8.0 ELECTRIC POWER

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8.0 ELECTRIC POWER

8.1 Introduction

The economic simplified boiling-water reactor (ESBWR) design, as presented, does not require Class 1E alternating current (ac) electrical power, except that provided by the Class 1E direct current (dc) batteries and their inverters, to accomplish the plant's safety-related functions.

Two independent offsite power sources provide reliable power for the plant's auxiliary loads, such that any single active failure can affect only one power source and cannot propagate to the alternate power source.

The onsite ac power system consists of Class 1E and non-Class 1E power systems. The two offsite power systems provide the normal preferred and alternate preferred ac power to the onsite power systems. In the event of a total loss of offsite power sources, two onsite independent nonsafety-related standby diesel generators (DGs) provide power to the plant investment protection (PIP) nonsafety-related loads and safety-related loads through safety-related isolation power centers (IPCs). Four independent safety-related 480-volt (V) ac divisions (IPC buses) provide power for the safety-related 250-V dc systems and uninterruptible power supply (UPS) systems.

Table 8.1 of NUREG–0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)", March 2007 (SRP), lists the applicable regulatory requirements, guidance, and associated acceptance criteria that apply to electric power systems. Sections 8.2, 8.3.1, 8.3.2, and 8.4 of this report analyze the application's conformance with the regulatory requirements and associated acceptance criteria listed in SRP Table 8.1 regarding electric power systems.

8.2 Offsite Power System

8.2.1 Regulatory Criteria

The offsite power system includes two physically independent circuits capable of operating independently of the onsite standby power sources. The review by the staff covers the information, analyses, and documents for the offsite power system and the stability studies for the electrical transmission grid. In general, the preferred power system is acceptable when it provides two separate circuits from the transmission network to the onsite Class 1E power distribution system, when adequate physical and electrical separation exist, and when the system has the capacity and capability to supply power to all safety loads and other required equipment.

The acceptance criteria for assessing the sufficiency of the offsite power system design are based on meeting the following relevant requirements:

- General Design Criterion (GDC) 5, "Sharing of structures, systems, and components," in Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," as it relates to sharing structures, systems, and components (SSCs) of the preferred power systems;

- GDC 17, “Electric power systems,” as it relates to the preferred power system’s (1) capacity and capability to permit functioning of SSCs important to safety, (2) 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 loss of power from the onsite electric power supplies, (3) physical independence, and (4) availability;

- GDC 18, “Inspection and testing of electric power systems,” as it relates to the inspection and testing of the offsite power systems;

- 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,” as they relate to the operation of the offsite electric power system, encompassed in GDC 17, to ensure that the safety functions of the systems described in GDC 33, 34, 35, 38, 41, and 44 are accomplished;

- 10 CFR 50.63, as it relates to an alternate ac power source (as defined in 10 CFR 50.2) provided for safe shutdown in the event of a station blackout (SBO) (not a design-basis accident [DBA]);

- 10 CFR 50.65(a) (4) (the maintenance rule), as it relates to the assessment and management of the increase in risk that may result from proposed maintenance activities before performing such activities.

Note that subsequent to the issuance of SRP Section 8.2, Revision 4, the staff determined that GDC 2, “Design bases for protection against natural phenomena,” and GDC 4, ”Environmental and dynamic effects design bases,” are not applicable to the offsite power system. The staff determination is documented in a January 23, 2009 e-mail from Thomas Bergman to Russ Bell, “NRC response to GDC 2, 4 and 5 one-pager.”

SRP Sections 8.1 and 8.2, and Appendix A to Section 8.2, explain how an application can meet the above regulations, in part, if the application uses the NRC-endorsed methodologies and technical positions found in the following:

- Regulatory Guide (RG) 1.32, “Criteria for Power Systems for Nuclear Power Plants,” Revision 3, issued March 2004.

- RG 1.155, “Station Blackout,” issued August 1988.

- RG 1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants,” Revision 2, issued March 1997.

- RG 1.182, “Assessing and Managing Risk before Maintenance Activities at Nuclear Power Plants,” Revision 0, issued May 2000.

- RG 1.204, “Guidelines for Lightning Protection of Nuclear Power Plants,” issued November 2005.

- Branch Technical Position (BTP) 8-3, “Stability of Offsite Power Systems.”

- BTP 8-6, “Adequacy of Station Electric Distribution System Voltages.”

- BTP Power Systems Branch (PSB) -1, “Adequacy of Station Electric Distribution System Voltages,” Revision 3, issued April 1996.

- BTP Instrumentation and Control Systems Branch (ICSB) -11, “Stability of Offsite Power Systems,” Revision 3, issued April 1996.

- SECY-90-016, “Evolutionary Light Water Reactor Certification Issues and Their Relationships to Current Regulatory Requirements,” issued 1990.

- SECY-91-078, “EPRI’s Requirements Document and Additional Evolutionary LWR Certification Issues,” issued 1991.

- SECY-94-084, “Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs,” issued 1994.

- SECY-95-132, “Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems (RTNSS) in Passive Plant Designs,” issued 1995.

8.2.2 Summary of Technical Information

Two independent offsite power supply systems supply power to the site, which include the normal preferred power supply (PPS) through the unit auxiliary transformers (UATs) and the alternate PPS through the reserve auxiliary transformers (RATs). The offsite system is designed and located to minimize the likelihood of simultaneous failure during a design basis accident (DBA) and under adverse environmental conditions.

The main generator normally provides power to the onsite power system through the two UATs as the normal preferred source. When the main generator is not available, the generator output breaker is opened, and the onsite auxiliary power is supplied from the switchyard by backfeeding through UATs as the normal preferred source. When the normal preferred source is not available, the plant auxiliary power is supplied from the switchyard through the two RATs as the alternate preferred source. In addition, two nonsafety-related onsite standby DGs supply power to selected loads in the event of the loss of two offsite preferred sources.

The main generator is connected to the offsite power system by three single-phase, step-up transformers. If the main generator is lost, an auto-trip of the generator breaker maintains the power to the onsite system without interruption from the PPS. A spare single-phase, step-up transformer is available, in case one of the main step-up transformers fails. The main step-up transformers are within the onsite power system.

Unit synchronization normally occurs through the onsite main generator circuit breaker, with the offsite switchyard circuit breaker supplying the normal preferred power source. Both the main generator circuit breaker and the normal PPS circuit breakers are equipped with dual trip coils and a redundant protective relaying logic scheme, and redundant nonsafety-related 125-V dc power systems supply control power to the circuit breaker.

The UATs consist of two three-phase transformers. Each UAT provides normal preferred power to two power generation (PG) buses and one PIP bus. The RATs consist of two three-phase transformers fed from the second offsite power source. Each RAT provides alternate preferred power to the plant’s two PG buses and one PIP bus in the event of a UAT failure. The main step-up transformers, UATs, and RATs are designed and manufactured to withstand the mechanical and thermal stresses produced by external short circuits, and meet the corresponding requirements of Institute for Electrical and Electronics Engineers (IEEE) Standard (Std) C57.12.00, “Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.” The main power transformers, UATs, and RATs have protective devices for overcurrent, differential current, ground overcurrent, and sudden overpressure.

An onsite generator circuit breaker can interrupt the maximum fault current. The generator circuit breaker allows the generator to be taken off the power supply system, and the switchyard offsite power system backfeeds power to the onsite ac power systems. Startup power is normally provided through UATs from the switchyard.

Protective relaying schemes used to protect the offsite power supply system in the switchyard are redundant and equipped with backup protection features, and the circuit breakers are equipped with dual trip coils. Each redundant protection circuit is powered from its redundant dc power supply and connected to a separate trip coil. Equipment and cabling associated with each redundant system are physically separate.

The offsite power system of the ESBWR plant is based on the following design bases:

- In the event of failure of the normal PPS system, the alternate PPS system remains available.

- The normal PPS system and the alternate power supply system are electrically independent and are physically separated from each other. Separate transmission lines, each capable of supplying the shutdown loads, feed the normal and the alternate PPS systems.

- The switching station to which the main offsite circuit is connected has two buses, arranged such that any incoming transmission line can be isolated by tripping a circuit breaker, without affecting another line, and faults of one bus are isolated without interrupting service to any line.

- Circuit breakers are sized and designed in accordance with IEEE Std C37.06, “AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis—Preferred Ratings and Related Required Capabilities.”

- Concrete barriers with a fire rating of 3 hours are used among the main transformers, the UATs, and the RATs, including the containment and collection of transformer oil.

- Cables associated with the normal and alternate PPS systems are routed separately and in separate raceways, apart from each other and onsite power system cables. However, they may share a common underground duct bank, as indicated below.

- Associated control, instrumentation, and miscellaneous power cables of the alternate preferred circuit are routed in separate raceways, if they are located underground in the same duct bank as cables associated with the normal PPS system between the switchyard and the onsite power systems.

- Interface protocols shall be established between the control room and the transmission operator, in accordance with the interconnection service agreement.

- Cables associated with the alternate preferred supply systems are routed in trenches within the switchyard, separate from cables associated with the normal preferred supply systems.

- A transmission system reliability and stability review of the site-specific configuration to which the plant is connected will determine the reliability of the offsite power supply system and verify that it is consistent with the probability risk analysis of Chapter 19 of the ESBWR design control document (DCD).

- The design provides for an auto-disconnect of the high side of a failed UAT through protective relaying to UAT input circuit breakers and RAT motor-operated disconnects (MODs).

- A station grounding system, consisting of a ground mat below grade at the switchyard that is connected to the foundation's embedded loop grounding system, serves the entire power block and associated buildings.

8.2.3 Staff Evaluation

The following paragraphs analyze compliance with the GDC and consistency with the RGs and other SRP guidance:

- GDC 5

  Because the ESBWR plant is designed as a single-unit plant, GDC 5 and RG 1.81, "Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants," Revision 1, issued January 1975, are not applicable.

- GDC 17

  With regard to GDC 17, the ESBWR plant design does not require offsite or diesel-generated ac power for 72 hours after an abnormal event. Safety-related dc power supports passive core cooling and containment safety-related functions. In Request for Additional Information (RAI) 14.3-394 S01, the staff asked the applicant to provide an interface requirement for demonstrating the capacity and capability of the offsite power system. In its response, the applicant incorporated the PPS definition into DCD Tier 2, Revision 6, Chapter 8, per IEEE Std 765, "IEEE Standard for Preferred Power Supply (PPS) for Nuclear Power Generating Stations," issued June 2002. The PPS consists of the normal preferred and alternate preferred power sources and includes those portions of the offsite power system and the onsite power system required for power flow from the offsite transmission system to the safety-related IPC incoming line breakers. Additionally, the applicant revised DCD Tier 2, Revision 5, Chapter 8, to clarify that GDC 17 applies to the entire PPS. The applicant added inspection, test, analysis, and acceptance criteria (ITAAC) to DCD Tier 1, Revision 6, Section 2.13.1, to address capacity, capability, and the physical and electrical separation of the normal preferred and alternate PPSs. The staff agrees with the applicant regarding the boundary of the PPS; i.e., at the incoming line breaker of the IPC bus. The staff confirmed that Revision 6 of the DCD includes the changes described above. Based on the applicant's response, RAI 14.3-394 S01 regarding GDC 17 is resolved. Chapter 14 of this report discusses RAI 14.3-394 S01 regarding ITAAC.

  The staff reviewed the offsite power system design-basis requirements in DCD Tier 2, are resolved Section 8.2.3, and finds that these design-basis requirements include (1) 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 loss of power from the onsite electric power supplies, (2) physical independence, and (3) for availability. These design bases are consistent with the requirements of GDC 17 and therefore the staff finds offsite power system design-basis requirements acceptable. Based on the above, the staff finds that the ESBWR standard design complies with GDC 17 with respect to two independent and separate offsite power sources.

For the degraded and overvoltage protection evaluation, refer to Section 8.3.1 of this report.

- GDC 18

  In RAI 8.2-15, the staff asked the applicant to discuss how it will comply with GDC 18 for the portion of the offsite system (MOD, UAT high-side breaker, UAT, PIP bus, 6.9/0.48-kilovolt (kV) transformer for normal PPS, and MOD, RAT, PIP bus, 6.9/0.48-kV transformer for the alternate PPS) that is within the DCD's scope. In response, the applicant stated that the above-mentioned equipment is part of the PPS and will be covered by procedures for testing and maintenance, as described by combined license (COL) Information Items 13.5-2-A and 13.5-6-A. These procedures will state the frequency requirements for tests and maintenance. Based on the applicant's response, RAI 8.2-15 is resolved. The staff finds that the ESBWR standard plant design complies with the requirements of GDC 18.

- GDC 33, 34, 35, 38, 41, and 44

  The potential risk contribution of a design-basis event is minimized because a passive reactor design does not require ac power sources for such events. Passive reactor designs incorporate passive safety-related systems for core cooling and containment integrity and, therefore, do not depend on the electric power grid connection and grid stability for safe operation. They are designed to automatically establish and maintain safe shutdown conditions after design-basis events for 72 hours, without operator action, following a loss of both onsite and offsite ac power sources. Therefore, the ESBWR offsite power system design is not required to meet the requirements of GDC 33, 34, 35, 38, 41, and 44.

- 10 CFR 50.63

  Section 15.5.5 of this report provides the staff's evaluation of the ESBWR coping capability with an ac-independent approach and finds it to be acceptable. Therefore, the ESBWR design also meets the requirements of 10 CFR 50.63. The EBSWR SBO evaluation is further discussed in Section 8.4.2.1 of this report.

- 10 CFR 50.65(a) (4)

  The maintenance rule requires a licensee to evaluate grid reliability as part of the maintenance risk assessment before performing grid-risk-sensitive maintenance activities. As described in DCD Tier 2, Revision 9, Section 17.4.1, the maintenance rule program is part of the operational reliability assurance program covered by COL Information Item 17.4-2-A, which is evaluated in Section 17.4 of this report.

- RG 1.32

  The offsite power system is not Class 1E. Therefore, RG 1.32 is not applicable to the ESBWR offsite power system.

- RG 1.155

  No ac power is required to achieve safe shutdown for the ESBWR. The ESBWR uses battery power to achieve and maintain safe shutdown. The safety-related batteries have sufficient stored capacity, without their chargers, to independently supply the safety-related loads continuously for 72 hours. This meets the ac independent coping capability guidelines of RG 1.155. (The SBO evaluation is further discussed in Sections 8.4.2.1 and 15.5.5 of this report.)

