U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD for NuScale SMR 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, 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 (GDC) 2, 4, 5, 17, 18, and 50 and will perform its intended functions during all plant operating and postulated accident conditions.

The NuScale application will include the classification of structures, systems, and components (SSCs), a list of risk-significant SSCs, and a list of equipment categorized as regulatory treatment of non-safety systems (RTNSS) equipment. Based on this information, the staff will review according to Design-Specific Review Standard (DSRS) Sections 3.2.1 and 3.2.2, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP), Sections 17.4 and 19.3, to confirm the determination of safety-related and risk-significant SSCs.

Emphasis is placed on confirming the functional adequacy of any safety-related, risk-significant portions of the onsite dc power system and ensuring that this system has 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 it provides the required redundancy of components and subsystems such that the system safety functions 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 reviewing any interconnections between redundant buses, buses and loads, and buses and power supplies; design criteria and bases governing the installation of electrical cable for redundant portions of the systems; and the physical arrangement of redundant switchgear and power supplies, as well as ensuring any sharing of the dc power system between reactor modules is in accordance with GDC 5.

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 alternating current (ac) for instrumentation and control power to ensure that they have sufficient capacity and capability to perform their intended functions. This will require an examination of (1) the characteristics and design requirements of each load, (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 95-percent-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 the 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 NuScale, a single unit is expected to contain 12 modular reactors. Sharing of any important-to-safety dc power supplies among the modules within a unit must meet the requirements of GDC 5.

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 important-to-safety systems, associated circuits assigned to redundant 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 important-to-safety 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 appropriate seismically 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 important-to-safety systems and their components have an appropriate 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 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 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 the onsite dc power system 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. The organization responsible for onsite dc power systems reviews the adequacy of the environmental qualification of important-to-safety electrical equipment, as part of its

primary review responsibility for DSRS Section 3.11. This includes a review of the capability of this electrical equipment to perform its intended functions when subjected to the effects of (a) accident environments, such as loss-of-coolant accidents (LOCAs) and 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 air conditioning (HVAC) systems, (d) seismic shaking, and (e) normal design environments on redundant important-to-safety electrical equipment that does not include design diversity (e.g., redundant components manufactured and designed by the same supplier).

3. 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 protection of the dc power system, as part of its primary review responsibility for SRP Sections 9.4.1 through 9.4.4. 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.

4. 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 SRP Sections 3.4.1, 3.5.1.1, 3.5.2, and 3.6.1.

5. 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 and 10.4.7, and SRP Sections 9.1.4, 9.2.1, 9.2.2, 9.2.4, 9.2.5, 9.2.6, 9.3.1, 9.3.3, 9.4.1 through 9.4.4, 9.5.1.1, 9.5.1.2 and 10.4.5.

6. 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 9.5.1.1 and 9.5.1.2. 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 all redundant circuits.

7. 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 Section 9.3.4 and SRP Section 9.3.2.

8. The organization responsible for the review of containment systems and severe accidents (as applicable) 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 6.2.4, and 6.2.5, and SRP Section 6.5.1. In addition, the organization responsible for the review specific to

NuScale Design, evaluates the adequacy of the containment vessel evacuation system as described in DSRS Section 9.3.6.

9. 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 Section 5.4.7, and SRP Section 4.6, as may be applicable.

10. 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 any safety-related display instrumentation, alarms, and other instrumentation systems (including bypass indication, status of batteries, and status of battery chargers), as part of its review responsibility for DSRS Chapter 7.

11. 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.

12. The organization responsible for quality assurance coordinates and performs the reviews of the design, construction, and operations phases of 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 any RTNSS components in passive plant designs, as part of its primary review responsibility for SRP Section 17.5.

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

14. 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.

15. 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, "Design Bases for Protection Against Natural Phenomena"

2. GDC 4, "Environmental and Dynamic Effects Design Bases"

3. GDC 5, "Sharing of Structures, Systems, and Components"

4. GDC 17, "Electric Power Systems"

5. GDC 18, "Inspection and Testing of Electric Power Systems"

7. GDC 50, "Containment Design Basis"

8. GDC 33, "Reactor Coolant Makeup"; GDC 34, "Residual Heat Removal"; GDC 35, "Emergency Core Cooling"; GDC 38, "Containment Heat Removal"; GDC 41, "Containment Atmosphere Cleanup"; and GDC 44, "Cooling Water"

9. 10 CFR 50.55a(h), as it relates to the incorporation of Institute of Electrical and Electronics Engineers (IEEE) Standard (Std.) 603-1991 (including the correction sheet dated January 30, 1995)

10. 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, -postmaintenance 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.

11. 10 CFR 52.47(b)(1) requires that the NuScale 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.

12. 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 that 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. As an alternative, and as described in more detail below, an applicant may identify the differences between a DSRS section and the design features (DC and COL applications only), analytical techniques, and procedural measures proposed in an application and discuss how the proposed alternative provides an acceptable method of complying with the NRC regulations that underlie the DSRS acceptance criteria.

DSRS 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 GDC 2, 4, 5, 17, 18, and 50 are identified in DSRS Section 8.1, Table 8-1.

