loads identified in electrical distribution diagrams. The staff will review the capability of the system by evaluating the performance characteristic curves that illustrate the response of the supplies to the most severe loading conditions at the plant. The performance characteristic curves would include voltage profile curves, discharge rate curves, and temperature effect curves. IEEE Std. 485 provides a method acceptable to the staff for sizing stationary lead acid batteries. The capacity of the dc supplies should be ensured by periodic discharge tests of the batteries, as described in IEEE Std. 450 and RG 1.129.

RG 1.128 and IEEE Std. 484 provide the basis for the review of design practices and procedures for storage, location, mounting, ventilation, instrumentation, preassembly, assembly, and charging of large lead storage batteries.

In coordination with other branches, the reviewer becomes familiar with the purpose and operation of each safety system, including system component arrangements as depicted on functional P&IDs, expected system performance as established in the accident and/or other relevant analyses (e.g., for SBO), modes of system operation and interactions during normal and accident conditions, and interactions among systems.

Subsequently, the reviewer will verify that the tabulation of all safety-related loads to be connected to each dc supply is consistent with the information obtained in coordination with other branches.

The characteristics of each load (such as motor horsepower and volt-amp ratings, inrush current, starting volt-amps, and torque), the length of time each load is required, and the basis used to establish the power required for each safety-related load (such as motor name plate rating, pump runout condition, or estimated load under expected flow and pressure) are used to verify the calculations establishing the combined load demand to be connected to each dc supply during the worst operating conditions. In reviewing the design of the thermal overload protection for motors of motor-operated safety-related valves, the reviewer uses RG 1.106.

If the proposed design provides for the connection and disconnection of nonsafety-related loads to and from the safety-related distribution buses, the review of the interconnections will consider isolation devices, as defined in RG 1.75, and engineering judgment to determine the adequacy of the design. To ensure that the interconnections between nonsafety-related loads and safety-related buses will not result in the degradation of the safety-related system, the isolation device through which dc power is supplied to the nonsafety-related load, including control circuits and connections to the safety-related bus, must be designed to meet safety Class 1E requirements. If the dc power supplies have not been sized to accommodate the added nonsafety-related loads during emergency conditions, the design must provide for the automatic disconnection of those nonsafety-related loads upon detection of the emergency condition. This action must be accomplished regardless of whether the load was already connected to the power supply. The review must ensure that dc power systems are not shared between units.

5. Identification of Cables, Raceways, and Terminal Equipment. The staff will review the identification scheme used for safety-related cables, raceways, and terminal equipment in the plant and internal wiring in the control boards to confirm that it is consistent with IEEE Std. 384, as augmented by RG 1.75. This includes the criteria for differentiating among (1) safety-related cables, raceways, and terminal equipment of different channels or divisions, (2) nonsafety-related cable that is run in safety raceways, (3) nonsafety-related cable that is not associated physically with any safety division, and (4) safety-

related cables, raceways, and terminal equipment of one unit with respect to the other units at a multiunit site.

6. Vital Supporting Systems. The reviewer will evaluate supporting systems identified as vital to the operation of safety-related loads and systems. As endorsed by RG 1.153, IEEE Std. 603 provides a method acceptable to the staff to evaluate all aspects of the instrumentation, control, and electrical portions of auxiliary supporting systems and features, including basic requirements that call for auxiliary supporting systems and features to satisfy the same criteria as the supported safety systems.

   The staff will review the instrumentation, control, and electrical aspects of the vital supporting systems and features to ensure that their design conforms to the same criteria as those for the systems that they support. Hence, the review procedure for ascertaining the adequacy of these systems and features is the same as that discussed herein for the onsite systems. In essence, the reviewer first becomes familiar with the purpose and operation of each vital supporting system and feature, including its component arrangement as depicted on functional P&IDs. Subsequently, the reviewer evaluates the design criteria, analyses, and description and the implementation of the instrumentation, control, and electrical equipment, as depicted on electrical drawings, to verify that the design is consistent with satisfying the acceptance criteria for Class 1E systems. In addition, the reviewer verifies that the vital supporting system redundant instrumentation, control devices, and loads are powered from the same redundant distribution system as the system that they support.

