8. ELECTRIC POWER

Chapter 8, "Electric Power," of this safety evaluation (SE) describes the Nuclear Regulatory Commission (NRC) review of Chapter 8, "Electric Power," of the United States - Advanced Pressurized Water Reactor (US-APWR) Design Control Document (DCD) submitted by Mitsubishi Heavy Industries (MHI), hereinafter referred to as the applicant, for the design certification (DC) of the US-APWR and the NRC staff's conclusions on the basis of that review.

8.1 Introduction

The US-APWR electric power system is the source of power for station auxiliaries during normal operation and for the reactor protection system (RPS) and engineered safety features (ESF) during abnormal and accident conditions. The objective of the review was to determine, based on the information provided by the applicant, the functional adequacy of the offsite power systems and safety-related onsite electric power systems and to ensure that these systems are designed to have adequate capability, redundancy, independence, and testability in conformance with the current criteria established by the NRC.

Section 8.1 of the US-APWR DCD describes the electric power system for the reference plant. It includes three alternating current (ac) power sources: the power supplied by the unit main generator, the offsite power supplied by the transmission grid system, and the onsite emergency, Class 1E (safety-related) power supplied by standby gas turbine generators (GTGs). The plant electric power system also includes an additional ac power capability consisting of two additional GTGs that are not Class 1E (i.e., the GTGs are not safety-related). These two non-Class 1E GTGs supply loads required to cope with a loss of all ac emergency onsite power sources as well as offsite power sources (station blackout (SBO)) for the time required to bring the plant to safe shutdown. In addition to the ac power sources, the plant is equipped with an onsite, direct current (dc) battery system that provides the required dc power to dc-operated components and to essential plant instrumentation.

The staff evaluation in this chapter discusses requests for additional information based on earlier revisions of the DCD. The conclusions however are based on the most recent revision of the DCD, Revision 4.

8.2 Offsite Power System

The US-APWR standard plant is designed to be connected to the offsite electric power grid via the switchyard interconnections. The offsite power system is intended to provide at least two independent sources of power for safe shutdown of the reactor and is designated as the preferred power system (PPS).

8.2.1 Introduction

The offsite power system consists of two separate and independent transmission lines from the offsite power grid. They are connected via site-specific switchyard circuit breakers to the reserve auxiliary transformers (RATs). The function of the offsite power system is to supply power to both Class 1E plant loads and plant loads that are not Class IE. The offsite power system is also connected to the main generator (MG) via its output transformer, the main transformer (MT). The safety function of the offsite power system is to provide sufficient capacity and capability to ensure that the structures, systems and components (SSCs) important to safety perform as intended. The objective of the NRC staff review is to verify that the offsite power system satisfies the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, Appendix A, General Design Criteria (GDCs) 5, 17, and 18, and will perform its design function during all plant operating and accident conditions.

8.2.2 Summary of Application

DCD Tier 1: The Tier 1 information associated with this section is found in DCD Tier 1, Section 2.6.1, “AC Electric Power Systems,” and Table 2.6.1-3, “AC Electric Power Systems Inspections, Tests, Analyses, and Acceptance Criteria.” Section 2.6.1 in DCD Tier 1 provides a general design description of the US-APWR standard ac electric power system. Table 2.6.1-3 provides the detailed inspections, tests, analyses, and acceptance criteria (ITAAC) for the ac electric power systems.

DCD Tier 2: The applicant has provided a Tier 2 system description in DCD Tier 2, Section 8.2, “Offsite Power System,” summarized here in part, as follows:

> The design and configuration of the switchyard is site-specific, and not in the scope of the referenced US-APWR design. However, in DCD Tier 2, Section 8.1, the applicant presents elements of the design basis interface requirements as well as voltage ratings for major US-APWR components (transformers, MG, and generator load-break switch) interfacing with the offsite power system.
>
> Offsite power to the US-APWR is provided by at least two physically independent utility transmission lines connected to the station switchyard. One of the transmission lines connects to the high-voltage side of the main transformer, and the other connects to the high-voltage side of the four RATs. The unit MG connects to the low-voltage side of the main transformer and to the high-voltage side of the four unit auxiliary transformers (UATs).
>
> Four independent, Class 1E, 6.9-kV buses (A, B, C, and D) are provided in the onsite safety-related power system. The normal preferred (offsite) source for the onsite Class 1E power system is via two of the RATs serving the four Class 1E, 6.9-kV buses. The alternate preferred source is provided by back-feeding offsite power via the MT and the UATs.
>
> The applicant also identifies a permanent power system, which includes two permanent non-Class 1E; 6.9-kV buses (P1 and P2) served by dedicated non-Class 1E GTGs, which are considered the alternate ac (AAC) source for SBO events.
>
> A generator load-break switch is provided between the MG and MT. With the MG on line, power is provided from the generator to the portion of the onsite power system that is not safety-related, except for the permanent power system, through the UATs. With the load-break switch open, offsite power is provided to the portion of the onsite power

system that is not safety-related, except for the permanent power system, through the main and UATs. The applicant also identifies two non-Class 1E, 13.8-kV buses (N1 and N2) and four non-Class 1E, 6.9-kV buses (N3, N4, N5, and N6).

For the medium-voltage (i.e., 6.9-kV and 13.8-kV) buses identified above, if power is lost from one source, the buses are automatically transferred to the other source by either a fast or slow transfer scheme, depending on voltage conditions. The applicant presents a summary of the design basis and a listing of applicable regulatory requirements, regulatory guidance, codes, and standards, governing the design and testing of the offsite power systems.

Inspection, Test, Analysis, and Acceptance Criteria: The ITAAC associated with Tier 2, Section 8.2, "Offsite Power System," are described in DCD Tier 1, Section 2.6, "AC Electric Power Systems," and the detailed ITAAC are given in Table 2.6.1-3, "AC Electric Power Systems Inspections, Tests, Analyses, and Acceptance Criteria."

Technical Specifications: The Technical Specifications associated with DCD Tier 2, Section 8.2, are given in DCD Tier 2, Chapter 16, "Technical Specifications," Sections 3.8.1, "AC Sources - Operating," and 3.8.2, "AC Sources - Shutdown."

US-APWR Plant Interfaces: This section of the DCD includes information related to the following plant interfaces that will be addressed in the Combined License (COL) designs:

A site-specific interface between the certified design and the local electrical grid is identified in the DCD. This includes:

- The offsite power transmission system outside the high-voltage terminals of the main and reserve transformers.
- Location and design of the switchyard and the equipment located therein.
- Design details such as voltage level for the MT.

Technical Reports: There are no technical reports associated with this section.

Topical Reports: There are no topical reports associated with this section.

8.2.3 Regulatory Basis

The relevant requirements of the Commission's regulations for the offsite power system and the associated acceptance criteria are given in Section 8.2 of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," and are summarized below. Review interfaces with other Standard Review Plan (SRP) sections can be found in Section 8.2 of NUREG-0800.

1. Appendix A, "General Design Criteria," of 10 CFR Part 50, GDC 5, "Sharing of Structures, Systems, and Components," as it relates to sharing of SSCs of the preferred

power systems among nuclear power units. The US-APWR plant is designed to be a stand-alone unit, even at multiple-unit sites.

2. GDC 17, "Electric Power Systems," as it relates to the preferred power system's (i) capacity and capability to permit functioning of SSCs 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, the loss of power from the transmission network, or the loss of power from the onsite electric power supplies; (iii) physical independence; (iv) availability; and (v) simultaneous failure under operating and postulated accident and environmental conditions.

3. GDC 18, "Inspection and Testing of Electric Power Systems," as it relates to inspection and testing of the offsite electric power systems.

4. 10 CFR 50.63, "Loss of all alternating current power," as it relates to an AAC power source (as defined in 10 CFR 50.2) provided for safe shutdown in the event of an SBO and the capability to withstand and recover from an SBO.

Acceptance criteria adequate to meet the above regulatory requirements include:

1. Regulatory Guide (RG) 1.32, "Criteria for Power Systems for Nuclear Power Plants," which endorses Institute of Electrical and Electronic Engineers (IEEE) Standard (Std.) 308-2001, "IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations," as related to the availability and number of immediate access circuits from the transmission network.

2. Acceptance is based on meeting the guidelines of RG 1.155, "Station Blackout," as they relate to the adequacy of the AAC source and the independence of the AAC power source from the offsite and onsite power systems and sources. New applications should provide an adequate AAC source of diverse design (with respect to ac onsite emergency sources) that is consistent with the guidance in RG 1.155 and capable of powering at least one complete set of normal safe shutdown loads.

3. RG 1.204, "Guidelines for Lightning Protection of Nuclear Power Plants," which endorses IEEE Std. 665-1995 (reaffirmed 2001), "IEEE Guide for Generating Station Grounding," IEEE Std. 666-1991 (reaffirmed 1996), "IEEE Design Guide for Electric Power Service Systems for Generating Stations," IEEE Std. 1050-1996, "IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations," and IEEE Std. C62.23-1995 (reaffirmed 2001), "IEEE Application Guide for Surge Protection of Electric Generating Plants," as they relate to the design, installation, and performance of station grounding systems and surge and lightning protection systems.

4. RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," as it relates to power system analytical studies and stability studies to

verify the capability of the offsite power systems and their interfaces with the onsite power system.

5. SECY-91-078, "Chapter 11 of the Electric Power Research Institute's (EPRI's) Requirements Document and Additional Evolutionary Light Water Reactor (LWR) Certification Issues," as it relates to the interface between the onsite ac power system and the offsite power system.

6. Bulletin 2012-01, "Design Vulnerability in Electric Power System," as it relates to whether any further NRC regulatory action is warranted to address the electric power design vulnerability due to open phase conditions.

8.2.4 Technical Evaluation

The NRC staff reviewed the offsite power system described in Section 8.2.1.2 of the US-APWR DCD, Tier 2, to determine whether the system: (1) provides the required minimum of two separate circuits from the transmission network to the onsite distribution system; (2) has adequate capacity and capability to supply power to all safety loads; (3) is designed with both physical and electrical separation between the two (or more) circuits to minimize the chance of simultaneous failure; and (4) provides an interface between the preferred power source and an AAC power source for safe shutdown in the event of an SBO.

Table 8-1 of the SRP lists GDC, RGs, industry standards, and branch technical positions (BTPs) that are applicable to the electrical power systems. The NRC staff has reviewed the applicable DCD information for compliance and conformance with the offsite power system requirements and guidance as described below.

In general, the offsite 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 interconnection of the preferred (offsite) power supply with an AAC power source for safe shutdown in the event of an SBO is also reviewed with respect to its adequacy and the independence of the AAC from the offsite and onsite power systems.

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, as stated in correspondence dated January 23, 2009 (Agencywide Document Access and Management System (ADAMS) Accession No. ML090260039).

8.2.4.1 Compliance with GDC 5

GDC 5 states that SSCs important to safety should not be shared among other units unless it can be demonstrated that the sharing will not significantly impair their ability to perform their safety functions. The US-APWR is designed to be a stand-alone unit with no sharing between each unit and any other unit at multiple unit sites. This aspect of the design is in full compliance with GDC 5.

8.2.4.2 Compliance with GDC 17

GDC 17 requires that the offsite power system provide at least two physically independent circuits (preferred and alternate) from the switchyard to the Class 1E loads. At least one of these two circuits must be immediately available after a loss of coolant accident (LOCA). The system must be capable of supplying all safety loads if the onsite emergency power system is not functioning. The system must include provisions to minimize the probability of loss of power from the offsite system as a result of loss of power generated by the nuclear power unit or from the onsite system.

The Class 1E loads are connected to the RATs as their preferred source of offsite power. If this preferred circuit becomes unavailable, the safety loads are transferred to the UATs. This is considered their alternate source of offsite power in the US-APWR design.

The MG is connected to the offsite power system by three single-phase, step-up transformers with one installed spare. Together, these transformers are called the unit MT. The MG provides power to the onsite non-Class 1E power system through the UATs as their normal power source. When the MG is not available, the generator load break switch (GLBS) is opened and offsite power to the onsite electric power buses that are not safety-related is supplied from the switchyard through the MT and the UATs.

In support of GDC 17, RG 1.206 calls, in part, for an applicant to follow the guidance set forth by SRP Section 8.2 in Appendix A, “Guidelines for Generator Circuit Breakers/Load Break Switches.” The guidance in RG 1.206 for generator breakers/load break switches used in an immediate-access source of power scheme is much more rigorous for such switches used in a delayed-access source of power scheme. Specifically, immediate-access devices should be qualified to isolate the MG under maximum postulated fault current conditions. Delayed-access devices do not need this capability, as they would not be used to isolate the MG prior to the clearing of any fault current. Accordingly, in Request for Additional Information (RAI) 4-205 (ML081550237), Question 08.02-6, the NRC staff requested that the applicant demonstrate that the design of the load-break switch conforms with the provisions of SRP Appendix A, Section 8.2, and specifically discuss how the design of the load-break switch is used as a means of providing access to the offsite power system for the onsite ac distribution system. In response to RAI 4-205, Question 08.02-6, the applicant stated that the load break switch is not used to provide an immediate access source of offsite power to the emergency loads, and therefore, the device does not have the fault-interrupting capability that it would need to have if it were the immediate-access means per Appendix A guidelines. In RAI 432-3206 (ML092170523), Question 08.02-15, as a follow-up to Question 08.02-6, the NRC staff requested that clarification on the use of the load break switch be documented in Section 8.2 of the DCD. In response to RAI 432-3206, Question 08.02-15, the applicant revised Section 8.2.2.1 to state that the generator load break switch is designed and tested in accordance with SRP Section 8.2, Appendix A. In particular, the load break switch is not used to provide immediate access to offsite power and does not have fault interrupting capability necessary to provide such access. Given this clarification, the staff concludes that the application of the load-break switch in the

US-APWR design is acceptable and RAI 4-205, Question 08.02-6 and RAI 432-3206, Question 08.02-15 are resolved and closed.

When the normal source from the MG is not available through the UATs, offsite power is provided to the onsite electric power buses that are not safety-related through the RATs as their alternate offsite source. In addition, safety-related emergency GTGs supply power to the safety loads in the event of a loss of offsite power (LOOP).

Section 8.2.1.2 of the DCD states that all plant medium-voltage (MV), 6.9-kV buses, including both safety-related buses and buses that are not safety-related, are connected to the RATs and UATs, respectively, through bus incoming circuit breakers. If power to any MV bus is lost from its normal source, it is automatically transferred to its alternate source. In order to assure that these transfer schemes meet the single failure criterion, the NRC staff requested details in RAI 4-205, Question 08.02-4 about the bus transfer scheme (slow or fast) that will be used to transfer power from the normal sources to the alternate sources. As part of this RAI, the NRC staff also requested details about the design features provided to prevent connection of the alternate power source to a faulted bus when the buses are transferred from the RATs to the UATs. In a letter dated May 30, 2008 (ML081550237), the applicant clarified that the detail of the bus transfer scheme is already described in DCD Section 8.3.1.1.2.4 and Figure 8.3.1-2. This transfer scheme, including the entire requisite permissive that would prevent this transfer onto a faulted bus, is described in detail in subsection 8.3.1.1.2.4. The applicant inserted a reference in Subsection 8.2.1.2 to Subsection 8.3.1.1.2.4 where these transfer schemes are described. Upon review of the applicant's actual revision to the DCD, the NRC staff determined that it only partially addressed the NRC staff's concern, as it did not explicitly address the protection from transferring onto a faulted bus. The NRC staff followed up this concern with RAI 432-3206, Question 08.02-13, in which the NRC staff again requested that the description of the protection scheme be added to Section 8.2 of the DCD. In a letter dated September 24, 2009, (ML082720621) the applicant committed to add this description to the DCD. In the letter, the applicant clarified that there is protective relaying in the protection scheme that senses a faulted bus and prevents a transfer to such busses. The staff has determined that these protective relays are adequate to prevent transfer to a faulted bus. The NRC staff's review of the transfer scheme is documented in Section 8.3.1 of this SE. In its September 24, 2009, letter the applicant also committed to add this response to Section 8.2.1.2 of the DCD. The staff has verified that the applicant included such language to the DCD, Tier 2, Section 8.2.1.2. Therefore, RAI 4-205, Question 08.02-4 and RAI 432-3206, Question 08.02-13 are resolved and closed.

In RAI 4-205, Question 08.02-8, the NRC staff requested that the applicant provide the acceptance criteria for the design of switchyard and offsite power systems to withstand the effects of natural phenomena such as high and low atmospheric temperatures, high wind, rain, lightning discharges, and ice and snow conditions. Section 8.2.2.1 of the DCD was revised to state explicitly that all of the above natural phenomena are included in the design basis of the switchyard and offsite power system. This addition to the DCD was verified by the NRC staff. Therefore, RAI 4-205, Question 08.02-8 is resolved and closed.

Section 8.2.1.2 of the DCD indicates that the UATs and RATs have been provided with protective devices for overcurrent and differential current. The MT is provided with a differential current protection scheme. IEEE Std. 666-1991, reaffirmed 1996, "IEEE Design Guide for Electric Power Service Systems for Generating Systems," recommends, in addition to overcurrent and differential current protection, sudden pressure and ground fault protection in order to fully protect large power transformers. This standard is endorsed in RG 1.204 with regard to the protection provided by these protective schemes against lightning strikes. Section 8.2.1.2 of the DCD did not, however, include ground fault and sudden pressure protection for the UATs and RATs. In order to assure protection for these transformers, the NRC staff, in RAI 4-205, Question 08.02-7, requested that the applicant provide justification for not including neutral overcurrent (ground fault) and sudden pressure protection for the UATs, RATs, or MT. Accordingly, the NRC staff issued RAI 432-3206, Question 08.02-16, to request the applicant to revise the design to provide for all protective features recommended by IEEE Std. 666-1991 and update the DCD to reflect the revised design. Section 8.2.2.2 of the DCD was revised to state clearly that all protective trips recommended by IEEE-Std-666 for large power transformers are to be included in the design and that the detailed implementation will be provided by the COL applicants (COL Information Item 8.2(10)). The NRC staff verified that the applicant included the detailed information in the DCD, which resolves RAI 4-205, Question 08.02-7, and RAI 432-3206, Question 08.02-16. Therefore, these two items are closed.

Section 8.2.1.2 of the DCD states that there are four three-winding RATs, namely: RAT1, RAT2, RAT3, and RAT4. However, Figure 8.1-1 depicts the RATs as two-winding transformers. In order to clarify this apparent discrepancy, the NRC staff, in RAI 4-205, Question 08.02-9, requested that the applicant clarify whether the RATs have one secondary winding or two secondary windings (i.e., are they designed to be two-winding or three-winding transformers?). In a letter dated May 30, 2008 (ML081550237), the applicant stated that the third winding on each of the RATs is a delta tertiary winding to suppress (filter) higher harmonics and is therefore not needed to be shown in Figure 8.1-1. With this clarification, the NRC staff finds that the RATs are properly depicted as two-winding transformers in DCD Figure 8.1-1 and this acceptably resolves RAI 4-205, Question 08.02-9 as closed.

In addition, GDC 17 specifies the safety function of the electric power systems as providing sufficient capacity and capability to assure that: (1) specified acceptable fuel design limits and design conditions of the reactor coolant system pressure boundary are not exceeded as a result of anticipated operational occurrences and (2) the core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents. The systems to which the offsite power system supplies power that accomplish these functions are governed by 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," for SSCs important to safety during normal and accident conditions, as necessary for the specific system condition. Since the switchyard is connected to a minimum of two independent and redundant transmission lines, and the switchyard design includes circuit breakers to isolate a faulted offsite transmission line upon a loss of one circuit (assuming the onsite power is not available), a loss of one circuit does not affect the availability of the other offsite circuit. Therefore, the offsite power to Class 1E buses will remain available to accomplish the safety functions identified in the above criteria.

For the reasons set forth above, the NRC staff finds that the applicant's design satisfies the requirements of GDC 17 with respect to the offsite power system on: (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 of circuits; and (4) availability of circuits to ensure that fuel design limits and design conditions of the reactor pressure boundary are not exceeded.

8.2.4.3 Compliance with GDC 18

GDC 18, with respect to the offsite power system, requires that the SSCs associated with the offsite power system (i.e., the switchyard and incoming circuits) are capable of being tested periodically to assess the continuity of the system and the condition of the components, and thereby assure proper functioning. The DCD states: "Compliance with this criterion is achieved by designing testability and inspection capability into the system and then implementing a comprehensive testing and surveillance program. Inspection and testing of the high voltage circuit breakers at the switchyard powering the transmission tie lines, and protective relaying can be conducted on a routine basis without removing any of the UATs, RATs, or transmission tie lines from service." The NRC staff finds that the applicant's design meets the testability requirements of GDC 18 with respect to the capability of inspection and testing of the offsite power system and equipment and is acceptable.

8.2.4.4 Compliance with 10 CFR 50.63

Section 50.63 of 10 CFR Part 50 requires measures to ensure that the plant can withstand for a specified duration and recover from a loss of all ac power (SBO). The main review of this issue is found in Section 8.4 of this SE. The NRC staff reviewed the offsite power system to assure that the failure of the offsite system will not affect the ability of the SBO power sources (AAC GTGs) to carry out their intended function.

Section 8.4.1.3 of DCD Tier 2 explains that the failure of the offsite system will not affect the ability of the SBO power sources (AAC GTGs) to carry out their intended function because disconnect switches in selector circuits A and B, which are not safety-related, and the Class 1E incoming circuit breakers in the Class 1E MV switchgear from the AAC GTGs are normally open and do not have any automatic closing function. They isolate the Class 1E system from the non-Class 1E system. The electrical connections are only remade manually in case of an SBO after loss of all ac power, including LOOP. This aspect of the design conforms to the guidance in RG 1.155, Appendix B, which provides an acceptable means for isolating the AAC sources from the onsite and offsite power systems.