- RG 1.160

  As described in DCD Tier 2, Revision 9, Section 17.4.1, the maintenance rule program is part of the operational reliability assurance program covered by COL Information Item 17.4-2-A, which is evaluated in Section 17.4 of this report.

- RG 1.182

  As described in DCD Tier 2, Revison 8, Section 17.4.1, the maintenance rule program is part of the operational reliability assurance program covered by COL Information Item 17.4-2-A, which is evaluated in Section 17.4 of this report.

- RG 1.204

  Section 8.3.1 of this report discusses this topic. The design is consistent with the guidance of RG 1.204.

- BTP 8-3 and BTP ICSB-11

  This topic is site-specific and will be addressed by the COL applicant (COL Information Item 8.2.4-9-A). See Section 8.2.4 of this report.

- BTP 8-6 and BTP PSB-1

  This topic is addressed in DCD Tier 1, Revision 9, Section 2.13.1, and is evaluated in Section 14.3.6 of this report.

- SECY-90-016

  This paper contains the Commission's approval for the evolutionary advanced light-water reactors (ALWRs) to have an alternate ac power source of diverse design capable of powering at least one complete set of normal shutdown loads to cope with SBO. This topic is not applicable to the ESBWR design, since no ac power is required to achieve safe shutdown, as discussed in the SBO evaluation in Section 8.4.2.1 of this report.

- SECY-91-078

  This paper relates to (1) the inclusion of an alternate power source for nonsafety-related loads in an evolutionary plant design and (2) at least one offsite circuit to each redundant safety division, to be supplied directly from one of the offsite power sources with no intervening nonsafety buses, in such a manner that the offsite source can power the safety buses if any nonsafety bus fails. As discussed in Section 8.4.2.2 of this report, the ESBWR design meets recommendation 1, above. The ESBWR design does not have to meet recommendation 2, because the design does not rely on active systems for safe shutdown.

- SECY-94-084 and SECY-95-132

  These papers relate to the use of alternate ac power sources and the application of RTNSS at ALWRs provided with passive safety systems. An alternate ac power source is not required to achieve safe shutdown in a passive design as discussed in Section 8.4.2.1 of this report as part of the SBO evaluation. The portions of the offsite power system which have RTNSS functions; i.e. the 6.9 kV PIP buses, are discussed in Sections 8.4.2.3 and 22 of this report.

8.2.4 Combined License Unit-Specific Information

The applicant stated that a COL applicant will address the following items:

- 8.2.4-1-A Transmission System Description
- 8.2.4-2-A Switchyard Description
- 8.2.4-3-A Normal Preferred Power
- 8.2.4-4-A Alternate Preferred Power
- 8.2.4-5-A Protective Relaying
- 8.2.4-6-A Switchyard DC Power
- 8.2.4-7-A Switchyard AC Power
- 8.2.4-8-A Switchyard Transformer Protection
- 8.2.4-9-A Stability and Reliability of the Offsite Transmission Power Systems
- 8.2.4-10-A Interface Requirements

These COL items identify ten items related to the offsite power system that the COL applicant will address. The staff agrees that these items are site specific and therefore appropriately addressed by the COL applicant. In addition, these COL items for the offsite power system, provided they are adequately addressed, provide reasonable assurance that the offsite power system meets the requirements of GDC 17. Therefore, the staff finds these COL information items acceptable.

8.2.5 Conclusions

The staff considers the applicant's description to be acceptable on the basis that it provides sufficient information on the scope of the offsite system and that the system meets the requirements discussed above. Further, the staff finds the design-bases requirements for the offsite power system to be acceptable. Therefore, the staff concludes that the design of the offsite power system for the ESBWR is acceptable and meets the requirements of GDC 17 and 18.

8.3 Onsite Power System

8.3.1 Alternating Current Power System

8.3.1.1 *Regulatory Criteria*

The onsite ac power system consists of a Class 1E and a non-Class 1E system that, in conjunction, provide reliable ac power to the electrical loads of the various Class 1E and non-Class 1E systems. These loads enhance an orderly shutdown under emergency (not accident) conditions. Additional loads for investment protection can be manually loaded on the standby power supply systems. The staff's review covers the descriptive information, analyses, and referenced documents for the ac onsite power system, as well as the applicable recommendations from the SRP and appropriate standards and design criteria, as follows:

- GDC 2, as it relates to SSCs of the ac power system being capable of withstanding the effects of natural phenomena without losing the ability to perform their safety functions

- GDC 4, as it relates to SSCs of the ac power system being capable of withstanding the effects of missiles and environmental conditions associated with normal operation, maintenance, testing, and postulated accidents

- GDC 5, as it relates to the sharing of SSCs of the ac power systems

- GDC 17, as it relates to the onsite ac power system's (1) capacity and capability to permit functioning of SSCs important to safety, (2) independence, redundancy, and testability to perform its safety function, assuming a single failure, and (3) 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

- GDC 18, as it relates to the inspection and testing of the onsite power systems

- GDC 33, 34, 35, 38, 41, and 44, as they relate to the operation of the onsite electric power system, encompassed in GDC 17, to ensure that the safety functions of the systems described in these GDC are accomplished

- GDC 50, "Containment Design Basis," as it relates to the design of containment electrical penetrations containing circuits of the ac power system and the capability of electric penetration assemblies in containment structures to withstand a loss-of-coolant accident (LOCA) without loss of mechanical integrity, as well as the external circuit protection for such penetrations

- 10 CFR 50.63, as it relates to the establishment of a reliability program for emergency onsite ac power sources and the use of the redundancy and reliability of DG units as a factor in limiting the potential for SBO events

- 10 CFR 50.65(a) (4), as it relates to the assessment and management of the increase in risk that may result from proposed maintenance activities before performing such activities

SRP Section 8.3.1 provides guidance on how an application can meet the above regulations.

- GDC 5 is satisfied as it relates to the sharing of SSCs of the ac power system and the following guidelines:
  - RG 1.32, as it relates to the sharing of SSCs of the Class 1E power system at multiunit stations
  - RG 1.81, as it relates to the sharing of SSCs of the ac power system, Regulatory Positions C.2 and C.3

- GDC 17 is satisfied, as it relates to the onsite ac power system's (1) capacity and capability to permit functioning of SSCs important to safety, (2) independence, redundancy, and testability to perform its safety function, assuming a single failure, and (3) 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, in conformance with the following guidelines:

- RG 1.6, “Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems (Safety Guide 6),” issued March 1971, as it relates to the independence of the onsite ac power system, Regulatory Positions D.1, D.2, D.4, and D.5
- RG 1.9, “Selection, Design, Qualification, and Testing of Emergency Diesel Generator Units Used as Class 1E Onsite Electric Power Systems at Nuclear Power Plants,” Revision 3, issued July 1993 (also IEEE Std 387, “IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations,” issued 1984)
- RG 1.32, as it relates to design criteria for onsite ac power systems (also IEEE Std 308, “IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations”)
- RG 1.53, “Application of the Single-Failure Criterion to Nuclear Power Plant Protection Systems,” Revision 2, issued November 2003, as it relates to the application of the single-failure criterion to safety systems (also IEEE Std 279, “IEEE Standard: Criteria for Protection Systems for Nuclear Power Generating Stations,” and IEEE Std 603, “IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations”)
- RG 1.75, “Criteria for Independence of Electrical Safety Systems,” Revision 3, issued February 2005, as it relates to the onsite ac power system (also IEEE Std 384, “IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits”)
- RG 1.153, “Criteria for Safety Systems,” Revision 1, issued June 1996, as it relates to criteria for electrical portions of safety-related systems (also IEEE Std 603)
- RG 1.155, as it relates to the use of onsite emergency ac power sources for SBO
- RG 1.204, as it relates to the lightning and surge protection for the onsite ac power system (also IEEE Std 665, “IEEE Guide for Generating Station Grounding”; IEEE Std 666, “IEEE Design Guide for Electric Power Service Systems for Generating Stations”; IEEE Std 1050, “IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations”; and IEEE Std C62.23, “IEEE Application Guide for Surge Protection of Electric Generating Plants”)

• GDC 18 is satisfied, as it relates to the testability of the onsite ac power system and the following guidelines:

  - RG 1.32, as it relates to the capability for testing the onsite ac power system (also IEEE Std 308)
  - RG 1.47, “Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems,” issued May 1973, with respect to indicating the bypass or inoperable status of portions of the protection system, systems actuated or controlled by the protection system, and auxiliary or supporting systems that must be operable for the protection system and the system it actuates to perform their safety-related functions
  - RG 1.118, “Periodic Testing of Electric Power and Protection Systems,” Revision 3, issued April 1995, as it relates to the capability for testing the onsite ac power system (also IEEE Std 338, “IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems”)

- RG 1.153, as it relates to the onsite ac power system (also IEEE Std 603)

- GDC 33, 34, 35, 38, 41, and 44 are satisfied as they relate to the operation of the onsite electric power system, encompassed in GDC 17, to ensure that the safety functions of the systems described in these GDC are accomplished.

- GDC 50, as it relates to the design of containment electrical penetrations containing circuits of the ac power system, is satisfied, in conformance with the guidelines of RG 1.63, “Electric Penetration Assemblies in Containment Structures for Nuclear Plants,” issued September 1987, 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, as well as to ensuring that electrical penetrations will withstand the full range of fault current (minimum to maximum) available at the penetration (see also IEEE Std 242, “IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems”; IEEE Std 317, “IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations”; and IEEE Std 741, “IEEE Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations”)

- 10 CFR 50.63, as it relates to using the redundancy and reliability of DG units as a factor in limiting the potential for SBO events, with acceptance based on meeting the following specific guidelines:
  - RG 1.9, as it relates to the adequacy of the DG surveillance criteria provided to attain and maintain the target reliability levels of DG units
  - RG 1.155, as it relates to using the reliability of emergency onsite ac power sources as a factor in determining the coping duration for SBO (noting that SRP Section 8.4 reviews this determination in detail) and the establishment of a reliability program for attaining and maintaining source target reliability levels.

- 10 CFR 50.65(a)(4), as it relates to the requirements to assess and manage the increase in risk that may result from proposed maintenance activities before performing such activities, with acceptance based on meeting the following specific guidelines:
  - RG 1.160, as it relates to the effectiveness of maintenance activities for onsite emergency ac power sources, including grid-risk-sensitive maintenance activities (i.e., activities that tend to increase the likelihood of a plant trip, increase loss-of-offsite-power (LOOP) frequency, or reduce the capability to cope with a LOOP or SBO)
  - RG 1.182, as it relates to implementing the provisions of 10 CFR 50.65(a)(4) by endorsing Section 11 of Nuclear Management and Resources Council 93-01, “Nuclear Energy Institute Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants,” dated February 22, 2000.

8.3.1.2 *Summary of Technical Information*

The main onsite ac power system is a non-Class 1E system. During PG mode, the turbine generator normally supplies electric power to the plant’s onsite auxiliary loads through UATs. The plant will be designed to sustain a load rejection from 100-percent power, with the turbine generator supplying the plant’s house loads.

During plant startup, shutdown, and maintenance, the generator breaker will be opened. Under this condition, the PPS systems supply the main ac power from the transmission switchyard through the two UATs. Each UAT supplies power to one of the two separate load groups of the onsite ac power system, each with a redundant RAT for backup as the alternate PPS system.

The onsite ac power system consists of the PPS and the onsite standby ac power supply system, as well as the electrical distribution systems. The preferred power systems consist of buses of two different voltage levels (i.e., 13.8-kV PG nonsafety-related buses and 6.9-kV PIP nonsafety-related buses).

- PG nonsafety-related buses have connections to the normal or alternate offsite PPS systems through the UATs or RATs, respectively. The PG nonsafety-related buses are the 13.8-kV unit auxiliary switchgear and associated lower voltage load buses.

- PIP nonsafety-related buses have connections to the normal or alternate offsite PPS systems through the UATs or RATs, respectively, with backup from the standby onsite ac power supply system. Reverse power relaying prevents backfeed to the standby onsite ac power supply system. The PIP nonsafety-related buses are the 6.9-kV PIP buses and associated lower voltage load buses, exclusive of the safety-related IPC 480-V ac buses.

The PG nonsafety-related buses feed nonsafety-related loads that are required exclusively for unit operation and are usually powered from the normal preferred power through the UATs. If the normal PPS system is not available, these buses are automatically transferred to the alternate PPS system through a fast transfer scheme. On restoration of the normal PPS, these buses are manually or automatically transferred to the normal PPS system, depending on the selection of manual or automatic transfer mode, or they remain powered from the alternate preferred power source.

The PIP nonsafety-related buses feed nonsafety-related loads generally required to remain operational at all times or when the unit is shut down. In addition, the PIP buses supply ac power to the safety-related buses, which are IPC buses. The PIP buses are backed up by the onsite standby power supply systems. These buses can also be powered from the alternate PPS through an automatic bus transfer, in the event that the normal PPS is unavailable. On restoration of the normal PPS, these buses are manually or automatically transferred to the normal PPS system, depending on the selection of manual or automatic transfer mode, or they remain powered from the alternate preferred power source.

8.3.1.2.1 Electrical Distribution System

Medium-Voltage Alternating Current Power Distribution System

The medium-voltage ac power distribution system consists of four 13.8-kV PG buses and two 6.9-kV PIP buses. The UATs and RATs, at 13.8 kV and 6.9 kV, supply the medium-voltage ac power to the PG and PIP buses. Each of the four PG buses is powered from one of the two UATs, or if the UATs are unavailable, from one of the two RATs. The incoming circuit breakers for each PG bus are electrically interlocked to prevent simultaneous connections of UATs and RATs to the PG bus.

Two 6.9-kV PIP buses (PIP-A and PIP-B) provide power for the nonsafety-related PIP loads, so that the unit can remain operational at all times or during shutdown. In addition, the PIP buses supply ac power to the safety-related load through the IPCs. PIP-A and PIP-B buses are each backed up by a separate onsite standby ac power supply system. Each PIP bus will be powered from the normal PPS system through the UAT. If the normal PPS system is unavailable, these buses will be automatically transferred to the alternate PPS system by a fast transfer scheme. When the normal and alternate PPS systems are not available, the 6.9-kV PIP buses will be automatically transferred to the standby power supply system. Upon restoration of the normal PPS system, these buses are manually transferred to the normal preferred system. The incoming circuit breakers for the normal and alternate PPS are electrically interlocked to prevent simultaneous connections of UATs and RATs to the PIP buses.