   The organization responsible for the review of plant ventilation systems evaluates the other aspects of the vital supporting systems to verify that the design, capacities, and physical independence of these systems are adequate for their intended functions. This review includes an assessment of the heating, ventilation, and air conditioning (HVAC) systems identified as necessary to Class 1E systems, such as the HVAC systems for the electrical switchgear, battery, charger, and inverter rooms. The organization responsible for the review of plant ventilation systems will verify the adequacy of the HVAC system design to maintain temperature and relative humidity in the room as required for proper operation of the safety equipment during both normal and accident conditions. This organization will also verify that redundant HVAC systems are located in the same enclosure as the redundant unit they serve or are separated in accordance with the same criteria as those for the systems they support.

7. System Testing and Surveillance. To ensure that the proposed periodic onsite testing capabilities of the safety-related dc power system satisfy the requirements of GDC 18 and the positions of RGs 1.32 and 1.118, the staff will review the descriptive information, functional logic diagrams, and electrical control and schematics to verify that the design has the built-in capability to permit integral periodic testing of safety-related dc systems when the reactor is in operation. The reviewer will also verify the built-in capability for the testing recommended in RG 1.129 (see also IEEE Std. 450). IEEE Std. 603, as endorsed by RG 1.153, also describes a method acceptable to the staff for reviewing the surveillance and testability of the safety-related aspects of the onsite dc power system.

   The staff will review the descriptive information and design implementation, as depicted on electrical drawings, of the means proposed for automatically indicating at the system level a bypassed or deliberately inoperative status of a redundant portion of a safety-related system to ascertain that the design is consistent with RG 1.47.

For review of the mPower™ DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements and site parameters), set forth in the design control document (DCD) meets the acceptance criteria. 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 DCD.

For review of both DC and COL applications, DSRS Section 14.3 should be followed for the review of ITAAC. The review of ITAAC cannot be completed until after the completion of this section.

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 type to be included in the staff's SER. The reviewer also states the bases for those conclusions.

The dc power systems include those dc power sources and their distribution systems and auxiliary supporting systems provided to supply motive or control power to safety-related equipment. Batteries and battery chargers serve as the power sources for the dc power system, and inverters convert dc from the dc distribution system to ac instrumentation and control power, as required. These three components, when combined, provide a uninterruptible power supply that furnishes a continuous, highly reliable source of ac supply.

The review of the mPower™ dc power system covered the single-line diagrams, station layout drawings, electrical control and schematic diagrams, and descriptive information. The basis for acceptance of the dc power system in the review was conformance of the design criteria and bases to the Commission's regulations in the GDC of Appendix A to 10 CFR Part 50. The staff concludes that the plant design is acceptable and meets the requirements of GDCs 2, 4, 5, 17, 18, and 50. This conclusion is based on the following:

1. The applicant has met the requirements of GDC 2 with respect to SSCs of the dc power systems that are capable of withstanding the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods because the dc power system and components are located in seismic Category I structures, which provide protection from the effects of tornadoes, tornado missiles, and floods. In addition, the dc power system and components have a quality assurance designation of Class 1E.

2. The applicant has met the requirements of GDC 4 with respect to SSCs of the dc power system that are capable of withstanding the effects of missiles and environmental conditions associated with normal operation and postulated accidents because of an adequate plant design and an equipment qualification program.

3. The applicant has met the requirements of GDC 5 with respect to SSCs of the dc power system. Physically separate seismic Category I structures house the dc power system and components associated with the multi-unit design, and they are not shared between units.

4. The applicant has met the requirements of GDC 17 with respect to the onsite dc power system's (1) capacity and capability to permit the functioning of SSCs important to safety, (2) the independence and redundancy necessary to perform their safety

functions, assuming a single failure, and (c) provisions to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit or the loss of power from the transmission network. Acceptability was based on the applicant's design of the dc power systems meeting the guidelines of Regulatory Positions D.1, D.2, and D.4 of RG 1.6 and the guidelines of RGs 1.32, 1.75, 1.53, 1.128, 1.129, and 1.153.