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

2. 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

3. RG 1.81, as it relates to the sharing of SSCs important to safety of the dc power system

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

5. 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 Class 1E onsite dc power systems. 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 any safety-related systems, including basic criteria for addressing single failures.

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

7. 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

8. RG 1.160 guidelines, as they relate to the effectiveness of maintenance activities for dc power systems, including compliance with the Maintenance Rule and verification that appropriate maintenance activities are covered therein, to be reviewed under DSRS Chapter 17

Technical Rationale

The technical rationale for applying 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 safety-related portions of 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 or climatology-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.

   As applied to NuScale plants, GDC 4 requires important-to-safety SSCs of the onsite dc power system 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 or dynamic effects.

3. General compliance with GDC 5 requires that SSCs important to safety 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 Class 1E dc systems in multiunit nuclear power plants not be shared. In this context, a single NuScale unit is expected to have 12 reactor modules. Sharing of any Class 1E dc power supplies among the modules within a unit must should the requirements of GDC 5 and the guidance of RG 1.81.

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 from the nuclear power unit, the transmission network, or 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 power important-to-safety loads, 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 1.32, 1.53, 1.75, 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 practicable, 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, and 1.153, and DSRS 7.2 Subsection 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 or impending failure under controlled conditions.

6. GDC 33, 34, 35, 38, 41, and 44 do not present a one-to-one correspondence with the system functions appropriate for the NuScale passive design. To the extent that the analogous requisite NuScale system functions require electrical power, these functions must be available during normal and accident conditions.

   Meeting analogous requirements of these criteria for NuScale, if appropriate, would provide 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, IEEE Std. 1184, IEEE Std. 1187, and IEEE Std. 1188 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. Selected Programs and Guidance—In accordance with the guidance in NUREG–0800, "Introduction – Part 2: Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: Light-Water Small Modular Reactor Edition" (NUREG-0800, Intro Part 2), as applied to this DSRS Section, the staff will review the information proposed by the applicant to evaluate whether it meets the acceptance criteria described in Subsection II of this DSRS. As noted in NUREG-0800, Intro Part 2, the NRC requirements that must be met by an SSC do not change under the small modular reactor (SMR) framework. Using the graded approach described in NUREG-0800, Intro Part 2, the NRC staff may determine that, for certain SSCs, the applicant's basis for compliance with other

selected NRC requirements may help demonstrate satisfaction of the applicable acceptance criteria for that SSC in lieu of detailed independent analyses. The design-basis capabilities of specific SSCs would be verified, where applicable, as part of completing the applicable ITAAC. The use of the selected programs to augment or replace traditional review procedures is shown in Figure 1 of NUREG-0800, Intro Part 2. Examples of such programs that may be relevant to the graded approach for these SSCs include:

- 10 CFR Part 50, Appendix A, GDC, Overall Requirements, Criteria 1–5
- 10 CFR Part 50, Appendix B, Quality Assurance (QA) Program
- 10 CFR 50.49, Environmental Qualification of Electrical Equipment (EQ) Program
- 10 CFR 50.55a, Code Design, Inservice Inspection, and Inservice Testing (ISI/IST) Programs
- 10 CFR 50.65, Maintenance Rule requirements
- Reliability Assurance Program (RAP)
- 10 CFR 50.36, “Technical Specifications”
- Availability Controls for SSCs Subject to Regulatory Treatment of Nonsafety Systems (RTNSS)
- Initial Test Program (ITP)
- Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)

This list of examples is not intended to be all inclusive. It is the responsibility of the technical reviewers to determine whether the information in the application, including the degree to which the applicant seeks to rely on such selected programs and guidance, demonstrates that all acceptance criteria have been met to support the safety finding for a particular SSC.

2. In accordance with 10 CFR 52.47(a)(8), (21), and (22), and 10 CFR 52.79(a)(17), (20), and (37), for DC or COL applications submitted under 10 CFR 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 which are identified in the version of NUREG-0933, “Resolution of Generic Safety Issues,” current on the date up to 6 months before the docket date of the application and which 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), for a DC application, and except paragraphs (f)(1)(xii), (f)(2)(ix), (f)(2)(xxv), and (f)(3)(v),for a COL application. 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.

3. <u>Conformance with the Single-Failure Criterion</u>. As required by GDC 17, a Class 1E 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 and 1.32. 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 any 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 applying 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 an onsite Class 1E power system from the offsite power system, as well as from any non-safety 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 battery chargers. In this case, the battery chargers have a dual mission with respect to isolation. The battery chargers should 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, prevent the dc system from trying to power any upstream ac loads. The reviewer should 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 qualification.

B. The reviewer will examine any proposed interconnections between redundant load centers through bus tie breakers and multifeeder breakers used to connect extra redundant loads to any 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 multifeeder breakers should preclude automatic transferring of load centers or loads from the designated supply to the redundant counterpart upon loss of the designated supply. 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 redundant systems, as discussed below.

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, a 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, the 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.

   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 piping and instrumentation drawings (P&IDs), expected system performance as established in the accident or other relevant analyses, modes of system operation and interactions during normal and accident conditions, and interactions among systems.