8.2.4.5 Conformance with RG 1.206 (BTP 8-3 Grid Stability)

Electrical grid stability is a key element in determining if a COL design fully meets the requirements of GDC 17. Since grid conditions and characteristics are site-specific, RG 1.206 calls for the DCD to include interface requirements for the COL application. In addition, the application as originally submitted did not specify the minimum voltage and frequency necessary to power the reactor coolant pumps (RCPs) in accordance with the DCD Chapter 15 analyses. As a result, RAI 4-205, Question 08.02-1 and Question 08.02-2 were sent to the applicant to request the above information regarding grid stability and a specific analysis which demonstrates the capability to meet the assumed three-second time delay to maintain voltage and frequency upon a LOOP. Further, the NRC staff issued RAI 432-3206, Questions 08.02-10 and 08.02-11, to request that the applicant include this information in the DCD. In response to these RAIs, the applicant provided an interface requirement for the COL applicant to perform sufficient analyses to demonstrate that the three-second delay for the RCPs in the plant safety analysis is met. In addition, the response provided a COL information item that fully incorporates the scope of the stability analyses called for in RG 1.206. Specifically, in response to the NRC staff's RAIs, Section 8.2.3 of the DCD, provides an interface requirement that the COL applicant perform grid stability studies to confirm the assumptions in the DCD Tier 2, Chapter 15 safety analysis, and Section 8.2.4 provides COL Information Item 8.2(11) which, as noted above, complies with RG 1.206. Because the analysis required of a COL applicant referencing the US-APWR standard design will assure minimum voltage and frequency to power the RCPs and will reflect local grid conditions, the staff finds this acceptable and RAI 4-205, Questions 08.02-1 and 08.02-2 and RAI 432-3206, Questions 08.02-10 and 08.02-11 resolved and closed.

In addition to the information discussed above, the DCD as originally submitted did not include sufficient interface requirements for stability studies for the electrical transmission grid. RAI 4-205, Question 08.02-3, was issued to request the applicant to provide the necessary interface requirement. Further, the NRC staff issued RAI 432-3206, Question 08.02-12, to reinforce the need to update the DCD to reflect the interface requirement. The applicant provided this interface requirement, which conforms to the guidance in RG 1.206, in Section 8.2.4 (COL 8.2(11)) of the DCD. COL 8.2(11) calls for the COL applicant to perform the following detailed stability and reliability studies of the offsite power system upon these events: loss of the unit, loss of the largest unit on the grid, loss of the largest load, or loss of the most critical transmission line, including operating range, for maintaining transient stability. COL 8.2(11) also calls for a COL applicant referencing the US-APWR standard design to perform a failure modes and effects analysis (FMEA). The staff has determined that this list is in full conformance with RG 1.206 and is therefore acceptable. RAI 4-205, Question 08.02-03, and RAI 432-3206, Question 08.02-12 are resolved and closed.

8.2.4.6 Conformance with BTP 8-6 (Adequacy of Station Electric System Voltages)

BTP 8-6, "Adequacy of Station Electric Distribution System Voltages," addresses the issue of degraded grid voltage conditions, their potential effect on the Class 1E loads, and the need to provide specific protection of the loads from those effects. DCD Tier 2, Section 8.2.2.1, "Applicable Criteria," under BTP 8-6 states that the US-APWR design provides a second level of undervoltage protection with time delays to protect the Class 1E equipment from sustained undervoltage. This design aspect is addressed in DCD Section 8.3.1.1.2.5 and is evaluated in Section 8.3 of this SER.

8.2.4.7 Conformance to BTP 8-9 (Open Phase Conditions in Electric Power System)

On July 27, 2012, the NRC staff issued Bulletin 2012-01, "Design Vulnerability in Electric Power System," to all holders of operating licenses and COLs. Bulletin 2012-01 requested information about the facilities' electric power system designs. The intended purpose of the bulletin was to affirm that all plants comply with the GDC 17 requirements, and to evaluate whether any NRC further regulatory action was warranted to address any open phase design vulnerability. On April 1, 2013, the NRC staff issued RAI 1017-7058 (ML13091A045), Question 08.02-17, requesting an evaluation on whether the applicant had addressed the open phase design vulnerability identified at the Byron nuclear power station in accordance with the requirements specified in GDC 17 and the design criteria for protection systems under 10 CFR 50.55a(h)(3) for the US-APWR design. Specifically, the NRC staff asked the applicant to (1) describe the protection scheme design for important to safety buses (whether or not safety-related) to detect and automatically respond to a single-phase open circuit condition or high impedance ground fault condition on credited offsite power circuits, (2) explain how the surveillance tests are performed to verify that a single-phase open circuit condition or high impedance ground fault condition on an off-site power circuit is detected if the important to safety buses are not powered by offsite power sources during at-power conditions, and (3) describe how the plant operating procedures, including off-normal operating procedures, specifically call for verification of the voltages on all three phases of the ESF buses.

On May 10, 2013 (ML13133A363), MHI responded and later supplemented their response on December 18, 2013 (ML13360A164). In its December 18, 2013, response, the applicant stated that the electrical protective devices will detect undervoltage conditions such as loss of voltage or degraded voltage conditions. However, the applicant also indicated that electrical protective devices are not designed to detect an open phase condition (OPC) or an OPC with a high impedance ground fault condition. To resolve this design issue, the applicant indicated that it would change the protection scheme design of the offsite power circuits by adding dedicated detection device(s) for protection against an OPC on the high voltage side of the RATs and MT. The applicant indicated that the dedicated detection device(s) would be capable of detecting an OPC on the high voltage side of the transformers, with or without grounding. The applicant stated further that, upon detection of an OPC, an alarm would be initiated in the main control room (MCR) for OPC and the offsite power circuit supplying the Class 1E buses would be isolated. The applicant also stated that the protective devices will detect a condition where two phases open, with or without grounding.

To provide context for the above response, the applicant explained that the US-APWR ESF buses are powered by offsite power sources via the RATs, and, therefore, surveillance tests to detect an OPC or an OPC with a high impedance ground fault are not required. The applicant also stated that the plant operating procedures, including off-normal operating procedures, will be provided in accordance with COL items in DCD Section 13.5. The applicant provided a COL Item 8.2(13) in the RAI response to provide surveillance requirements for the device(s) used to detect an OPC on the high voltage side of the RATs and MT with or without grounding.

As explained in more detail below, the staff has determined that the applicant response to RAI 1017-7058, Question 08.02-17, did not completely address detection and mitigation strategies as described in BTP 8-9. BTP 8-9 discusses the electric power system design vulnerability due to OPC in offsite electric power systems. In order to verify the applicant has addressed the design vulnerability in accordance with the requirements specified in GDC 17 and the design criteria for protection systems under 10 CFR 50.55a(h), the staff requested additional information in RAI 1096-8266 (ML15314A001), Question 08.02-18, dated November 06, 2015. Specifically, the staff requested that the applicant address four topics. First, the staff requested the applicant to include a description in the DCD which explains how the US-APWR design meets the guidance in BTP 8-9. Second, the staff requested that the applicant describe the design features that would be provided in the event that offsite power is functionally degraded due to an open-phase condition and safe shutdown capability is not assured. In such an event, the staff indicated that the safety-related buses should be designed to be transferred automatically to the alternate reliable offsite power source or onsite standby power system within the time assumed in the accident analysis and without actuating any protective devices, given a concurrent design basis event. Third, the staff requested that the applicant provide an ITAAC to verify that the design as built includes protective devices that can accomplish the following functions: (a) monitor and detect an OPC, (b) initiate an alarm in the control room in the event of the OPCs, and (c) automatically separate the Class 1E safety-related buses from the affected offsite power source and transfer safety-related loads to the unaffected offsite power source or the emergency diesel generators. Fourth, the staff requested the applicant to provide Technical Specifications (TS) in accordance with 10 CFR 50.36(c)(2) and 10 CFR 50.36(c)(3) to govern the protective devices.

In its response to the first topic of RAI 1096-8266, Question 08.02-18 (ML16258A455) stated above, the applicant indicated that the US-APWR will meet the guidance in BTP 8-9. In Attachment 1 of the response to RAI 1096-8266, Question 08.02-18, the applicant discusses that the OPC detection system (non-Class 1E) can detect all expected OPCs on the high voltage circuits of the MT and RAT. For the US-APWR, the normal preferred source is grid power through the RATs to the safety-related Class 1E 6.9 kV buses. The applicant stated that the RAT will be immediately isolated and the Class 1E buses will be transferred to the UAT side in case of a one or two OPC at the RAT side and an alarm will go off in the MCR. In addition, the applicant stated that actual specifications of the detection system will be identified considering the site-specific offsite power system configuration in the site-specific detailed design phase. Specifications include setpoints and delayed timer setting to minimize spurious actuation and isolate the affected offsite power appropriately. The staff finds that the US-APWR design will meet the guidance in BTP 8-9, as discussed above, since the proposed non-Class 1E protection features will assure that OPC monitoring, detection, alarm, and automatic transfer of safety-related buses to an alternate source is accomplished when an OPC occurs on the high voltage side of the RAT and MT. The applicant will revise the DCD to include the information in the Attachment 1 of the RAI response. Therefore, RAI 1096-8266, Question 08.02-18 is subject to **Confirmatory Item 08.02-01** pending verification that the proposed changes are incorporated into the next DCD revision.

In the response to the second topic of RAI 1096-8266, Question 08.02-18, identified above, the applicant stated that in the event that offsite power circuit is functionally degraded due to open-phase conditions, the safety-related buses will be transferred automatically to the alternate reliable offsite power source or onsite standby power system within a few seconds. The applicant described the conceptual logic for the detection system for the high voltage side of the RAT and MT in Figure-1 (RAT) and Figure-2 (MT) of the RAI response. The applicant indicated that the RAT or MT/UAT will be immediately isolated when there is an OPC and there is no undetected failure of the detection device. Additionally, DCD Tier 1, Table 2.6.1-3 ITAAC Item 6.b and 6c, specifies that the safety-related buses will be transferred automatically to the alternate reliable offsite power source or onsite standby power system. Specifically, ITAAC Item 6.b, states that if power through the RATs is not available, each Class 1E medium voltage bus is automatically transferred to the UATs, if available. ITAAC Item 6.c, states that if both offsite power sources are not available, each Class 1E medium voltage bus automatically connects to its respective emergency power source (EPS). The staff finds that the design concept and ITAAC 6.b and 6.c are adequate to verify that the Class 1E buses will be protected by isolating the RAT or MT/UT immediately when an OPC is detected.

The staff determined that the applicant in response to the third topic of RAI 1096-8266, Question 08.02-18 identified above did not completely address whether ITAAC Item 28 includes OPC detection, alarm, and monitoring in the control room since the design commitment, the Inspections, Tests, and Analyses, and the Acceptance Criteria do not include language that includes these three OPC features. Accordingly, the staff requested additional information in RAI 1100-9574 (ML18289B026), Question 08.02-19, to provide an explicit statement in ITAAC Item 28 that clarifies that OPC monitoring, detecting, and alarming in the control room are verified by ITAAC. In its response to RAI 1100-9574, Question 08.02-19 (ML18331A158), the applicant revised ITAAC 28 to include confirmation of OPC detection, alarm, and monitoring in the control room. Completion of ITAAC Item 28 will provide verification that the as-built design includes protective devices to protect the Class IE buses and to provide an alarm in the control room if an OPC occurs. The staff finds that ITAAC Item 28 is acceptable because it will verify that design features for detection, alarming, and monitoring of an OPC will be implemented as proposed in the design.

In its response to RAI 1096-8266, Question 08.02-18, the applicant stated that the undervoltage detection system can detect all OPCs on the secondary side of the UATs and RATs. While the staff understands this response, during an OPC, if the secondary side of the transformer is regenerating a lost phase, there will be no change in voltage magnitude that would actuate the under-voltage relays. However, there will be a change in the phase angle and the current on the secondary side of the transformer. Since the undervoltage relays will be incapable of detecting the loss of phase as a function of phase angle, the staff has determined that the applicant did not completely address how the undervoltage detection can detect all OPCs on the secondary side of the UATs and RATs.

The staff requested additional information in RAI 1100-9574, Question 08.02-19 to provide clarification whether the COL applicant will address the details of the specific design of OPC protective devices during the COL stage. If not, the staff requested the applicant to clarify how the undervoltage detection system can detect all OPCs on the secondary side of the UATs and RATs and provide simulations and analysis that demonstrates that the undervoltage detection system can demonstrate this capability. In response to RAI 1100-9574, Question 08.02-19, the applicant stated that the COL applicant will address the details of the specific design of OPC Detection and Protection system during the COL stage as stated in COL Item 8.2(12). The staff verified in DCD, Tier 2, Table 1.8-2 and Section 8.2.4, that COL Item 8.2(12) requires the COL applicant to address the details of the specific design of OPC Detection and Protection system. Therefore, the staff finds the applicant’s response acceptable, and this RAI is closed.

In its response regarding the fourth topic of RAI 1096-8266, Question 08.02-18, identified above, the applicant stated that the TS will be modified to incorporate the surveillance requirements for OPC protection. The applicant revised TS surveillance requirement 3.3.5.2 to include channel calibration for the OPC detection devices. The channel calibration is a complete check of the instrument loop, including the sensor, local control panel, and interface to the Engineered Safety Features Actuation System (ESFAS). The test verifies that each signal responds to a measured parameter within the necessary range and accuracy. The staff has determined that completion of TS surveillance requirement 3.3.5.2 will ensure that the OPC detection system is properly calibrated and the measured parameters are within the necessary range and accuracy.

The staff finds that the proposed design changes to add a non-Class 1E OPC detection system to protect against OPC, including DCD changes, ITAAC, COL Item, and descriptions conforms to the guidance in BTP 8-9 as it relates to the protection features to mitigate and provide a response to the OPC event, and hence, complies with GDC 17 as it pertains to OPC. The staff finds that the US-APWR OPC design acceptable, since it will ensure there is detection of an OPC, provide an alarm in the MCR, and ensure that the safety buses are not affected.

8.2.4.8 Conformance with SECY-91-078

The NRC staff Commission Paper, SECY-91-078, "Chapter 11 of the Electric Power Research Institute's (EPRI's) Requirements Document and Additional Evolutionary Light Water Reactor (LWR) Certification Issues," recommends that an evolutionary plant design, such as the US-APWR, should include at least one offsite circuit to each redundant safety division supplied directly from one of the offsite power sources, with no intervening non-safety buses, in such a manner that the offsite source can power the safety buses upon a failure of any non-safety bus.

In Section 8.2.1.2, "Offsite Power System," Figure 8.1-1 indicates that the safety-related buses and buses that are not safety-related are fed from the same RAT. However, Section 8.2 does not describe how the applicant's design addresses the SECY-91-078 concern. In RAI 4-205, Question 08.02-5, the NRC staff requested that the applicant explain how it addresses the SECY-91-078 recommendation. In its response (ML081550237), the applicant stated that the RATs are the normal source of power for the Class 1E buses and the UATs are the normal source of power for the non-Class 1E buses. In other words, the RAT would only power the non-Class 1E loads in a backup capacity. Therefore, in accordance with SECY-91-078, the non-Class 1E loads do not share the same transformer with the Class 1E loads as part of the normal operating configuration of the design. These design details were in Section 8.2 of the DCD without specifically mentioning the SECY paper. In RAI 432-3206, Question 08.02-14, as a followup to the response to Question 08.02-5, the NRC staff requested that this clarification be documented in the DCD. In Section 8.2.1.2 of the DCD, the applicant provided the requested documentation. The NRC staff finds this explanation acceptable because the safety-related buses and buses that are not safety-related are normally powered by separate transformers from the offsite power system, and this clarification resolves RAI 4-205, Question 08.02-5 and RAI 432-3206, Question 08.02-14 as closed.

8.2.5 Combined License Information Items

The following is a list of item numbers and descriptions from Table 1.8-2 of the DCD.

Table 8.2-1
US-APWR Combined License Information Items

Item No.	Description	Section
8.2(1)	The COL applicant is to address the transmission system of the utility power grid and its interconnection to other grids.	8.2.1.1
8.2(2)	Deleted	NA
8.2(3)	The COL Applicant is to address the plant switchyard which includes layout, control system and characteristics of circuit breakers and buses, and lightning and grounding protection equipment.	8.2.1.2.1 8.2.3
8.2(4)	The COL applicant is to provide detail description of normal preferred power.	8.2.3
8.2(5)	The COL applicant is to provide detail description of alternate preferred power.	8.2.3
8.2(6)	Deleted	NA
8.2(7)	The COL applicant is to address protective relaying for each circuit such as lines and buses.	8.2.1.2.1
8.2(8)	The COL applicant is to address switchyard dc power as part of switchyard design description.	8.2.3
8.2(9)	The COL applicant is to address switchyard ac power as part of switchyard design description.	8.2.3
8.2(10)	The COL applicant is to address transformer protection corresponding to site-specific scheme.	8.2.1.2
8.2(11)	The COL Applicant is to address the stability and reliability study of the offsite power system. The stability study is to be conducted in accordance with 8TP 8-3 (Reference 8.2-17). The study should address the loss of the unit, loss of the largest unit, loss of the largest load, or loss of the most critical transmission line including the operating range, for maintaining transient stability. A failure modes and effects analysis (FMEA) is to be provided. The grid stability study shows in part that, with no external electrical system failures, the grid will remain stable and the transmission system voltage and frequency will remain within the interface requirements (±10% for voltage and ±5% for frequency) to maintain the RCP flow assumed in the Chapter 15 analysis for a minimum of 3 seconds following reactor/turbine generator trip.	8.2.3

Table 8.2-1
US-APWR Combined License Information Items

Item No.	Description	Section
8.2(12)	The COL applicant is to determine the specific type of the OPC detection devices which properly address and meet the requirements of 8.1. & 8.2. of BTP 8-9, taking into account the site-specific design configuration, installation condition, (field) performance testing and qualification status, and operation experiences of the OPC Detection and Protection system. The COL applicant is also to provide the detailed design of the OPC Detection and Protection system for the COL applicant site. The COL applicant is to perform a field simulation on the site-specific design of the offsite power system to ensure that the settings of the OPC Detection and Protection system are adequate and appropriate for the COL applicant site.	8.2.1.2
8.2(13)	The COL Applicant is to provide surveillance requirements for the device(s) used to detect open phase condition on the high voltage side of, the RATs and MT with or without grounding.	8.2.1.2

8.2.6 Conclusions

The NRC staff's review of Section 8.2 of the US-APWR DCD, Tier 2, related to the "Offsite Power System," included all of the relevant information that is applicable to the US-APWR offsite power system design and evaluated its compliance to GDC 5, 17 and 18 and conformance to RGs, industry standards and BTPs committed to by the applicant. The NRC staff also reviewed the COL information items found in Section 8.2.5 of this SER. On the basis of the NRC staff's review and evaluation of the information in Section 8.2 of the DCD, with the exception of Confirmatory Item 08.02-01 the NRC staff concludes that the applicant has provided sufficient information in the DCD and identified necessary analyses to support the basis for their conclusions of their offsite power system design for the COL applicant. The NRC staff concludes that the design of the US-APWR offsite power system meets the appropriate regulatory requirements for offsite power systems as shown in the NRC staff technical evaluation in Section 8.2.4 of this SER.

8.3 Onsite Power System

The US-APWR onsite ac power system provides power to the plant auxiliary and service loads during all modes of plant operation. The onsite power system consists of both an ac power system and a dc power system. Both ac and dc systems include Class 1E and non-Class 1E systems. The onsite ac power system and its connections to the offsite power system are described in Section 8.3.1 of the SER. The Class 1E and non-Class 1E dc power systems are described in Subsection 8.3.2 of this SER.

8.3.1 Alternating Current Power Systems

The US-APWR onsite ac power system includes normal, permanent, and emergency power systems powered from the offsite power sources. Emergency power systems are backed-up by Class 1E GTGs and permanent power systems are backed-up by non-Class 1E AAC GTGs.

8.3.1.1 Introduction

The onsite power system backs up the offsite power system, which is the PPS. When the offsite power system is not available, the safety function of the onsite power system is to provide sufficient capacity and capability to ensure that SSCs important to the safety perform as intended. The onsite power system must satisfy the requirements of 10 CFR Part 50, Appendix A, GDC 2, 4, 5, 17, 18 and 50 and must perform its design function during all plant operating and design-basis accident conditions.

8.3.1.2 Summary of Application

Section 8.3.1 of the DCD describes design parameters for the US-APWR on-site ac power system. It also provides design information for the Class 1E and non-Class 1E power distribution systems that together provide reliable ac power to the various Class 1E and non-Class 1E system electrical loads. The loads are designed to enhance an orderly shutdown under normal operation and to respond to postulated accident conditions. In addition, the applicant specifies the use of Class 1E GTGs as an emergency power source for the onsite ac power systems. MHI Licensing Technical Report MUAP-07024-P, "Qualification and Test Plan of Class 1E Gas Turbine Generator System" (ML100710263), describes the design criteria, features, testing, and qualification for the Class 1E GTG units. This review was conducted in accordance with the guidance found in Section 8.3.1 of the SRP. The review areas include: System Redundancy Requirements, Conformance with the Single-Failure Criterion, Onsite and Offsite Power System Independence, Standby Power Supplies, Identification of Cables, Raceways, and Terminal Equipment, Auxiliary Supporting Systems/Features, System Testing and Surveillance, and Reliability Program for Emergency Onsite ac Power Sources.