5. The applicant has met the requirements of GDC 18 with respect to the onsite dc power system. The dc power system is designed to be testable during operation of the nuclear power generating station, as well as during those intervals when the station is shutdown. Acceptability was based on the applicant meeting the test capability guidelines of RG 1.32 and the guidelines of RGs 1.118, 1.129, and 1.153.

6. The applicant has met the requirements of GDC 50 with respect to penetrations containing circuits of the safety- and nonsafety-related dc power system. Containment electric penetrations have been designed to accommodate, without exceeding their design leakage rate, the calculated pressure and temperature conditions resulting from any LOCA concurrent with the maximum short-circuit current versus time condition that could occur given single random failures of circuit overload protective devices. This meets the positions of RG 1.63.

7. The applicant has met the requirements of 10 CFR 50.55a(h), as it relates to the incorporation of IEEE Std. 603. Acceptability is based on meeting the relevant positions of RG 1.153.

8. The applicant has met the requirements of 10 CFR 50.65(a)(4) with respect to the onsite dc power system. The acceptability is based on meeting the relevant positions of RG 1.182.

For DC as well as the subsequent COL reviews, the findings will also summarize the staff's evaluation of requirements and restrictions (e.g., interface requirements and site parameters) and COL action items relevant to this DSRS section.

In addition, to the extent that the review is not discussed in other SER sections, the findings will summarize the staff's evaluation of the ITAAC, including design acceptance criteria, as applicable.

V. IMPLEMENTATION

The staff will use this DSRS section in performing safety evaluations of mPower™-specific DC, or 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™ 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 (ADAMS) Accession No. ML102510405), to develop risk-informed licensing review plans for each of the small modular reactor 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 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^{TM} 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. DSRS Section 8.1, Table 8-1, “Acceptance Criteria and Guidelines for Electric Power Systems.” (See Table 8-1 for a detailed list of acceptance criteria and guidance references for all DSRS Chapter 8 sections.)

2. Intentionally left blank

3. RG 1.68, “Initial Test Programs for Water-Cooled Nuclear Power Plants.”

4. NUREG-0933, “A Prioritization of Generic Safety Issues,” November 2005.

5. NUREG-1793, “Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design,” September 2011.

6. RG 1.6, “Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems.”

7. RG 1.32, “Criteria for Power Systems for Nuclear Power Plants.”

8. RG 1.63, “Electric Penetration Assemblies in Containment Structures for Nuclear Power Plants.”

9. RG 1.47, “Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems.”

10. RG 1.53, “Application of the Single Failure Criterion to Safety Systems.”

11. RG 1.75, “Criteria for Independence of Electrical Safety Systems.”

12. RG 1.81, “Shared Emergency and Shutdown Electric Systems for Multi- Unit Nuclear Power Plants.”

13. RG 1.118, “Periodic Testing of Electric Power and Protection Systems.”

14. RG 1.128, "Installation Design and Installation of Vented Lead-Acid Storage Batteries for Nuclear Power Plants."

15. RG 1.129, "Maintenance, Testing, and Replacement of Vented Lead-Acid Storage Batteries for Nuclear Power Plants."

16. RG 1.153, "Criteria for Safety Systems."

17. Intentionally left blank

18. RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants."

19. RG 1.182, "Assessing and Managing Risk Before Maintenance Activities at Nuclear Power Plants."

20. RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

21. Intentionally left blank

22. Intentionally left blank

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

24. IEEE Std. 379-2000, "Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems."

25. IEEE Std. 450-2002, "Recommended Practice for Maintenance, Testing and Replacement of Vented Lead-Acid Batteries for Stationary Applications."

26. IEEE Std. 484-2002, "Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications."

27. IEEE Std. 485-1997, "Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications."

28. IEEE Std. 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations."

29. IEEE Std. 946-2004, "Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations."

30. IEEE Std. 1375-1998, "Guide for the Protection of Stationary Battery Systems."

31. IEEE Std. 1184-2006, "Guide for Batteries for Uninterruptible Power Supply Systems."

32. Economic Simplified Boiling-Water Reactor Final Safety Evaluation Report, March 10, 2011, ADAMS Accession No. ML103470210.

33. "Consolidation of SECY-94-084 and SECY-95-132," July 24, 1995 (ADAMS Accession No. ML003708048).