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

   If the proposed design provides for the connection and disconnection of nonsafety-related loads to and from 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 interconnections between nonsafety-related loads and safety-related buses will not result in 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, should be designed to meet safety Class 1E requirements. If the dc power supplies have not been sized to accommodate the added non-safety-related loads during emergency conditions, the design should provide for the automatic disconnection of those non-safety-related loads upon detection of the emergency condition. This action should be accomplished regardless of whether the load was already connected to the power supply. For the review of new designs, such as NuScale, the reviewer should verify that the batteries are sized with sufficient margin that load stripping under all known plant conditions will not be necessary.

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) non-safety-related cable that is run in safety raceways, (3) non-safety-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 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 safety-related dc power systems 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. 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 NuScale 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, SRP Section 14.3 should be followed for the review of ITAAC. The ITAAC review 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 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 an uninterruptible power supply that furnishes a continuous, highly reliable source of ac supply.

The review of the NuScale 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 GDC 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.

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. Any important-to-safety portions of the dc power system shared between modules are shared such that the sharing does not degrade the capacity and capability of those SSCs to perform their intended functions,

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 RGs 1.32, 1.75, 1.53, 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 shut down. Acceptability was based on the applicant meeting the test capability guidelines of RG 1.32 and the guidelines of RGs 1.118 and 1.153.

6. The applicant has met the requirements of GDC 50 with respect to penetrations containing circuits of the safety- and non-safety-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 1.160.

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 regulations in 10 CFR 52.17(a)(1)(xii), 10 CFR 52.47(a)(9), and 10 CFR 52.79(a)(41) establish requirements for applications for ESPs, DCs, and COLs, respectively. These regulations require the application to include an evaluation of the site (ESP), standard plant design (DC), or facility (COL) against the SRP revision in effect 6 months before the docket date of the application. While the SRP provides generic guidance, the staff developed the SRP guidance based on the staff's experience in reviewing applications for construction permits and operating licenses for large light-water nuclear power reactors. The proposed SMR designs, however, differ significantly from large light-water nuclear power plant designs.

In view of the differences between the designs of SMRs and the designs of large light-water power reactors, the Commission issued Staff Requirements Memorandum (SRM)-COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights To Enhance Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010. In the SRM, the Commission directed the staff to develop risk-informed licensing review plans for each of the SMR design reviews, including plans for the associated pre-application activities. Accordingly, the staff has developed the content of the DSRS as an alternative method for evaluating a NuScale-specific application submitted pursuant to 10 CFR Part 52, and the staff has determined that each application may address the DSRS in lieu of addressing the SRP, with specified exceptions. These exceptions include particular review areas in which the DSRS directs reviewers to consult the SRP and others in which the SRP is used for the review. If an applicant chooses to address the DSRS, the application should identify and describe all differences between the design features (DC and COL applications only), analytical techniques, and procedural measures proposed in an application and the guidance of the applicable DSRS section (or SRP section, as specified in the DSRS), and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria.

The staff has accepted the content of the DSRS as an alternative method for evaluating whether an application complies with NRC regulations for NuScale SMR applications, provided that the application does not deviate significantly from the design and siting assumptions made by the NRC staff while preparing the DSRS. If the design or siting assumptions in a NuScale application deviate significantly from the design and siting assumptions the staff used in preparing the DSRS, the staff will use the more general guidance in the SRP, as specified in 10 CFR 52.17(a)(1)(xii), 10 CFR 52.47(a)(9), or 10 CFR 52.79(a)(41), depending on the type of application. Alternatively, the staff may supplement the DSRS section by adding appropriate criteria to address new design or siting assumptions..

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, “Resolution of Generic Safety Issues,” November 2005.

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

6. Intentionally left blank

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. Intentionally left blank

15. Intentionally left blank

16. RG 1.153, “Criteria for Safety Systems.”

17. Intentionally left blank

18. RG1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants.”

19. RG 1.206, “Combined License Applications for Nuclear Power Plants (LWR Edition).”

20. Staff Requirements Memorandum (SRM)COMGBJ-10-0004/COMGEA-10-0001, “Use of Risk Insights To Enhance Safety Focus of Small Modular Reactor Reviews,” dated August 31, 2010.

21. Intentionally left blank

22. IEEE Std. 308-2001, “Criteria for Class 1E Power Systems for Nuclear Power Generating Stations.”

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

24. Intentionally left blank

25. Intentionally left blank

26. Intentionally left blank

27. IEEE Std. 603-1991, “Criteria for Safety Systems for Nuclear Power Generating Stations.”

28. IEEE Std. 946-2004, “Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations.”

29. IEEE Std. 1375-1998,”Guide for the Protection of Stationary Battery Systems.”

30. IEEE Std. 1184-2006, “Guide for Batteries for Uninterruptible Power Supply Systems.”

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

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

33. IEEE Std. 1187-2013, “Recommended Practice for Installation Design and Installation of Valve-Regulated Lead Acid Batteries for Stationary Applications.”

34. IEEE Std. 1188-2005 (R2010), “Recommended Practice for Maintenance, Testing and Replacement of Valve-Regulated Lead Acid Batteries for Stationary Applications.”