8. 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 that supply power to the plant are designed to provide reliable power for the plant 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 total loss of offsite power sources, two onsite independent non-safety-related standby diesel generators (DGs) provide power to the plant's investment protection (PIP) non-safety-related loads and safety-related loads through safety-related isolation power centers. Four independent safety-related 480-volt (V) ac divisions (isolation power center buses) provide power for the safety-related 250-V dc systems and uninterruptible power supply (UPS) systems.

Table 8.1 of the NUREG-8000 lists the applicable regulatory requirements and associated acceptance criteria that apply to electric power systems. The following sections of this SER Section 8.2, 8.3.1, 8.3.2 and 8.4 analyze and discuss the application's conformance with the regulatory requirements and associated acceptance criteria listed in Table 8.1 regarding electric power systems.

8.2 Offsite Power System

8.2.1 Regulatory Evaluation

The offsite power system includes two physically independent circuits capable of operating independently of the onsite standby power sources. The staff's review 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 can be concluded that two separate circuits from the transmission network to the onsite Class 1E power distribution system are provided, adequate physical and electrical separation exists, and 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 Criteria (GDC 2), "Design bases for protection against natural phenomena," found in Appendix A to 10 CFR Part 50, as it relates to structures, systems, and components of the offsite power systems being capable of withstanding the effects of natural phenomena (excluding seismic, tornado, and flood) without the loss of the capability to perform their safety functions.

- General Design Criteria (GDC 4), "Environmental and dynamic effects design bases," as it relates to structures, systems, and components of the offsite power systems being protected against dynamic effects, including the effects of missile that may result from equipment failures during normal operation, maintenance, testing, and postulated accidents.

- GDC 5, "Sharing of structures, systems, and components," as it relates to sharing of structures, systems, and components of the preferred power systems.

- GDC 17, "Electric power systems," as it relates to the preferred power system's (I) capacity and capability to permit functioning of structures, systems, and components important to safety; (ii) 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; (iii) physical independence; (iv) availability.

- GDC 18, "Inspection and testing of electric power systems," as it relates to 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's 33, 34, 35, 38, 41, and 44 are accomplished.

- 10 CFR 50.63, as it relates to an alternative ac (AAC) power source (as defined in 10 CFR 50.2) provided for safe shutdown (non-DBA) in the event of a station blackout.

SRP Sections 8.1, 8.2 and Appendix A to 8.2 specify that an application meets the above requirements, in part, if the application applies the NRC-endorsed methodologies and technical positions found in the following:

- RG 1.32, "Criteria for Power Systems for Nuclear Power Plants," Revision 3, issued March 2004.

- RG 1.555, "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, “Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident,” Revision 3, issued November 2003.

- 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,”1990.

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

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

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

8.2.2 Offsite System Description

Two independent offsite power supply systems, which are the normal preferred power supply through the unit auxiliary transformers (UATs) and alternate preferred power supply through the reserve auxiliary transformers (RATs), supply power to the site.

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 non-safety-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 preferred power supply. 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 and consist of three single-phase transformers and an installed spare transformer.

Unit synchronization normally occurs through the onsite main generator circuit breaker, with the offsite switchyard circuit breaker supplying the normal preferred power source that is also designed for unit synchronization during island mode operation. Both the main generator circuit breaker and the normal preferred power supply circuit breakers are equipped with dual trip coils and redundant protective relaying logic scheme, and control power to the circuit breaker is supplied from redundant non-safety-related 125 V dc power systems.

The UATs consist of two three-phase transformers. The UATs provide normal preferred power to each of the plant's two power generation load groups. The RATs consist of two three-phase transformers fed from the second offsite power source. The RATs provide alternate preferred power to the plant's two power generation load groups 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 the faults, and meet the corresponding requirements of Institute of Electrical and Electronic Engineers (IEEE) Standard C57.12.00, "General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers."

An onsite generator circuit breaker can interrupt the maximum fault current. The generator circuit breaker meets the criteria of IEEE Standard C37.06, "AC High-Voltage Circuit Breakers Rated on Symmetrical Current Basis." 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. Start-up 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 effects of anticipated process disturbances and postulated component failures are examined to determine their consequences and to evaluate plant capabilities to control or accommodate a station blackout (SBO). The requirements of 10 CFR 50.63 state that all nuclear power plants must have the capability to withstand a loss of all ac power for an established period of time, and to recover from this loss. The ESBWR design minimizes the potential risk contribution of an SBO by not requiring ac power supply for design-basis events. Safety-related systems do not need a non-safety-related ac power supply to perform safety functions. The ESBWR safety-related passive systems automatically establish and maintain safe-shutdown conditions for the plant following a design-basis event, including an extended loss of ac power.

8.2.3 Technical Evaluation

(1) In accordance with Table 8-1 and Section 8.2 of the SRP, the design of the preferred offsite power distribution system is consistent with the following criteria, insofar as they apply to safety and non-safety-related equipment and systems:

- With regards to GDC 2 and 4, the ESBWR reference plant design does not require offsite or diesel generator ac power for 72 hours after an abnormal event. Therefore, they are not applicable.

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

- With regards to GDC 17, the ESBWR reference 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.

- With regards to GDC 18 “Inspection and Testing of Electric Power Systems”—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. Therefore, GDC 18 is satisfied.