Low-Voltage Alternating Current Power Distribution System

The low-voltage ac power distribution system consists of the onsite electric power distribution circuits that operate at 480 V through 120 V from the power center transformers. The low-voltage ac power distribution system includes power centers, motor control centers (MCCs), distribution transformers, and distribution panels, as well as the associated protective relaying and local instrumentation and control. The power centers are single-fed or double-ended, depending on the redundancy requirements of the loads powered by a given power center. Different buses supply power to the double-ended power center transformers of the PIP buses. Each double-ended power center transformer of the PIP buses will be supplied from different buses, and each will be powered by its normal power supply through its power supply main breaker, with the alternate power supply breaker open. The normal and alternate supply circuit breakers to the power center are electrically interlocked to prevent simultaneous supply to the power center by normal and alternate power supply systems.

Isolation Power Centers

The PIP nonsafety-related buses power the IPCs through step-down transformers, 6.9/0.48 kV, which receive backup power from the standby DGs. The four IPCs, one each for Divisions 1, 2, 3, and 4, are double-ended and can be powered from either of the PIP buses. The normal and alternate source main breakers of each IPC are electrically interlocked to prevent powering the IPC from the normal and alternate sources simultaneously. The IPCs are safety-related and are located in the seismic Category I reactor building in their respective divisional areas. The IPCs supply power to safety-related loads of their respective divisions. These loads consist of the safety-related battery chargers and rectifiers.

The normal and alternate power supply circuits from the PIP buses to the IPC buses are physically separated by distance or physical barriers, so as to minimize, to the extent practical, the likelihood of simultaneous failure under design-basis conditions. The normal power supply circuit-breaker control power, instrumentation, and control circuits are electrically independent and are physically separated from alternate power supply circuit-breaker control power, instrumentation, and control circuits by distance or physical barriers, to minimize, to the extent practical, the likelihood of simultaneous failure under design-basis conditions.

Each IPC will have undervoltage and underfrequency protective relays to protect against degraded voltage and frequency conditions to provide alarms and facilitate IPC bus isolation and transfer functions, using two-out-of-three logic to prevent spurious actuation.

Motor Control Centers

MCCs supply ac power to motors, control power transformers, process heaters, motor-operated valves, and other small electrically operated auxiliaries, including 480 V-to-208 V/120 V and 480 V-to-240 V/120 V transformers. MCCs are assigned to the same load group as the power center that supplies their power.

8.3.1.2.2 Safety-Related Uninterruptible Alternating Current Power Supply System

The safety-related UPS system provides safety-related 120-V ac power to four independent divisions of safety system logic and control, the reactor protection system (RPS), and the safety-related loads requiring uninterruptible power. Each UPS division has two rectifiers, two battery banks, and two inverters. Each rectifier receives 480-V ac power from the IPC of the same division and converts it to 250-V dc power. The 480-V ac/250-V dc rectifier and a safety-related 250-V battery bank, connected through its diodes to a common inverter, convert 250-V dc power to uninterruptible single-phase 120-V ac power. Upon loss of ac power to the IPCs, the safety-related UPS load will be powered automatically by its respective division's safety-related battery through the inverter. The two inverters in each safety-related division will be configured for parallel redundant operation to allow load sharing and the equal discharge of the division's safety-related batteries. Each inverter normally carries approximately 50 percent of the load. If one inverter fails, 100 percent of the load is picked up by the remaining inverter for a period of time greater than 36 hours but less than 72 hours. If both inverters in a division are lost, the associated 120-V ac UPS buses are deenergized. An alarm will sound in the main control room (MCR) for any of the alternate operating lineups.

The plant design and system layout of the UPS provide physical separation of the equipment, cabling, and instrumentation essential to plant safety. The equipment of each division of the safety-related UPS distribution system will be located in an area separated physically from the other divisions. No provisions exist for the interconnection of the safety-related UPS buses of one division with those of another division or nonsafety-related power. All components of safety-related UPS ac systems are housed in seismic Category I structures.

Four divisions of safety-related UPSs provide 120-V ac power for the qualified distributed control and instrumentation system (Q-DCIS) loads/logic components and other safety-related loads requiring uninterruptible power. Two divisions (1 and 2) of safety-related power supply the scram pilot valve solenoids in the RPS, and the same two divisions supply power to the main steam isolation valve solenoids.

Plant staff can conduct routine maintenance on equipment associated with the safety-related UPS system. Inverters, rectifiers, and solid-state switches can be inspected, serviced, and tested channel by channel without tripping the RPS logic.

8.3.1.2.3 Nonsafety-Related Uninterruptible Alternating Current Power Supply System

The nonsafety-related UPS provides uninterruptible ac power for nonsafety-related equipment needed for continuity of plant operation. The five nonsafety-related UPS systems each provide UPS ac power to five load groups (load groups A, B, C, technical support center (TSC)-A, and TSC-B). Two of the UPS systems (A and B) each have two of the following: rectifiers, battery banks, inverters, solid-state transfer switches, manual transfer switches, and regulating transformers. The rectifier and battery bank, connected through the diode to a common inverter, convert to 120-V ac power. The third UPS system (C) has a single set of the power supply, which consists of a battery bank, rectifier, solid-state transfer switch, manual transfer switch, and regulating transformer. Upon loss or failure of the inverter, a static transfer switch automatically transfers nonsafety-related UPS loads from the inverter to a direct ac power supply through the 480-V/120-V regulating transformer.

The normal power supply for each of the nonsafety-related UPS will be through the rectifier and inverter from a nonsafety-related 480-V ac power center. If the 480-V ac power supply fails, transfer from the 480-V ac power supply to the nonsafety-related 250-V dc battery bank occurs automatically. An alarm in the MCR activates when an alternate lineup of the nonsafety-related UPS occurs. The 480-V ac power centers, which provide power to the nonsafety-related battery chargers, are connected to PIP buses that are backed up by onsite standby DGs.

Two dedicated nonsafety-related UPS systems supply ac power to the TSCs in a two-load group configuration. Uninterruptible power for each TSC will normally be supplied from a 480-V ac power center in the same load group. If the normal power supply (through the rectifier and inverter from the 480-V ac power center) fails, a static transfer switch automatically transfers the UPS loads to a direct ac power supply through the regulating transformer. If the 480-V ac power supply fails, a transfer from the 480-V ac power center to the nonsafety-related 125-V dc battery bank, through the inverter, occurs automatically.

8.3.1.2.4 Onsite Standby Alternating Current Power Supply System

The onsite standby ac power system, powered by the two onsite standby DGs, will not be relied on to perform any safety-related function or safe shutdown and, thus, is classified as nonsafety-related. The standby power supply system provides a backup ac power supply to the PIP nonsafety-related buses in the event of a loss of normal and alternate preferred ac power supplies. The PIP buses provide power for various auxiliary and investment protection load groups and safety-related IPCs. An undervoltage relay trips the circuit breaker to the preferred ac power supply and trips major loads on the PIP bus, except for the standby DG auxiliary 480-V power center feeder, before closing the standby ac source breaker. The standby DG starts automatically on loss of bus voltage. When the standby DG reaches full speed and voltage, the standby source breaker will be closed. The large motor loads are connected sequentially and automatically to the PIP bus, after closing the onsite standby ac source breaker.

The source incoming breakers on the PIP buses are interlocked to prevent the inadvertent connection of the onsite standby DG and preferred ac power sources to the PIP buses at the same time. The standby DG, however, can be manually paralleled with the PPS for periodic testing of the generator. Each onsite standby DG operates independently of the remaining standby DG and will be connected to the PIP bus during testing or bus transfer. Each of the onsite standby DGs conforms to the following criteria:

- Capable of starting, accelerating, and supplying its loads in the proper sequence necessary for PIP without exceeding an unacceptable voltage drop

- Capable of reaching full speed and rated voltage within 2 minutes after receiving a signal to start, and being fully loaded within the acceptable time that will not challenge the standby DG capacity

- Has a continuous power rating greater than the sum of the loads of PIP bus and safety-related battery chargers that could be powered concurrently during hot standby, normal plant cooldown, or plant outages

- Has the capability for the generator exciter and voltage regulator system to provide full voltage control during operating conditions, including postulated fault conditions

The standby DG will be shut down and the standby DG breaker will be tripped under the following conditions during all modes of operation and testing:

- Overspeed
- Motoring of generator
- Overload
- Loss of excitation
- Overtemperature
- Ground fault
- Undervoltage
- Overvoltage
- Underfrequency
- Internal fault in generator (differential relay)

The protective functions for these fault conditions of the standby DG and the generator breaker and other off-normal conditions trigger alarms and other indications in the MCR.

Each onsite standby ac power supply can be started or stopped manually from the MCR. Operator action may transfer start/stop control and bus transfer control to a local control station.

The standby ac power supplies are RTNSS systems and their RTNSS functions are discussed in Section 8.4.2.3 of this report.

8.3.1.2.5 Ancillary Alternating Current Diesel Generators

Two nonsafety-related ancillary DGs provide 480V ac power to meet the post-72-hour power requirements following an extended loss of all other ac power sources. The ancillary DGs are RTNSS systems and their RTNSS functions are discussed in Section 8.4.2.3 of this report.

Each ancillary DG output will be connected to a 480-V ancillary diesel bus. The ancillary DGs are seismic Category II, as are their associated auxiliaries, controls, electrical distribution buses, and fuel oil tanks. The ancillary DGs and associated equipment are housed in a seismic Category II structure. The ancillary power will not be required to support safety-related loads for the first 72 hours following the loss of all other ac power sources.

The ancillary DGs also have the capability to support prestart and starting functions for the onsite standby DGs, if they failed to start upon initial demand and required a delayed start. Power can also be supplied to the nonsafety-related 125-V dc battery chargers, with their batteries disconnected, to power equipment such as the protective relaying and breaker controls required for restoring offsite or onsite standby DG power to the ESBWR systems and equipment.

These 480-V ancillary diesel buses are normally powered by the offsite power supply systems or onsite standby DGs through the PIP buses and the 6900/480-V step-down transformers. On sensing undervoltage to their buses or a low ancillary diesel room temperature, the 480-V ac ancillary diesel bus feeder breaker will trip and send a start signal to the ancillary DG. The signal starts the ancillary DG and closes the ancillary generator power supply breaker.

8.3.1.2.6 Electric Heat Tracing

The electric heat tracing system provides freeze protection, where required, for outdoor service components and for warming process fluids, if required, either indoors or outdoors. The heat tracing will be safety-related and will be powered from safety-related distribution buses, if heat tracing is required for proper operation of a safety-related system. Safety-related heat tracing will be assigned to the appropriate division of safety-related power. Nonsafety-related heat tracing will be supplied from the same power center or MCC as the components protected.

8.3.1.2.7 Cathodic Protection

A cathodic protection system will be provided to the extent required. Its design will be plant–specific, be tailored to the site conditions, and meet the requirements of the National Association of Corrosion Engineers standards. COL Information Item 8A.2.3-1-A states that the COL applicant will provide the minimum requirements for the design of the cathodic protection system.

8.3.1.2.8 Safety-Related Systems Description

1. Physical Separation and Independence

    - Electrical equipment will be separated in accordance with RG 1.75, GDC 17, and IEEE Std 384.

    - Separation and independence of safety-related equipment will be achieved by using separate safety-related structures, barriers, or a combination thereof.

    - To meet the provisions of policy issue SECY-89-013, “Design Requirements Related to the Evolutionary Advanced Light Water Reactors (ALWRs),” issued January 1989, which relates to fire tolerance, the design calls for 3-hour-rated fire barriers among areas of different safety-related divisions throughout the plant, except in the primary containment and the control room complex.

    - The safety-related electrical equipment will be located in separate seismic Category I rooms in the reactor building to ensure electrical and physical separation among the divisions.

    - Electrical and control equipment, panels and racks, and cables and raceways grouped into separate divisions are identified by color-coding, so that their electrical divisional assignment will be apparent and so that an observer can visually differentiate between safety-related equipment and wiring of different divisions, and between safety-related and nonsafety-related equipment and wiring.

    - Independence of the electrical equipment and raceway systems, among the different divisions, will be maintained primarily by a firewall-type separation, where feasible, and by spatial separation.

2. Design Bases and Criteria

    - Plant design specifications for electrical equipment require that such equipment be capable of continuous operation with equipment terminal voltage fluctuations of plus or minus (±) 10 percent of rated voltage limits.

- Power supply systems will be capable of supplying the power of voltage and frequency within acceptable tolerances.

- The interrupting capacity of distribution panels will be at least equal to the maximum available fault current to which the panels are exposed under all modes of operation. Circuit breakers and their applications are in accordance with American Nuclear Standards Institute specification, ANSI C37.50-1989, “1989 Switchgear – Low-Voltage AC Power Circuit Breakers Used in Enclosures – Test Procedures”.

- Refurbished circuit breakers shall not be used in either safety-related or nonsafety-related circuitry in the ESBWR design. New circuit breakers shall be specified in all ESBWR purchase specifications. (NRC Bulletin (BL) 88-10, “Nonconforming Molded-Case Circuit Breakers,” issued November 1988, and Information Notice 88-46, “Licensee Report of Defective Refurbished Circuit Breakers,” issued July 1988, identify problems with defective refurbished circuit breakers.)

3. Testing

   The design provides for periodic testing of the channel from the sensing devices through actuated equipment to ensure that safety-related equipment will function in accordance with design requirements and the requirements of RG 1.118 and IEEE Std 338.