DCD Tier 1: The Tier 1 information associated with this section is found in DCD Tier 1, Sections 2.6.1, 2.6.4, and Tables 2.6.1-3, 2.6.3-3, and 2.6.4-1. Section 2.6.1, "AC Electric Power Systems," contains the design description and the ITAAC for the ac electric power system. Section 2.6.4, "Emergency Power Sources (EPS)," contains the design description and the ITAAC for the EPS, which provides an emergency power supply to each of the four divisions of the Class 1E power distribution systems. Table 2.6.1-3, "AC Electric Power Systems Inspections, Tests, Analyses, and Acceptance Criteria," contains the design commitment, the ITA, and the acceptance criteria for the onsite electric power system. Table 2.6.3-3, "I&C Power Supply Inspections, Tests, Analyses, and Acceptance Criteria," contains the design commitment, the ITA, and the acceptance criteria for the Class 1E I&C power supply systems. Table 2.6.4-1, "EPS Systems Inspections, Tests, Analyses, and Acceptance Criteria," contains the design commitment, the ITA, and the acceptance criteria for the Class 1E EPS and the Fuel Oil Storage (FOS) systems.

DCD Tier 2: The applicant has provided a Tier 2 system description in DCD Tier 2, Section 8.3.1, "AC Power Systems," summarized here in part, as follows:

> The applicant presents a single-line diagram of the onsite power systems in DCD Figure 8.3.1-1, and a tabulation of loads. The onsite Class 1E power system comprises four independent and redundant Class 1E systems. Safety systems that have four load groups credit any two of the four load groups for performing their safety function.
>
> Four independent Class 1E MV (6.9-kV) buses (A, B, C, and D) are provided. The normal preferred (offsite) source for the onsite Class 1E power system is via two of the RATs serving the four Class 1E 6.9-kV buses. The alternate preferred source is provided by back-feeding offsite power via the MT and the UATs. Each of the Class 1E 6.9-kV buses has a dedicated Class 1E GTG for backup emergency power if the preferred sources are not available. The GTGs are credited to achieve rated voltage and frequency within 100 seconds after a start signal. Each Class 1E 6.9-kV bus serves a 480-Vac load center, which serves loads that include 480-Vac motor control centers (MCCs). Four independent divisions of Class 1E 120-Vac uninterruptible instrument power are also provided. Each division includes a 120-Vac inverter powered by nominal 125-Vdc from its associated station vital battery, distribution panels, and a 480/120-Vac instrument power transformer.
>
> The applicant also identifies a permanent power system, which includes two permanent non-Class 1E, 6.9-kV buses (P1 and P2) served by dedicated non-Class 1E GTGs, which are considered the AAC source for SBO events. The 'A' AAC GTG can be connected to Class 1E, 6.9-kV Bus A or B, and the 'B' AAC GTG can be connected to Class 1E, 6.9-kV Bus C or D.
>
> For the 6.9-kV buses identified above, if power is lost from one source, the buses are automatically transferred to the other source by either a fast or slow transfer scheme, depending on voltage conditions.
>
> The applicant presents a summary of the design basis and a listing of applicable regulatory requirements, regulatory guidance, codes, and standards, governing the design and testing of the onsite ac power systems and equipment.

Inspection, Test, Analysis and Acceptance Criteria (ITAAC): The ITAAC associated with Tier 2, Section 8.3.1 are given in DCD Tier 1, Sections 2.6.1, 2.6.3, 2.6.4, and Tables 2.6.1-3, 2.6.3-3, and 2.6.4-1.

Technical Specifications (TS): TS applicable to the onsite ac power systems can be found in DCD Tier 2, Chapter 16, "Technical Specifications," Sections 3.8.1, 3.8.2, 3.8.3, 3.8.7, 3.8.8, 3.8.9, and 3.8.10. Section 3.8.1, "AC Sources - Operating," contains the Limiting Conditions for Operation (LCOs) and surveillances related to the ac electrical power sources under plant operating conditions. Section 3.8.2, "AC Sources - Shutdown," contains the LCOs and surveillances related to ac electrical power sources under plant shutdown conditions. Section 3.8.3, "Class 1E Gas Turbine Generator Fuel Oil, Lube Oil, and Starting Air," contains the LCO and surveillances related to Class 1E GTG Fuel Oil, Lube Oil, and Starting Air subsystem. Section 3.8.7, "Inverters - Operating," contains the LCO and surveillances related to inverters under plant operating conditions. Section 3.8.8, "Inverters - Shutdown," contains the LCO and surveillances related to inverters under plant shutdown conditions. Section 3.8.9, "Distribution Systems - Operating," contains the LCO and surveillances related to ac, dc, and ac vital bus electrical power distribution subsystems under plant operating conditions. Section 3.8.10, "Distribution Systems - Shutdown," contains the LCO and surveillances related to ac, dc, and ac vital bus electrical power distribution subsystems under plant shutdown conditions.

Technical Reports: MHI Technical Report MUAP-07024-P, "Qualification Test Plan of Class 1E Gas Turbine Generator System."

Topical Reports: There are no topical reports associated with this section.

US-APWR Plant Interfaces: The DCD, Tier 2, Sections 8.2.4, "Combined License Information," and 8.3.4, "Combined License Information," includes information that relates to the following plant interfaces, which will be addressed by COL applicants that reference the US-APWR Design Certification:

- Onsite ac power transmission system connections to the switchyard and the connection to the plant power distribution system (COL Information Item Numbers: COL 8.2(1), COL 8.2(3), COL 8.2(4) COL 8.2(5), and COL 8.2(11)).

- Lightning protection and grounding system grid (COL Information Item 8.3(2)).

Conceptual Design Information (CDI): There is no CDI associated with this section.

8.3.1.3 Regulatory Basis

The relevant requirements of the Commission's regulations for the onsite ac power system, and the associated acceptance criteria, are given in Section 8.3.1 of NUREG-0800, the SRP, and are summarized below. Review interfaces with other SRP sections can be found in Section 8.3.1 of NUREG-0800.

1. 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection Against Natural Phenomena," 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.

2. 10 CFR Part 50, Appendix A, GDC 4, "Environmental and Dynamic Effects Design Bases," 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.

3. 10 CFR Part 50, Appendix A, GDC 5, "Sharing of Structures, Systems, and Components," as it relates to sharing of SSCs of the ac power systems.

4. 10 CFR Part 50, Appendix A, GDC 17, “Electric Power Systems,” 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.

5. 10 CFR Part 50, Appendix A, GDC 18, “Inspection and Testing of Electric Power Systems,” as it relates to inspection and testing of the onsite power systems.

6. 10 CFR Part 50, Appendix A, 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 and the external circuit protection for such penetrations.

7. 10 CFR 50.55a(h), “Codes and standards. Protection and safety systems,” as it relates to the incorporation of IEEE Std. 603-1991, “IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations,” (including the correction sheet dated January 30, 1995).

8. 10 CFR 50.63, as it relates to consideration of the reliability and redundancy of emergency onsite ac power sources as factors for establishing coping duration.

Guidance and acceptance criteria for meeting the above regulatory requirements are as follows:

1. RG 1.6, “Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems (Safety Guide 6),” Positions D.1, D.3, and D.4, as they relate to the independence between redundant onsite ac power sources and between their distribution systems.

2. RG 1.9, “Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants,” as it relates to the design and testing of the onsite power supply.

3. RG 1.32, “Criteria for Power Systems for Nuclear Power Plants,” as it relates to the design, operation, and testing of the safety-related portions of the onsite ac power system. Except for sharing of safety-related ac power systems in multi-unit nuclear power plants, RG 1.32 endorses IEEE Std. 308-2001.

4. RG 1.47, “Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems,” as it relates to the bypass and inoperable status of the onsite power supply.

5. RG 1.53, “Application of the Single-Failure Criterion to Nuclear Power Plant Protection Systems,” as it relates to the application of the single-failure criterion.

6. RG 1.63, "Electric Penetration Assemblies in Containment Structures for Nuclear Power Plants," 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 (GDC-50).

7. RG 1.75, "Physical Independence of Electric Systems," as it relates to the physical independence of the circuits and electrical equipment that comprise or are associated with the onsite ac power system.

8. RG 1.81, "Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants," as it relates to the sharing of SSCs of the ac power system. Regulatory Position C.1 states that multi-unit sites should not share ac systems. The US-APWR is designed to operate as a single, independent-unit plant, even in multiple unit installations; therefore, this RG is not applicable to the US-APWR.

9. RG 1.118, "Periodic Testing of Electric Power and Protection Systems," as it relates to the capability to periodically test the onsite ac power system (GDC-18).

10. RG 1.153, "Criteria for Safety Systems," 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. RG 1.153 provides supplemental guidance for implementing IEEE Std. 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," to satisfy the NRC regulatory requirements.

11. RG 1.155, "Station Blackout," as it relates to the capability and the capacity of the onsite ac power system for an SBO, including the operation of the AAC power source(s). The applicant's onsite ac power system conformance with RG 1.155 and its conformance to SECY-90-016 are also being addressed in Section 8.4 of this SER.

12. RG 1.204 "Guidelines for Lightning Protection of Nuclear Power Plants," and 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," as they relate to the design, installation, and performance of station grounding systems and surge and lightning protection systems.

13. RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," as it relates to power system analytical studies and stability studies to verify the capability of the offsite power systems and their interfaces with the onsite power system.

14. BTP 8-1, "Requirements for Motor-Operated Valves in the Emergency Core Cooling System (ECCS) Accumulator Lines," in SRP Chapter 8, as it relates to required features for safety injection system accumulator motor-operated isolation valves.

15. BTP 8-2, "Use of Diesel-Generator Sets for Peaking," which states that emergency diesel generators will not be used for peaking service.

16. BTP 8-4, "Application of the Single-Failure Criterion to Manually Controlled Electrically Operated Valves," as it relates to the evaluation of the safe shutdown systems for potential inadvertent movement of manually controlled, electrically operated valves that could result in the loss of system safety-related function.

17. BTP 8-5, "Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems," as it relates to bypassed or inoperable status indicators that are displayed in the main control room.

18. BTP 8-6, "Adequacy of Station Electric Distribution System Voltages," as it relates to the analysis, testing, and selection of the undervoltage and degraded voltage setpoints and associated time delays.

8.3.1.4 Technical Evaluation

The NRC staff has reviewed the onsite ac power system presented in DCD Tier 2, Section 8.3.1. This section provides descriptive information, analyses, and referenced documents, including electrical single-line diagrams, tables, and physical arrangements. The review is to evaluate whether the US-APWR onsite ac power system satisfies applicable regulatory requirements to ensure its intended safety functions are accomplished during all plant operating and accident conditions. The US-APWR onsite ac power system consists of standby power sources, distribution systems, and auxiliary supporting systems provided to supply power to safety-related equipment or equipment important to safety for all normal operating and accident conditions.

NUREG-0800, Table 8-1 lists GDC, RGs, industry codes and standards, and BTPs that are applicable to electrical power systems. The NRC staff has reviewed the following US-APWR DCD information that relates to compliance with requirements applicable to onsite ac power system design and conformance to applicable guidance as described below.

8.3.1.4.1 Compliance with GDC 2

GDC 2, "Design Bases for Protection Against Natural Phenomena," requires that SSCs important to safety, which include the onsite ac power systems, be capable of withstanding the effects of natural phenomena without the loss of the capability to perform their safety functions.

The US-APWR onsite ac power distribution system consists of four independent and redundant trains which are physically separated in different rooms. Section 9.5.1.1 of DCD Tier 2 explains that redundant safe shutdown components and associated redundant Class 1E electrical trains are separated from the other Class 1E and non-Class 1E systems by three-hour rated fire barriers to preserve the capability to safely shut down the plant following a fire. DCD Tier 2, Section 1.2.1.7.1, "General Plant Arrangement," states that the Reactor Building (R/B) and safety-related Power Source Buildings (PS/B) are structurally designed to meet seismic Category I requirements as defined in RG 1.29, "Seismic Design Classification." These structures are designed to withstand the effects of natural phenomena such as hurricanes, floods, tornados, tsunamis, and earthquakes without the loss of capability to perform safety functions. The electrical equipment identified as safety-related is qualified as Class 1E and is designated as seismic Category I. The key site parameters, including their values, for the US-APWR design are described in DCD Tier 2, Chapter 2, "Site Characteristics." The US-APWR design for wind, tornado, flood, and seismic (earthquake) is evaluated as part of the NRC staff's review of Sections 3.3, 3.4, and 3.7, respectively, of DCD Tier 2, Chapter 3, "Design of Structures, Components, Equipment and Systems."

All equipment and components of the safety-related Class 1E ac power systems are located in Seismic Category I buildings and their mountings and installations are designed to seismic Category I standards. The Class 1E ac power systems are designed to withstand the effects of natural phenomena including the design basis earthquake, tornado, hurricane, flood, tsunami, and seiche without losing the capability to perform their intended safety functions. Compliance with GDC 2 for all safety-related SSCs is generically addressed in the DCD Tier 2, Section 3.10, "Seismic and Dynamic Qualification of Mechanical and Electrical Equipment," and will be reviewed in Chapter 3 of this SER. Since the onsite ac power system is located inside seismic Category 1 structures, since the onsite ac power system is designed as Class 1E, and since the onsite ac equipment is seismically qualified, the staff finds that the ac electric equipment and structures will be designed to withstand the effects associated with natural phenomena without the loss of capability to perform their safety functions during an accident. Given the above, the staff finds that the onsite ac power system complies with GDC 2.

8.3.1.4.2 Compliance with GDC 4

GDC 4, "Environmental and Dynamic Effects Design Bases," requires that SSCs important to safety, which include the onsite ac power system, be capable of withstanding the effects of missiles and environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs. Specifically, the onsite ac power system must be designed to accommodate the effects of and to be compatible with the environmental conditions, and to be appropriately protected against dynamic effects, including the effects of missiles that may result from equipment failures.

As set forth below, the NRC staff has reviewed the applicant's onsite Class 1E ac distribution system components. The safety-related ac power systems are composed of four independent trains that are electrically isolated, functionally independent, and physically separated. The major electrical distribution equipment of each train, including Class 1E equipment such as 6.9kV switchgear, 480V load centers, 480V MCCs, Motor-Operated Valve (MOV) inverters, 480V MOV MCCs, and 120V vital ac distribution panels, is located in a separate electrical room. There are no high or moderate energy lines routed through these safety-related electrical rooms. Each room is also provided with a redundant safety-related heating, ventilation, and air conditioning system that maintains ambient environmental conditions during normal operations and Design Basis Events (DBEs). All equipment and components of the safety-related ac power systems are qualified for Class 1E application in accordance with IEEE Std. 323 and all applicable IEEE equipment qualification standards. Compliance to GDC 4 for all safety-related SSCs is generically addressed in DCD Tier 2, Section 3.1, "Conformance with NRC General Design Criteria."

In addition, for that equipment located in harsh environments, the environmental qualification (EQ) program for electrical equipment ensures that all equipment and components of the safety-related ac power systems remain functional during and following exposure to harsh environmental conditions as a result of a DBE. EQ of mechanical and electrical equipment described in DCD Tier 2, Section 3.11, "Environmental Qualification of Mechanical and Electrical Equipment," lists GDC 4 as one of its acceptance criteria. DCD Tier 2, Table 3D-2 of Appendix 3D, lists safety-related electrical and mechanical equipment located in a harsh environment that must be qualified. Electrical equipment designated as safety-related or important to safety is addressed in the EQ program as described in DCD Tier 2, Section 3.11. The US-APWR EQ program verifies that the safety-related equipment is capable of performing its design function(s) under all anticipated service conditions as defined in 10 CFR 50.49(b)(1)(ii). Also, electrical equipment located in harsh environments is qualified pursuant to the guidance delineated in IEEE Std. 323-1974. The staff's review of the environmental qualification program is in Section 3.11 of this report.

In DCD Tier 2, Section 8.3.1.1.3.2, the applicant provided a description of the Class 1E GTG starting system, which is the system that provides for a reliable GTG start following a LOOP, but failed to provide a discussion on whether the Class 1E GTG can also be started from the Remote Shutdown Panel (as required by Appendix R) in case of evacuation of the main control room (MCR) due to a fire. In RAI 10-453 (ML082040271), Question 08.03.01-16, the NRC staff asked the applicant to provide its rationale for not including the capability of starting the Class 1E GTGs from the Remote Shutdown Panel (RSP). In response to RAI 10-453, Question 08.03.01-16, the applicant stated that the RSP is designed to allow the Class 1E GTG to be started from the RSP in case of an evacuation of the MCR. The NRC staff has determined that the applicant's response to the above RAI Question is acceptable because the capability of starting the GTGs from either the MCR or the RSP provides redundancy in terms of starting the Class 1E emergency power sources. The applicant stated that there was no change needed to be made to the DCD as a result of this RAI question, but the NRC staff determined that the DCD should fully describe the functional capabilities of the RSP including the starting of the Class 1E GTGs. The applicant's response to RAI 10-453, Question 08.03.01-16 (ML082040271) was inadequate since the applicant did not describe in the DCD whether the Class 1E GTGs can be started from the RSP in case of evacuation of the MCR due to a fire

Accordingly, in RAI 386-2859 (ML091620136), Question 08.03.1-28, the NRC staff asked the applicant a follow-up RAI question to the original RAI 10-453, Question 08.03.01-16. Specifically, the staff asked the applicant to revise its DCD, consistent with its response dated July 18, 2008, to state that the RSP is designed to allow the Class 1E GTG to be started from the RSP in case of an evacuation of the MCR.

The applicant responded to RAI 386-2859, Question 08.03.1-28 (ML092090058), stating that DCD Subsection 8.3.1.1.3.1 states "…the Class 1E GTGs are started by manual starting from remote shutdown room in the R/B." This means the Class 1E GTGs can be started from the RSP. Since the clarification submitted by the applicant establishes that the capability of starting the GTGs from either the MCR or the RSP provides redundancy in terms of starting the Class 1E emergency power sources, and that this information has been included in the DCD, the NRC staff concludes that the applicant complies with the requirements of GDC 17 pertaining to the redundancy of onsite ac power sources with respect to the location of Class 1E GTG controls. The NRC staff considers this issue resolved, and RAI 10-453, Question 08.03.01-16, and RAI 386-2859, Question 08.03.1-28, to be closed.

Based on the above, the NRC staff finds the onsite ac power system design for US-APWR can perform safety-related functions following physical effects of an internal hazard. The onsite Class 1E ac distribution system components are located in seismic Category I structures and rooms constructed in such a manner that any internal hazard is confined to a single structure and affects only one train of the ac distribution system. With the above and the EQ program, the onsite Class 1E ac distribution system components are capable of withstanding the effects of missiles and environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs. Thus, the onsite ac power system design for US-APWR meets the requirements of GDC 4.

8.3.1.4.3 Compliance with GDC 5

GDC 5 requires SSCs important to safety, which includes the dc power system, not be shared among other nuclear units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions. The applicant's plant is designed as a single-unit station. The SSCs of the onsite ac power system for the US-APWR are not designed to be shared between individual nuclear power units. Therefore, GDC 5 and RG 1.81 do not apply to the onsite ac power system.

8.3.1.4.4 Compliance with GDC 17

GDC 17 requires, in part, that an onsite ac power system be provided to permit functioning of SSCs important to safety. GDC 17 requires that this system have the safety function to provide sufficient capacity and capability to assure that specified acceptable fuel design limits and design conditions of the reactor coolant system (RCS) are not exceeded as a result of anticipated operational occurrences (AOOs), and that the core is cooled and component integrity and other vital functions are maintained in the event of postulated accidents. The systems to which the onsite ac power system supplies power that accomplishes these functions are governed by 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," during normal and accident conditions, as necessary for the specific system condition. GDC 17 requires further that this onsite ac power system have sufficient independence, redundancy, and testability to perform its safety functions assuming a single failure. GDC 17 also requires that the onsite system include 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 describing Class 1E GTG testing conducted during plant operation, the applicant indicated in DCD Tier 2, Section 8.3.1.1.3.8, "Testing," that it will load the Class 1E GTG to the "maximum expected load-carrying capability" but failed to quantify the "maximum expected load-carrying capability." RAI 10-453, Question 08.03.01-17, asked the applicant to: (1) explain the term "maximum expected load-carrying capability" in view of the criteria given in RG 1.9 (although RG 1.9 discusses EDGs, the guidance for EDGs is good engineering practice and applies to GTGs) and IEEE Std. 387 for loading an emergency power source to 90-100 percent of the continuous rating until temperature equilibrium is attained; (2) discuss the power factor (PF) of the load when conducting this test; and (3) provide its rationale for using a PF of the load for this test that is different than the rated PF of the machine, or the LOOP and ECCS load PF. In its response to RAI 10-453, Question 08.03.01-17 (ML082040271), the applicant agreed to conduct the loading test for GTGs at 90-100 percent of the safety-related GTG's nameplate rating. In addition, the applicant agreed to conduct this test at a PF of 0.8, which is the nameplate value of GTG that has been selected for the US-APWR design. Also, in its response the applicant agreed to revise the description in DCD Section 8.3.1.1.3.8 to state that the loading test will be performed at 90-100 percent of the Class 1E GTG rating. The staff determined that this response is acceptable because it provides the NRC staff with the actual maximum expected load carrying capability of the GTGs during testing, and the PF that will be used for testing, which, by being the worst-case scenario that the GTGs will undergo when operating, envelops all the operating scenarios. However, the applicant failed to commit to revising the DCD to include PF test values. Accordingly, in RAI 386-2859, Question 08.03.1-29, the NRC staff asked a follow-up RAI to the original RAI 10-453, Question 08.03.01-17. Specifically, the staff asked the applicant to revise its DCD to include its response dated July 18, 2008, stating that the maximum expected load carrying capability during the loading test for GTGs would be at 90-100 percent of the safety-related GTG's nameplate rating.

In response to RAI 386-2859, Question 08.03.1-29, the applicant tendered a letter dated July 22, 2009, in which it stated that it would revise its DCD to include information related to load testing condition of the Class 1E GTG. The applicant's proposed language would be added as Item 2.b in Subsection 8.3.1.1.3.8 of the DCD:

> Demonstrate load-carrying capability, with load equivalent to 90-100 percent of the continuous rating of the Class 1E GTG for an interval of not less than one hour. This test may be accomplished by synchronizing the Class 1E GTG with the offsite power system from either a RAT or the UAT, and loading at the maximum practical rate as recommended by the manufacturer. Testing may be performed at a PF of 0.8 within the Class 1E GTG capability.