- With regards to 10 CFR 50.63, the ESBWR design bases do not rely on an offsite power system to achieve and maintain safe shutdown and, thus, the relevant provisions of 10 CFR 50.63 are not applicable (see the SBO evaluation in Section 15.5.5 of this SER).

- With regards to 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 1.47, “Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems,” issued May 1973, and BTP ICSB 21, “Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems,” Revision 3, issued April 1996—The offsite power system is non-Class 1E. Therefore, RG 1.47 and BTP ICSB 21 are not applicable to the ESBWR offsite power system because they are not technically relevant.

- BTP ICSB 11, “Stability of Offsite Power Systems”—This topic is site-specific. See Section 8.2.4 of this document.

(2) The ESBWR design does not require ac power sources to mitigate design-basis events. Although the ESBWR is designed with reliable non-safety-related offsite and onsite diesel-generated ac sources that are normally expected to be available for important plant functions, the plant does not rely on non-safety-related ac power to maintain core cooling or containment integrity. The offsite power system of the ESBWR reference plant is based on the following design bases (as the term, “design bases,” is defined by 10 CFR 50.2):

- In the event of failure of the normal preferred power supply system, the alternate preferred power supply system remains available.

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

preferred and the alternate preferred power supply 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.

- The main, unit auxiliary, and reserve auxiliary transformers meet the requirements of IEEE Standard C57.12.00.

- Circuit breakers are sized and designed in accordance with IEEE Standard C37.06.

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

- Cables associated with the normal preferred and alternate preferred power supply 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 reserve circuit, if located underground in the same duct bank as cables associated with the normal preferred power supply system between the switchyard and the onsite power systems, are routed in separate raceways.

- 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 be performed to determine the reliability of the offsite power supply system and verify that it is consistent with the probability risk analysis of Chapter 19.

- 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 is provided consisting of a ground mat below grade at the switchyard that is connected to the foundation embedded loop grounding system provided for the entire power block and associated buildings.

8.2.4 Combined Operating License Unit-Specific Information

The combined operating license (COL) application will address the following items:

- transmission system description

- switchyard description
- normal preferred power supply system and alternate preferred power supply system
- unit synchronization scheme
- protective relaying application
- switchyard dc power system
- switchyard ac power system
- transformer protection
- stability and reliability of the offsite transmission power systems (reliability and stability study to be included in the COL application)
- generator circuit breaker (meets the requirements of Appendix A, Section 8.2, to the SRP and the IEEE industry standards
- interface requirements

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 the system meets the requirements discussed above. Further, the staff considers 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.

8.3 Onsite Power System

8.3.1 AC Power System

8.3.1.1 Regulatory Evaluation

The onsite ac power system is consists of a Class 1E and a non-Class 1E systems that, in conjunction, provide reliable ac power to the various Class 1E and non-Class system electrical loads. 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.

Acceptance criteria for reviewing the sufficiency of ac power (onsite) are based on meeting the following relevant requirements:

  - GDC 2, as it relates to SSCs of the ac power system being capable of withstanding the effects of natural phenomena without the loss of the capability 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 sharing of SSCs of the ac power systems.

  - GDC 17, as it relates to the onsite ac power system’s (a) capacity and capability to permit functioning of SSCs important to safety; (b) independence, redundancy, and testability to perform its safety function assuming a single failure; and © 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 inspection and testing of the onsite 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 onsite electric power system, encompassed in GDC 17, to ensure that the safety functions of the systems described in GDCs 33, 34, 35, 38, 41, and 44 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 LOCA without loss of mechanical integrity and the external circuit protection for such penetrations.

NUREG-0800, Section 8.3.1 specifies that an application meets the above requirements, if the application satisfies the following criteria:

- 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 multi-unit stations.

  - RG 1.81, “Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants,” Revision 1, issued January 1975, as it relates to the sharing of SSCs of the ac power system, positions C.2 and C.3.

- GDC 17 (as it relates to the onsite ac power system's: (a) capacity and capability to permit functioning of SSCs important to safety; (b) independence, redundancy, and testability to perform its safety function assuming a single failure; and (c) provisions to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit or the loss of power from the transmission network) is satisfied per the 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, positions D.1, D.2, D.4, and D.5.

- RG 1.9, “Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants,” Revision 4, issued March 2007 (see also IEEE Std 387).

- RG 1.32, (see also IEEE Std 308), as it relates to design criteria for onsite ac power systems.

- RG 1.53, “Application of the Single-Failure Criterion to Nuclear Power Plant Protection Systems,” Revision 2, issued November 2003 (see also IEEE Stds 279 and 603), as it relates to the application of the single failure criterion to safety systems.

- RG 1.75, “Physical Independent of Electric Systems,” Revision 3, issued February 2005 (see also IEEE Std 384), as it relates to the onsite ac power system.

- RG 1.153 (see also IEEE Std 603), as it relates to criteria for electrical portions of safety-related systems.

- RG 1.155, as it relates to the use of onsite emergency ac power sources for station blackout.

- RG 1.204 (see also IEEE Stds 665, 666, 1050, and C62.23), as it relates to the lightning and surge protection for the onsite ac power system.

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

  - RG 1.32 (see also IEEE Std 308), as it relates to capability for testing of the onsite ac power system.