8.3.1.2.9 Electrical Circuit Protection Description

Protective relays will be used to isolate a fault. Protective relay schemes and direct acting trip devices will be provided throughout the onsite power system to do the following:

- Isolate faulted equipment, circuits, or both from the power system
- Prevent damage to equipment
- Protect personnel
- Minimize system disturbances
- Maintain continuity of the power supply

1. Grounding

   - The electrical grounding system will comply with the guidelines provided in IEEE Std 665-1995 and IEEE Std 1050-1996. The electrical grounding system comprises the following:

     – Instrument and computer grounding network

     – Equipment grounding

     – Plant grounding grid

     – Lightning protection network for protection of transformer and equipment located outside buildings

   The plant instrumentation will be grounded through a separately insulated radial grounding system composed of buses and insulated cables. The instrumentation grounding system will be connected to a discrete point of the station grounding grid at a dedicated instrumentation grounding rod by exothermic welding. The instrumentation grounding system will be insulated from all other grounding and surge protection circuits, up to the point of connection at the ground grid. A separate instrumentation grounding system will be provided for plant analog and digital instrumentation systems.

The equipment grounding network will be such that all major equipment, structures, and tanks are grounded with two diagonally opposite ground connections. The ground bus of all switchgear assemblies, MCCs, and control cabinets will be connected to the station ground grid through at least two parallel paths. Bare copper risers will be furnished for all underground electrical ducts and equipment and for connections to grounding systems within buildings. One bare copper cable will be installed with each underground electrical duct run, and all metallic hardware in each manhole will be connected to the cable.

A plant grounding grid, consisting of bare copper cables, limits step and touch potentials to safe values under all fault conditions. The buried grid will be connected to the ground mat at the switchyard and connected to systems within the buildings by a bare copper loop, which encircles each building.

The plant's main generator will be grounded with a neutral grounding device to limit the magnitude of fault current resulting from a phase-to-phase fault. Although the impedance of the neutral grounding device limits the maximum phase current under short-circuit conditions, it does not limit the current to a value less than that for a three-phase fault at its terminals.

The onsite, medium-voltage ac distribution system will be resistance-grounded at the neutral point of the low-voltage windings of the UATs and RATs. The neutral point of the generator windings of the onsite standby ac power supply will be through neutral grounding resistors, sized for continuous operation in the event of a ground fault.

The neutral point of the low-voltage ac distribution systems will be either solidly or impedance grounded to ensure proper coordination of ground fault protection. The dc systems are ungrounded.

2. Lightning Protection

The lightning protection system covers all major plant structures and will be designed to prevent direct lightning strikes to the buildings, electric power equipment, and instruments. It consists of air terminals, bare downcomers, and buried grounding electrodes. Lightning arresters will be provided for each phase of all tie lines connecting the plant electrical systems to the switchyard and offsite lines. These arresters will be connected to the high-voltage terminals of the main step-up transformers, UATs, and RATs. Plant instrumentation located outdoors or connected to cabling running outdoors has surge suppression devices to protect the equipment from lightning-induced surges.

3. Bus Protection

The incoming circuit breakers to the medium-voltage (13.8-kV and 6.9-kV) bus will be equipped with inverse-time overload, ground fault, bus differential, undervoltage, and degraded voltage protection.

Feeder breakers for power centers and the medium-voltage motors will be equipped with instantaneous, inverse-time overload, and ground fault protection.

Feeder breakers for 480-V MCC buses will be equipped with long-time and short-time overload and ground fault protection.

The IPC buses will be equipped with inverse-time overload and ground fault protection. In addition, loss of voltage, degraded voltage, and underfrequency protection serve to isolate these buses from the nonsafety-related system under degraded conditions of voltage and frequency.

The 480-V MCCs will be equipped with instantaneous and inverse-time overload protection. The 480-V power center motor feeder breakers have instantaneous, inverse-time overload and ground fault protection.

4. Containment Electric Penetrations

   Separate electrical penetrations are provided for circuits of each safety-related division and for nonsafety-related circuits. The circuits of each electrical penetration are of the same voltage class. Redundant overcurrent interrupting devices are provided for electrical circuits routed through containment penetrations, if the maximum available fault current will be greater than the continuous rating of the penetration. This avoids penetration damage in the event of failure of any single overcurrent device to clear a fault within the penetration or beyond it. Electrical penetration assemblies of different safety-related divisions are separated by 3-hour-rated fire barriers, are in separate rooms, or are located on separate floor levels. Separation by distance without barriers will be allowed only in the inerted containment. Separation between divisional and nondivisional penetrations will be in accordance with IEEE Std 384. Grouping of circuits in penetration assemblies follows the same raceway voltage groupings. Electrical penetrations design bases include compliance with GDC 50 and following the guidance of RG 1.63.

8.3.1.2.10 Load Shedding and Sequencing on Plant Investment Protection Buses Description

Load shedding, bus transfer, and sequencing on the 6.9-kV PIP buses are initiated on loss of bus voltage. Only loss of preferred power (LOPP) to the 6.9-kV PIP bus trips the loads on the bus. The standby DG protective relaying (voltage and frequency) logic and control system for the electric power distribution system generates PIP bus ready-to-load signals.

Onsite standby DGs are of sufficient size to accommodate required loads with an acceptable starting sequence.

- LOPP

  The 6.9-kV PIP buses are normally energized from the normal PPS. When the normal PPS system is not available, a fast transfer scheme will be activated to transfer power from the normal preferred supply to the alternate preferred supply. If both PPS systems fail, incoming circuit breakers to the PIP bus will trip, and the loads on the bus will shed through an undervoltage signal. The signal starts the onsite standby DGs and closes the standby power supply breaker with an acceptable level of voltage and frequency. The loads will be started in sequence, as required. Transfer back to the PPS will be a synchronized closure of the feeder breaker by manual action.

- LOCA

  A LOCA that occurs without a LOPP has no effect on the onsite ac electrical distribution system. The plant remains on a preferred power source, and the onsite standby diesel generator will not be started.

- LOPP Following LOCA

  If the bus voltage (normal or alternate preferred power) is lost during post-accident operation, transfer to the standby onsite ac power source occurs as described in the LOPP section above.

- LOCA Following LOPP

  If a LOCA occurs following the loss of both the normal and alternate preferred power supplies, the standby onsite ac power source should have already started from the low bus voltage. As discussed in the LOPP section above, automatic load sequencing will start.

- LOCA when Onsite Standby Is Parallel to Preferred Power Supply System during Testing

  If a LOCA occurs when the standby DG is paralleled with either of the PPS systems through the 6.9-kV PIP bus, the standby DG automatically disconnects from the 6.9-kV PIP bus.

- Loss of Normal PPS during Onsite Standby Power Supply System Paralleling Test

  If the normal PPS is lost during the standby onsite ac power source paralleling test, the normal PPS breaker and standby DG breaker are automatically tripped and the alternate PPS accepts loads to reenergize the selected bus loads.

- Loss of Alternate PPS during Onsite Standby Power Supply System Paralleling Test

  If the alternate PPS is used for load testing the standby DG and the alternate PPS is lost, the alternate PPS breaker and standby DG breaker are automatically tripped. The affected bus will then be transferred back to the normal PPS.

8.3.1.2.11 Raceway and Cable Installation

Power and control cables are specified for continuous operation at conductor temperatures not exceeding 90 degrees Celsius (C) (194 degrees Fahrenheit (F)) and should withstand an emergency overload temperature of up to 130 degrees C (266 degrees F), in accordance with Insulated Cable Engineers Association (ICEA) S 95-658/ National Electrical Manufacturers Association (NEMA) WC-70, “Non-shielded 0-2 kV Cables.” The base ampacity rating of the cables will be established as published in IEEE Std 835, “IEEE Standard Power Cable Ampacity Tables,” and ICEA P-54-440/NEMA WC-51, “Ampacities of Cable in Open-Top Cable Trays.”

Cables are specified to continue to operate at 100 percent relative humidity with a service life expectancy of 60 years. Safety-related cables are designed to survive the LOCA ambient condition at the end of the 60-year lifespan. Certified proof tests are performed on cables to demonstrate a 60-year lifespan, and resistance to radiation, flame, and the environment. The testing methodology ensures that such attributes are acceptable for the 60-year lifespan.

All cables specified for safety-related systems and circuits are moisture- and radiation-resistant, are highly flame-resistant, and evidence little corrosive effect when subjected to heat or flame, or both. Certified proof tests are performed on cable samples.

Cable tray fill will be limited to 40 percent of the cross-sectional area for trays containing power cables and 50 percent of the cross-sectional area for trays containing instrumentation and control cables. If tray fill exceeds the above maximum fills, the tray fills are justified and documented. Medium-voltage cable tray fill will be a single layer with maintained spacing.

Cable splices in the raceway are prohibited. Cable splices are made only in manholes, boxes, or suitable fittings. Splices in cables passing through the containment penetration assemblies are made in terminal boxes located adjacent to the penetration assembly.

Three-hour fire rated concrete barriers are used among the RATs, the UATs, and the main transformers and spare main transformer, including the containment and collection of transformer oil. The concrete barriers provide separation and independence of the system.

Cables are installed in trays in accordance with their voltage ratings. The raceways are arranged, physically, top to bottom, based on the function and the voltage class of the cables. Each division of safety-related ac and dc system cables will have its own independent and separate raceway system.

8.3.1.3 *Staff Evaluation*

Industry experience has shown that the voltage transient during islanding (the main generator supplying station auxiliary loads with offsite power disconnected) after loss of the electrical grid, or a generator voltage regulator malfunction, can propagate through the plant's electrical distribution system, resulting in tripping or a loss of safety-related equipment. In RAI 8.2-14, the staff asked how the ESBWR design accommodates the voltage and frequency transient. In response to RAI 8.2-14, the applicant stated that the plant's safety-related and nonsafety-related equipment is designed to accommodate operational voltage and frequency transients, such as the islanding transient, and faulted conditions, such as generator voltage regulator malfunctions. The Forsmark incident, the subject of NRC Information Notice 2006-18, "Significant Loss of Safety-Related Electrical Power at Forsmark, Unit 1, in Sweden," highlights the importance of coordinating the protective trip among the UPS input rectifiers, battery chargers, and inverters. The ESBWR battery chargers and UPS input rectifiers are designed to accommodate the expected islanding transient without tripping. The design includes trip coordination among input rectifiers, battery chargers, and inverters, so that rectifiers and battery chargers trip on excessive high bus voltage and inverters continue to supply the safety-related loads, using stored energy from safety-related batteries. The protective relaying scheme for the ESBWR will be completed as part of the detailed design, to ensure protection for the safety-related and nonsafety-related equipment, as required. However, the staff determined that additional details on the UPS (rectifier and inverter) and battery charger (rectifier) response to high bus voltage were needed.

In RAI 8.2-14 S01, the staff asked the applicant how the rectifier and inverter trip are coordinated. Additionally, the staff asked the applicant to explain the impact of excessive high bus voltage on safety-related loads when fed from the regulating transformer during the islanding mode of operation. In its response, the applicant stated that the safety-related battery chargers and UPS input rectifier high dc voltage trips are coordinated, such that the associated inverters do not trip on high dc input voltage during voltage transients on the ac distribution system. The trips are coordinated such that the inverter high dc input voltage trip setpoint will be greater than the associated battery charger and UPS input rectifier high dc output trip setpoints. In addition, the time delay for the inverter high dc input voltage trip will be greater than the time delay for the battery charger and UPS input rectifier high dc output voltage trips.

In this way, the high dc voltage protection will be coordinated in both magnitude and time, so the battery charger and UPS input rectifier always trip before their dc output voltage reaches the level that would cause an inverter trip on high dc input voltage. This is a functional requirement for the battery charger and UPS equipment; the actual trip magnitude and time margins are a function of the vendor-specific equipment design.

Additionally, the applicant stated that it eliminated the safety-related UPS bypass transformers from the ESBWR design because of the potential for disruptive voltages and frequencies to reach the safety-related loads. The 100-percent redundant UPS rectifiers and inverters within each division negate the need for a bypass transformer. The battery chargers and UPS will be designed to have the required fault clearing and load inrush capability, without the need to switch to a bypass source. Each inverter within a division can be taken out of service for maintenance without the need to deenergize the UPS bus; however, the division will be inoperable according to the technical specifications (TSs). The applicant revised the DCD Tier 1 and Tier 2, Revision 5, to reflect the removal of the safety-related UPS bypass transformer and other changes discussed above. Based on the applicant's response, RAI 8.2-14 is resolved. The staff confirmed that Revision 6 of the DCD includes the changes described above.

In RAI 14.3-413, the staff asked the applicant to provide an ITAAC to verify the trip coordination of safety-related battery chargers and UPS input rectifiers with inverters. In its response, the applicant revised DCD Tier 1, Revision 5, to include the requirement to verify the trip coordination of the safety-related battery chargers and UPS input rectifiers with inverters. This new DCD Tier 1 ITAAC is based on new information added to DCD Tier 2 that discusses coordination of the rectifier and inverter high dc voltage trips. Based on the applicant's response, RAI 14.3-413 is resolved. Section 14.3.6 of this report discusses RAI 14.3-413 regarding the ITAAC. The staff confirmed that Revision 6 of the DCD includes the changes described above.

In RAI 14.3-394 S01, the staff asked the applicant to provide an interface requirement for demonstrating the capacity and capability of the offsite power system. In its response, the applicant incorporated the PPS definition into DCD Tier 2, Revision 6, Chapter 8, per IEEE Std 765. The PPS consists of the normal and alternate PPSs and includes those portions of the offsite and onsite power systems required for power flow from the offsite transmission system to the safety-related IPC incoming line breakers. Additionally, the applicant revised DCD Tier 2, Revision 5, Chapter 8, to clarify that GDC 17 applies to the entire PPS and added ITAAC in Tier 1, Section 2.13.1, to address capacity, capability, and the physical and electrical separation of the normal and alternate PPS. Based on the applicant's response, RAI 14.3-394 S01 is resolved. Section 14.3.6 of this report discusses RAI 14.3-394 S01 regarding ITAAC. The staff confirmed that Revision 6 of the DCD includes the changes described above.

In RAI 8.2-16, the staff asked the applicant to discuss the protection of the main transformer, UATs, RATs, isolated phase bus, and nonsegregated phase bus. Additionally, the staff asked the applicant to provide the rating of these devices. In its response, the applicant modified DCD Tier 2, Revision 5, Section 8.3.1.1, to add that the main transformer, UATs, and RATs are protected against overcurrent, differential current, ground overcurrent, and sudden overpressure. Additionally, the applicant modified Section 8.3.1.1 to include the protection of the isolated phase bus and nonsegregated bus against overcurrent and bus differential. The ratings of the devices will not be known until the completion of the ESBWR detailed design. However, the response to RAI 14.3-394 S01 added ITAAC Item 9 to DCD Tier 1, Revision 6, Section 2.13.1, to ensure the equipment within the onsite portion of the PPS is rated to supply necessary load requirements, including power, voltage, and frequency, during design-basis operating modes. This ITAAC confirms that the transformer and buses are sized and rated appropriately. Based on the applicant's response, RAI 8.2-16 is resolved. The staff confirmed that Revision 6 of the DCD includes the changes described above.