Since the applicant provided the NRC staff with the actual maximum expected load carrying capability of the GTGs during testing, which, by being the worst-case scenario that the GTGs will undergo when operating, envelops all the operating scenarios, it satisfied the requirement in GDC 17 pertaining to the capacity of onsite power systems to provide power to ECCS loads. The NRC staff verified that the text stated above was acceptable and had been added to the DCD in Section 8.3.1.1.3.8; therefore, RAI 10-453, Question 08.03.01-17, and RAI 386-2859, Question 08.03.1-29 are closed and the issue is resolved.

DCD Tier 2, Table 8.3.1-2, "Electrical Equipment Ratings-Voltage and Frequency," shows the following under the column listing acceptable variations for voltage and frequency: voltage variation of ±10 percent and frequency variation ±5 percent. The listing did not clearly indicate whether these limits are applied independently or as combined voltage and frequency limits. In RAI 10-453, Question 08.03.01-18, the NRC staff asked the applicant to correct the criteria for voltage and frequency as listed in Table 8.3.1-2 to reflect the industry guidance given in National Electrical Manufacturers Association (NEMA) MG-1-20.45.A3, "Variations from rated voltage and rated frequency," which states that a combined variation in voltage and frequency of ±10 percent of rated values provided the frequency does not exceed ±5 percent of rated frequency, or provide justification for departure from industry recommended practice for voltage and frequency variations. While this NEMA standard has not been endorsed by the NRC, NEMA MG-1-20.45.A3 is widely used by the industry and its use is considered sound technical basis and good engineering practice, as applied to this application. In a response to RAI 10-453, Question 08.03.01-18 dated July 18, 2008 (ML082040271), the applicant refers to Section 8.3.1.1.9, "Design Criteria for Class 1E Equipment," and Table 8.3.1-2 for acceptable bus and motor voltages. In its response, the applicant stated that the US-APWR design conforms to the guidance given in NEMA MG-1-20.45.A3 on the variations from rated voltage and frequency. The applicant also stated in its response that there is no need to change the DCD, but the NRC staff disagreed because it is not clear from the description in the DCD how the design conforms to NEMA MG-1-20.45.A3 criteria of a combined variation in voltage and frequency of ±10 percent of rated values, or that the frequency does not exceed ±5 percent of rated frequency. Accordingly, in RAI 386-2859, Question 08.03.01-30, the NRC staff asked a follow-up RAI to the original RAI 10-453, Question 08.03.01-18. Specifically, the NRC staff asked the applicant to revise its DCD to include its response dated July 18, 2008, showing the revised Table 8.3.1-2 to clearly state that the US-APWR design conforms to the guidance of NEMA MG-1- 20.45.A3 on combined variation in voltage and frequency of ±10 percent.

In a letter dated July 22, 2009 (ML092090058), MHI committed to revise its DCD to reflect conformance with NEMA MG-1. Since Table 8.3.1-2 has been revised to incorporate NEMA

MG-1-20.45.A3 criteria of a combined variation in voltage and frequency of ±10 percent, the NRC staff considers RAI 10-453, Question 08.03.01-18, and RAI 386-2859, Question 08.03.01-30 closed, and the issue resolved. The staff finds that the applicant conforms to the guidance in NEMA MG-1-20.45.A3, as it relates to the variations from rated voltage and rated frequency.

The applicant has established the onsite ac power system's compliance with GDC 17 by demonstrating conformance to applicable guidance. The NRC staff evaluation of whether the US-APWR onsite ac system design conforms to the applicable guidance which is set forth in RGs 1.6, 1.9, 1.32, 1.53, 1.75, 1.153, 1.155, 1.204, and SECY-91-078, is discussed in the following sections.

8.3.1.4.4.1 Conformance with RG 1.6

The DCD Tier 2, Section 8.3.1.2.2 states conformance with RG 1.6. The NRC staff reviewed the onsite ac power system design that provides independent and redundant standby power sources that supply the safety-related loads. The Class 1E onsite ac power systems provide power to the safety-related loads credited during LOOP and postulated accident conditions. The power from the offsite transmission system to the Class 1E distribution is the preferred power source under accident and post-accident conditions. The Class 1E onsite ac power system consists of four independent and redundant trains A, B, C and D, each of which is normally powered from the preferred power source, which is the offsite power system. Two independent connections to the offsite power system are provided to each of the Class 1E 6.9kV ac onsite buses. Each redundant train is backed-up by and can be powered by a Class 1E GTG. Each offsite power circuit is capable of supplying the Class 1E loads during all plant operating conditions, AOOs, and DBEs. Any two Class 1E trains, including the power sources (i.e., Class 1E GTGs), are adequate to supply the full complement of safety-related systems credited during LOOP and LOCA conditions occurring simultaneously.

The four trains are physically separated and electrically isolated from each other and also from the non-Class 1E systems. However, the applicant indicated in DCD Tier 2, Section 8.3.1.1.2.4 as follows. . . bus transfer schemes are provided to automatically restore power to the Class 1E buses from the alternate preferred offsite source, if available, or from the Class 1E GTG. Transfer back to an RAT is by manual operation. Availability of power from any two Class 1E GTGs to the associated Class 1E trains is adequate to meet the maximum emergency load requirements during LOOP and LOOP+LOCA conditions. There are no automatic tie connections between the redundant Class 1E trains. The manual tie connection between the train B load center and train A load center A1, and between the train C load center and train D load center D1 are closed manually, and only open during the maintenance of the Class 1E A-GTG or Class 1E D-GTG. The tie circuit breakers are mechanically interlocked to prevent parallel connection of load center A1 to load centers A and B, and load center D1 to load centers C and D.

The DCD's conformance to RG 1.6 for the regulatory positions identified in SRP, Subsection 8.3.1, "AC Power Systems (Onsite)," is described below:

- Regulatory position D.1 - This regulatory position states that the electrically powered safety loads (ac and dc) should be separated into redundant load groups such that loss of any one group will not prevent the minimum safety functions from being performed. The applicant has stated that the electrically powered ac safety loads for the US-APWR are separated into four different redundant load groups, powered by four redundant trains of the safety-related ac power system. The applicant further stated that since any two of the four redundant trains are credited for minimum safety functions, the ac power system design conforms to the single failure criterion while one redundant train is out of service.

- Regulatory Position D.2 - This regulatory position states that each ac load group should have a connection to the preferred (offsite) power source and to a standby (onsite) power source (usually a single diesel generator). The standby power source should have no automatic connection to any other redundant load group. At multiple nuclear unit sites, the standby power source for a one load group may have an automatic connection to a load group of a different unit. A preferred power source bus, however, may serve redundant load groups. The applicant has stated that for the US-APWR, each Class 1E ac load group has two connections to the preferred offsite power sources and to an onsite standby power source. The applicant further stated that the onsite standby power source of one load group has no automatic connection to any other redundant load group.

- Regulatory Position D.4 - This regulatory position states that when operating from the standby sources, redundant load groups and the redundant standby sources should be independent of each other at least to the following extent:

  a. The standby source of one load group should not be automatically paralleled with the standby source of another load group under accident conditions;

  b. No provisions should exist for automatically connecting one load group to another load group;

  c. No provisions should exist for automatically transferring loads between redundant power sources;

  d. If means exist for manually connecting redundant load groups together, at least one interlock should be provided to prevent an operator error that would parallel their standby power sources.

  The applicant has stated the following: The redundant onsite ac power sources for the US-APWR and their distribution systems are completely independent. The equipment, components and circuits of each safety train and non-safety load groups are electrically isolated and physically separated from each other. There is no provision for automatic parallel operation of offsite and onsite power sources. No provisions exist for automatically connecting one load group to another load group. No provisions exist for automatically transferring loads between redundant power sources.

- Regulatory Position D.5 - This regulatory position states that a single generator driven by a single prime mover is acceptable as the standby power source for each ac load group of the size and characteristics typical of recent applications. If other arrangements such as multiple diesel generators operated in parallel or multiple prime movers driving a single generator are proposed, the applicant should demonstrate that the proposed arrangement has an equivalent reliability. Common mode failures as well as random single failures should be considered in the analysis. For the US-APWR, the applicant has stated in its DCD that one Class 1E GTG is used as the standby power source for each Class 1E ac load group, the generator size and ratings are comparable to generators used in other United States (US) nuclear plants, and each generator is driven by one prime mover, which is a gas turbine. Use of a GTG is not typical in US nuclear power plants. Suitability of GTG application in the onsite Class 1E standby power source is addressed in Technical Report MUAP-07024-P, “Qualification and Test Plan of Class 1E Gas Turbine Generator System,”

The staff confirmed that the original application conformed to each regulatory position in RG 1.6 except for several matters discussed in detail below. The DCD states that the incoming circuit breaker from the UAT is closed within one second after detection of loss of offsite power from an RAT and simultaneous LOCA, which indicates a slow transfer from the RAT to UAT. One of the conditions described under this scenario is that the MT circuit breaker is closed or GLBS is closed in order to have power available from the UAT. DCD Tier 2, Section 8.3.1.1.2.4.D, indicates that several scenarios involving the loss of offsite power from a RAT and LOCA occurring simultaneously, and the automatic transfer of a Class 1E bus from a RAT to a UAT. In RAI 10-453, Question 08.03.01-12, the NRC staff asked the applicant to answer several questions based on loss of power scenarios in order to assess the availability of power to Class 1E buses. Under a scenario involving the loss of offsite power from a RAT and a LOCA occurring simultaneously, the NRC staff asked whether it was correct to assume that offsite power would be lost only from a RAT but not from the switchyard. The NRC staff also asked the applicant to describe the conditions and automatic transfer schemes for the scenario when offsite power is not available in the switchyard. In a letter dated July 18, 2008, the applicant stated that the slow transfer from a RAT to a UAT for this scenario is carried out when an undervoltage signal is initiated, whether or not the power supply from a UAT is available. If the power supply from both the UAT and RAT are not available due to a failure in the switchyard, the applicant stated that the power supply from the UAT is not used and the GTG will backup continuously.

Under the same scenario, the applicant was asked in RAI 10-453, Question 08.03.01-12 to assume that the motor loads on the affected bus are tripped and, after one second, the incoming breaker from the UAT is closed, and the accident loads are started by the ECCS load sequencer. A load sequencer includes relays and time delay circuits and controls the timing of electrical loads being sequenced on the emergency GTGs after a LOOP. The NRC staff asked the applicant to discuss whether the residual voltage of the motors that were tripped at the beginning of this sequence would have decayed sufficiently so as to not cause out-of-phase closing of the motor loads to the bus. The NRC staff also asked the applicant to discuss what protection features are installed in the motor load circuits to prevent these motors from loading on to the bus under out-of-phase conditions. In a letter dated July 18, 2008, the applicant stated that at the slow transfer, loads are tripped by an undervoltage signal 0.8 second (typical value) later than the time at which the undervoltage (UV) signal is initiated, and the UAT incoming breaker is closed 1 second later than that. The applicant also stated that loads are restarted in accordance with the ECCS sequencer. The applicant explained that even restarts of the first load (safety injection pump) begin five seconds later, and under such an out-of-phase restarting of the loads, more restarted loads don't affect the bus. The staff finds this acceptable since out of phase closing of the motor loads do not affect the bus, due to the timing of the motor restarts.

In the scenario assuming loss of all offsite power, in which the UAT cannot be supplied, the MT and the GLBS remains closed for at least 15 seconds to supply power to the UATs; the UAT cannot supply ECCS loads beyond 15 seconds for mitigating a LOCA. The NRC staff asked the applicant in RAI 10-453, Question 08.03.01-12 to revise this section of the DCD to clarify the transfer of Class 1E bus from a RAT to a UAT when offsite power is available from the MT breaker and the GLBS. In a letter dated July 18, 2008 (ML082040271), the applicant stated that the Class 1E GTG is designed to start and restore the Class 1E bus within 100 seconds from initiating the starting signal. The safety analysis is performed under the condition in which there is no power supply for 100 seconds from the time at which a LOCA occurs. If a LOOP occurs concurrent with a LOCA, the ECCS loads operate for 15 seconds until the turbine trips, and after the actual 15 seconds interval passes, these ECCS loads are tripped again by an undervoltage signal. The applicant has discussed the outcomes of several scenarios involving the automatic transfer of Class 1E buses from a RAT to a UAT due to the LOOP and LOCA occurring simultaneously. The NRC staff finds the part of RAI 10-453, Question 08.03.01-12 pertaining to the assessment of the availability of power to Class 1E buses closed because the safety analysis is performed with the assumption that there is no power supply for 100 seconds from the time at which a LOCA occurs, and considers the issues to be resolved.

The NRC staff also asked about grid stability in RAI 10-453, Question 08.03.01-12. In a letter dated February 8, 2008, the applicant provided a response to the question on grid stability analysis that justified the assumed three second time delay for loss of offsite power. The applicant also stated in the letter that if a turbine trip occurs, the GLBS opens after a time delay of 15 seconds, and that it can be assumed that with a turbine trip, the unit generator will be running in parallel with the offsite power, which will feed the UAT via the MT, with the MT breaker and the GLBS both closed. The NRC staff asked the applicant to clarify and revise this section of the DCD because the conditions the applicant postulated for this event appeared contrary to the conditions the applicant described in Section 8.3.1.1.2.4.D of the DCD. In a letter dated July 18, 2008, the applicant stated that even if a LOCA and LOOP occur concurrently, power from the offsite transmission system can be expected to be available for a short period, such as three seconds. The applicant also stated that power from the MG can be expected to remain available during turbine inertia for as long as 15 seconds. The applicant further indicated that the LOOP transfer scheme and actuation logic of the onsite power system are initiated by the "3 seconds" and "15 seconds" scenarios discussed above. The applicant's analysis presumes that the power supply to the reactor coolant pumps following a reactor/turbine trip is maintained at least 3 seconds by the main generator (turbine generator coast down) or the offsite power in Chapter 15. Transmission system stability is consistent with the condition of the transient and accident analysis in Chapter 15. Therefore, the applicant's response is consistent with Chapter 15 analysis and the staff's evaluation can be found in Chapter 15 of this report.

Since MHI has discussed the outcomes of several scenarios involving the automatic transfer of Class 1E buses from RAT to UAT due to a LOOP and LOCA occurring simultaneously, and has provided an assessment of the availability of power to Class 1E buses and these scenarios have been considered in Chapter 15, the NRC staff finds the remaining part of RAI 10-453, Question 08.03.01-12 pertaining to the analysis of several scenarios during a simultaneous LOOP and LOCA closed, and considers the issues it raised to be resolved.

As originally submitted, DCD Tier 2, Section 8.3.1.1.2.4.A, "Automatic fast transfer of Class 1E buses from RAT to UAT," failed to describe the time needed to accomplish the fast transfer from RAT to UAT for a Class 1E bus. By RAI 10-453, Question 08.03.01-9, the NRC staff asked the applicant to describe the RAT protective relays and the approximate time to accomplish the fast transfer from RAT to UAT. In its response (ML082040271), the applicant committed to provide a description about transformer protective relay types in Section 8.3.1.1.2.4 of the DCD and stated that the fast transfer will take approximate 150 milliseconds including mechanical open/close time (each three cycles) of circuit breakers and relay circuit actuation time (approximate 50 milliseconds as maximum). This response was deemed inadequate by the NRC staff because it did not reflect the standard time of 100 milliseconds that is used in US plants for fast bus transfers, and it did not include any analysis to justify that the alternate time of 150 milliseconds to complete a fast transfer would not result in out-of-phase transfer of motor loads. Accordingly, in RAI 386-2859, Question 08.03.01-24, the NRC staff asked a follow up RAI to the original RAI 10-453, Question 08.03.01-9. Specifically, the NRC staff asked the applicant to describe protective relays that initiate the fast bus transfer from RAT to UAT transformers and the time to accomplish the transfer. In its response letter to RAI 386-2859, Question 08.03.01-24 (ML092090058), MHI described that the fast bus transfer is accomplished by the main and back-up differential relays in about 150 milliseconds (nine cycles). The applicant explained that fast bus transfer is not directly initiated by a protection relay. Rather, the applicant explained that the fast transfer is started by opening of the incoming breaker for normal offsite power. The applicant indicated that the incoming breaker may open upon actuation of a protection relay, opening of the circuit breaker for the high-side of the transformer, or spurious trip of the incoming breaker.

The applicant further explained that fast transfer time depends on the time from opening of an incoming circuit breaker to closing of back-up circuit breaker. The applicant indicated that the 150 millisecond period cited in the response to the previous RAI 10-453, Question 08.03.01-9 conservatively included a 100 millisecond interval for closing the circuit breaker and a 50 millisecond interval for operation time for the protective relays. The applicant indicated further, however, that the protective relays operate before the opening of the incoming circuit breaker, so there is no need to include the operation time of the protective relays in this assessment. Therefore, the applicant indicated that it would revise the transfer time stated in the DCD to a 100 millisecond (six cycles) interval. Further, the applicant indicated that preliminary analysis about fast transfer will be added in a new technical report. The applicant committed to revise the description of the bus transfer in Subsection 8.3.1.1.2.4 of the DCD to include this information. Since the applicant has clarified that the US-APWR design is capable of closing the circuit breaker in a 100 millisecond interval, and that the additional 50 millisecond interval accounted for in the 150 millisecond interval corresponded to the operation time for the protective relays, the NRC staff finds that the US-APWR design follows the industry's practice of having a standard time of 100 milliseconds for fast bus transfers. Therefore, RAI 10-453, Question 08.03.01-9, and RAI 386-2859, Question 08.03.01-24 are closed, and the NRC staff consider these issues resolved.

DCD Tier 2, Section 8.3.1.1.2.4, describes the use of the LOOP load sequencer when a slow bus transfer from the RAT to the UAT is unsuccessful following an undervoltage signal. In RAI 10-453, Question 08.03.01-10, the NRC staff asked the applicant to discuss why the LOOP load sequencer is used to load the affected buses when there is no LOOP, and to explain what happens to the loads that were already running before the transfer takes place. In its response dated July 18, 2008, the applicant explained that in the US-APWR design, the loads are restarted with the LOOP sequencer, but did not provide an adequate description of the bus transfer schemes, the relays associated with each scheme, or the use of the LOOP sequencer. Accordingly, in RAI 386-2859, Question 08.03.01-25, the NRC staff asked a follow up RAI to RAI 10-453, Question 08.03.01-10. Specifically, the NRC staff asked the applicant to explain the Class 1E bus transfer schemes (automatic fast transfer and slow transfer) and the use of the LOOP load sequencer when there is no turbine/reactor trip with loss of power from the RAT.

In a letter dated July 22, 2009 (ML092090058), MHI submitted a response to RAI 386-2859, Question 08.03.01-25 (ML092090058), which explained that Class 1E buses of the US-APWR have both fast transfer and slow transfer schemes as follows: When a Class 1E bus experiences an undervoltage condition, the incoming breaker from the UAT is opened and motor feeder breakers are opened. One second after the UAT breaker opens, the incoming breaker from the RAT is closed. During this time, the motor loads are kept to the stop position [held de-energized]. Therefore, automatic starting of the credited loads via the LOOP load sequencer reduces operator burden during this condition and in addition, the voltage drop can be controlled, as the applicant indicated in response to RAI 10-453, Question 08.03.01-10. Interlocks are simplified by unifying the automatic load starting signal to the LOOP sequence, whether the Class 1E buses are powered from offsite power or an emergency power source. This simplifies the testing of the equipment since it is an automatic function. This discussion was provided by the applicant in Section 8.3.1.1.2.4. The staff finds that the use of the LOOP load sequencer allows for control of the voltage drop and reduces operator burden and hence, use of the LOOP load sequencer in bus transfer schemes is acceptable. Since the applicant has revised DCD Tier 2, Section 3.1.1.2.4 8, RAI 10-453, Question 08.03.01-10 and RAI 386-2859, Question 08.03.01-25 are closed, and the issues raised by these RAIs are resolved.

For the reasons set forth above, the NRC staff finds that the design features discussed above conform to the applicable guidance of RG 1.6, and that the US-APWR onsite power systems have sufficient independence to perform their safety functions assuming a single failure, as required by GDC 17.

8.3.1.4.4.2 Conformance with RG 1.9

The applicant states in DCD Tier 2, Section 8.3.1.2.2 that GTGs for the onsite ac power system will be qualified in accordance with IEEE Std. 387, "Criteria for Diesel Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations," and will be designed to conform with the guidance specified by RG 1.9, "Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants," that endorses IEEE Std. 387-1995.

The NRC staff has reviewed the four safety-related GTGs that serve as the Class 1E standby power sources for the US-APWR plant and provide backup power to the Class 1E 6.9kV onsite ac buses. Each redundant Class 1E power supply train is provided with a dedicated and independent Class 1E GTG connected to the Class 1E 6.9kV bus in that train. The Class 1E GTGs are housed in separate rooms of the Power Source Buildings, which are seismic Category I structures that are built to provide physical protection for the GTGs against natural phenomena (hurricanes, floods, tornados, tsunamis, earthquakes, etc.), postulated internal events (fires, and flooding), and internally-generated or externally-generated missiles.

Following the review of the GTG ambient temperature range, the NRC staff noted that the applicant specified a minimum ambient temperature for the GTG, but not a maximum ambient temperature. The NEMA standard MG-1 "Motors and Generators" specifies the maximum ambient temperature of 40 degrees Celsius or 104 degrees Fahrenheit (104°F) without specifying the minimum temperature. In RAI 5-272 (ML081620088), Question 08.03.01-5, the applicant indicated that the ambient temperature condition of US-APWR is set within -40 degrees F to 115 degrees F and that the Class 1E GTG of US-APWR can generate over 4500kW at 115 degrees. In RAI 5-272 (ML081620088), Question 08.03.01-5, the NRC staff asked the applicant to discuss the significance of the lower range temperature on the performance of the GTG, and the derating factors associated with the GTG for locations where the ambient temperature may exceed 104°F. In its response to RAI 5-272, Question 08.03.01-5 (ML081620088), the applicant explained that the most critical aspect of the low side ambient temperature is the characteristics of the fuel oil, because fuel oil liquid is changed to mist for combustion. The applicant provided other general details about the performance of the GTG under low side ambient temperatures, but failed to provide counter measures against the effects of low side ambient temperatures on fuel oil and lube oil.