  - 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 (see also IEEE Std 338), as it relates to the capability for testing the onsite ac power system.

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

- The design requirements for an onsite ac power supply for systems covered by GDCs 33, 34, 35, 38, 41, and 44 are encompassed by GDC 17.

- GDC 50, as it relates to the design of containment electrical penetrations containing circuits of the ac power system, is satisfied per conformance with the guidelines of RG 1.63, "Performance-Based Containment Leak-Test Program," issued September 195 (see also IEEE Stds 242, 317, and 741), 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.

8.3.1.2 <u>AC Systems Description</u>

The main onsite ac power system is a non-Class 1E system that does not perform any safety-related function. During power generation mode, the turbine generator normally supplies electric power to the plant onsite auxiliary loads through UATs. The plant is designed to sustain a load rejection from 100-percent power, with the turbine generator supplying the plant house loads.

During plant startup, shutdown, and maintenance, the generator breaker is opened. Under this condition, the preferred power supply 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 preferred power supply system.

The onsite ac power system consists of the preferred power supply and onsite standby ac power supply system and the electrical distribution systems. The preferred power systems consist of two different voltage level of buses, which are 13.8 kV power generation (PG) non-safety-related buses and 6.9-kV PIP non-safety-related buses:

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

- PIP non-safety-related buses have connections to the normal or alternate preferred offsite power supply 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 non-safety-related buses are the 6.9-kV PIP buses and associated lower voltage load buses exclusive of the safety-related isolation power center 480-V ac buses.

UATs and RATs at 13.8 kV and 6.9 kV supply medium-voltage power to PG and PIP buses. There are four PG buses, each being powered from one of the two UATs, or if the UATs are unavailable, from one of the two RATs.

The PG non-safety-related buses feed non-safety-related loads that are required exclusively for unit operation and are normally powered from the normal preferred power through the UATs. If

the normal preferred power supply system is not available, these buses are automatically transferred to the alternate preferred power supply system through a fast transfer scheme. On restoration of the normal preferred power supply system, these buses are manually transferred to the normal preferred power supply system.

The PIP non-safety-related buses feed non-safety-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 isolation power center buses. The PIP buses are backed up by the onsite standby power supply systems. These buses can also be powered from the alternate preferred power supply through an auto bus transfer, in the event that the normal preferred power supply is unavailable. On restoration of the normal preferred power supply, these buses are manually transferred to the normal preferred power supply system.

8.3.1.2.1 Medium-Voltage AC Power Distribution System

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 non-safety-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 isolation power centers. PIP-A and PIP-B buses are each backed up by a separate onsite standby ac power supply system. Each PIP bus is normally powered from the normal preferred power supply system through the UAT. If the normal preferred power supply system is unavailable, these buses are automatically transferred to the alternate preferred power supply system by a fast transfer scheme. When the normal and alternate preferred power supply systems are not available, the 6.9-kV PIP buses are automatically transferred to the standby power supply system. Upon restoration of the normal preferred power supply system, these buses are manually transferred to the normal preferred system. The incoming circuit breakers for the normal and alternate preferred power supply are electrically interlocked to prevent simultaneous connection of UATs and RATs to the PIP buses.

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 (I&C). The 480 V power centers supply power to motor loads of approximately 100 kilowatts (kW) through 249 kW, and to the 480 V MCCs. The power centers are of the single-fed or double-ended type 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 is supplied from different buses, and each is normally powered by its normal power supply through its normal 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.

The Isolation Power Centers

The PIP non-safety-related buses power the isolation power through step-down transformers 6.9/0.48 kV, which receive backup from the standby DGs. The four isolation power centers, one each for Divisions 1, 2, 3, and 4 are double-ended and can be powered from either of the PIP buses. The isolation power centers supply power to safety-related loads of their respective divisions. These loads consist of the safety-related battery chargers, rectifiers, and regulating transformers.

Each isolation power center is equipped with undervoltage and under-frequency protective relays to protect against degraded voltage and frequency conditions to prevent tripping of all isolation power center loads, in accordance with BTP PSB 1.

Motor Control Centers

MCCs supply ac power to 99 kW and smaller 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 have molded case circuit breakers and motor starters that have thermal overload protection. Thermal overload devices protect non-safety-related motor-operated valves.

8.3.1.2.2 Safety-Related Uninterruptible AC 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 isolation power center 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, 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 isolation power centers, the safety-related UPS load is powered automatically and passively by its respective division’s safety-related battery through the inverter. If the inverter fails, a static bypass switch automatically transfers safety-related UPS ac loads from the Class 1E inverter to a direct ac power supply through a safety-related 480 V/120 V regulating transformer from the division’s isolation power center. In addition, a manual bypass switch can transfer the safety-related UPS ac loads from the inverter to a direct ac supply from the safety-related divisional isolation power center through a safety-related regulating transformer to perform inverter maintenance without interruption of power supply to safety-related loads.

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 is located in an area separated physically from the other divisions. All components of safety-related UPS ac systems are housed in seismic Category I structures.