In RAI 8.3-60, the staff asked the applicant to clarify several issues concerning degraded voltage conditions. In response, the applicant stated that IPC buses are double-ended, such that each bus can receive power from either standby DG-backed 6.9-kV PIP bus. The IPC buses are equipped with degraded voltage and frequency protection to facilitate bus isolation and transfers. This relaying also serves as a backup to the ac input monitoring built into the safety-related battery chargers and UPS for protection against voltage and frequency transients on the ac supply. Additionally, the applicant revised DCD Tier 2, Revision 5, Section 8.3.1.1.2, to state that IPCs are protected against degraded voltage and frequency conditions by using voltage and frequency relays installed in each IPC to provide alarms and facilitate IPC bus isolation and transfer functions, using two-out-of three logic to prevent spurious actuation. The applicant further stated that degraded voltage and undervoltage protection is provided on the medium-voltage bus incoming line breakers. This provides protection for all medium-voltage buses, low-voltage buses, and connected loads from degraded voltage conditions on the normal and alternate preferred offsite power sources. Underfrequency protection will not be provided on medium-voltage or low-voltage buses. Plant auxiliary loads are able to operate within a ± 5 percent frequency tolerance; the grid underfrequency load shedding scheme will act to maintain the frequency well within this band, or turbine generators on the line will begin to trip within a few seconds. If islanding or connected to the onsite standby DGs, underfrequency relaying associated with these sources will actuate and remove the out-of-tolerance source from the bus. The safety-related frequency protection on the IPC bus will remove it from the source to protect the safety-related loads.

The staff finds that the safety-related loads fed from the IPC bus are battery chargers (rectifiers) and UPSs. The safety-related loads are able to operate within ±10 percent voltage tolerance. The UPS consists of a rectifier and an inverter. Each rectifier receives 480-V ac power from the IPC bus and converts it to 250-V dc power. The 250-V dc is then inverted to 120-V ac (uninterruptible) by the inverters. The degraded voltage scheme will initiate transfer to the alternate PPS (i.e., RAT) if the normal PPS is degraded (i.e., UAT problem). Also, the degraded voltage protection on the isolation bus will remove it from the source if both normal preferred and alternate preferred power supplies are degraded. Under this situation, the inverters continue to supply safety-related loads (e.g., Q-DCIS, scram pilot valves, main steam isolation valve solenoids), using stored energy from the safety-related batteries. Based on the above, the staff finds that the applicant has adequately addressed degraded voltage issues and, therefore, RAI 8.3-60 is resolved. The staff confirmed that Revision 6 of the DCD includes the changes described above.

In RAI 14.3-427, the staff asked the applicant to provide ITAAC for grounding and lightning protection systems. In its response, the applicant added ITAAC, as the staff requested. The applicant also removed from DCD Tier 2, Revision 5, Appendix 8A.1.1, the statement that lightning protection ground rods would be separate from the normal grounding system. The ITAAC verifies that a connection exists between the lightning protection system and the station ground grid. The applicant stated that this change, and allowing the lightning protection ground rods to tie to the ground grid, will make the lightning protection system more robust by providing additional volume to adequately dissipate lightning strikes. The staff finds that the applicant adequately addressed the issue and RAI 14.3-427 is resolved. Section 14.3.6 of this report discusses RAI 14.3-427 regarding ITAAC. The staff confirmed that Revision 6 of the DCD includes the changes described above.

DCD Tier 2, Revision 6, Section 8.3.3.2, did not address the use of underground cables or cables in a wetted environment. Operating experience has shown that cross-linked polyethylene or high-molecular-weight polyethylene insulation materials are susceptible to water tree formation. Cable failures have a variety of causes: manufacturing defects, damage caused by shipping and installation, and exposure to electrical transients or abnormal environmental conditions during operation. Electrical cables in nuclear power plants are usually located in dry environments, but some cables are exposed to moisture from condensation and wetting in inaccessible locations, such as buried conduits, cable trenches, cable troughs, aboveground and underground duct banks, underground vaults, and direct buried installations. Since underground cables are susceptible to moisture, in RAI 8.3-67, the staff asked the applicant to identify the cables that are inaccessible or routed underground that support equipment and other systems within the scope of 10 CFR 50.65 (the maintenance rule). Additionally, the staff asked the applicant to indicate whether there are any plans to implement a program for testing and inspection of inaccessible or underground power, control, and instrumentation cables, in accordance with Generic Letter (GL) 2007-01, “Inaccessible or Underground Power Cable Failures that Disable Accident Mitigation Systems or Cause Plant Transients,” issued February 2007; and the frequency for such testing and inspection, or to provide justification for not developing such a program. In its response, the applicant stated that the standard ESBWR plant design will have its principal plant structures, as listed in DCD Tier 2, Revision 9, Section 1.2.1, connected by a series of tunnel structures that will enable the routing of cables and raceways in areas not subject to water intrusion. For other ESBWR structures not listed in Section 1.2.1 as well as site specific structures requiring electric power, the detail design is within owner’s yard scope, not considered part of the standard plant design and is covered by the COL applicants. The applicant identified two ESBWR systems (plant service water system [PSWS] and standby DG fuel oil transfer system) with accident mitigating functions that have power and control cables that are in a potentially wetted environment due to manholes. These two systems are in the COL applicant’s yard scope and covered by the COL applicant per the maintenance rule. The applicant revised DCD Tier 2, Revision 6, Subsection 8.3.3.2 and Table 1.10-1 to add a new COL Information Item 8.3.4-2-A. The COL Information Item 8.3.4-2-A requires the identification and monitoring of underground or inaccessible power and control cables to the PSWS and standby DG fuel oil transfer system equipment that have accident mitigating functions. Additionally, the applicant revised DCD Tier 2, Revision 6, Subsection 8.3.3.2 to include the statement, “A water-tree formation retardant is specified when polyethylene cable insulation is selected for medium voltage use. A dry cure process is specified for cable insulation.” The staff finds the applicant’s addition of COL Information Item 8.3.4-2-A is appropriate to address the issue discussed in GL 2007-01 and COL Information Item 8.3.4-2-A is consistent with the guidance of SRP Section 8.3.1. Additionally, the staff finds that the selection of water-tree formation retardant and dry cure process for cable insulation for medium voltage cable will improve medium voltage cable design for wetted environment. Based on the applicant’s response, RAI 8.3-67 is resolved. The staff confirmed that Revision 7 of the DCD includes the changes described above.

The following paragraphs analyze compliance with the GDC and consistency with the RGs and other SRP guidance:

- GDC 2 and GDC 4

  All components of the safety-related IPCs and UPS system are housed in seismic Category I structures designed to protect them from natural phenomena. These components are qualified to the appropriate seismic, hydrodynamic, and environmental conditions as part of the qualification program described in DCD Tier 2, Revision 9, Section 3.11 and evaluated in Section 3.11 of this report. The safety-related IPCs and UPS system are in compliance with the requirements of GDC 2 and 4.

- GDC 5, RG 1.81, and RG 1.32

  The ESBWR plant is designed as a single-unit plant, and, thus GDC 5, RG 1.81, and RG 1.32 are not applicable.

- GDC 17

  The safety-related dc power supply supports passive core cooling and containment safety-related functions. The ESBWR design complies with GDC 17 with respect to two independent and separate offsite power supply and onsite standby power supply systems.

- RG 1.6

  The standby power sources (i.e. standby DGs) are nonsafety-related. The standby power sources are designed with the required independence. The 120-V UPS systems, together with safety-related IPCs, are designed with the required independence. The design is consistent with the guidance of RG 1.6.

- RG 1.9

  The ESBWR design does not require safety-related DGs, and hence, RG 1.9 is not applicable.

- RG 1.32

  The design provides for safety-related 120-V UPS systems to support passive core cooling and containment integrity safety functions. The design is consistent with the guidance of RG 1.32.

- RG 1.53

  The safety-related 120-V UPS system is designed so that no single active failure in any division of the 120-V UPS system results in conditions that could prevent the safe shutdown of the plant while a separate division is out of service for maintenance. Therefore, the design is consistent with the guidance of RG 1.53.

- RG 1.75

  The ESBWR design provides the physical separation and independence of the division of the electrical circuit and equipment comprised of, or associated with, the Class 1E power systems, Class 1E protection systems, systems actuated or controlled by the protection system, and auxiliary or supporting systems that must be operable for the protection system and systems it actuates to perform their safety-related functions. The design provides separation to maintain the independence of sufficient circuits and equipment so that the protective functions required during and following any design-basis event can be accomplished. Also, this design provides physical and electrical separation of safety-related circuits from nonsafety-related circuits. Therefore, the ESBWR design is consistent with the recommendations of RG 1.75, which is related to GDC 17.

- RG 1.153

  Safe shutdown relies upon the 120-V UPS system and meets the design requirements for redundancy. The redundant safety-related loads are distributed between redundant distribution systems, and power systems are supplied from the related redundant distribution systems. Therefore, the design is consistent with the guidance of RG 1.153.

- RG 1.155

  The ESBWR design does not require safety-related emergency DGs, and hence, this RG is not applicable.

- RG 1.204

  The lightning arresters are connected to the high-voltage terminals of the main step-up transformers, UATs, and RATs. Plant instrumentation located outdoors or connected to cables running outdoors has surge suppression devices to protect the equipment from lightning-induced surges. The design is consistent with the guidance of RG 1.204.

- GDC 18

  The offsite and onsite power systems that supply ac power to SSCs important to safety are testable. Thus, the ESBWR design complies with GDC 18 and is consistent with the guidance of RG 1.32, RG 1.47, RG 1.118, and RG 1.153.

- GDC 33, 34, 35, 38, 41, and 44

  The potential risk contribution of a design-basis event is minimized because the passive reactor design does not require ac power sources for such events. Passive reactor designs incorporate passive safety-related systems for core cooling and containment integrity and, therefore, do not depend on the onsite standby power source. They are designed to automatically establish and maintain safe shutdown conditions after design-basis events for 72 hours, without operator action, following a loss of both onsite and offsite ac power sources. Therefore, the ESBWR design is not required to meet the requirements of GDC 33, 34, 35, 38, 41, and 44.

- GDC 50

  Redundant overcurrent interrupting devices are provided for electrical circuits routed through containment penetrations if the maximum available fault current is greater than the continuous rating of the penetration. This avoids penetration damage in the event of a failure of any single overcurrent device to clear a fault within the penetration or beyond it. Electrical penetrations are in compliance with GDC 50 and follow the guidance of RG 1.63.

- 10 CFR 50.63

  With regard to 10 CFR 50.63, the ESBWR design bases do not rely on an onsite ac power system to achieve and maintain safe shutdown (see the SBO evaluation in Sections 8.4.2.1 and 15.5.5 of this report). RG 1.9 and RG 1.155, regarding a reliability program for emergency onsite ac power source, are not applicable.

- 10 CFR 50.65(a) (4), RG 1.160, and RG 1.182

  As described in DCD Tier 2, Section 17.4.1, the maintenance rule program is part of the operational reliability assurance program covered by COL Information Item 17.4-2-A, which is evaluated in Section 17.4 of this report.

The applicant has provided information to demonstrate that the ancillary DG will be capable of providing the post-72-hour power requirements to onsite loads, including the safety-related UPS loads. These and other RTNSS functions of the ancillary DG are discussed in Section 8.4.2.3 of this report. Also, this system design provides the isolation devices to separate the safety-related and nonsafety-related systems. Therefore, the staff finds the ancillary ac DGs to be acceptable.

8.3.1.4 *Combined License Unit-Specific Information*

The applicant stated that the COL applicant will address the cathodic protection system via COL Information Item 8A.2.3-1-A. Additionally, the COL applicant will address the underground or inaccessible power and control cable monitoring program via COL information item 8.3.4-2-A.

These COL items identify two items related to the ac power system that the COL applicant will address. The staff agrees that these items are site-specific and therefore appropriately addressed by the COL applicant. In addition, these COL items for the ac power system, provided they are adequately addressed, provide reasonable assurance that the ac power system meets the requirements of GDC 17. Therefore, the staff finds this COL information item acceptable.

8.3.1.5 *Conclusion*

The staff has reviewed the onsite ac power supply system, including the UPS systems. Based on its review, the staff concludes that the applicant has provided sufficient information to demonstrate that the onsite ac power supply systems are consistent with the guidance of cited RGs and are capable of providing the power supply to onsite loads needed to support the plant’s safe operation. The design of the onsite ac power supply systems is acceptable and meets the requirements of GDC 2, 4, 17, 18, and 50.

8.3.2 Direct Current Power Systems

8.3.2.1 *Regulatory Criteria*

The dc power systems include those dc power sources (and their distribution systems and auxiliary supporting systems) that supply motive or control power to safety-related and nonsafety-related equipment. The staff’s review covers the information, analyses, and referenced documents for the dc onsite power system. Acceptance criteria are based on GDC 2, 4, 5, 17, 18, 33, 34, 35, 38, 41, 44, and 50, and on 10 CFR 50.63, 10 CFR 50.55a(h), and 10 CFR 50.65(a)(4), as they relate to the capability of the onsite electrical power system to facilitate the functioning of SSCs important to safety. SRP Sections 8.1 and 8.3.2 contain specific review criteria.