Accordingly, in RAI 394-3048 (ML091690220), Question 08.03.01-37, the NRC staff asked a follow-up question to RAI 5-272, Question 08.03.01-5. Specifically, the NRC staff asked the applicant to address the significance of changing the range of temperatures from the nameplate values of 41 and 104 degrees F on the performance of the GTGs. The NRC staff requested that the applicant provide a detailed description of the preheating design and equipment to address low temperatures including information on whether the preheat system uses GTG exhaust gas, or if it is a stand-alone system. If the preheat system uses the GTG's exhaust gas, then the description of the preheat system should include a discussion on the operation of the heating system from start-up until the GTG reaches steady-state temperatures.

In a letter dated July 23, 2009 (ML092100293), the applicant explained that the gas turbine engine, itself, does not need warm-up, as would a diesel engine, and there is no significant impact from operating a gas turbine engine at a lower range of temperatures. Ensuring the acceptability of fuel oil and lube oil under low temperature conditions is, however, necessary. Concerning fuel oil, in response to RAI 318-2227 (ML090960768), Question 09.05.04-20, the applicant explained that an electric heater is installed to maintain proper temperature, the fuel oil's high quality, and to maintain the fuel oil above the cloud-point temperature. Concerning a lube oil keep-warm system, the applicant stated that the keep-warm system is not necessary as explained in DCD Tier 2, Section 9.5. The NRC staff has verified that the applicant revised its DCD Tier 2, Section 9.5.4.3 to include a detailed description of the electric heater for the fuel oil system. The staff's evaluation is in Section 9.5 of this report.

The NRC staff has verified that the applicant revised its DCD Tier 2, Section 9.5.4.3 to include a discussion regarding the temperature of the fuel oil, including the process by which the fuel oil's high quality will be maintained. Since the applicant has provided a detailed explanation on the impact of the minimum ambient temperature on the GTG being the most affected component, the fuel oil system, and the countermeasures to maintain proper temperature of the fuel oil, the NRC staff considers RAI 394-3048, Question 08.03.01-37 closed and the issue resolved.

In RAI 818-5872 (ML112430460), Question 08.03.01-42, the staff asked the applicant to clarify an inconsistency that surfaced during the ACRS Subcommittee Meeting on April 22, 2011, where MHI discussed the test sequence for the GTG qualification, and affirmed that the qualification testing was stopped every 50 starts to perform maintenance on the injectors, and that maintenance restart was not part of the qualification testing. This particular maintenance activity was not outlined in the Qualification Plan Technical Report, MUAP-07024-P(R2) (ML103120097), or the Technical Specifications pertaining to the GTG, therefore, the staff asked the applicant to explain whether or not this maintenance activity is recommended by the manufacturer, or to provide the technical basis to support such activity. Also, the NRC staff asked the applicant to provide the GTG test log for all tests performed during the qualification testing including all stops and maintenance activities performed during the length of each test. The applicant was also requested to provide DCD markups in order to document the information in all relevant sections. In its response dated October 7, 2011, the applicant provided the Qualification Testing Log for the Gas Turbine Generator (GTG) qualification. The log provided in the response indicated the performance of maintenance activities (Fuel Nozzle Cleaning) consisted of removing, cleaning, and re-installing the fuel nozzle in each of the two combustion chambers. However, the applicant did not provide information to support that the scheduled maintenance activity conducted was part of the test procedures because this information was not provided in the submitted technical reports, MUAP-07024-P (R2), MUAP-10023-P (R3), "Initial Type Test Result of Class 1E GTG System" (ML112710206), and Technical Specifications. Also, the applicant did not provide the parameters monitored during the qualification testing, a detailed plan related to the maintenance procedures defined prior to conducting the start and load acceptance tests, and documentation of the fuel nozzle cleaning as a maintenance activity in the US-APWR DCD in all appropriate sections where GTG qualification is discussed, as well as in the Qualification Plan Technical Report, MUAP-07024-P. The NRC staff asked follow-up RAI 876-6210, Question 08.03.01-43, related to the fuel nozzle cleaning maintenance activity for the proposed Class 1E GTGs, and follow-up RAI 962-6578, Question 08.03.01-46 to request a technical specification surveillance requirement addressing the testing frequency required for the fuel nozzle cleaning maintenance activity.

In RAI 876-6210 (ML113410220), Question 08.03.01-43, the staff asked the applicant to provide information to support that the scheduled maintenance activity conducted, the fuel nozzle cleaning, was part of the test procedures. The staff also asked the applicant to provide the parameters monitored during the qualification testing, a detailed plan related to the maintenance procedures defined prior to conducting the start and load acceptance tests, and documentation of the fuel nozzle cleaning as a maintenance activity in the US-APWR DCD in all appropriate sections where GTG qualification is discussed. Further, the staff requested that this information be reflected in the technical specifications, ITAAC, and related technical reports. In its response dated July 19, 2012, the applicant clarified that the fuel nozzle cleaning maintenance procedure was documented in the engine manufacturer's procedures and that they existed prior to the test. The applicant also confirmed that an engine manufacturer's representative was present to support the test and perform the manufacturer's recommended maintenance and inspections. The applicant's response also provided markups of various documents. The DCD, Tier 2, Chapter 8, Section 8.3.1.1.3.9 was revised to document fuel nozzle cleaning as a maintenance activity. MUAP-07024-P was revised to include a summary of the fuel nozzle cleaning procedure. MUAP-10023-P was revised to include the fuel nozzle maintenance under Appendix K of the report, and the factory test procedure for the Emergency GTG, and the parameters monitored during the qualification testing were included under Appendix D of the report. The NRC staff has verified that the revisions provided via markups have been implemented in the latest version of the documents as referenced above. The applicant's response to RAI 962-6578, Question 08.03.01-46 (ML12275A047) provided Technical Specification Surveillance Requirement (SR) 3.8.1.20 to document cleaning of the fuel nozzles for each Class 1E gas turbine generator once per 50 GTG starts.

Because the applicant revised its DCD and Technical Reports MUAP 07024-P, and MUAP-10023-P, to document the fuel nozzle cleaning maintenance activity which was performed as part of the qualification of the GTGs, and Technical Specification Surveillance Requirement (SR) 3.8.1.20 as discussed above, the applicant has demonstrated that it conforms to the guidance in RG 1.9, IEEE Standard 387-1995, Section 6.1, related to the documentation of a written plan that defines analysis and tests to be performed, parameters to be monitored during tests, test instrumentation, and acceptance criteria for equipment, and Section 6.2.2, Item e.2, related to documentation of maintenance procedures during testing. Therefore, the NRC staff considers RAI 876-6210, Question 08.03.1-43, and RAI 962-6578, Question 08.03.01-46 closed, and this issue resolved.

For the reasons set forth above, the NRC staff finds that the US-APWR onsite power systems conform to RG 1.9 in regard to the design and testing recommendations of RG 1.9 for the onsite power supply since it provided sufficient information regarding the design, qualification, and periodic testing of GTGs.

8.3.1.4.4.3 Conformance with RG 1.32

DCD Tier 2, Section 8.3.1.2.2 states conformance with RG 1.32, "Criteria for Power Systems for Nuclear Power Plants." The NRC staff has reviewed design criteria and design features for the US-APWR onsite ac power system to determine if it will perform its safety functions under the conditions produced by a postulated DBE and whether methods for tests and surveillance of the safety-related power systems are adequate to verify this capability during the operational life of the plant. The NRC staff has also reviewed electrical and physical separation of redundant power sources and distribution systems, initial plant startup test programs, electrical independence, and analyses described in the DCD.

The NRC staff determined that the description in DCD Tier 2, Section 8.3.1.1.2.6, on the testing of the onsite ac power system was incomplete because it did not address the design's compliance with GDC 18, nor did it demonstrate conformance to the RGs that describe acceptable methods to test the onsite ac power system or provide an alternative method to show adequate testing of the ac onsite power system. In RAI 10-453, Question 08.03.1-15, the NRC staff asked the applicant to address specifically how it meets the guidance of RG 1.32, RG 1.47, RG 1.118 and RG 1.153 on testing of the onsite electrical power system and equipment in order to satisfy GDC 18.

In a letter dated July 8, 2008, the applicant stated that it will add the description in Section 8.3.1.1.2.6 of the DCD that states that testing of the onsite ac power system is determined in accordance with the requirements in IEEE Std. 603 and the detailed guidance of IEEE Std. 308 and IEEE Std. 338, which are endorsed in RG 1.32, RG 1.47, RG 1.118, and RG 1.153. The applicant also revised the description in the DCD to include detailed requirements described in the above-referenced regulatory guidance. The staff verified that DCD Section 8.3.1.1.2.6 now includes all provisions of the guidance applicable to GTG testing. Because the applicant revised its DCD Section 8.3.1.1.2.6 to comply with IEEE Std. 603 and conform to the guidance in IEEE Std. 308 and IEEE Std. 338, which the NRC endorsed in RG 1.32, RG 1.47, RG 1.118, and RG 1.153, this represents an acceptable method to comply with the requirements of GDC 18, therefore, the NRC staff considers RAI 10-453, Question 08.03.1-15 closed, and this issue resolved.

The NRC staff determined that the onsite ac power system has been designed in accordance with IEEE Std 308-2001, "IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations," as endorsed by RG 1.32, with an exception that pertains to sharing of dc power systems at multi-unit nuclear power plants. Because the US-APWR is designed to operate as a single-unit plant with no shared safety systems even when multiple units are planned for the same site, the foregoing exception in RG 1.32 is not applicable to the US-APWR. Accordingly, the US-APWR ac power system design, operation and testing fully conform to the regulatory guidance in RG 1.32.

8.3.1.4.4.4 Conformance with RG 1.53

DCD Tier 2, Section 8.3.1.2.2, states that the onsite ac power systems have been designed to conform with RG 1.53, "Application of the Single-Failure Criterion to Safety Systems," which endorses IEEE Std. 379-2000, "Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems."

To demonstrate the capability of the onsite ac distribution system in the presence of a single failure, the applicant has stated in DCD Tier 2, Section 8.3.1.1.2.2, that the Class 1E ac power system is comprised of four trains of completely independent systems, each with its own Class 1E GTG and power distribution equipment. The components and equipment of each train are electrically isolated and located in separate rooms in a seismic Category I building with a minimum three hour-rated fire barrier between rooms. The HVAC systems that support operation of the Class 1E ac power system are powered from the redundant train Class 1E ac power system. Hence, according to the applicant, any postulated DBE may render no more than one train of the Class 1E ac power system inoperable.

In its review, the NRC staff determined that both the safety-related GTGs and the GTGs that are not safety-related were of the same manufacture and design. Since there is no diversity in design among safety-related GTGs and GTGs that are not safety-related, the NRC staff questioned the impact of the lack of diversity between GTGs on common cause failure. In RAI 5-272, Question 08.03.01-6, the NRC staff asked the applicant to provide a more detailed description of the design features that would limit the potential for common cause failure in the safety-related and GTGs that are not safety-related, since they are of the same manufacture and design. Also, the applicant was asked to discuss whether the 4000kW GTG is sized to power one safety division and one division of permanent loads that are not safety-related during worst-case shutdown (to cold shutdown), and whether the 4000kW GTG has the capability to power these loads with some margin for load growth when operating within its continuous rating.

In its response (ML081620088), the applicant limited the difference between the safety-related and the GTGs that are not safety-related to different components and starting methods, and did not provide sufficient information to resolve the NRC staff's question regarding limiting the potential for common cause failure. The NRC staff considered this response inadequate because the difference in components does not provide the adequate degree of diversity that would minimize the potential for common cause failure.

As a follow-up, the NRC staff asked RAI 394-3048, Question 08.03.01-38. In RAI 394-3048, Question 08.03.01-38, the NRC staff requested additional information on the diversity between the Class 1E GTGs and the non-Class 1E AAC GTGs in view of the guidance given in SECY papers and SRP review guidance. By the subject RAI, the NRC staff asked the applicant to address SECY-90-16, "Evolutionary Light Water Reactor (LWR) Certification Issues and Their Relationships to Current Regulatory requirements." In SECY-90-16, the NRC staff recommended that all evolutionary advanced light water reactors (ALWRs) have an AAC power source of diverse design capable of powering at least one set of normal shutdown loads. Also, RG 1.206 provides guidance on meeting 10 CFR 50.63 (SBO Rule) for evolutionary designs. Similarly to SECY-90-16, it calls for the installation of an AAC power source of diverse design with sufficient capacity, capability, and reliability that will be available on a timely basis for powering at least one complete set of normal safe shutdown loads to bring the plant to safe shutdown. In SECY-91-078, Item 5.2.3, "Power Rating of the Combustion Turbine Generators," the NRC staff concluded that, as a minimum, a GTG used for this purpose should be capable of powering one safety division and one division of permanent loads that are not safety-related during worst-case shutdown (to cold shutdown) and that it should have capability to power these loads with some margin for load growth when operating within its continuous rating. In the US-APWR design, the 4000 kW rated GTGs proposed for meeting 10 CFR 50.63 are of the same design and manufacture as the Class 1E onsite GTG power sources. The applicant stated in DCD Section 8.3.1.1.1 that AAC GTGs and Class 1E GTGs are diverse because AAC GTGs are started by dc supplied from batteries whereas the Class 1E GTGs are started by a compressed air system. In view of the guidance given in the SECY-90-16, SECY-91-078, and Chapter 8.4 of the SRP, the NRC staff concluded that this information did not demonstrate that the Class 1E GTGs and AAC GTGs proposed for the US-APWR design are diverse.

In response to RAI 394-3048, Question 08.03.01-38 (ML113332A121), the applicant acknowledged two acceptable approaches to achieve diversity between the Class 1E GTGs and the non-Class 1E AAC GTGs: (1) An AAC GTG is diverse if its manufacturer differs from that of the Class 1E GTG, (2) If the same manufacturer is utilized, the applicant needs to provide verification that the probability of common cause failure is minimized by analysis. MHI indicated that it understood that using a different AAC GTG manufacturer from the Class 1E GTG manufacturer would ensure diversity between these two GTGs. Therefore, if the applicant elected to use safety-related GTGs and GTGs that are not safety-related from the same manufacturer, the applicant would have been needed to submit an evaluation report to provide analysis to show that the probability of common cause failure is minimized. During a public meeting that took place on August 6, 2009 (ML092570575), the applicant indicated that it would use different GTG manufacturers to ensure diversity. The NRC staff verified that DCD Section 8.3.1.2.2 has been revised to clarify that the US-APWR's safety-related GTGs and GTGs that are not safety-related will be acquired from different manufacturers. Because the applicant revised its DCD to demonstrate diversity between the safety-related GTGs and the GTGs that are not safety-related, the application therefore conforms to the guidance given in SECY-90-16, SECY-91-078, and Chapter 8.4 of the SRP. Therefore, the NRC staff considers RAI 394-3048, Question 08.03.01-38, closed, and this issue resolved.

The applicant has committed to choose different manufacturers for the safety-related GTGs and that GTGs that are not safety-related, thus providing design diversity for the GTGs. Accordingly, the NRC staff finds that the US-APWR design conforms to RG 1.53, and also finds that the applicant's safety-related systems have the necessary electrical power to perform their safety-related functions with the presence of a single failure.

8.3.1.4.4.5 Conformance with RG 1.63

DCD Tier 2, Section 8.3.1.2.2 states that RG 1.63 endorses IEEE Std. 317, and conformance to RG 1.63 is discussed in Subsection 8.3.1.2.1. The applicant indicated the following in DCD Tier-2, Section 8.3.1.2.1:

> The cables of the ac circuits that feed ac loads inside the containment vessel go through electric penetration assemblies. The design, construction, testing, qualification and installation of electric penetration assemblies used for Class 1E and non-Class 1E ac circuits conform to the requirements of IEEE Std. 317. The electrical penetration assemblies are qualified in accordance with and IEEE Std 323 and IEEE Std. 317 for the worst temperature and pressure condition resulting from any LOCA without exceeding the design leakage rate. The protection system design of the electric penetration assemblies conforms to the applicable criteria of IEEE Std. 741 and RG 1.63. All electrical penetrations are protected with both primary and back up protection.

Because the electric penetration assemblies conform to the guidance in IEEE Std. 317 on electric penetration assemblies, the NRC staff finds that the US-APWR onsite ac power systems conform to RG 1.63 in regard to the design, construction, testing, qualification and installation of electric penetration assemblies used for Class 1E and non-Class 1E ac circuits.

8.3.1.4.4.6 Conformance with RG 1.75

DCD Tier 2, Section 8.3.1.2.2 states conformance with RG 1.75. The NRC staff has reviewed the isolation and separation of the non-Class 1E components from the Class 1E system. The isolation and separation measures prevent degradation of the Class 1E system to an unacceptable level in accordance with RG 1.75, which endorses IEEE Std. 384-1992, "Criteria for Independence of Class 1E Equipment and Circuits," and RG 1.32, which endorses IEEE Std. 308-2001, for circuit breakers or fuses that are automatically opened by fault current. The NRC staff has also reviewed the isolation and separation of the non-Class 1E components from the Class 1E system in accordance with RG 1.32.

The Class 1E power systems have four independent, redundant trains (Trains A, B, C, and D). The Class 1E 6.9 kV switchgear, 480V Load Centers, 480V MCCs, MOV inverters, and 480V MOV MCCs of each redundant train are located in separate electrical rooms in the R/B. All Class 1E uninterruptible power supply (UPS) units and other electrical distribution equipment of redundant I&C power systems are also located in separate rooms in the R/B. Since only two trains are sufficient to mitigate a DBE condition, the Class 1E power systems meet the single failure criterion with one train out of service for maintenance. During maintenance of the Class 1E GTG that powers the A train, the A train is powered from train B sources. During maintenance of the Class 1E GTG that powers the B train, the B train is powered from train A power sources. During maintenance of either the A or B train GTG, for analysis purposes, the A and B trains are considered as one train, completely independent from trains C and D. During maintenance of any one train, availability of any two of these three trains is sufficient to mitigate any DBE condition.

Similarly, during maintenance of the Class 1E GTG for the D train, the D train is powered from train C sources. During maintenance of the Class 1E GTG for the C train, the C train is powered from train D power sources. During maintenance of either the D or C train GTG, for analysis purposes, the D and C trains are considered as one train, completely independent from trains A and B. During maintenance of any one train, availability of any two of these three trains is sufficient to mitigate any DBE condition.

The applicant indicated the following in DCD Tier 2 Section 8.3.1.2.2:

> Only one GTG is permitted to be out of service for maintenance during all modes of plant operation, except the refueling mode. When all four trains are available, operability of least one train of trains A or D, in conjunction with one of the three remaining trains, is required to mitigate a DBE condition.

The applicant stated that trains A or D in conjunction with one of the three remaining trains is required to mitigate a DBE condition, and the staff interprets this to mean that trains B and C together are not sufficient to mitigate a DBE condition. This clarification on the capability of trains B and C is **Confirmatory Item 08.03.01-01.** The confirmatory item is not material to the isolation or separation of the four trains, and, based on the foregoing, the staff finds that the applicant's safety-related onsite ac power systems have independence to perform their safety-related function. The electrical isolation and physical separation of all Class 1E equipment and circuits between redundant trains, and between each train and non-Class 1E equipment and circuits, conforms with the guidance in RG 1.75.

8.3.1.4.4.7 Conformance with RG 1.153

RG 1.153, "Criteria for Safety Systems," addresses the need for functional and design independence and separation measures for onsite ac power system distribution for nuclear power plants. DCD Tier 2, Section 8.3.1.2.2, states conformance with RG 1.153. RG 1.153 provides supplemental guidance for implementing IEEE Std. 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," to satisfy the NRC regulatory requirements.

The NRC staff has reviewed the applicant's onsite ac electrical distribution safety-related configuration and its functions to determine whether the ac safety-related system is in accordance with IEEE Std. 603-1991 for safety-related system independence. The IEEE standard addresses independence between redundant portions of a safety system and effects of a DBE.

DCD Tier 2, Section 8.3.1.1.2.3, states the following: The components of the redundant Class 1E ac systems are independent, physically separated, and electrically isolated. Each of the major Class 1E distribution equipment of trains A, B, C and D is physically separated in a different room. Redundant safe shutdown components and associated redundant Class 1E electrical trains are separated from the other Class 1E and non-Class 1E systems by three-hour rated fire barriers to preserve the capability to safely shut down the plant following a fire. The staff finds that the arrangement of redundant Class 1E power systems ensures that a single failure in one train will have no impact on the availability of the remaining three trains to perform the credited safety function. For any DBE, only two trains are sufficient for safe shutdown of the plant.

In reviewing the criteria for safety systems for the onsite ac power systems, the NRC staff noticed that the starting air provisions for the GTGs were different from those typically used for emergency diesel generators. In RAI 5-272, Question 08.03.01-1, the NRC staff asked the applicant to discuss the safety significance and provide bases to explain why three air-start attempts are adequate for the GTG, when SRP Section 9.5.6 calls for five air-start attempts for emergency diesel generators. In its response dated June 6, 2008, the applicant stated that in regard to starting air requirements for the Class 1E GTGs, any two out of four GTGs (any two-50 percent divisions) can power equipment necessary for safe shut down. However, the applicant failed to explain how safe shutdown would be accomplished with any two trains for all systems. Accordingly, in RAI 394-3048, Question 08.03.1-34, the NRC staff asked a follow up RAI to the original RAI 5-272, Question 08.03.01-1. Specifically, the NRC staff asked the applicant to verify that there is similar redundancy in the mechanical and fluid systems as exists in the electrical system for shutting the plant down with any two out of four divisions of safety equipment. RAI 394-3048, Question 08.03.01-34 also asked the applicant to revise its DCD to include additional language to Section 8.3.1 to explain how safe shutdown will be accomplished with any two trains for all systems (mechanical and fluid) based on the four-train system.