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 Non-Safety-Related Uninterruptible AC Power Supply System

The non-safety-related UPS provides uninterruptible ac power for non-safety-related equipment needed for continuity of plant operation. The three non-safety-related UPS systems each provide UPS ac power to three load groups. Two (A and B) of the UPS power supply systems each have two rectifiers, two battery banks, two inverters, and two regulating transformers. The rectifier and battery bank through its diode to a common inverter convert to 120 V ac power. The third UPS power supply system has a single set of the power supply, which consists of a battery bank, a rectifier, and a regulating transformer. Upon loss or failure of the inverter, a static transfer switch automatically transfers non-safety-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 non-safety-related UPS is through the rectifier and inverter from a non-safety-related 480 V ac power center. If the 480 V ac power supply fails, transfer from the 480 V ac power supply to the non-safety-related 250 V dc battery bank occurs automatically and passively. An alarm in the main control room (MCR) activates when an alternate lineup of the non-safety-related UPS occurs. The 480 V ac power centers, which provide power to the non-safety-related battery chargers, are connected to PIP buses that are backed up by onsite standby DGs.

Two dedicated non-safety-related UPS systems supply ac power to the technical support centers (TSCs) in a two-load group configuration. Uninterruptible power for each TSC is normally 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 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 non-safety-related 125 V dc battery bank through the inverter occurs automatically and passively.

8.3.1.2.4 Instrumentation and Control Power Supply System

The 480-V ac power center distributed control and information system (DCIS) swing bus, through regulating step-down transformers, provides 208-V/120-V ac power to the I&C loads not requiring uninterruptible power. The I&C buses are each supplied independently through separate step-down regulating transformers from the 480 V ac power centers. This system supplies ac loads of the nonessential distributed control and information system (N-DCIS), solenoid valves, and other I&C loads. The I&C power supply system does not perform any safety-related function.

8.3.1.2.5 Onsite Standby ac Power Supply System

The onsite standby ac power system, powered by the two onsite standby DGs, is not relied on to perform any safety-related function or safe shutdown, and thus, is classified as non-safety-related. The standby power supply system provides a backup ac power supply to the PIP non-safety-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 isolation power centers. An undervoltage relay trips the circuit breaker to the preferred ac power supply and trips major loads on the PIP bus, except for the diesel generator (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 is 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 DG, however, can be manually paralleled with the preferred power supply for periodic testing of the generator. Each onsite standby DG operates independently of the remaining standby DG and is connected to the PIP bus during testing or bus transfer. Each of the onsite standby DGs conforms to the following criteria:

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

- reaching full speed and rated voltage within 1 minute after receiving a signal to start, and being fully loaded within the specified time that will not challenge the DG capacity.

- having 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.

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

During all modes of operation and testing, the onsite standby DG is shut down. The DG breaker is tripped under the following conditions:

- overspeed
- motoring of generator
- overload
- loss of excitation
- overtemperature
- undervoltage
- overvoltage
- underfrequency
- internal fault in generator (differential relay).

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

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

The standby DGs will be included in the scope of the Maintenance Rule. The standby DGs have been classified as an RTNSS system, and the regulatory oversight for this function should be availability controls. These availability controls will define the periodic surveillance and testing to be performed. Chapter 19, based on RG 1.9, “Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants,” Revision 4, issued March 2007,

and IEEE 387, "Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations," will discuss these availability controls.

8.3.1.3 Safety-Related Systems Description

(1) Physical Separation and Independence

- Electrical equipment is separated in accordance with RG 1.75, GDC 17, and IEEE Standard 384, "Criteria for Independence of Class 1E Equipment and Circuits."

  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 between areas of different safety-related divisions throughout the plant except in the primary containment and the control room complex.

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

(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.

- Power supply systems are capable of supplying power of voltage and frequency within acceptable tolerances.

- The interrupting capacity of distribution panels is 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 (ANSI) specifications.

- Refurbished circuit breakers shall not be used in either safety-related or non-safety-related circuitry of the ESBWR design. New circuit breakers shall be specified in all ESBWR purchase specifications. (NRC Bulletin 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 is functioning in accordance with design requirements, and requirements of RG 1.118, "Periodic Testing of Electric Power and Protection Systems," Revision 3, issued April 1995, and IEEE 338, "Standard for Transformers and Inductors in Electronic Power Conversion Equipment."

8.3.1.4 Electrical Circuit Protection Description

(1) Grounding

- The electrical grounding system will comply with the guidelines provided in IEEE 665-1995, “Guide for Generating Station Grounding,” and IEEE 1050-1996, “Guide for Instrumentation and Control Equipment Grounding in Generating Stations.” 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 is grounded through a separately insulated radial grounding system composed of buses and insulated cables. The instrumentation grounding systems are connected to the station grounding grid at discrete points and are insulated from all other grounding circuits. Separate instrumentation grounding systems are provided for plant analog and digital instrumentation systems.

The equipment grounding network is 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 is connected to the station ground grid through at least two parallel paths. Bare copper risers are furnished for all underground electrical ducts and equipment, and for connections to grounding systems within buildings. One bare copper cable is installed with each underground electrical duct run, and all metallic hardware in each manhole is 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 is located at the switchyard and connected to systems within the building by a 500 kcmil bare copper loop, which encircles each building.

The plant’s main generator is 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 is 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 is through neutral resistors, sized for continuous operation in the event of a ground fault.

The lightning protection system covers all major plant structures and is 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, which are separated from the normal grounding system. Lightning arresters are provided for each phase of all tie lines connecting the plant electrical systems to the switchyard and offsite lines. These arresters are connected to the high-voltage terminals of the main step-up and reserve transformers. Plant instrumentation located outdoors or connected to cabling running outdoors has surge suppression devices to protect the equipment from lightning-induced surges.