Acceptance criteria for the evaluation of dc power systems (onsite) are based on meeting the following relevant requirements:

- 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 this report and reviewed by the organizations with primary responsibility for the reviews of plant systems, civil engineering and geosciences, and mechanical engineering

- 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 this report and reviewed by the organizations with primary responsibility for the reviews of plant systems, materials, and chemical engineering

- GDC 5, as it relates to sharing dc power system SSCs

- 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

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

- GDC 33, 34, 35, 38, 41, and 44, as they relate to the operation of the onsite electric power system, encompassed in GDC 17, to ensure that the safety functions of the systems described in GDC 33, 34, 35, 38, 41, and 44 are accomplished

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

- 10 CFR 50.63, as it relates to the ability of the onsite dc power system to support the plant in withstanding, or coping with and recovering from, an SBO event

- 10 CFR 50.55a (h), as it relates to the incorporation of IEEE Std 603-1991 (including the correction sheet, dated January 30, 1995) and IEEE Std 279 for protection and safety systems

- 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, including but not limited to, surveillances, post-maintenance testing, and corrective and preventive maintenance (noting that SRP Chapter 17 reviews compliance with the maintenance rule, including verification that appropriate maintenance activities are covered therein)

SRP Section 8.3.2 provides guidance on how an application can meet the above regulations.

- RG 1.6, Regulatory 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

- RG 1.32, as it relates to the design, operation, and testing of the safety-related portions of the onsite dc power system, noting that, except for sharing safety-related dc power systems in multiunit nuclear power plants, RG 1.32 endorses IEEE Std 308-2001

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

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

- RG 1.128, “Installation Design and Installation of Vented Lead-Acid Storage Batteries for Nuclear Power Plants,” issued October 1978, as it relates to the installation of vented lead-acid (VLA) storage batteries in the onsite dc power system

- RG 1.129, “Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Nuclear Power Plants,” issued February 1978, as it relates to maintenance, testing, and replacement of vented lead-acid (VLA) storage batteries in the onsite dc power system

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

- 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, noting that, 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

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

- 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

- RG 1.155, as it relates to the capability and the capacity of the onsite dc power system to withstand an SBO, including batteries associated with the operation of the alternate ac power source(s) (if used)

- RG 1.160, as it relates to the effectiveness of maintenance activities for dc power systems

- 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

8.3.2.2 *Summary of Technical Information*

The onsite dc power systems consist of safety-related and nonsafety-related power systems. Each system consists of an ungrounded battery bank, battery chargers, and dc distribution equipment.

The design provides for eight independent safety-related Class 1E 250-V dc batteries, two each for Divisions 1, 2, 3, and 4. They provide four divisions of independent and redundant onsite dc power supplies for safety-related loads, monitoring, and emergency lighting for the MCR and the remote shutdown area.

The design provides for seven independent nonsafety-related dc batteries, consisting of five 250-V dc and two 125-V dc batteries. The nonsafety-related dc systems supply dc power for control and switching, switchgear control, TSC, instrumentation, and station auxiliaries.

The Class 1E dc system also supplies power for the safe shutdown of the plant without the support of battery chargers, during a loss of all ac power sources coincident with a DBA. The system will be designed so that no single failure will result in a condition that will prevent the safe shutdown of the plant.

The non-Class 1E dc system provides power to the plant's non-Class 1E control and instrumentation equipment and loads that are required for plant operation and investment protection. Operation of the non-Class 1E dc supply system will not be required for plant safety.

8.3.2.2.1 Safety-Related Direct Current System

Safety-related Divisions 1, 2, 3, and 4 each consists of two separate 250-V dc battery banks. Each battery bank supplies dc power to the loads through the safety-related inverter for at least 72 hours following a design-basis event. Each of the safety-related battery systems has a 250-V battery bank, battery charger, main distribution panel, and ground detection panel. One divisional battery charger will be used to supply each group dc distribution panel and its associated battery. The divisional battery charger will be fed from its divisional 480-V isolation power center.

Each division has a standby charger as backup to either of the battery banks of its respective division.

The 250-V dc systems supply dc power to Divisions 1, 2, 3, and 4 and are designed as safety-related equipment, in accordance with IEEE Std 308 and IEEE Std 946, "IEEE Recommended Practice for the Design of Safety-Related dc Auxiliary Power Systems for Nuclear Power Generating Stations." The design ensures that no single active failure in any division of the system results in conditions that prevent the safe shutdown of the plant while a separate division is out of service for maintenance.

The plant design and circuit layout of the dc systems provide physical separation of equipment, cabling, and instrumentation essential to plant safety. Each 250-V dc battery will be separately housed in a ventilated room apart from its charger, distribution, and ground detection panels. Equipment of each division of the dc distribution system will be located in an area separated physically from the other divisions. All components of safety-related 250-V dc systems are housed in seismic Category I structures.

Each division has two 250-V safety-related batteries, and each battery supplies power to its safety-related inverter for at least 72 hours following a DBA. The minimum dc system battery bank terminal voltage at the end of the discharge period will be 210 V (1.75 V per cell). The maximum equalizing charge voltage for safety-related batteries will be site-specific and specified by the battery vendor and as allowed by the voltage rating of the connected loads (inverters). The UPS inverters are designed to supply 120-V ac power with dc input less than the minimum discharged voltage of 210-V dc and greater than the maximum equalizing charge voltage, which is site specific, as specified by the battery vendor. The COL applicant will specify the safety-related battery float voltage and equalizing voltage values, as described in COL Information Item 8.3-4-1-A.

The safety-related battery chargers are full-wave, silicon-controlled rectifiers. The housings are freestanding, National Electrical Manufacturers Association (NEMA) [Standards Publication 250-2003, “Enclosures for Electrical Equipment (1000 Volts Maximum)”] Type 1, and are ventilated. The chargers are suitable for float charging the batteries and operate from a 480-V, three-phase, 60-hertz (Hz) supply. The power for each divisional battery charger will be supplied by that division’s dedicated IPC. Each battery charger will be capable of recharging its battery from the design minimum charge to a fully charged condition within 24 hours, while supplying the full load associated with the individual battery. The battery chargers are the constant voltage type, adjustable between 240 V and 290 V, with the ability to operate as battery eliminators.

The battery eliminator feature will be incorporated as a precautionary measure to protect against the effects of inadvertent disconnection of the battery. The battery chargers are designed to function properly and remain stable if the battery is disconnected. Variation of the charger output voltage is less than ±1 percent, with or without the battery connected. The maximum output ripple for the charger is 30 millivolt root mean square with the battery, and less than 2 percent root mean square without the battery.

The battery chargers’ output will have a current-limiting design. The chargers are designed to prevent their ac source from becoming a load on the batteries because of power feedback from a loss of ac power. The battery chargers’ output voltage will be protected against overvoltage by a high-voltage shutdown circuit. When high voltage occurs, the unit disconnects the auxiliary voltage transformer, which results in charger shutdown. An alarm in the MCR indicates the loss of charger input voltage and charger shutdown.

Ventilation

A safety-related ventilation system will not be required for the batteries to perform their safety-related functions. However, battery rooms are ventilated by a system designed to remove the hydrogen gas produced during the charging of batteries. The system will be designed to preclude the possibility of hydrogen accumulation as described in DCD Tier 2, Revision 9, Section 9.4.6.

Monitoring and Alarms

Important system components are either self-alarming on failure or capable of clearing faults, or they are being tested during service to detect faults. All abnormal conditions of important system parameters, such as system grounds, charger failure, and low bus voltage, are alarmed in the MCR, locally, or both.

Inspection, Maintenance, and Testing of Direct Current System

An initial composite test of the onsite dc power system will be a prerequisite to initial fuel loading. This test verifies that each battery capacity will be sufficient to satisfy a design-basis load demand profile under the conditions of a LOCA and a LOPP. Conducted in accordance with IEEE Std 450, “IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications,” these tests ensure that the battery has the capacity to meet safety-related load demands.

The applicant stated that the ESBWR technical specifications (TS) describe the inservice tests, inspections, and maintenance of the dc power systems, including the batteries, chargers, and auxiliaries.

8.3.2.2.2 Nonsafety-Related Direct Current Systems

The nonsafety-related dc systems consist of five divisions of 250 V and two divisions of 125 V. The dc systems are ungrounded for reliability. The 125-V batteries provide dc power for nonsafety-related loads. The 250-V battery bank provides dc power for the plant's nonsafety-related distributed control and instrumentation system (DCIS) and nonsafety-related dc motors. Each of the dc systems has a battery, battery charger, standby battery charger, main dc distribution bus, and ground detection panel, except the 250-V dc load groups A and B. The A and B load groups each have two normal battery chargers, one standby battery charger, two batteries, a ground detection panel, and two distribution buses. The main distribution buses feed the local dc distribution panels, UPS inverter, and dc MCC. The plant design and circuit layout of the nonsafety-related dc systems provide physical separation of the equipment, cabling, and instrumentation associated with the load groups of nonsafety-related equipment. Each 125-V and 250-V battery will be separately housed in a ventilated room apart from its charger, distribution panel, and ground detection panel. Equipment of each load group of the dc distribution system will be located in an area separated physically from the other load groups.

The 125-V nonsafety-related battery bank will be sized for 2-hour duty cycles at a discharge rate of 2 hours, based on a terminal voltage of 1.75-V per cell at 25 degrees C (77 degrees F). The dc system minimum battery terminal voltage at the end of the discharge period is 105 V. The maximum equalizing charge voltage for the 125-V batteries is specified by the battery vendor.

The 250-V nonsafety-related batteries are sized for 2-hour duty cycles at a discharge rate of 2 hours, based on a terminal voltage of 1.75 V per cell at 25 degrees C (77 degrees F). The dc system minimum battery terminal voltage at the end of the discharge period is 210 V. The maximum equalizing charge voltage for 250-V batteries is specified by the battery vendor.

The nonsafety-related batteries have sufficient stored capacity, without their chargers, to independently supply their loads continuously for at least 2 hours. The batteries are sized so that the sum of the required loads does not exceed the battery ampere-hour rating, or the warranted capacity at end-of-installed-life with 100-percent design demand. The battery banks are designed to permit replacement of individual battery cells.

The nonsafety-related battery chargers are full-wave, silicon-controlled rectifiers or an acceptable alternative design. The housings are freestanding, NEMA Type 1, and are ventilated. The chargers are suitable for float charging the batteries. The chargers operate from a 480-V, three-phase, and 60-Hz ac supply. A separate power center, backed up by the onsite standby DG, supplies each charger. Standby chargers are used to equalize battery charging. Standby chargers are supplied from a different power center than the normal battery charger.

The battery chargers are the constant-voltage type, with the 125-V dc system chargers having a voltage adjustable between 120 V and 145 V, and the 250-V dc system chargers having a voltage adjustable between 240 V and 290 V, with the capability of operating as battery eliminators. The battery eliminator feature will be incorporated as a precautionary measure to protect against the effects of inadvertent disconnection of the battery. The battery chargers are designed to function properly and remain stable when the battery bank is disconnected. Variation of the charger output voltage will be less than ±1 percent, with or without the battery bank connected.

The battery chargers are designed to be output-current limiting and to have protection against power feedback from the battery bank to the ac supply system. The battery charger will be equipped with overvoltage protection by a high-voltage shutdown circuit to protect equipment from damage caused by high voltage. An alarm in the MCR indicates a loss of voltage to the charger and charger shutdown. Battery rooms are ventilated by a system designed to remove the hydrogen gas produced during the charging of batteries. The design of the system precludes the possibility of hydrogen accumulation.

8.3.2.3 *Staff Evaluation*

The safety-related batteries are specified in DCD Tier 2, Revision 3, to have sufficient capacity, without their chargers, to independently supply the safety-related loads continuously for at least 72 hours. Batteries must be sized for the dc load, in accordance with IEEE Std 485, "IEEE Recommended Practice for Sizing Large Lead Storage Batteries for Nuclear Power Generating Stations," with an expected 20-year service life. In RAI 8.3-49 and RAI 8.3-52 and its supplements, the staff requested the loading profile to evaluate whether the safety-related 250-V batteries are of a size sufficient to meet the design requirements of their connected loads, without the charger support, for the corresponding period of 72 hours. In response to RAI 8.3-49 and RAI 8.3-52 S01, the applicant indicated that the final loading profile will not be determined until the DCIS loads are established during procurement. Instead, the inspection, maintenance, and testing program states that battery capacity tests will be conducted in accordance with IEEE Std 1188, "IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications." These tests ensure that the battery has the capacity to meet safety-related load demands. The final load profile will include the analyses and will be tested in accordance with ITAAC, Table 2.13.3-1, Items 3a and 3b, "Acceptance Criteria."

3a. Analyses reports of the as-built batteries exist and conclude that two sets of safety-related batteries in each division have the capacity, as determined by the vendor performance specification, to supply its rated constant current, for a minimum of 72 hours without recharging.

3b. Test reports conclude that the capacity of each as-built safety-related battery equals or exceeds the analyzed battery design duty cycle capacity.

The applicant also indicated that the safety-related batteries are sized to meet the design requirements of their connected load, without the charger support, for the corresponding period of 72 hours. A preliminary battery size has been selected to meet the estimated maximum design load profile, with the ability to increase the battery size by 50 percent of the estimated battery size. The selected batteries are capable of being sized to meet the above-stated criteria without expansion of the current rooms designated for each division's batteries. The battery bank will be designed to replace any defective cells without an interruption of service. However, the staff found that the applicant did not provide the loading profile to demonstrate that the safety-related 250-V batteries are sized to meet the design requirement of their connected load for the corresponding time period of 72 hours without the charger's support.

In RAI 8.3-52 S03, the staff requested information regarding the batteries' capacity to meet the design requirement of their connected load for the corresponding time of 72 hours without the battery charger's support. RAI 8.3-52 was being tracked as open item in the SER with open items. In response to RAI 8.3-52 S03, the applicant added a new DCD Tier 2, Revision 5, Table 8.3-3 to provide the nominal load requirements for each safety-related division. The applicant also independently submitted a summary of the safety-related battery sizing calculation, including relevant parameters and factors used in the calculation. The load cycle is based on the conservative estimation of the safety-related UPS loads provided in DCD Tier 2, Revision 5, Table 8.3-3. The battery sizing calculation summary confirms that this load cycle incorporates applicable safety-related UPS loads and includes conservative adjustments for inverter efficiency and power factor. DCD Tier 2, Revision 5, Section 8.3.2.1.1, identifies the following additional considerations included in battery sizing: (1) the dc system's minimum battery terminal voltage at the end of the discharge period is 210 V dc (1.75 V per cell), (2) the batteries are sized for the dc load, in accordance with IEEE Std 485, with an expected 20-year service life, and (3) the batteries include a margin to compensate for uncertainty in determining the battery state of charge. The battery sizing calculation summary included these considerations, including the design margin, aging factor, and temperature correction factor, consistent with IEEE Std 485. The temperature correction factor is consistent with the minimum cell temperature of 60 degrees F (15.6 degrees C) specified in DCD Tier 2, Revision 6, Table 8.3-3, Note (3). The calculation also includes a factor for uncertainty in float current monitoring. The staff finds that the battery sizing calculation summary confirms that batteries, based upon the considerations for determining battery size identified in DCD Tier 2, Revision 6, Chapter 8 are sized adequately and sufficiently to supply uninterruptible power for 72 hours. Therefore, the staff concluded that the battery sizing is acceptable. However, the staff determined that additional battery capacity information was needed in the DCD.