The applicant responded to RAI 394-3048, Question 08.03.01-34 (ML092100293), explaining that there are four-train safety systems and two-train safety systems, as described in DCD Subsection 8.3.1.1.2.1. Four-train safety systems include the ECCS, Containment Heat Removal System (CHRS), Emergency Water System (EWS), and Component Cooling Water

System (CCWS) as major examples. Each of these systems consist of four 50 percent trains. Assuming that one 50 percent train is out of service for maintenance at the same time that there is a single failure in another train, the two remaining trains are designed to perform the safety function of shutting the plant down. The above descriptions for the ECCS, CHRS, EWS and CCWS systems are in DCD Subsection 6.3.1.5, 6.2.2.14, 9.2.1.3 and 9.2.2.1.1. The NRC staff confirmed that two trains of a four-train safety system are sufficient to shut down the plant, and verified that the applicant incorporated this response to the DCD under Section 8.3.1.1.2.1. Therefore RAI 5-272, Question 08.03.01-1, and RAI 394-3048, Question 08.03.1-34, are considered closed, and the issues they raised are resolved.

In addition, the staff determined that the onsite ac power electrical distribution equipment (switchgear, load centers, MCCs, transformers, breakers) has functional and design independence and separation measures. Accordingly, the NRC staff finds that the US-APWR onsite ac electrical distribution system design conforms to the independence and separation guidance of RG 1.153.

8.3.1.4.4.8 Conformance with RG 1.155

DCD Tier 2, Section 8.3.1.2.2 states conformance with RG 1.155, “Station Blackout.” The US-APWR DCD did not clearly describe which loads are powered by the buses that are not safety-related, P1 and P2, during an SBO. Therefore, the NRC staff asked the applicant in RAI 10-453, Question 08.03.01-13 to clarify the loads credited on P1 and P2 buses during an SBO. Also, the NRC staff asked the applicant to discuss what administrative controls and procedures the applicant plans to put in place to minimize the probability of overloading the AAC GTG during an SBO event. In its response to RAI 10-453, Question 08.03.01-13 (ML082040271), the applicant stated that the only loads retained on the P1 and P2 buses during an SBO total 200 kW respectively, and all other load supply breakers are manually locked open. However, the applicant did not commit to revising the DCD to reflect the above-stated clarification. Accordingly, in RAI 386-2859, Question 08.03.1-26, the NRC staff asked a follow up RAI to RAI 10-453, Question 08.03.01-13. Specifically, RAI 386-2859, Question 08.03.1-26 asked the applicant to revise its DCD to include additional information to show what P1 or P2 loads are not credited during an SBO and to discuss the administrative controls and procedures for shedding and locking these loads out.

In the response to RAI 386-2859, Question 08.031-26, dated July 22, 2009 (ML092090058), the applicant explained that it would modify the design to state that the AAC can supply power to a Class 1E bus without supplying power to the permanent bus in the SBO condition. The applicant stated that by not supplying power to the loads that are not credited under an SBO, the AAC GTGs have additional capacity margin, and are capable of supplying sufficient power to bring and maintain the plant in a safe shutdown condition during an SBO. Therefore, the applicant concluded that during an SBO, the probability of overloading the AAC is minimized by separating the permanent bus from the AAC. The applicant revised the DCD to show minimum required non-safety loads, which are supporting equipment of the AAC source during an SBO. DCD Tier 2, Table 8.3.1-6 was revised accordingly. The NRC determined that separating the AAC from the permanent bus would assure the AAC has adequate capacity to supply power to loads necessary to achieve and maintain safe shutdown in the event of an SBO. The staff also verified that the above information has been included in the DCD, therefore RAI 10-453, Question 08.03.01-13 and RAI 386-2859, Question 08.03.1-26 are closed, and the issues are resolved.

Further details on the conformance of the applicant's onsite ac power system with RG 1.155 and its conformance to SECY-90-016 are discussed in Section 8.4 of this SER.

8.3.1.4.4.9 Conformance with RG 1.204

The applicant has stated in DCD Tier 2, Section 8.3.1.2.2, that its onsite power supply design fully conforms to RG 1.204, "Guidelines for Lightning Protection of Nuclear Power Plants," which endorses IEEE Std. 665-1995, (Reaffirmed 2001), "IEEE Guide for Generating Station Grounding"; IEEE Std. 666-1991 (Reaffirmed 1996), "IEEE Design Guide for Electric Power Service Systems for Generating Stations"; IEEE Std. 1050-1996, "IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations"; and IEEE Std. C62.23-1995 (Reaffirmed 2001), "IEEE Application Guide for Surge Protection of Electric Generating Plants." Also, the applicant stated that coordination studies on the onsite electrical system protection features will be performed to limit the extent and duration of the interruption in power supply whenever a circuit fault occurs on any portion of the onsite ac power system, and to minimize damage to the system components involved in the fault, including faults caused by lightning strikes. The studies are to be performed in accordance with IEEE Std. 242, "IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems." IEEE Std. 242 is widely used by the industry and is recognized as an electrical engineering reference book, and is acceptable to the staff for the purpose of the coordination studies described in the application.

The NRC staff reviewed the grounding and lightning protection system, which consists of the station ground grid, system neutral grounding, equipment grounding, I&C grounding, and lightning protection. The applicant stated that: (1) the station ground grid consists of buried, interconnected bare copper conductors and ground rods forming a plant ground grid matrix that maintains a uniform ground potential and limits the step-and-touch potentials to safe values under all fault conditions, (2) the system neutral grounding provides grounding of the neutral points of the MG, Class 1E GTGs, and AAC GTGs through grounding transformers that provide high resistance grounding, the MT and station service transformer (SST) low voltage neutrals are solidly grounded, and the UAT and RAT low voltage winding neutrals will be resistance grounded, (3) the equipment grounding provides bonding of the equipment enclosures, raceways, metal structures, metallic tanks and ground bus of switchgears, load centers, MCCs, switchboards, panelboards, and control cabinets to the station ground grid, (4) the I&C grounding provides the isolated signal ground required by plant I&C systems, and a separate radial grounding system consisting of isolated instrumentation ground buses and insulated cables is provided, and (5) the lightning protection for the plant is accomplished by providing a low-impedance path by which a lightning strike discharge can enter the earth directly.

The applicant further described the lightning protection system as follows. The system consists of air terminals, interconnecting cables, and downcomers to ground. The system is connected directly to the station ground to facilitate dissipation of the large current of a lightning strike. The lightning arresters are connected directly to the ground in order to provide a low-impedance path to the ground for the surges caused or induced by lightning. Surge arrestors are provided to protect the MT, UATs, RATs, isolated phase bus duct, and the MV switchgear from lightning surges. Thus, the applicant concluded that fire or damage to the plant from a lightning strike is avoided. The applicant provided COL Information Item 8.3(2) which requires COL applicants to provide information regarding ground grid and lightning protection. The staff finds that the grounding and lightning protection system adequate, considering the above design features. The NRC staff finds the COL information item acceptable because it requires the COL applicant to provide information addressing the details of such protection as recommended in RG 1.204. However, the applicant failed to identify whether the applicant or the COL applicant would be responsible to perform the coordination studies that provide assurance that the ground grid and lightning protection provided were properly selected and coordinated to mitigate the impact of the lightning strike to the plant.

Circuit coordination studies consider whether protective devices activate under faulted conditions so as to prevent or minimize damage to insulation of electrical components. Achieving insulation coordination depends on site-specific parameters such as as-procured operating characteristics of transformers and surge arresters. The applicant stated that coordination studies will be performed to provide for proper insulation levels, but failed to clearly identify in the DCD whether the DC applicant or the COL applicant will perform the circuit protective devices and a coordination study. In RAI 10-453, Question 08.03.01-20, the NRC staff requested additional information on circuit protective devices and a coordination study to show that distribution equipment, including containment penetration assemblies are protected adequately. In its response to RAI 10-453, Question 08.03.01-20 (ML082040271), the applicant stated that the detailed protection and coordination of devices will not be done until the procurement of such equipment. The RAI response was inadequate because it failed to identify whether the applicant or the COL applicant would be responsible for performing the protective devices and coordination studies. Accordingly, in RAI 386-2859, Question 08.03.01-32, the NRC staff asked a follow up RAI to the original RAI 10-453, Question 08.03.01-20. RAI 386-2859, Question 08.03.1-32 asked the applicant to revise its DCD to clearly identify in the DCD whether the DC or the COL applicant will perform this analysis.

In its response to RAI 386-2859, Question 08.03.1-32 (ML092090058), the applicant indicated that protective relay settings and selection of molded case circuit breakers (MCCBs) depend on features of each device. Therefore, a coordination study will be addressed by the COL applicant. The applicant committed to revise the COL information items in the DCD to include this information. The NRC staff has verified that the applicant included COL Information Item COL 8.3(10), "The COL applicant is to provide protective devices coordination," in Subsection 8.3.4 of the DCD. Since the applicant clearly identified who is responsible of performing the circuit protective devices and a coordination study and the DCD was revised accordingly, this issue is resolved. RAI 10-453, Question 08.03.01-20, and RAI 386-2859, Question 08.03.01-32 are considered closed.

Accordingly, the NRC staff finds that the US-APWR onsite ac electrical distribution system design's onsite ac grounding and lightning protection system conforms to the guidance of RG 1.204 since these design features protect the transformers against the effects of lightning. Because achieving insulation coordination depends on site-specific parameters such as transformers, and the operating characteristics of surge arresters, the NRC staff also finds it is acceptable that MHI specified that the COL applicant will perform the coordination analyses under Item 2.6.7 in DCD Tier 1, Table 2.5.7-1, "Grounding and Lightning Protection System Inspections, Tests, Analyses, and Acceptance Criteria."

8.3.1.4.4.10 Conformance with NUREG/CR-0660

DCD Tier 2, Section 8.3.1.2.1, states that the GTG design is in conformance with NUREG/CR-0660. The NRC staff reviewed whether the GTG meets the recommendations of RG 1.9 and that of NUREG/CR-0660, "Enhancement of Onsite Emergency Diesel Generator Reliability," February 1979. NUREG/CR-0660 recommends that EDG systems include the following design features: (1) starting system air dryer (as described in Section 9.5.6.2.1.6), (2) continuous lube oil system with a set temperature when in standby (as described in Section 9.5.7.1), and (3) local instrument panels in the diesel rooms at the engine are isolated from engine vibration.

Since the US-APWR design includes all the above features, the NRC staff finds that the GTG for the US-APWR design is in conformance with the recommendations of NUREG/CR-0660.

8.3.1.4.5 Compliance with GDC 18

GDC 18 requires that electric power systems important to safety, which include the onsite ac power system, be designed to permit appropriate periodic inspection and testing of important areas and features to assess the continuity of the systems and the condition of their components. These systems shall be designed with a capability to test periodically: (1) the operability and functional performance of the components of the systems, such as onsite power sources, relays, switches, and buses, and (2) the operability of the systems as a whole and under conditions as close to design as practical.

The applicant stated in DCD Tier 2, Section 8.3.1.1.2.1, the following: Four-train safety system loads are distributed on the four redundant Class 1E trains A, B, C, and D. Four-train safety system loads (e.g., safety injection pumps, containment spray (CS)/residual heat removal (RHR) pump, essential service water (ESW) pump, component cooling water (CCW) pump) are designed to perform their function with any two out of four redundant Class 1E trains. Therefore, the US-APWR design allows testing of one train in a division without affecting safety-related functions because the remaining trains will be available to provide power for safety system loads.

The US-APWR safety-related ac power system has been designed to permit periodic inspection and testing of key areas and features in order to assess system continuity and availability, and verify the condition of system components. The ac power systems are designed to provide the capability to perform integral periodic testing of Class 1E systems. The TS will include testing requirements at least once every 24 months after the plant is in operation. Tests may be performed during any mode of plant operation, as required by TS. Such tests include a test for maximum expected load-carrying capability for 24 hours; a functional capability test at full load temperature conditions (this verifies that the Class 1E GTG starts upon receipt of a manual or auto-start signal); tests of the loss of the largest single load and of complete loss of load; and a test to verify that an ECCS signal overrides the test mode.

The NRC staff has evaluated whether the onsite ac power system provides the capability to perform integral testing of Class 1E systems on a periodic basis. The NRC concludes that the applicant has established the onsite ac power system's compliance with GDC 18 by demonstrating that the onsite ac power systems have been designed with a capability to test periodically in order to assess the continuity of the systems and the condition of their components and by conforming to the applicable guidance of RGs 1.47 and 1.118. The NRC staff evaluation of whether the US-APWR onsite ac system design conforms to the applicable guidance set forth in RGs 1.47 and 1.118 follows.

8.3.1.4.5.1 Conformance with RG 1.47

DCD Tier 2, Section 8.3.1.2.2 states that the design is in conformance with RG 1.47, "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems." Current design of protection systems and ESF systems are such that certain safety-related functions of a nuclear power plant may be bypassed or made inoperable during the performance of periodic tests or maintenance. RG 1.47 describes an acceptable method of complying with the requirements to indicate the inoperable or bypassed status of Class 1E systems or portions of such systems. The applicant's DCD states that indication of a bypassed component is automatically annunciated in the MCR to indicate the system or component condition. Since the ac onsite power system is available to power the protection system and its auxiliary or supporting safety-related systems, and two Class 1E power sources provide power to the protection and safety monitoring system (PSMS) for I&C equipment status, the plant operator can identify systems actuated or controlled by the protection system in accordance with RG 1.47. DCD Tier 2, Section 7.5.1.2.1, "Design of Bypassed and Inoperable Status Indication," provides information on testability of bypassed or inoperable status indicators that are displayed. The NRC staff's evaluation of this information is in SER Section 7.5. As indicated in SER Section 7.5, the information in DCD Tier 2, Section 7.5.1.2.1 is acceptable.

8.3.1.4.5.2 Conformance with RG 1.118

DCD Tier 2, Section 8.3.1.2.2 states that the design is in conformance with RG 1.118. RG 1.118 provides guidance on the capability for periodic surveillance testing and calibration of safety-related equipment to be provided while retaining the capability of the safety-related systems to accomplish their safety-related functions in accordance with IEEE Std. 338-1987, "Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems." Chapter 16 of the DCD sets forth TS that would require testing and calibration of safety-related system equipment at the US-APWR during power operation. This testing duplicates, as close as practical, the demonstration that safety-related equipment can perform its specified functions.

In its review, the NRC staff noted a lack of information regarding a program to monitor and mitigate the degradation of inaccessible cables in accordance with the guidance of Generic Letter (GL) 2007-01, "Inaccessible or Underground Power Cable Failures That Disable Accident Mitigation Systems or Cause Plant Transients." In RAI 10-453, Question 08.03.01-21, the NRC staff asked the applicant to include in its discussion on medium voltage cables how the US-APWR design incorporates a program to monitor and mitigate the degradation of inaccessible cables in accordance with the guidance of GL 2007-01. Since it will be necessary to address this issue over the life of the plant in accordance with the guidance of GL 2007-01, the NRC staff also asked the applicant to include in the DCD a COL Action Item identifying the responsibility of the COL applicant to propose a program to monitor and mitigate the degradation of inaccessible cables in accordance with the guidance of GL 2007-01.

In its response to RAI 10-453, Question 08.03.01-21 (ML11318A011), the applicant committed to add the following language in the US-APWR DCD:

> In accordance with the guidance of Generic Letter 2007-01, for preventing the degradation of medium voltage cables that are installed in underground duct banks, the manholes are at the low point with the conduits in the connecting duct banks sloped for water drain into the manholes. The manholes are available for temporary sump pumps for water draining. The medium voltage cables whether in a duct bank or in a conduit are monitored by periodic testing, such as partial discharge testing, time domain reflectometry, dissipation factor testing, and very low frequency AC testing.

The method the applicant proposes to prevent degradation of underground MV cables is acceptable because it provides assurance that the MV cables will be monitored and tested periodically and provides a mitigation mechanism to prevent the degradation of inaccessible cables in accordance with the guidance of GL 2007-01. The applicant has provided an acceptable method to prevent degradation of underground MV cables, and the NRC staff has verified that the text stated above was added to the DCD in Section 8.2.1.2. The NRC staff has also verified that a COL information item identifying the responsibility of the COL applicant to propose a program to monitor and mitigate the degradation of inaccessible cables in accordance with the guidance of GL 2007-01 has been added to the DCD, Tier 2, Section 8.3.4 as COL 8.3(12). Accordingly, the issue related to the COL information item is resolved, and RAI 10-453, Question 08.03.01-21 is closed.

Based on the foregoing, the NRC staff finds that the US-APWR design conforms to the positions of RG 1.118. Therefore, the NRC staff finds that the US-APWR onsite ac power system is designed to be testable during operation of the nuclear power generating station, as well as during those intervals when the station is shut down.

8.3.1.4.6 Compliance with GDC 50

GDC 50 requires, in part, that the design of containment penetrations, including electrical penetrations containing circuits of the ac power system in containment structures, must withstand a LOCA without loss of mechanical integrity. In order to satisfy this requirement, the penetration assemblies in the containment structures must be capable to withstand all ranges of overload and short circuit currents up to the maximum fault current-versus-time conditions that could occur given a single random failure of a circuit protective device.

The applicant indicated the following in DCD Tier 2, Section 8.3.1.2.1: The design, construction, testing, qualification, and installation of electric penetration assemblies used for Class 1E and non-Class 1E ac circuits conform to the provisions of IEEE Std. 317. The electrical penetration assemblies are qualified in accordance with IEEE Std. 323 and IEEE Std. 317 for the worst temperature and pressure condition resulting from any LOCA. The protection system design of the electric penetration assemblies conforms to the applicable criteria of IEEE Std. 741 and RG 1.63. All electrical penetrations are protected against faults with both primary and back up protection. Separation between the electrical penetrations of Class 1E trains and the electrical penetrations of non-Class 1E trains complies with IEEE Std. 384, as endorsed by RG 1.75.

Circuits in the containment vessel penetrations are in the same groups as in the raceway voltage groupings. Specifically, modules for MV power (e.g., 6.9 kV) are in MV power penetrations; modules for low voltage power (e.g., 480 V) are in low voltage power penetrations; modules for control power (e.g., 120/125V) are in control power penetrations and modules for instrumentation signals are in instrumentation penetrations. Electric penetrations of different Class 1E trains are separated by three hour rated fire barriers and separate rooms and or locations on separate floor levels in the reactor building. Separation by distance without barriers is allowed only inside the containment vessel. The penetrations are protected in accordance with IEEE Std. 741.

In view of the above, the NRC staff finds that the design of the applicant's containment electrical penetrations will satisfy the requirement of GDC 50 to withstand a LOCA without loss of mechanical integrity because the design includes appropriate external circuit protection against faults and are qualified in accordance with IEEE Std. 323 and IEEE Std. 317.

8.3.1.4.7 Compliance with 10 CFR 50.55a(h)

10 CFR 50.55a(h) requires compliance with the relevant positions for plant protection and safety systems for design, reliability, qualification, and testability of the power and I&C portions of safety systems. RG 1.153 provides supplemental guidance for implementing IEEE Std. 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," to satisfy the NRC regulatory requirements.

The applicant states in DCD Tier 2, Section 8.3.1.2.2, that the proposed safety and protection systems of the US-APWR onsite ac power system design conform to RG 1.153, and will be confirmed by the electrical distribution system protection and coordination studies, and construction of these systems will be verified via ITAAC (see DCD Tier 1, Table 2.6.4-1, "Emergency Power Systems ITAAC"). Furthermore, DCD Tier 2, Section 8.3.1.1.2.5 discusses protection mechanisms for the Class 1E AC power system, including protection against undervoltage, loss of voltage, degraded voltage, overcurrent, differential, ground fault, motor overload, and short circuit. Accordingly, the NRC staff finds that the US-APWR onsite ac power system design meets the requirements of 10 CFR 50.55a(h) since the design includes the aforementioned protection. The aspects of IEEE Std. 603 that apply to Instrumentation & Control are evaluated in Chapter 7 of this SER.

8.3.1.4.8 Compliance with 10 CFR 50.63

US-APWR compliance with 10 CFR 50.63 relates to the use of the redundancy and reliability of diesel generator units as a factor in limiting the potential for SBO events. RG 1.9, "Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants," will be used to set the target reliability levels of emergency onsite ac power sources (i.e., GTGs) as a factor in determining the coping duration for an SBO and establishing a reliability program for attaining and maintaining ac source target reliability levels. There is no operating experience for GTGs in the US nuclear fleet, therefore, the applicant should perform type tests that will assure the NRC staff that the GTGs will perform at the target reliability levels set forth in RG 1.9.

In RAI 5-272, Questions 08.03.01-2 and 08.03.01-3, the NRC staff asked the applicant to furnish run reliability data of GTGs that are similar to the GTGs proposed as Class 1E power sources. In this RAI question, the NRC staff also asked the applicant to discuss how the reliability data given in Section 7 of the qualification and test plan of the Class 1E GTG system report complies with the provision calling for 100 starts with no failures in IEEE Std. 387 "IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations," which is endorsed by RG 1.9. In responses to RAI 5-272 Question(s) 08.03.01-2 and 08.03.01-3 (ML081620088), the applicant provided reliability data of commercial-grade GTGs and the component reliability data given in NUREG/CR-6928 for justifying a reliability of 0.995 for the proposed Class 1E GTGs. Based on its review, the NRC staff concluded that the applicant's use of the commercial-grade GTGs reliability data and the NUREG/CR6928 data did not justify a reliability value of 0.995 for the Class 1E GTGs. The NRC staff assessment was based upon the fact that the commercial-grade GTGs reliability data used limited samples and lacked additional failure information on components included in the data, thereby making the results derived from the reliability data inconclusive. The data presented in NUREG/CR-6928 was not applicable to the commercial components to be used in the GTGs. To resolve these issues, the NRC staff asked RAI 394-3048, Question 08.03.1-35, as a follow up RAI to RAI 5-272, Questions 08.03.01-2 and 08.03.01-3. Specifically, the NRC requested the applicant to perform 100 initial type tests without any failures to achieve 0.95 reliability target with 95 percent confidence.