(2) Bus Protection

The incoming circuit breakers to the medium-voltage (13.8 kV/6.9 kV) bus are equipped with inverse-time overload, ground fault, bus differential, and undervoltage protections.

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

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

The isolation power center buses are equipped with inverse-time overload and ground fault protection. In addition, undervoltage and underfrequency protections serve to isolate these buses from the non-safety-related system under degraded conditions of voltage and frequency.

The 480 V MCCs are equipped with instantaneous and time-inverse overload protection.

(3) Containment Electric Penetrations

Each electrical service level has individual electric penetrations. Electrical circuits passing through electrical penetrations have primary and backup protective devices. These devices coordinate with the thermal capability of the penetration assemblies. These penetrations are rated to withstand the maximum short-circuit current available without exceeding their thermal limits, for at least longer than the field cables of the circuits. This ensures that protective devices interrupt the fault or overload currents before a potential penetration failure occurs. Penetrations are protected for the full range of currents up to the maximum short circuit available.

The containment electrical penetration assemblies are designed to withstand, without loss of mechanical integrity, the maximum available fault current for a period of time sufficient to allow the backup circuit protection to operate, assuming a failure of the primary protection devices. The containment electric penetrations meet the requirements set forth in IEEE Std 317-1972, “Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations,” as augmented by the recommendations of RG 1.63, and therefore, are acceptable.

8.3.1.5 Load Shedding and Sequencing on PIP 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 trips the loads on the bus. The 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 capability.

- LOPP

  The 6.9-kV PIP buses are normally energized from the normal preferred power supply. When the normal preferred power supply system is not available, a fast transfer scheme is activated to transfer power from the normal preferred supply to the alternate preferred supply. If both preferred power supply 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 are started in sequence as required. Transfer back to the preferred power supply is a synchronized closure of the feeder breaker by manual action.

- Loss-of-Coolant Accident (LOCA)

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

- LOCA When Onsite Standby Is Parallel to Preferred Power Supply System During Testing

  When a LOCA occurs the standby DG is paralleled with either preferred power supply system through the 6.9-kV PIP bus, and the standby DG automatically disconnects from the 6.9-kV PIP bus.

- LOPP During Onsite Standby Power Supply System Paralleling Test

  When either the normal or alternate preferred power supply system connected in parallel with the onsite standby DG is failed during the load testing, the connected preferred power supply breaker and DG breaker are automatically tripped, and the other preferred power supply accepts loads.

8.3.1.6 Technical Evaluation

The following paragraphs analyze compliance with the GDCs, RGs, and other criteria consistent with the SRP.

- GDC 2, “Design Basis for Protection against Natural Phenomena, and GDC 4, “Environmental and Dynamic Effects Design Bases”

The design meets the requirements of GDC 2 and 4, in that all components of the safety-related power system are housed in seismic Category I structures designed to protect them from natural phenomena.

- GDC 5 and RG 1.81 “Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants.”

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

- GDC 17, “Electrical Power Systems”

  The safety-related dc power supply supports passive core cooling and containment safety-related functions. No offsite or onsite standby DG is required to permit the functioning of structures, systems, and components important to safety for 72 hours after an abnormal event. However, the ESBWR design complies with GDC 17 with respect to two independent and separate offsite power supply and onsite standby power supply systems.

- GDC 18, “Inspection and Testing of Electrical Power Systems”

  The non-safety-related offsite and onsite power systems that supply ac power to the isolation power centers are testable, as are the safety-related UPS and 480 V ac isolation power centers associated with the safety-related DC power supply system. Therefore, ESBWR design complies with GDC 18.

- GDC 50, “Containment Design Basis”

  The ESBWR design meets the requirements of GDC 50 related to the containment electrical penetration assemblies as discussed in Section 8.3.1.4, (3) Containment Electrical Penetration.

- RG 1.75, “Physical Independence of Electric Systems”

  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 non-safety-related circuits. Therefore, ESBWR design complies with the recommendations of RG 1.75, which is related to GDC 17.

8.3.1.7 Conclusion

The NRC 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 meet applicable design criteria and 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 therefore, acceptable.

8.3.2 DC Power Systems

8.3.2.1 Regulatory Evaluation

The dc power systems include those dc power sources (and their distribution systems and auxiliary supporting systems) provided to supply motive or control power to safety-related and non-safety-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, 17, 18, and 50 as they relate to the capability of the onsite electrical power system to

facilitate the functioning of structures, systems, and components 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 the SAR and reviewed by 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 the SAR 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 (a) the capacity and capability of the onsite dc power system to enable the functioning of SSCs important to safety and (b) 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 18, as it relates to inspection and testing of the onsite power systems.

- GDC 33, GDC 34 GDC 35, GDC 38, GDC 41, and GDC 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 GDCs 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 non-safety-related dc power systems.

NUREG-0800, Section 8.3.1 specifies that an application meets the above requirements, if the application conforms with the following guidance:

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

- RG 1.32, as it relates to the design, operation, and testing of the safety-related portions of the onsite dc power system. Except for sharing of safety-related dc power systems in multi-unit 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 structures, systems, and components of the dc power system. Regulatory Position C.1 states that multi-unit sites should not share dc systems.