In RAI 8.3-52 S04, the staff requested information regarding the battery capacity in ampere-hours, the specifications for the charger, rectifier, inverter, and regulating transformer, and the UPS protective scheme against faults. In its response, the applicant added a new Table 8.3-4 to DCD Tier 2, Revision 5, which includes nominal values for the battery capacity and the specifications for the charger, inverter, and regulating transformer. The applicant explained that the UPS rectifier specification is considered to be included as part of the overall UPS, as its sizing and specification are dictated by the UPS (inverter) specification found in the new Table 8.3-4. The applicant further stated that the safety-related UPS is protected against overvoltage, undervoltage, overfrequency, underfrequency, overcurrent, and fault current. The UPS protection features are integral to the unit and will be set based on the calculation performed as part of the ESBWR detailed design. Additionally, regulating transformers were deleted in response to RAI 8.2-14 S01, as discussed in Section 8.3.1.3 of this report. The staff found that the applicant provided the requested information and that the battery capacity, charger sizing, and inverter sizing are consistent with the dc load profile. The staff confirmed that Table 8.3-4 was included in Revision 5 of the DCD. Based on the applicant's response, RAIs 8.3-49 and 8.3-52 are resolved.

DCD Tier 2, Revision 5, Section 8.3.2.2.1, stated that the safety-related batteries meet the qualification requirements of IEEE Std 535, "IEEE Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations." Section 1.1, "Scope," of IEEE Std 535 states that the standard describes qualification methods for Class 1E VLA batteries and that consideration of other types of batteries are beyond the scope of the standard. Consequently, IEEE Std 535 does not apply to VRLA batteries. In RAI 8.3-63, the staff asked the applicant to explain how these batteries were going to be qualified, including both the methods used and the process flow. In its response, the applicant referred to the change of the ESBWR safety-related batteries to VLA, in response to RAI 8.3-62, which is discussed below. The method of qualifying VLA batteries is discussed in response to RAI 8.3-64. Based on the applicant's response, RAI 8.3-63 is resolved.

DCD Tier 2, Revision 5, Section 8.3.2.2.1, stated that the safety-related batteries meet the qualification requirements of IEEE Std 535, which was written under the assumption of an 8-hour duty cycle. IEEE Std 535 does not apply to duty cycles longer than 8 hours. In RAI 8.3-64, the staff asked the applicant to identify the methodology to be used to qualify these batteries for an extended duty cycle of 72 hours. Also, the staff asked the applicant to discuss the failure mode(s) for this type of battery for the 72-hour duty cycle. In addition, in RAI 8.3-65, the staff requested the applicant to justify a 20-year battery service life. In response to RAIs 8.3-64 and 8.3-65, the applicant stated that safety-related batteries are qualified to meet IEEE Std 535 by type test, with the exception that the duty cycle is 72 hours, and that supplemental discharge cycle testing is required to meet the harsh environment qualification process of IEEE Std 323-1974, “IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.” Additionally, the equipment qualification process for batteries includes the evaluation of significant aging mechanisms that are related to failure mechanisms from radiation exposure, time-temperature aging, and cycle aging; age testing for significant aging mechanisms for a 20-year qualified life; seismic tests; and performance testing for the 72-hour duty cycle. The applicant submitted Licensing Topical Report, NEDE-33516P, “ESBWR Qualification Plan Requirements for a 72-Hour Duty Cycle Battery,” July 27, 2009. The applicant provided a detailed testing plan in the topical report. The acceptability of the 72-hour duty cycle battery qualification plan is evaluated in the SER for NEDE-33516P. Based on the applicant’s response and NEDE-33516P, RAIs 8.3-64 and 8.3-65 are resolved.

The following evaluation documents the compliance of the safety-related dc power supply systems with the regulatory criteria and their consistency with the guidance of the SRP. The ESBWR four-division design allows the systems to sustain a credible single active failure with one division already out of service and the remaining two divisions fully performing their safety function for 72 hours without chargers. The dc power supply systems comply with GDC 2, 4, 17, 18, 33, 34, 35, 38, 41, 44, and 50, and with 10 CFR 50.63 and 10 CFR 50.55a(h), based on conformance with the following RGs:

- RG 1.6

  In RAI 8.3-61, the staff asked the applicant to revise the section related to RG 1.6 and discuss how the design meets the RG 1.6 regulatory positions. In its response, the applicant stated that the applicability statement found in DCD Tier 2, Revision 5, Section 8.3.2.2.2, regarding RG 1.6 had an editorial error that stated that RG 1.6 for “Standby (Onsite) Power Sources” is not applicable to the passive ESBWR design. The applicant revised the applicability text at Section 8.3.2.2.2 for RG 1.6. Based on the applicant’s response, RAI 8.3-61 is resolved. The staff confirmed that Revision 6 of the DCD includes the change described above. The dc power systems are designed with required independence. Based on the above, the staff finds that the design is consistent with the guidance of RG 1.6.

- RG 1.32

  The design provides for safety-related dc power supply systems to support passive core cooling and containment integrity safety functions. The design is consistent with the guidance of RG 1.32.

- RG 1.53

  The safety-related dc system is designed so that no single active failure in any division of the 250-V dc system results in conditions that prevent the safe shutdown of the plant while a separate division is out of service for maintenance. Therefore, the design is consistent with the guidance of RG 1.53.

- RG 1.63

  Redundant overcurrent interrupting devices are provided for electrical circuits routed through containment penetrations if the maximum available fault current is greater than the continuous rating of the penetration. Therefore, the design is consistent with the guidance of RG 1.63.

- RG 1.75

  Safe shutdown relies upon dc-derived power and meets the design requirements for physical independence. Therefore, the design is consistent with the guidance of RG 1.75.

- RG 1.81

  The ESBWR plant will be designed as a single-unit plant, and, thus, GDC 5 and RG 1.81 are not applicable.

- RG 1.128 and RG 1.129

  In RAI 8.3-62, the staff asked the applicant to explain how these two RGs are applicable to VRLA batteries. In its response, the applicant revised the DCD to reflect a change for the safety-related batteries to VLA. Therefore, RG 1.128 and RG 1.129 apply to “large lead storage batteries,” and their endorsed IEEE standards are applicable to the ESBWR design. The applicant also revised DCD Tier 2, Revision 5, to state that the maximum equalizing charge voltage for safety-related batteries will be site specific and that the COL applicant will specify the safety-related battery float voltage and equalize voltage. The applicant added COL Information Item 8.3.4-1A. The applicant also added two notes (Notes 3 and 4) to Table 8.3-3 to state that 60 degrees F (15.6 degrees C) will be the minimum operable temperature used in the sizing calculation for the safety-related batteries and that the battery sizing calculation used the methodology of IEEE 485, which includes an overall margin that will be conservative and bounding. Based on the applicant’s response, RAI 8.3-62 is resolved. The staff confirmed that Revision 6 to the DCD includes the change described above. The staff finds that the battery sizing calculation will be conservative and hence, acceptable. The staff finds that the design is consistent with the guidance of RG 1.128 and RG 1.129.

- RG 1.118

  The ESBWR TSs include in-service tests and inspections and the resulting maintenance of the dc power systems, including the batteries, chargers, and auxiliaries. Therefore, the design is consistent with the guidance of RG 1.118.

- RG 1.153

  Safe shutdown relies upon dc-derived power and meets the design requirements for redundancy. The redundant safety-related loads are distributed between redundant distribution systems and power systems are supplied from the related redundant distribution systems. Therefore, the design is consistent with the guidance of RG 1.153.

- RG 1.155

  The ESBWR uses battery power to achieve and maintain safe shutdown. The safety-related batteries have sufficient stored capacity, without their chargers, to independently supply the safety-related loads continuously for 72 hours. Thus, the ESBWR meets the intent of RG 1.155. (See the SBO evaluation in Sections 8.4.2.1 and 15.5.5 of this report.)

- RG 1.160

  As described in DCD Tier 2, Revision 9, Section 17.4.1, the maintenance rule program is part of the operational reliability assurance program covered by COL Information Item 17.4-2-A, which is evaluated in Section 17.4 of this report.

- RG 1.182

  As described in DCD Tier 2, Revision 9, Section 17.4.1, the maintenance rule program is part of the operational reliability assurance program covered by COL Information Item 17.4-2-A, which is evaluated in Section 17.4 of this report.

The ESBWR plant is designed as a single-unit plant, and, thus GDC 5 is not applicable. As described in DCD Tier 2, Revision 9, Section 17.4.1, for 10 CFR 50.65(a)(4), the maintenance rule program is part of the operational reliability assurance program covered by COL Information Item 17.4-2-A, which is evaluated in Section 17.4 of this report.

8.3.2.4 *Combined License Unit-Specific Information*

The applicant stated that the COL applicant will address safety-related battery float and equalizing voltage values via COL Information Item 8.3.4-1-A. This COL item identifies an item related to the dc power system that the COL applicant will address. The staff agrees that this item is site-specific and therefore appropriately addressed by the COL applicant. In addition, this COL item for the dc power system, provided it is adequately addressed, provides reasonable assurance that the dc power system meets the requirements of GDC 17. Therefore, the staff finds this COL information item acceptable.

8.3.2.5 *Conclusion*

Based on its review, the staff concludes that the applicant has provided sufficient information to demonstrate that the onsite dc power supply systems meet applicable regulatory requirements and are capable of providing the power supply to onsite loads needed to support the plant's safe operation. The design of the onsite dc power supply systems is acceptable and meets the requirements of GDC 2, 4, 17, 18, 33, 34, 35, 38, 41, 44, and 50, and of 10 CFR 50.63 and 10 CFR 50.55a(h).

8.4 Safety Analysis Issues

8.4.1 Generic Issues and Operational Experience

8.4.1.1 *Technical Evaluation*

The staff evaluated the generic issues (GI) (Task Action Plan items and new GIs identified in NUREG–0933, "Resolution of Generic Safety Issues," issued August 2008) and operational experience (GLs and BLs) described in the sections below.

8.4.1.1.1 Task Action Plan Items

The staff evaluated the following four Task Action Plan items:

5. A-25, “Nonsafety Loads on Class 1E Power Sources”—If nonsafety-related loads are allowed to be connected to the Class 1E power system, it is possible that they may cause degradation by introducing loss of redundancy or another failure mechanism. The 120-V ac emergency lighting in the MCR and in the remote shutdown area is non-Class 1E and is fed from a Class 1E UPS, through series isolation devices that are coordinated with upstream 120-V ac distribution panel circuit breakers. The ESBWR design meets RG 1.75 as discussed in Section 8.3.1.3 of this report. RG 1.75 allows the connection of nonsafety loads to Class 1E (emergency) power sources, if it can be shown that the connection of nonsafety loads will not result in the degradation of the Class 1E system. In the ESBWR design, either of these protective devices is able to interrupt any fault current before initiation of a trip of any upstream protective device. No failure of non-Class 1E equipment or system will degrade the Class 1E system below an acceptable level. Therefore, the issue is resolved.

6. A-30, “Adequacy of Safety-Related dc Power Supplies”—New GI 128 addresses the reliability of onsite electrical systems and encompasses GI A-30. See the staff discussion below on GI 128.

7. A-35, “Adequacy of Offsite Power Systems”—As applied to the ESBWR, Task Action Plan Item A-35 is associated with minimizing the likelihood of simultaneous failure of both the offsite power supply circuits. The offsite power system of the ESBWR plant is based on the following design bases: Two independent and physically separate offsite circuits supply reliable power to the plant. Electric power from the utility grid to the offsite power system is provided by transmission lines designed and located to minimize the likelihood of failure while ensuring grid reliability. The transmission systems supply the two offsite power circuits through their respective transformers in the switchyard. Any single active failure can affect only one power supply and cannot propagate to the alternate power supply. In addition, the ESBWR design does not require any offsite ac power to achieve and maintain safe shutdown for 72 hours. Therefore, this issue is resolved.

8. A-44, “Station Blackout”—GI A-44 was resolved with the publication of 10 CFR 50.63, which requires that LWRs be able to withstand, for a specified duration, and recover from, an SBO. It addresses the likelihood of the loss of all ac power at the site and the potential for severe core damage after an SBO. The ESBWR is designed to shut down safely without reliance on offsite or DG-derived ac power for 72 hours, which exceeds SBO requirements. Section 8.4.2.1 of this report discusses in detail how the design successfully addresses this issue. Therefore, this issue is resolved for the ESBWR standard plant design.

8.4.1.1.2 New Generic Issues

The staff addressed the following two new GIs:

9. GI 128, “Electrical Power Reliability”—GI 128 addresses the reliability of onsite electrical systems and encompasses GI 48, “LCO for Class 1E Vital Instrumentation Buses in Operating Reactors”; GI 49, “Interlocks and LCO for Class 1E Tie Breakers”; and GI A-30, “Adequacy of Safety-Related dc Power Supplies.” The staff has reviewed the applicant’s

submittal and concludes that the ESBWR design addresses GIs 48, 49, and A-30 for the following reasons:

- GI 48—The applicant provided the limiting condition for operation (LCO) in the event of a loss of one or more Class 1E 120-V ac vital instrument buses and associated inverters. The staff finds this LCO acceptable.
- GI 49—The ESBWR design does not include Class 1E tie breakers.
- GI A-30—The staff has evaluated the Class 1E dc distribution system design for the aspects addressed by GI A-30 in Section 8.3.2 of this report and concludes that it is acceptable.

Therefore, GI 128 is resolved for the ESBWR design.