In a letter dated July 23, 2009, submitted in response to RAI 394-3048, Question 08.03.1-35, the applicant reiterated that the 0.95 reliability target with 95 percent confidence is the minimum to establish reliability of an emergency power source. RG 1.155 indicates that a Class 1E EDG should have a reliability of 0.975 with 95 percent confidence or 0.95 with 95 percent confidence. MHI has chosen 0.975 with 95 percent confidence as a reliability target. The staff reviewed Technical Report MUAP-10023-P, which states that to satisfy the starting reliability of 0.975 with 95 percent confidence, as stated in RG 1.155, 150 start tests should be performed with no failure. MHI performed 150 start and load acceptance tests of the GTGs with zero failures. These tests prove that the GTGs satisfy the reliability criterion of 0.975 with 95 percent confidence. The staff verified in Technical Report MUAP-07024-P that a total of 150 starts has been performed for start and load acceptance test. Therefore, the staff finds the applicant's response acceptable, and this issue is resolved.

Based upon the above, the NRC staff finds that the applicant's approach to demonstrating Class 1E GTG reliability is adequate for establishing the SBO coping time in accordance with the requirements of 10 CFR 50.63.

8.3.1.4.9 Compliance with 10 CFR 50.65(a)(4)

Under 10 CFR 50.65(a)(4), COL applicants assess and manage the increase in risk that may result from proposed maintenance activities for onsite ac power equipment before performing the maintenance activities. These activities include surveillances, post maintenance testing, and corrective and preventive maintenance. The US-APWR DCD states that the design is in conformance with RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," and RG 1.182, "Assessing and Managing Risk Before Maintenance Activities at Nuclear Power Plants," which is generically addressed in Section 1.9 of this SER.

DCD Tier 2, Table 1.9.2-8, "US-APWR Conformance with Standard Review Plan Chapter 8 Electrical Power," Item 9, captures the applicant's commitment to comply with the acceptance criteria set forth in 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 the maintenance activities. Also, COL Information Item 17.4(2) assigns the responsibility for the development and implementation of the operational reliability assurance program (O-RAP) including the Maintenance Rule program. COL Information Item 17.4(2) states:

> The COL Applicant shall be responsible for the development and implementation of the O-RAP, in which the RAP activities should be integrated into the existing operational program (i.e., Maintenance Rule, surveillance testing, in-service inspection, in-service testing, and QA). The O-RAP should also include the process for providing corrective actions for design and operational errors that degrade non-safety-related SSCs within the scope of the RAP. A description of the proposed method for developing/integrating the operational RAP into operating plant programs (e.g., maintenance rule, quality assurance) is performed during the COL application phase. The development/integration of the operational RAP is performed during the COL license holder phase and prior to initial fuel loading. All SSCs identified as risk-significant within the scope of the D-RAP should be categorized as high-safety-significant (HSS) within the scope of initial Maintenance Rule. The integration of reliability assurance activities into existing operational programs will also address establishment of:
>
> > 1) Reliability performance goals for risk-significant SSCs consistent with the existing maintenance and quality assurance processes on the basis of information from the design reliability assurance program (D-RAP) (for example, implementation of the maintenance rule following the guidance contained in RG 1.160 is one acceptable method for establishing performance goals provided that SSCs are categorized as HSS within the scope of the Maintenance Rule program), and
> >
> > 2) Performance and condition monitoring requirements to provide reasonable assurance that risk-significant SSCs do not degrade to an unacceptable level during plant operations.

Considering the Maintenance Rule program is used during operation, the staff is confirming that the COL applicant will implement the O-RAP, and this is **Confirmatory Item 08.03.01-2.** Because the description of a Maintenance Rule program is the COL applicant's responsibility and such responsibility is outlined in the DCD as COL Item 17.4(2), the NRC staff finds that the applicant need not further address the provisions of 10 CFR 50.65(a)(4).

8.3.1.4.11 Conformance with BTP 8-1

DCD Tier 2, Section 8.1.5.3.3 states that the design is in conformance with BTP 8-1, "Requirements on Motor-Operated Valves in the Emergency Core Cooling System (ECCS) Accumulator Lines." The NRC staff has reviewed DCD Tier 2, Section 7.1.1.10, which describes features for the PSMS, including the RPS, Engineered Safety Features Actuation System (ESFAS), Safety Logic System (SLS), conventional switches, and safety Virtual Display Units (VDU), and states that these systems are powered from onsite Class 1E Power Sources, which include the GTGs. The SLS provides the component-level control logic for safety actuators (e.g., MOVs, solenoid-operated valves, switchgear). The NRC staff finds that the power supplied by the onsite Class 1E power sources, which include the GTGs, to those safety actuators provides for their indications, alarm features, and control features in conformance with BTP 8-1, as explained in DCD Section 7.6. Evaluation of DCD Tier 2, Section 7.6 is set forth in Chapter 7 of this SER.

8.3.1.4.12 Conformance with BTP 8-2

Although not stated explicitly in BTP 8-2, this provision is applicable to the GTGs of the US-APWR because the purpose of BTP 8-2 was to prohibit the use of the emergency standby/alternate ac power source, of whatever type, for peaking loads. DCD Tier 2, Section 8.1.5.3.3, states that the design is in conformance with the guidelines of BTP 8-2, "Use of Diesel-Generator Sets for Peaking," that are pertinent to a GTG in the US-APWR design. The Class 1E GTGs provide backup power to the Class 1E 6.9kV onsite ac buses in the event of a loss of the offsite PPS(s). The GTGs are periodically connected to the offsite power source, one at a time, only for surveillance testing in accordance with station TS surveillance requirements and post maintenance testing. Accordingly, the NRC staff finds that the US-APWR GTGs will not be used for peaking service, in conformance with BTP 8-2.

8.3.1.4.13 Conformance with BTP 8-4

DCD Tier 2, Section 8.1.5.3.3, states that the design will be in conformance with the guidelines of BTP 8-4, "Application of the Single-Failure Criterion to Manually Controlled Electrically Operated Valves." In a LOCA, the functions of the ECCS accumulators are to supply water to the reactor vessel during the blowdown phase and well into the core reflooding phase. For an accumulator to be considered operable, the isolation valve must be fully open, power must be removed above 1920 psig, and the limits established in the surveillance requirements for contained volume, boron concentration, and nitrogen cover pressure must be met. The DCD explains that in the event that one accumulator is disabled as a result of a misaligned electrically operated valve, the US-APWR safe shutdown systems include system redundancy sufficient to provide 100 percent cooling capacity. To prevent inadvertent movement of this valve from isolating the safety injection accumulator when it is required to be operable, power is removed from the valve motor. This action will be performed under administrative controls and will be periodically verified in accordance with plant TS surveillance requirements as indicated in DCD Tier 2, Chapter 16, Section 3.5.1.5. The staff's evaluation is in Chapter 16 of this report.

Verification that power is removed from each accumulator isolation valve operator when the RCS pressure is ≥ 1920 psig ensures that an active failure could not result in the undetected closure of an accumulator motor operated isolation valve. If an undetected closure of an accumulator motor operated isolation valve occurs coincident with a LOCA, only two accumulators would be available for injection. Since power is removed under administrative control, the 31 day frequency will provide adequate assurance that power is removed, or the Surveillance Frequency is based on operating experience, equipment reliability, and plant risk is controlled under the Surveillance Frequency Control Program. The Surveillance Requirement allows power to be supplied to the motor operated isolation valves when the RCS pressure is < 1920 psig, thus allowing operational flexibility by avoiding unnecessary delays to manipulate the breakers during plant startups or shutdowns.

Based upon the above, the US-AWPR's capability to provide power to the motor operated isolation valves in ECCS accumulator lines is in accordance with BTP 8-4, and the NRC staff finds the US-APWR design is in conformance with BTP 8-4.

8.3.1.4.14 Conformance with BTP 8-5

In addition to conforming to RG 1.47, DCD Tier 2, Section 8.1.5.3.3, states that the guidelines of BTP 8-5, "Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems," has been incorporated into the design of the bypassed and inoperable status indicators.

The system level Bypass and Inoperable Status Indication is discussed in detail in Topical Report MUAP-07007, "Human System Interface Description and Human Factors Process," (ML081840356). Because the onsite power systems provide power for I&C equipment status, the plant operator can identify systems actuated or controlled using the indications that are displayed as the SDCV information on LDP in the MCR, in accordance with RG 1.47. All bypassed or inoperable status indicators that are displayed are indicated in DCD Tier 2, Chapter 7 and the staff's evaluation can be found in Chapter 7. Therefore, the NRC staff finds the US-APWR design is in conformance with BTP 8-5.

8.3.1.4.15 Conformance with BTP 8-6

DCD Tier 2, Section 8.1.5.3.3, states that the design is in conformance with the guidelines of BTP 8-6, "Adequacy of Station Electric Distribution System Voltages." BTP 8-6 prescribes that nuclear power plants implement a degraded voltage monitoring scheme to protect safety-related equipment on Class 1E buses from degraded voltage conditions.

The applicant has identified COL Information Item, COL 8.3(1), for confirmation of the transmission voltages, which include the MT voltage rating as well as the RAT voltage rating. COL Information Item 8.3(1) is acceptable because it provides the NRC staff with the specific voltages necessary for this equipment to operate, which is essential to the assumptions for the load flow and short circuit studies to be performed by the COL applicant.

However, the applicant did not address the degraded voltage protection for the onsite power distribution system in accordance with BTP 8-6 as it relates to ac power system's capacity and capability to permit functioning of systems important to safety. The DCD states that the voltage levels at the Class 1E buses are optimized for maximum and minimum load conditions and for the voltage variations of the offsite power system. The applicant did not provide analyses or data to support its conclusions. In RAI 10-453, Question 08.03.01-14, the NRC staff asked the applicant to provide additional information on how it met the guidance given in BTP 8-6 as it relates to the onsite ac power system. It is the responsibility of the DCD applicant to determine what voltage is needed at the safety buses for plant distribution loads. In its response to RAI 10-453, Question 08.03.01-14 (ML082040271) the applicant failed to provide voltage boundary conditions for the onsite power distribution systems. To resolve this issue, the NRC staff asked RAI 386-2859, Question 08.03.1-27, as a follow up RAI to RAI 10-453, Question 08.03.01-14. Specifically, in this RAI, the NRC staff asked the applicant to revise its DCD to define the voltage boundary conditions for the onsite power distribution systems in accordance with the guidance given in BTP 8.6, to include the onsite voltage boundary conditions in the DCD as the COL interface action items, and to clearly specify who will be responsible (DC or COL applicant) for load flow, SC analysis, and protective trip device coordination studies.

In a letter dated July 22, 2009 (ML092090058), the applicant submitted a response to RAI 386-2859, Question 08.03.1-27, indicating that it would docket this response as a new technical report that includes analysis about degraded voltage protection for the onsite power system. On March 12, 2010, the NRC staff received Technical Report, MUAP-09023, Revision 0, "Onsite AC Power System Calculation," (ML100950170). The report provides a preliminary assessment of the onsite ac power system in the US-APWR to verify that plant electrical equipment will start and operate as designed under an array of electrical power configurations and operational modes. The assessment is preliminary because the information needed to perform these studies comes from as-procured equipment and, thus, the studies need to be completed by the COL applicant. Electrical parameters included in this study are steady state load flow, motor starting, SC, transfer of MV switchgear, and harmonic analysis. Operational modes encompassed in this study are normal operation, startup, and shutdown. The report presents all of the assumptions per the acceptance criteria as described for each SSC, properly analyzes three conditions for each operational mode, and the calculations show that safety-related equipment on Class 1E buses are protected from degraded voltage conditions. These three conditions are 1) the normal condition when Class 1E buses are powered from the RATs and non-Class 1E buses are powered from the UATs, 2) the condition where the UAT is unavailable so all buses are powered from the RAT, and 3) the condition where the RAT is unavailable, so all buses are powered from the UAT.

The applicant also stated that the responsibility of the COL applicant related to compliance with BTP-6 is indicated in the DCD. For confirmation of the trip setpoints and allowable values, the applicant has identified Item 17, "Reactor Trip Breaker Undervoltage and Shunt Trip Mechanisms," of Table 3.3.1-1, Chapter 16 of the DCD. This confirmation is expected to be supplied by the COL applicant after the completion of a plant-specific study following the selection of the plant specific instrumentation. Since these values will be specified in the COL applicant's TS through application of the setpoint control program, the adequacy of which the staff will review in Chapter 16 of this SER, the NRC staff concurs with the applicant that this information is not necessary to be listed as an additional COL information item in DCD Tier 2, Table 1.8-2. The staff's evaluation of the setpoint control program is evaluated in Chapter 16 of this report.

Based on the above, the NRC staff finds that the issues raised in RAI 386-2859, Question 08.03.1-27, are resolved and considers this RAI closed. Since the voltage measurement per BTP 8-6 and the applicant performed analyses regarding the onsite ac power system's capability to start and operate as designed under an array of electrical power configurations and operational modes, the NRC staff finds that the analysis in the US-APWR DCD conforms to BTP 8-6.

8.3.1.4.16 Conformance with BTP 8-7

DCD Tier 2, Section 8.1.5.3.3, states that the design is in conformance with the guidelines of BTP 8-7, "Criteria for Alarms and Indications Associated with Diesel Generator Unit Bypassed and Inoperable Status," to the extent applicable to GTGs. To allow operators to respond to emergency demand, DCD Tier 2, Section 8.3.1.1.3.3, describes the trip protective functions for the Class 1E GTGs, and how GTG bypass or inoperable conditions are automatically alarmed in the MCR to provide operators with accurate information about the status of each GTG. Indications and alarms are listed in DCD Tier 2, Chapter 8, Table 8.3.1-8. This listing conforms to positions 1.6 through 1.9 of RG 1.9, "Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants," which mirror the guidance in BTP 8-7. Therefore, the NRC staff finds the US-APWR design, conforms to BTP 8-7 in this regard.

8.3.1.4.17 Conformance with RG 1.206

Section 8.3.1.3 of the DCD describes the ac system Electrical Power System Calculations and Distribution System Studies for the US-APWR consistent with Section C.I.8.3.1.3 of RG 1.206. The applicant has performed the following electrical power system calculations and distribution system studies for onsite ac power systems on a preliminary basis for the standard design:

- Load Flow/Voltage Regulation Studies and Under/Overvoltage Protection
- Short-Circuit Studies
- Equipment Sizing Studies
- Equipment Protection and Coordination Studies
- Insulation Coordination (Surge and Lightning Protection)
- Power Quality Limits

The electrical power system calculations and distribution system studies utilized the Electrical Transient Analyzer Program (ETAP) to analyze the ac distribution system for load flow, voltage regulation, motor starting, and SC studies. The applicant stated that ETAP conforms to the requirements of 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," and American Society of Mechanical Engineers (ASME) NQA-1, "Quality Assurance Program Requirements for Nuclear Facility Applications." Onsite ac power system calculations are presented in Technical Report MUAP-09023. The NRC staff has determined that this technical report adequately addresses this subject because it includes steady state load flow, motor starting, SC, transfer of MV switchgear, and harmonic analysis, and presents all of the assumptions and the acceptance criteria in Technical Report MUAP-09023, as described for each SSC, and properly analyzes the three conditions identified in Section 8.3.1.4.15 of this report for each operational mode.

DCD Tier 2, Figure 8.3.1-1 shows a possibility that non-Class 1E buses could provide power to safety loads. The NRC staff asked the applicant to clarify the normal and alternate power sources for the Class 1E buses based on Figure 8.3.1.1.1. In RAI 10-453, Question 08.03.01-8, the NRC staff asked, in Part A, a three-part question regarding Figure 8.3.1-1. The NRC staff asked the applicant to discuss the impact on the safety bus voltage if one large RCP pump motor (7431 kVA) was started. The NRC staff also asked the applicant to discuss the impact on the safety bus voltage if one RCP pump motor was running and a second RCP pump motor was starting, and whether the applicant had performed a voltage drop and load flow analysis for this limiting condition. If the applicant performed the latter analysis, the NRC staff requested that the applicant provide and discuss the results and assumptions of such an analysis and the impact on the safety bus voltage regulation. The NRC staff also asked the applicant, in Part C, to discuss the impact on the safety buses assuming a stuck breaker in the non-safety system fails to clear a fault in the non-Class 1E system, and to discuss and provide a rationale showing how the proposed design meets the guidance given in SECY-91-078, which indicates that an offsite source can power the safety buses upon a failure of any non-Class 1E bus. In response to RAI 10-453, Question 08.03.01-8 (ML082040271), the applicant provided motor starting transient graphs in Attachment A showing that the starting of the large pump motors will not cause a substantial dip in the voltage at the safety buses. Part of the applicant's response to this RAI was not satisfactory because the applicant had assumed a failure in a feeder breaker in the non-Class 1E bus P1 or P2, which is not bounding or conservative. The applicant did not provide information requested by Part C of the RAI because the applicant believed that it had already addressed the question. The NRC staff's concern was not completely addressed by this response because the assumptions to support its analysis were not clearly identified, and the assumed failure in a feeder breaker in the non-Class 1E bus P1 or P2 was not bounding or conservative.

In RAI 386-2859, Question 08.03.1-23, the NRC staff asked a follow up to RAI to RAI 10-453, Question 08.03.01-8. Regarding the motor starting transient graphs in Attachment A in the applicant's response to RAI 10-453, Question 08.03.01-8, which showed that the starting of the large pump motors will not cause a substantial dip in the voltage at the safety buses, the NRC staff asked the applicant to provide assumptions used in the motor starting transient analysis (graphs). The NRC staff also requested that the applicant docket its response including this information to resolve this RAI question. In its response to RAI 386-2859, Question 08.03.1-23 dated July 22, 2009 (ML092090058), MHI committed to submit Technical Report MUAP-09023-P as revision of Attachment A of response to RAI 10-453, Question 08.03.01-8, to resolve Part A of this question.

Because the applicant assumed a failure in a feeder breaker in the non-Class 1E bus P1 or P2 which is not bounding or conservative, the NRC staff determined that a failure (stuck breaker) of the main breaker in the non-safety bus (P1 or P2) that fails to open would then necessitate opening of the primary side breaker of the RAT3 or RAT 4, thereby de-energizing the safety buses A and B (or C and D). The NRC staff was concerned that a failure in the non-Class 1E bus (main breaker failed) in P1 (or P2 bus) would cause a failure in the respective safety buses, and that the US-APWR electrical design did not adhere to the guidance provided by the NRC on offsite power systems for evolutionary plants. Accordingly, in RAI 386-2859, Question 08.03.1-23, NRC staff requested that the applicant change the electrical design for supplying the non-Class 1E MV buses P1 and P2 from the RAT to the UAT, and revise the corresponding schematics and DCD description. The NRC staff also asked MHI to discuss and provide a rationale showing how the proposed electrical design meets the guidance given in SECY-91-078, which states that offsite source can power the safety buses upon a failure of any non-Class 1E bus. The NRC staff also requested that the applicant docket its response confirming the above actions.

In a response to RAI 386-2859, Question 08.03.1-23 dated July 22, 2009 (ML0920990058), the applicant stated that the normal and alternate power of permanent buses will be changed. Normal offsite power of permanent buses is changed from the RAT to the UAT. Alternate offsite power of permanent buses is changed from UAT to RAT. The applicant revised the DCD to reflect this information.

Since the applicant has submitted Technical Report MUAP-09023-P, including clearly-stated assumptions, steady state load flow, motor starting, SC, transfer of MV switchgear, and harmonic analysis, and properly analyzes three conditions, as indicated in Section 8.3.1.4.15 of this report, for each operational mode, the NRC staff considers this response adequate. The applicant's revision of the DCD is adequate to resolve these issues because the applicant changed the electrical design for supplying the P1 and P2 MV buses, which are not safety-related, from the RAT to UAT, which meets the guidance given in SECY-91-078 that indicates that an offsite source can power the safety buses upon a failure of any non-Class 1E bus. Accordingly, the NRC staff considers RAI 10-453, Question 08.03.01-8, and RAI 386-2859, Question 08.03.1-23 closed, and the issues they raised to be resolved.

In RAI 10-453, Question 08.03.01-19, the NRC staff asked the applicant to clarify whether the applicant has performed SC current calculations for the selection of switchgear, load centers, MCCs, distribution panels, and transformer impedances. The NRC staff requested the result of the analyses, and assumptions used in the analysis to evaluate acceptable ratings for equipment if such analyses have been conducted; if the analyses hadn't been conducted, the NRC staff asked the applicant to explain who would conduct the analyses. If the applicant's position is that it is the responsibility of the COLA applicant to conduct these analyses and provide the results and supporting assumptions, then the NRC staff asked the applicant to identify these actions as COL Action Items in the DCD. In response to RAI 10-453, Question 08.03.01-19 (ML082040271), the applicant submitted the analyses, but the NRC staff had concerns about several aspects presented in the response. Accordingly, the NRC staff asked RAI 386-2859, Question 08.03.01-31, as a follow up RAI to RAI 10-453, Question 08.03.01-19. Specifically, the NRC staff inquired about the following:

- Safety-related GTG are not running and therefore not included in the analysis;
- The voltage assumed is 1.0 of nominal which is not conservative;

- The interrupting rating of the breakers in each safety bus (A, B, C and D) is different for each breaker, which is not correct;

- No analysis is provided on the steady-state load flow (distribution system voltage drop analysis), which is called for by BTP 8-6 of the SRP.