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

- RG 1.129, as it relates to maintenance, testing, and replacement of vented lead-acid 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. 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 loss of coolant accident without loss of mechanical integrity and the external circuit protection for such penetrations.

- RG 1.155 issued August 1988, as it relates to the capability and the capacity of the onsite dc power system for an SBO, including batteries associated with the operation of the alternate ac (AAC) 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 DC Power System Description

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

The design provides for eight independent safety-related Class 1E 250 V dc systems, 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 main control room (MCR) emergency lighting.

The design provides for five independent non-safety-related dc systems, consisting of three 250 V dc and two 125 V dc power supply systems. The non-safety-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 design-basis accident. The system is 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 is not required for plant safety.

8.3.2.2.1 Safety-Related DC System

Safety-related Divisions 1, 2, 3, and 4 each consist 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. Four separate 480 V isolation power centers supply power to the four safety-related divisions. Each division has a standby charger as backup to either of the battery banks of its respective division.

The safety-related 250 V dc system is designed as safety-related equipment in accordance with IEEE 308, “Criteria for Class 1E Power Systems for Nuclear Power Generating Stations,” and IEEE 946, “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 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 is separately housed in a ventilated room apart from its charger, distribution, and ground detection panels. Equipment of each division of the dc distribution system is 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 battery banks, and each of these banks is sized to exceed 72-hour SBO conditions. The minimum dc system battery bank terminal voltage at the end of the discharge period is 210 V (1.75 V per cell). The maximum equalizing charge voltage is 282 V (2.35 V per cell) as specified by the battery vendor and 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 of 282 V dc specified by the battery vendor.

GEH will provide safety-related batteries that 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, “Recommended Practice for Sizing Large Lead Storage Batteries for Nuclear Power Generating Stations,” with an expected 20-year service life. In request for additional information (RAI) 8.3-49, 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 the above RAIs, GEH indicated that the loading profile will not be provided until the DCIS loads are established. The draft safety-related DCIS loads are currently scheduled for approximately September 2008 with confirmed loads not being known until June 2012, based on having actual procured vendor loads for the load profile. The inspection, maintenance, and testing program states that battery capacity tests will be conducted in accordance with IEEE Std 1188, “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 demand. The final load profile will have the analyses performed and will be tested in accordance with inspection, test, analyses, and acceptance criteria (ITAAC), Table 2.13.3-1, 3a. & 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 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 is designed to replace any defective cells without an interruption of service. However, GEH did not provide the loading profile to

demonstrate that the safety-related 250V 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. Therefore, the staff identified this issue as open for the safety-related 250V dc system. This is **Open Item 8.3-52 S03**.

The safety-related batteries meet the qualification requirements of IEEE 535, “Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations,” and are installed in accordance with IEEE Std 1187, “Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Batteries for Stationary Applications.” Due to the open item that remains to be resolved for this section, the staff was unable to finalize its conclusion regarding acceptability.

The safety-related battery chargers are full-wave, silicon-controlled rectifiers. The housings are freestanding, National Electrical Manufacturers Association (NEMA) Type 1, and are ventilated. The chargers are suitable for float charging the batteries and operate from a 480 V, three-phase, 60 Hz supply. Each battery charger is 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 capability of operating as battery eliminators. The battery eliminator feature is 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 (mV) root mean square (RMS) with the battery, and less than 2 percent RMS without the battery.

The battery chargers output is of 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 loss of ac power. The battery chargers output voltage is 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 loss of charger input voltage and charger shutdown.

Monitoring and Alarms

Each battery bank, including the spare, is equipped with a battery monitor system which detects battery open circuit conditions and monitors battery voltage. The battery monitor provides a trouble alarm locally and in the MCR. The battery monitors are not required to support any function.

Section 7.4 of IEEE 946-1992, “Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations,” offers some considerations in monitoring the dc power systems. These general considerations state that the dc systems (batteries, distribution system, and chargers) should be monitored to ascertain that they are ready to perform their required functions. The recommended instruments, controls, alarms, and their locations are described below:

Instrument/alarms/control	MCR	Local
battery current (ammeter, charge/discharge)		X
battery charger output current (ammeter)		X
dc bus voltage (voltmeter)	X	X
battery charger output voltage (voltmeter)		X
ground-detector (voltmeter)		X
dc bus undervoltage alarm	X	
dc system ground alarm	X	
battery breaker/switch open alarm	X	
battery-charger output-breaker open alarm	X	
battery charger dc output failure alarm	X	
cross-tie breaker closed alarm	X	
battery charger ac power failure alarm	X	
charger low dc voltage alarm	X	
charger high dc voltage shutdown relay (opens main ac supply breaker to the charger)		X
battery test breaker closed alarm	X	

Inspection, Maintenance, and Testing of DC System

An initial composite test of the onsite dc power system is prerequisite to initial fuel loading. This test verifies that each battery capacity is sufficient to satisfy a design-basis load demand profile under the conditions of LOCA and LOPP. Conducted in accordance with IEEE 1188, these tests ensure that the battery has the capacity to meet safety-related load demands.