10. GI 107, "Main Transformer Failures"—As applied to the ESBWR, GI 107 is associated with minimizing the effects of transformer oil leaks and resulting fires. The ESBWR has design features to address this issue. Three-hour fire rated concrete barriers are used between the RATs, the UATs and the main transformers and spare main transformer. Pits are provided for the containment and collection of transformer oil should it leak. Also, the main transformers are included in the ESBWR fire hazard analysis in the DCD Tier 2, Revision 9, Section 9A.4.7, which describes the fire protection systems for the main transformer. The staff finds that these systems are consistent with the guidelines of GI 107. Therefore, this issue is resolved.

8.4.1.1.3 Generic Letters

The staff addressed the following five GLs:

11. GL 84-015, "Proposed Staff Actions to Improve and Maintain Diesel Generator Reliability," dated July 2, 1984—This item is not applicable to the ESBWR design, since it does not require a safety-related emergency diesel generator (EDG).

12. GL 88-015, "Electric Power System—Inadequate Control over Design Processes," dated September 12, 1988—This GL informs the licensees of the various problems with electrical systems occurring with increasing frequency at nuclear power plants. These problems include onsite distribution system voltages lower than required for proper operation of safety equipment, EDG loading exceeding design, inadequate EDG response to actual loading, overloading Class 1E buses, inadequate breaker coordination, and inadequate fault current interruption capability. Problems associated with EDGs are not applicable to the ESBWR design, since it does not require an EDG. DCD Tier 1, Revision 9, Table 2.13.1-2, discusses the voltage adequacy, breaker coordination, and fault current interrupting capability. DCD Tier 2, Revision 9, Section 8.3.2 discusses degraded voltage and overvoltage. Based on the above, this GL is resolved for the ESBWR design.

13. GL 91-006, "Resolution of Generic Issue (GI) A-30—'Adequacy of Safety-Related dc Power Supplies,' Pursuant to 10 CFR 50.54(f)," issued in 1991—GI A-30 is integrated into GI 128. See the staff discussion above on GI 128.

14. GL 91-011, "Resolution of GI 48, 'LCOs for Class 1E Vital Instrument buses,' and GI 49, 'Interlocks and LCOs for Class 1E Tie Breakers,' Pursuant to 10 CFR 50.54 (f)," dated July 8, 1991—GI 48 and GI 49 are integrated into GI 128. See the staff discussion above on GI 128.

15. GL 94-001, "Removal of Accelerated Testing and Special Reporting Requirements for Emergency Diesel Generators," dated May 31, 1994—This item is not applicable to the ESBWR design, since the design does not require an EDG.

8.4.1.1.4 Bulletin

The issue addressed in BL 82-04, "Deficiencies in Primary Containment Electrical Penetration Assemblies," dated December 3, 1982, applies to a specific equipment supplier that is no longer selling primary containment electrical penetration assemblies. The ESBWR will use primary containment electrical penetration assemblies that are qualified to IEEE Std 317 requirements, in accordance with RG 1.63. DCD Tier 2, Revision 9, Section 3.11, discusses the qualification of primary electrical penetrations. Therefore, the issue is resolved.

8.4.1.2 *Conclusion*

Based on the above discussion, the staff concludes that the GIs and operational experience issues are resolved for the ESBWR design.

8.4.2 Advanced Light-Water Reactor Certification Issues

The following sections discuss the policy, technical, and licensing issues pertaining to passive designs that relate to the electrical portion of the ESBWR design.

8.4.2.1 *Station Blackout*

The term SBO refers to the complete loss of ac electric power to the essential and nonessential switchgear buses in a nuclear power plant. An SBO, therefore, involves the loss of the offsite electric power system ("preferred power system"), concurrent with a turbine trip and the unavailability of the emergency alternating current (EAC) power system. An SBO does not include the loss of available ac power to buses fed by station batteries through inverters or by alternate ac sources specifically provided for SBO mitigation. Because many safety systems necessary for reactor core decay heat removal depend on ac power, an SBO could result in a severe core damage accident. The risk of SBO involves the likelihood and duration of the loss of all ac power and the potential for severe core damage after a loss of all ac power. DCD Tier 2, Revision 9, Section 15.5.5, discusses SBO.

8.4.2.1.1 Regulatory Criteria

The acceptance criteria for evaluating whether a plant is capable of withstanding and recovering from an SBO are based on meeting the relevant requirements of the following regulations:

- GDC 17, as it relates to (1) the capacity and capability of onsite and offsite power systems to permit the functioning of SSCs important to safety in the event of anticipated operational occurrences and postulated accidents and (2) provisions to minimize the probability of losing electric power from the transmission network (grid) as a result of, or coincident with, the loss of power generated by the nuclear power unit or loss of power from the onsite electric power supplies

- GDC 18, as it relates to periodic testing and inspection of offsite and onsite power systems important to safety

- 10 CFR 50.63, as it relates to the capability to withstand and recover from an SBO

- 10 CFR 50.65(a)(4), as it relates to the assessment and management of the increase in risk that may result from proposed maintenance activities before performing the maintenance activities, including, but 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.

SRP Section 8.4 specifies that an application meets the above requirements if the application satisfies the following guidance:

- The guidelines of RG 1.155, as they relate to compliance with the requirements of 10 CFR 50.63

- The guidelines and criteria of SECY-90-016 and SECY-94-084, as they relate to the use of alternate ac power sources and RTNSS at plants provided with passive safety systems

- The guidelines of RG 1.9 and RG 1.155, as they relate to the reliability program implemented to ensure that the target reliability goals for onsite EAC power sources (typically, DG units) are adequately maintained

- The guidelines of RG 1.160, as they relate to the effectiveness of maintenance activities for onsite EAC power sources, including grid-risk-sensitive maintenance activities (i.e., activities that tend to increase the likelihood of a plant trip, increase LOOP frequency, or reduce the capability to cope with a LOOP or SBO)

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

8.4.2.1.2 Summary of Technical Information

DCD Tier 2, Revision 9, Section 15.5.5, documents the ESBWR SBO analysis. As a passive plant, the ESBWR does not rely on ac power to achieve hot or stable shutdown. With regard to electrical power topics, the SBO evaluation assumes that the loss of all ac power occurs at time zero. The evaluation also shows that Q-DCIS provides control power, closure, and position indication for containment isolation valves. DCD Tier 2, Revision 9, Section 8.3.2.1.1, describes the power supply.

8.4.2.1.3 Staff Evaluation

DCD Tier 2, Revision 9, Section 15.5.5, documents the ESBWR SBO analysis. This section describes the criteria, assumptions, and analyses used to show that the ESBWR can cope with SBO conditions without ac power for 72 hours. Section 15.5.5 of this report provides the staff evaluation of the ESBWR SBO analysis. This section contains the Chapter 8 staff evaluation applicable to passive plants.

The requirements of 10 CFR 50.63 state that "each light-water-cooled nuclear power plant licensed to operate must be able to withstand for a specified duration and recover from a station blackout." The ESBWR design will not have EAC power sources, and it is not required to evaluate SBO coping duration, as long as the design will be capable of performing safety-related functions for 72 hours without ac power. An alternate ac power source is not necessary for passive plant designs that (1) do not need ac power to perform safety-related functions for 72 hours following the onset of an SBO and (2) meet the guidelines in Section C.IV.9 of RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," issued June 2007, regarding RTNSS (refer to Chapter 22 of this report for RTNSS). The ESBWR design minimizes the potential risk contribution of an SBO by not relying on the ac power supply to perform safety-related functions.

The following paragraphs analyze compliance with the regulatory criteria:

- GDC 17

  With regard to GDC 17, the ESBWR plant design does not require offsite or diesel-generated ac power for 72 hours after an SBO event. However, the offsite ac power meets GDC 17 (see the staff evaluation in Section 8.2 of this report). Safety-related dc power supports passive core cooling and containment safety-related functions for 72 hours. Safety-related dc power meets GDC 17 (see the staff evaluation in Section 8.3.2 of this report).

- GDC 18

  Safety-related dc power supports passive core cooling and containment safety-related functions. No offsite or diesel-generated ac power is required for 72 hours after an abnormal event. Safety-related dc power meets GDC 18 (see the staff evaluation in Section 8.3.2 of this report).

- 10 CFR 50.63 and RG 1.155

  Section 15.5.5 of this report evaluated the ESBWR coping capability with an ac-independent approach and finds it to be acceptable. Therefore, the ESBWR design also meets the requirements of 10 CFR 50.63.

  In RAI 8.1-21, the staff asked the applicant to address procedures and training to cope with an SBO. In its response, the applicant stated that, after 72 hours, required loads will be powered from the ancillary DGs, or the standby DGs or offsite power, if available. This is consistent with the ancillary diesels being designated as RTNSS, as described in DCD Tier 2, Revision 9, Appendix 19 A. Emergency procedures will cover the starting and connection of the diesels and restoration of ac power, as required by Section 3.4 of RG 1.155. The development of procedures is described in DCD Tier 2, Revision 9, Section 13.5.2, and is covered by the COL information items found in DCD Tier 2, Revision 9, Section 13.5.3. Training is described in DCD Tier 2, Revision 9, Section 13.2, and COL information items for training are covered in DCD Tier 2, Revision 9, Section 13.2.5. However, these sections do not specifically address SBO events. Instead, they commit to procedures and training for all of the plant's normal, abnormal, and emergency events. This would include SBO. To address this, the applicant added a note in DCD Tier 2, Revision 6, Table 8.1-1, to state that procedures and training for SBO response guidelines, ac power restoration, and severe weather guidelines are developed per Sections 13.2 and 13.5. The staff finds that the applicant adequately addressed the issue and, therefore, RAI 8.1-21 is resolved. The staff confirmed that Revision 6 of the DCD includes the change described above. The staff finds that the description of SBO procedures and training are consistent with the guidelines of RG 1.155.

- SECY-90-016

  This paper contains the Commission's approval for the evolutionary ALWRs to have an alternate ac power source of diverse design capable of powering at least one complete set of normal shutdown loads to cope with SBO. This topic is not applicable to the ESBWR design, since no ac power is required to achieve safe shutdown.

- SECY-94-084 and SECY-95-132

  Section 8.4.2.3 and Section 22 of this report discuss this topic.

- 10 CFR 50.65(a) (4), RG 1.160, and RG 1.182

  As described in DCD Tier 2, Revision 9, Section 17.4.1, the maintenance rule program is part of the operational reliability assurance program covered by COL Information Item 17.4-2-A, which is evaluated in Section 17.4 of this report.

- RG 1.9 and RG 1.155

  RG 1.9 and RG 1.155 regarding a reliability program for emergency onsite ac power source are not applicable.

8.4.2.1.4 Conclusion

The ESBWR reactor core and associated coolant, control, and protection systems, including station batteries and other necessary support systems, provide sufficient capacity and capability to ensure that the core will be cooled and will have appropriate containment integrity for 72 hours in the event of an SBO. The staff concludes that the safety-related passive systems are capable of withstanding a loss of all ac power for 72 hours. The staff further concludes that the ESBWR design will be in compliance with the provisions of GDC 17 and 18 and 10 CFR 50.63, as they relate to the capability to achieve and maintain hot or stable shutdown in the event of an SBO.

8.4.2.2 *Electrical Distribution*

8.4.2.2.1 Technical Evaluation

The Commission approved the following recommendations in SECY-91-078 for plant designs:

16. An alternate offsite power source will be available for nonsafety-related loads, unless the design margins for loss of nonsafety-related loads are no more severe than turbine-trip-only events in current plants.

17. At least one offsite circuit to each redundant safety division will be supplied directly from offsite power sources, with no intervening nonsafety-related buses.

The medium-voltage PG and PIP buses feed nonsafety-related loads in the ESBWR design. These buses are usually powered from the normal preferred power source through the UATs. These buses are also capable of being powered from the alternate preferred power source RATs through an automatic bus transfer, in the event that the normal preferred power source is unavailable. Thus the ESBWR design meets recommendation 1. The ESBWR design does not have to meet recommendation 2, because the design does not rely on active systems for safe shutdown.

8.4.2.2.2 Conclusion

The ESBWR design meets recommendation 1. The ESBWR design does not have to meet recommendation 2, because the design does not rely on active systems for safe shutdown.

8.4.2.3 *Regulatory Treatment of Nonsafety Systems*

8.4.2.3.1 Technical Evaluation

The staff considered whether the applicant identified RTNSS functions and availability controls for electrical systems, consistent with the Commission's policy in SECY-95-132.

DCD Tier 2, Revision 9, Table 19.A-2, shows that the onsite standby DGs and the 6.9-kV PIP buses have RTNSS functions. The standby DGs supply ac power to the PIP nonsafety-related buses. The PIP buses feed nonsafety-related loads required for a unit's normal operation and shutdown. In addition, the PIP nonsafety-related buses supply ac power to the safety-related IPCs. The standby DGs are required to provide power for recharging batteries to support post-accident monitoring and the fuel and auxiliary pools cooling system (FAPCS). In addition, the standby DGs provide power to the reactor water cleanup/shutdown cooling (RWCU/SDC) system operating in the shutdown cooling mode in the event of a loss of preferred power. The staff finds the onsite standby DGs and the 6.9-kV PIP buses RTNSS functions acceptable.

Additionally, DCD Tier 2, Revision 9, Table 19.A-2, shows that the ancillary DGs have RTNSS functions. The two nonsafety-related, seismic Category II ancillary DGs provide 480-V ac power for post-accident support loads when the normal and alternate preferred 6.9-kV power supplies and the standby DGs are not available. The staff finds the ancillary DGs RTNSS functions acceptable.

The availability controls require that one standby DG, its auxiliary systems (fuel storage tank and transfer system), and PIP buses be available during Modes 1, 2, 3, and 4 to support FAPCS and the ability to recharge batteries to support post-accident monitoring. Two standby DGs, their auxiliary systems (fuel storage tank and transfer system), and PIP buses are required to be operable during Modes 5 and 6 when core heat will be removed by the RWCU/SDC system. Planned maintenance should not be performed on standby DGs during operation in Modes 5 and 6. The availability controls require that two ancillary DGs with fuel tanks, fuel oil transfer pumps, and ancillary buses be available during all modes of plant operation. The staff finds that the applicant has provided acceptable availability controls for the electrical systems that have RTNSS functions and has included these controls in the DCD.

8.4.2.3.2 Conclusion

The staff reviewed the RTNSS designation and availability controls of electrical systems and finds them acceptable. Chapter 22 of this report provides additional discussion on RTNSS.