GDC 18 requires that electric power systems important to safety shall be designed to permit (1) appropriate periodic inspection and testing of important areas and features (such as wiring, insulation, connections, and switchboards) in order to assess the continuity of the systems and the condition of their components, (2) periodic testing of the operability and functional performance of the components of the systems, and (3) periodic testing of the operability of the systems as a whole (under conditions as close to design as practical) and the full operation sequence that brings the systems into operation.

The applicant stated that the ESBWR technical specifications describe the inservice tests, inspections, and maintenance of the dc power systems including the batteries, chargers, and auxiliaries. The staff agrees that the specifications conform to IEEE 1188 and manufacturer recommendations, and correspondingly that the Class 1E dc power system is periodically tested and inspected in accordance with GDC 18, and therefore is acceptable.

8.3.2.2.2 Non-Safety-Related DC Systems

The non-safety-related dc systems consist of three 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 non-safety-related loads, communications, lighting, and other dc loads. The 250-V battery bank provides dc power for the plant N-DCIS and non-safety-related dc motors. Each of the dc systems has a battery, battery charger, standby battery charger, main dc distribution panel, and ground detection panel. The main distribution buses feed the local dc distribution panels, UPS inverter, and/or the dc MCC.

The plant design and circuit layout of the non-safety-related dc systems provide physical separation of the equipment, cabling, and instrumentation associated with the load groups of non-safety-related equipment. Each 125 V and 250 V battery is 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 is located in an area separated physically from the other divisions.

The 125 V non-safety-related battery bank is 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 °C (77 °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 141 V (2.35 V per cell).

The 250 V non-safety-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 °C (77 °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 282 V (2.35 V per cell).

GEH is committed to non-safety-related batteries that 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 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 non-safety-related battery chargers are full-wave, silicon-controlled rectifiers or an acceptable alternate 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, 60 hertz (Hz) ac supply. A separate power center, backed up by the onsite standby DG, supplies each charger. Each division has a standby charger to equalize battery charging. Standby chargers are supplied from a different power center than the normal battery charger, except when the power center swing bus supplies both.

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 is 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 is less than 1 percent with or without the battery bank connected. The maximum output ripple for the charger is 30 mV RMS with the battery bank, and less than 2 percent RMS without the battery.

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 is 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 loss of voltage to charger and charger shutdown.

Battery rooms are ventilated by a system designed to remove the minor amounts of gas produced during the charging of batteries. The design of the system precludes the possibility of hydrogen accumulation.

8.3.2.3 Technical Evaluation

The following discussion demonstrates the compliance of the safety-related dc power supply systems with the GDC, RGs, and other criteria consistent with the SRP. The analyses establish the ability of the systems to sustain 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, and 50 based on conformance with the following Regulatory Guides.

- GDC 5 and RG 1.81 “Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants.”

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

- RG 1.6, “Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems.,” issued March 1971

  Because the ESBWR does not need or have any safety-related standby ac power sources, this RG is not applicable to ESBWR design. However, the ESBWR offsite and onsite non-safety-related power sources do comply with the criteria for independence and redundance between their source and distribution systems.

- RG 1.32, “Criteria for Power Systems for Nuclear Power Plants (Rev. 2),” (DG-1079, Proposed Revision 3, issued April 2003)”

  The design provides for safety-related dc power supply systems to support passive core cooling and containment integrity safety functions. No offsite or onsite standby ac power supply is required for 72 hours after a design-basis event. Therefore, this RG is not applicable.

- RG 1.128, “Installation Design and Installation of Vented Lead-Acid Storage Batteries for Nuclear Power Plants,” issued February 2007

  The valve-regulated lead acid batteries for the ESBWR will limit the release of hydrogen to less than 1 percent while battery room temperature is within specified vendor limits during charging evolutions. IEEE 344, “Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations,” IEEE 323, “Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations,” and IEEE 450, “Recommended Practice for Maintenance, Testing, and Replacement of Vented lead-Acid Batteries for Stationary Applications,” are not applicable because they only apply to a specific type of battery, which is not part of the ESBWR design.

- Cables and Raceway

  Power and control cables are specified for continuous operation at conductor temperature not exceeding 90 °C (194 °F) and should withstand an emergency overload temperature of up to 130 °C (266 °F) in accordance with Insulated Cable Engineers Association (ICEA) S-66-524/NEMA WC-7, "Cross-Link Thermosetting Polyethylene Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy." The base ampacity rating of the cables is established as published in IEEE 835, "Standard Power Cable Ampacity Tables," and ICEA-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 life span. Certified proof tests are performed on cables to demonstrate 60-year life, and resistance to radiation, flame, and the

  environment. The testing methodology ensures that such attributes are acceptable for the 60-year life.

  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 is 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 I&C cables. If tray fill exceeds the above maximum fills, the tray fills are justified and documented.

  Cable splices in 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 between the RATs, the UATs, and the main transformers and spare main transformer, including containment/collection of transformer oil. The concrete barriers provide separation and independence of the system. Therefore, ESBWR design complies with GDC 17.

8.3.2.4 <u>COL Unit-Specific Information</u>

The COL application will address the following items:

- Administrative Controls for Bus Grounding Circuit Breakers

  Bus grounding circuit breakers provide safety grounds during maintenance operations. Administrative controls are implemented via plant procedures.

- Periodic Testing of Power and Protection Systems

  The program for periodic testing of electric power and protection systems is in accordance with RG 1.118 and IEEE 338 and is implemented via plant procedures.

- Maintenance Rule Program

  The programs section of the COL application addresses the Maintenance Rule program in accordance with RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," Revision 2, issued March 1997.

8.3.3 Conclusion

With respect to the safety-related dc power systems, the staff concludes that the system design is acceptable on the basis that the system design meets the requirements of the appropriate criteria and standards, except for the capacity and capability of the batteries as discussed above. Therefore, the staff concludes that the sizing of the batteries in the design of the dc power system for the ESBWR is an open item.

8.4 <u>Safety Analyses Issues</u>

8.4.1 Regulatory Evaluation

The term "station blackout" (SBO) refers to the complete loss of ac electric power to the essential and nonessential switchgear buses in a nuclear power plant (NPP). An SBO, therefore, involves the loss of the offsite electric power system ("preferred power system") concurrent with a turbine trip and unavailability of the emergency ac (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 (AAC) 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.

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 requirements:

- GDC 17, as it relates to (a) the capacity and capability of onsite and offsite power systems to permit functioning of SSCs important to safety in the event of anticipated operational occurrences and postulated accidents and (b) 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.

NUREG-0800, Section 8.4 specifies that an application meets the above requirements, if the application satisfies the following criteria:

- 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, “Evolutionary Light Water Reactor (LWR) Certification Issues and Their Relationship to Current Regulatory Requirements,” 1990, and SECY-94-084, “Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs,” 1994, as they relate to the use of AAC power sources and RTNSS at plants provided with passive safety systems.

- 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 Station Blackout

The effects of anticipated process disturbances and postulated component failures are examined to determine their consequences and to evaluate plant capabilities to accommodate a SBO. 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 minimizes the potential risk contribution of an SBO by not relying on the ac power supply to perform safety-related functions. The ESBWR safety-related passive systems automatically establish and maintain safe-shutdown conditions for the plant following design-basis events, including an extended loss of ac power supply. The passive systems can maintain these safe-shutdown conditions after design-basis events for 72 hours, without operator action, following a loss of both onsite and offsite ac power supplies. The ESBWR design intends to meet GDC 50, which includes the following acceptance criteria:

- Reactor Vessel Coolant Integrity—Adequate reactor coolant inventory shall be maintained such that reactor level is maintained above the core.

- Hot Shutdown Condition—The plant shall achieve and maintain those shutdown conditions specified in the plant technical specifications as ”hot shutdown.”

- Containment Integrity—If containment isolation is involved, the maximum containment and suppression pool pressures and temperatures shall be maintained below their design limits.

The applicant analyzed the plant design to meet the acceptance criteria and concluded that based on the vessel inventory analysis, the reactor vessel level will be maintained above the core during the 72 hours of the transient. Subsequent to an SBO event, the plant can achieve and maintain hot shutdown condition by operation of isolation condenser (IC) systems. Therefore, the design meets the requirement for achieving and maintaining hot shutdown condition.

With the operation of IC systems, the containment and suppression pool pressures and temperatures are maintained within their design limits, since there is no release into the wetwell or the drywell. Therefore, the integrity for containment is maintained.

Analysis shows that reactor pressure vessel leakage is minimal for three reasons—(1) there are no recirculation pumps in the design, (2) isolation occurs at Level 2, and (3) IC systems reduce the pressure significantly. However, if leakage is significant and power has not been restored, the level could drop below the Level 1 setpoint. In this scenario, the automatic depression system, gravity-driven cooling system, and passive containment cooling system are available to provide core cooling, inventory control, and containment heat removal. Because the IC system provides significant depressurization, the impact of depressurization from the automatic depression system would not be as significant as initiation from rated pressure.

8.4.3 Regulatory Treatment of Non-safety Systems

In SECY-95-132, the NRC set forth policy regarding those systems in passive light-water reactors that are designed as non-safety-related but that may have a significant role in accident and consequence mitigation. The non-safety-related active systems in passive light-water reactor designs, like this the ESBWR design, provide defense-in-depth functions and supplement the safety-related passive systems. The process of identifying regulatory oversight of no-nsafety-related systems is referred to as RTNSS.

In the ESBWR design, the DGs supply ac power to the PIP non-safety-related buses. The PIP buses feed non-safety-related loads required for unit normal operation and shutdown. In addition, the PIP non-safety-related buses supply ac power to the safety-related buses and isolation power centers. Therefore, the DCD identified the onsite standby DGs and RTNSS.

Therefore, the DCD included the RTNSS process and identified the onsite standby DGs as RTNSS.

8.4.4 Technical Evaluation

The following paragraphs analyze compliance with the GDCs, RGs, and other criteria consistent with the SRP:

- GDC 17, the ESBWR reference 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.

- 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. Therefore GDC 18 is satisfied.

- GDC 50, ESBWR is designed so that the containment structure and its internal compartments can accommodate without exceeding the design leakage rate and with sufficient margin therefore, ESBWR design complies with GDC 50.

- 10 CFR 50.63, as discussed in Section 8.4.2, analysis demonstrates that reactor pressure vessel leakage is minimal. Therefore, the ESBWR design also meets the requirements of 10 CFR 50.63.

8.4.5 Conclusion

With respect to safety analyses issues, the staff concludes that station blackout and RTNSS are acceptable on the basis that the system design meets the requirements of the appropriate criteria and standards.