The applicant submitted a response RAI 386-2859, Question 08.03.01-31 (ML092090058), indicating that it would docket its response as a new technical report that includes analysis regarding the addition of the safety-related GTGs to the analysis, different voltage assumptions that show conservatism, a correction of the interrupting rating of breakers in each safety bus (A, B, C and D), and steady-state load flow (distribution system voltage drop analysis).

On March 12, 2010, the NRC staff received Technical Report, MUAP-09023-P, Revision 0. The report provides an assessment of the onsite ac power system in the US-APWR to verify that plant electrical equipment will start and operate as designed under an array of electrical power configurations and operational modes. Also, the applicant provided COL Information Item 8.3(3) which requires the COL applicant to address the SC analysis for the ac power system, since the system contribution is site-specific. This COL information item is adequate because it addressed the site-specific characteristics of the plant site and analyses them in light of the specific conditions the plant would experience throughout its life. Based upon the review of the technical report (as discussed in the resolution of RAIs 10-453, Question 08.03.01-8, and 386-2859, Question 08.03.1-23) above, and the fact that the applicant changed the electrical design to meet the guidance given in SECY-91-078 which states that an offsite source can power the safety buses upon a failure of any non-safety bus, these RAIs are resolved. The NRC staff considers RAI 10-453, Question 08.03.01-19, and RAI 386-2859, Question 08.03.1-31 closed and the issues they raised resolved.

In RAI 10-453, Question 08.03.01-22, the NRC staff requested that the applicant include in the DCD the results of the electrical power calculations and distribution system studies as listed in RG 1.206, Section C.1.8.3.1.3, “Electrical Power System Calculations and Distribution system studies for AC System.” Also, RAI 10-453, Question 08.03.01-22 requested that MHI include in the DCD information on the electrical power system calculations and distribution system studies called for the ac power system in accordance with Section C.1.8.3.1.3 of RG 1.206. In response to RAI 10-453, Question 08.03.01-22 (ML082040271), the applicant directed the NRC staff to information contained in Attachment A of the applicant’s response. The NRC staff deemed this response inadequate because Attachment A to the applicant’s response dated June 18, 2008, lacked the assumptions and summary results of the studies listed in Section C.1.8.3.1.3 of RG 1.206 for each voltage level distribution system needed to support the design. Accordingly, the NRC staff asked RAI 386-2859, Question 08.03.01-33, as a follow up RAI to RAI 10-453, Question 08.03.01-22. Specifically, the staff requested the applicant to incorporate in Attachment A to the June 18, 2006, response the six studies needed to support the design and submit the appropriate documents for the NRC staff's review. Further, the staff requested the applicant to state clearly in the DCD who will be responsible for the system studies that are listed in RG 1.206, Section C.1.8.3.1.3.

In response to RAI 386-2859, Question 08.03.01-33 (ML0092090058), the applicant indicated that it would submit a new technical report that includes analysis regarding the onsite ac power systems information called for by Section C.I.8.3.1.3 of RG 1.206, and that the results of the calculations and studies will be included in an upcoming revision of the DCD. In these calculations and studies, equipment protection and coordination studies discussed in Question 08.03.01-22 and insulation coordination, which is based on site-specific information, will be addressed by the COL applicant. Also, the applicant committed to provide a COL information item regarding insulation coordination (surge and lightning). On March 12, 2010, the NRC staff received Technical Report, MUAP-09023-P, Revision 0. The report provides a preliminary assessment of the onsite ac power system in the US-APWR to verify that plant electrical equipment will start and operate as designed under an array of electrical power configurations and operational modes. The assessment is preliminary because the information needed to perform these studies comes from as-procured equipment and, thus, the studies need to be completed by the COL applicant. This technical report specifies that equipment protection and coordination studies and Insulation coordination are site-specific and are to be addressed by the COL applicant. The NRC staff verified that the applicant included COL Information Items COL 8.3(10), "The COL applicant is to provide protective device coordination," and COL 8.3(11), "The COL applicant is to provide insulation coordination (surge and lightning)," in Subsection 8.3.4 of the DCD. The onsite electrical system protection and coordination are performed to limit the extent and duration of the interruption in power supply whenever a circuit fault occurs on any portion of the onsite ac power system, and to minimize damage to the system components involved in the fault. The studies are performed in accordance with IEEE Std. 242. Protection coordination is dependent on the characteristics of installed protective devices; therefore, the studies are to be performed by the COL applicant. The insulation coordination studies are performed in accordance with IEEE Std. 1313.1 and IEEE Std. 1313.2. Lightning protection is site-specific design as described in Subsection 8.3.1.1.11. Therefore, insulation coordination is to be provided by the COL applicant. Although IEEE Std. 242, as well as IEEE Std. 1313.1 and 1313.2 haven't been endorsed by the NRC, they are widely used by the industry and they are considered acceptance standards for the performance of the studies.

The staff reviewed the technical report and finds the assumptions and methodology acceptable, because they employ accepted industry codes and standards. Because the applicant performed calculations and studies on the performance of the onsite power system using these assumptions and methodology, the staff finds that the onsite ac power system in the US-APWR will operate as designed under an array of electrical power configurations and operational modes. Based upon the review of the technical report (as discussed in the resolution of RAIs 10-453, Question 08.03.01-8, and RAI 386-2859, Question 08.03.1-23) above, the NRC staff considers RAI 10-453, Question 08.03.01-22, and RAI 386-2859, Question 08.03.1-33 closed.

Based on the information submitted by the applicant and its RAI responses, the NRC staff finds the US-APWR design is in conformance with the guidance of RG 1.206, since it has performed the calculations as discussed above.

8.3.1.5 Combined License Information Items

The following is a list of item numbers and descriptions from Table 1.8-2 of the DCD:

Table 8.3.1-1
US-APWR Combined License Information Items

Item No.	Description	Section
8.3(1)	The COL applicant is to provide transmission voltages. This includes MT and RAT voltage ratings.	8.3.1.4.15
8.3(2)	The COL applicant is to provide ground grid and lightning protection.	8.3.1.4.4.9
8.3(3)	The COL applicant is to provide SC analysis for the ac power system, since the system contribution is site-specific.	8.3.1.4.17
8.3(4)	Deleted	NA
8.3(5)	Deleted	NA
8.3(6)	Deleted	NA
8.3(7)	Deleted	NA
8.3(8)	The COL applicant is to provide SC analysis for the dc power system.	8.3.2.4.4.2
8.3(9)	Deleted	NA
8.3(10)	The COL applicant is to provide protective device coordination.	8.3.1.4.17
8.3(11)	The COL applicant is to provide insulation coordination (surge and lightning).	8.3.1.4.17
8.3(12)	The COL Applicant is to provide the cable monitoring program for underground and inaccessible cables with the scope of the maintenance rule (10 CFR 50.65).	8.3.1.4.5.2

8.3.1.6 Conclusions

As set forth above, the NRC staff has reviewed all of the relevant information that is applicable to the US-APWR onsite ac power system design and evaluated its compliance with GDC 17, 18, and 50, and conformance to RGs, industry codes and standards, and BTPs committed to by the applicant. The NRC staff also reviewed the COL information items in DCD Tier 2, Table 1.8-2. With the exception of confirmatory items discussed in this section, the NRC staff concludes that the design of the US-APWR onsite ac power system meets the appropriate regulatory requirements listed in SE Section 8.3.1.3, and shown in the NRC staff technical evaluations in Sections 8.3.1.4 and 8.3.1.5 of this SER.

8.3.2 DC Power Systems

The US-APWR onsite dc power system is comprised of four Class 1E and four non-Class 1E independent systems. Each Class 1E and non-Class 1E dc power system is provided with its own battery, battery charger, and power distribution equipment.

8.3.2.1 Introduction

The safety function of the onsite dc power system (assuming the offsite power system is not functioning) is to provide sufficient capacity and capability to ensure that SSCs important to safety perform as intended.

The objective of the NRC staff review is to determine whether the onsite dc power system satisfies the requirements of 10 CFR Part 50, Appendix A, GDCs 2, 4, 5, 17, and 18 and will perform its design function during all plant operating and accident conditions as well as SBO conditions.

8.3.2.2 Summary of Application

This section of the DCD provides descriptive information, analyses, and referenced documents, including electrical single-line diagrams, electrical schematics, logic diagrams, tables, and physical arrangement drawings for the onsite dc power system. The onsite dc power systems include those power sources and their distribution systems that supply motive or control power to safety-related equipment. The portions of the onsite dc power systems that are not safety-related are described only in sufficient detail to permit an understanding of their interactions with the safety-related portions. This section of the DCD identifies the safety loads and states the length of time they would need to be available in the event of a loss of all power. The plant dc power system is comprised of independent Class 1E and non-Class 1E dc power systems. Each system consists of ungrounded stationary batteries, dc distribution equipment, and UPS.

The Class 1E dc system provides reliable power for the safety-related equipment credited for plant instrumentation, control, monitoring, and other vital functions needed to shut down the plant. In addition, the Class 1E dc system provides power to the normal and emergency lighting in the MCR and at the remote shutdown control panel.

DCD Tier 1: The Tier 1 information associated with this section is found in DCD Tier 1, Section 2.6.2, and Table 2.6.2-2, Section 2.6.2, “DC Power Systems,” states the design description, and the ITAAC for the dc power system. Table 2.6.2-2, “DC Power Systems Inspections, Tests, Analyses, and Acceptance Criteria,” describes the ITAAC for the dc power systems.

DCD Tier 2: The applicant has provided a Tier 2 system description in DCD Tier 2, Section 8.3.2, “DC Power System,” summarized here in part, as follows:

> The onsite dc power system comprises independent Class 1E and non-Class 1E, 125-Vdc power systems. The Class 1E dc power system comprises four independent systems, one for each safety train. The non-Class 1E dc power system also comprises four separate dc power systems. Each Class 1E and non-Class 1E dc power system division includes a battery, battery charger, and power distribution equipment.
>
> The Class 1E dc power system provides uninterruptible power to the safety-related dc loads, to the inverters that serve the Class 1E 120-Vac instrument power system, and to the three phase 480-Vac inverters that serve motor-

operated valves that rely on uninterruptible power. In addition, it provides power to the emergency lighting systems for the vital plant areas.

The non-Class 1E dc power system provides reliable continuous dc power to the plant's dc loads that are not safety-related and to the non-Class 1E I&C power supply system. Operation of the non-Class 1E dc power system is not credited for coping with design basis events.

The applicant presents a single-line diagram of the dc power system and a list of safety-related dc loads.

ITAAC: The ITAAC associated with Tier 2, Section 8.3.2, are given in DCD Tier 1, Section 2.6, and Table 2.6.2-2.

Technical Specifications: TS applicable to the onsite dc power systems can be found in Tier 2, Chapter 16, Sections 3.8.4, 3.8.5, 3.8.6, 3.8.9, and 3.8.10. Section 3.8.4, "DC Sources - Operating," states the LCO and surveillances related to dc electrical power sources under plant operating conditions. Section 3.8.5, "DC Sources - Shutdown," states the LCO and surveillances related to dc electrical power sources under plant shutdown conditions. Section 3.8.6, "Battery Parameters," states the LCO and surveillances related to dc electrical power sources under plant operating conditions. Section 3.8.9, "Distribution Systems - Operating," states the LCO and surveillances related to dc electrical power sources under plant operating conditions. Section 3.8.10, "Distribution Systems- Shutdown," states the LCO and surveillances related to dc electrical power sources under plant operating conditions.

8.3.2.3 Regulatory Basis

The relevant requirements of the Commission's regulations for this area of review, and the associated acceptance criteria, are given in Section 8.3.2 of NUREG-0800 and are summarized below.

1. GDC 2, as it relates to SSCs of the dc power system being capable of withstanding the effects of natural phenomena without the loss of the capability to perform their safety functions.

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

3. GDC 5, as it relates to sharing of SSCs of the dc power systems of different nuclear power units.

4. GDC 17, as it relates to the onsite dc 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.

5. GDC 18, as it relates to inspection and testing of the onsite dc power systems.

6. GDC 50, as it relates to the design of containment electrical penetrations containing circuits of the dc 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.

7. 10 CFR 50.63, as it relates to the station batteries which provide sufficient capacity and capability to power essential equipment that ensures core cooling and preserves containment integrity for a specified duration.

8. 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 for the onsite dc power system. These activities include, but are not limited to, surveillances, post-maintenance testing, and corrective and preventive maintenance.

9. 10 CFR 50.55a(h), as it relates to the incorporation of IEEE Std. 603-1991 (including the correction sheet dated January 30, 1995), for protection and safety systems.

Acceptance criteria for meeting the regulatory requirements listed above are as follow:

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

2. 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.

3. RG 1.47, as it relates to the bypass and inoperable status of the onsite power supply.

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

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

6. 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.

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

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

9. RG 1.128, "Installation Design and Installation of Vented Lead-Acid Storage Batteries for Nuclear Power Plants," as it relates to the installation of vented lead-acid storage batteries in the onsite dc power system.

10. RG 1.129, "Maintenance, Testing, and Replacement of Vented Lead-Acid Storage Batteries for Nuclear Power Plants," as it relates to maintenance, testing, and replacement of vented lead-acid storage batteries in the onsite dc power system.

11. 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.

12. RG 1.155, 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 AAC power source(s).

13. The guidelines of RG 1.160, as they relate to the effectiveness of maintenance activities for dc power systems. Compliance with the maintenance rule, including verification that appropriate maintenance activities are covered therein, is reviewed under Chapter 17 of NUREG-0800.

14. 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.

15. RG 1.206, as it relates to power system analytical studies and stability studies to verify the capability of the offsite power systems and their interfaces with the onsite dc power system.

16. BTP 8-5, "Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems," as it relates to bypassed or inoperable status indicators that are displayed in the MCR.

8.3.2.4 Technical Evaluation

The NRC staff has reviewed the onsite dc power system of US-APWR DCD. The DCD provides descriptive information, analyses, and referenced documents, including electrical single-line diagrams, tables, and physical arrangements. The onsite dc power system of the US-APWR DCD is composed of independent Class 1E and non-Class 1E dc power systems. The

Class 1E dc power system consists of four independent power supply systems, identified as A, B, C, and D trains. Each system consists of a main distribution switchboard fed from a battery and a battery charger. The non-Class 1E dc power system consists of four separate power supply systems, identified as N1, N2, N3, and N4. Each system consists of a main distribution switchboard, fed from a battery and a battery charger. In addition, there are two spare battery chargers. This review evaluates whether the US-APWR onsite dc power system satisfies the applicable regulations to ensure its intended safety functions are met during all plant operating and accident conditions. Table 8-1 of NUREG-0800 lists GDCs, RGs, IEEE Standards, and BTPs that are applicable for the onsite dc power systems. The NRC staff has reviewed the following areas that are applicable to the US-APWR onsite dc power system design:

8.3.2.4.1 Compliance with GDC 2

GDC 2 requires that SSCs important to safety, which include the onsite dc power systems, be capable of withstanding the effects of natural phenomena without the loss of the capability to perform their safety functions.

The US-APWR onsite dc power distribution system consists of four redundant systems. Each train's equipment and components of the safety-related Class 1E 125V dc power system are located in seismic Category I buildings and their mounting and installations are seismically designed. Each train's equipment and components are located in separate rooms in each of these buildings, which provide physical separation among the four redundant divisions. The nature and magnitude of the natural phenomena considered in the US-APWR design are described in DCD Tier 2, Chapter 2, "Site Characteristics." The Class 1E 125V dc system is designed to withstand the effects of natural phenomena such as design basis (safe shutdown) earthquake, tornado, hurricane, flood, tsunami, or seiche without losing its capability to perform its intended safety functions. The applicant's discussion in regard to the application's compliance to GDC 2 for all safety-related SSCs is addressed in DCD Tier 2, Section 3.1, "Conformance with NRC General Design Criteria."

All Class 1E components of the US-APWR onsite power systems are located in seismic Category I structures, protected from the effects of natural phenomena such as tornadoes, tornado missiles, and floods. The location of the onsite dc power system inside seismic Category I structures, the design of the onsite dc power system as Class 1E, and the seismic qualification of that equipment, will provide assurance that equipment and structures are designed to withstand the effects associated with natural phenomena without loss of capability to perform their safety functions during an accident.

Based on the above, the NRC staff finds that the US-AWPR onsite dc power system meets the requirements of GDC 2.

8.3.2.4.2 Compliance with GDC 4

GDC 4 requires that SSCs important to safety, which include the onsite dc power systems for the US-APWR, be capable of withstanding the effects of missiles and environmental conditions associated with normal operation, maintenance, testing, and postulated accidents.

The applicant's discussion in regard to the application's compliance to GDC 4 for all safety-related SSCs is addressed in DCD Tier 2, Section 3.1, "Conformance with NRC General Design Criteria." In its review of this information, the NRC staff determined that all equipment and components of the US-APWR safety-related 125V dc power system are located in seismic Category I buildings in an area without high or moderate energy lines or missile generating rotating equipment, and in rooms constructed in such a manner that any internal hazard only affects the respective division. The NRC staff review of the design details and construction of safety-related structures indicates that no high energy lines are routed through the dedicated electrical rooms containing batteries, battery chargers, inverters, MCCs, panel boards, or switch boards. In addition, these rooms are also provided with air conditioning that maintains ambient environmental conditions within the equipment qualification limits during normal operations, DBEs, and SBO. The NRC staff also determined that all equipment and components of the safety-related dc system are qualified for Class 1E application, in accordance with IEEE Std. 323 and all applicable IEEE equipment qualification standards. Therefore, the NRC staff finds that the US-APWR safety-related 125 dc power system is designed to withstand the effects of, and be compatible with, the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, and are appropriately protected against dynamic effects that may result from equipment failures, including missiles. The safety-related dc power system is designed to perform its intended safety functions during normal, abnormal, accident, and post-accident conditions.

In addition, for that equipment located in harsh environments, the environmental qualification program for electrical equipment assures that equipment remains functional during and following exposure to harsh environmental conditions as a result of a DBE. Environmental qualification of mechanical and electrical equipment described in DCD Tier 2, Section 3.11, "Environmental Qualification of Mechanical and Electrical Equipment," lists GDC 4 as one of the acceptance criteria. DCD Tier 2, Table 3D-2, "US-APWR Environmental Qualification Equipment List," lists safety-related electrical and I&C equipment located in a harsh environment that must be qualified. Based on the above, the NRC staff finds that the onsite dc power system design for US-APWR can perform safety-related functions following physical effects of an internal hazard.

Considering ambient temperature controls and adequate plant design, the onsite dc power system components for the US-APWR are capable of withstanding the effects of missiles and environmental conditions associated with normal operation and postulated accidents. The NRC staff finds that the US-APWR dc power systems meet the requirements of GDC 4.

8.3.2.4.3 Compliance with GDC 5

Compliance with GDC 5 requires that SSCs important to safety (i.e., dc power system) not be shared among nuclear units unless it can be shown that such sharing will not significantly impair the SSCs' ability to perform their safety functions. Since the US-APWR is designed as a single unit plant, the safety-related dc systems and components (i.e., batteries, chargers, or inverters) are not shared between individual nuclear power units. Thus, GDC 5 and RG 1.81 are not applicable to the dc power system of the US-APWR.

8.3.2.4.4 Compliance with GDC 17

GDC 17 requires that the onsite power supplies, which include the dc power supplies, and the associated electrical distribution system, have sufficient capacity, capability, independence, redundancy, and testability to perform their safety functions, assuming a single failure. Thus, no single failure should prevent the onsite power system from supplying electric power, thereby enabling safety functions and other vital functions.

The onsite dc power system for the US-APWR comprises independent Class 1E and non-Class 1E 125V dc power systems. The Class 1E dc power system comprises four independent systems, one for each safety train. The non-Class 1E dc power system also comprises four separate dc power systems. Each Class 1E and non-Class 1E dc power system division includes a battery, battery charger and power distribution equipment.

The Class 1E dc power system provides uninterruptible power to the safety-related dc loads, to the inverters that serve the Class 1E 120-Vac instrument power system, and to the three phase, 480-Vac inverters that serve motor-operated valves that rely on uninterruptible power. In addition, it provides power to the emergency lighting systems for the vital plant areas.

The non-Class 1E dc power system provides reliable continuous dc power to the plant dc loads that are not safety-related and to the non-Class 1E I&C power supply system. Operation of the non-Class 1E dc power system is not credited for coping with design basis events.

GDC 17 specifies that the safety function of the electric power systems is to provide sufficient capacity and capability to assure that: (1) specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of AOOs, and (2) the core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents. The systems to which the onsite dc power system supplies control power that accomplish these functions are governed by 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,” for SSCs important to safety during normal and accident conditions, as necessary for the specific system condition. The design of the US-APWR onsite dc power distribution system is such that any two of the four independent trains are required to be operable to mitigate any abnormal or design-basis accident conditions. The analysis to assess the adequacy of the safety-related dc power systems is addressed in SE Section 8.3.2.4.4.2, Conformance with RG 1.32, under the evaluation of RAI 8-343 (ML081960254), Question 08.03.02-14. The staff has determined that each train of safety-related batteries and the dc power system distribution equipment and components, including all cables and circuits, has sufficient capacity and capability to perform its associated safety functions during all normal and emergency modes of plant operation including DBEs. Hence, the US-APWR onsite dc power distribution system is capable of performing its safety functions assuming a single failure in one train and another train being out of service for maintenance. This designed provision of redundancy and independence is more conservative than what is required by GDC 17.

The US-APWR onsite dc power system's compliance with GDC 17 is accomplished through the design of the onsite power dc distribution system capacity, capability, independence, and redundancy and the components have the required independence, and redundancy to perform their safety-related functions in the presence of a single failure. The applicant's onsite dc system design conforms to the guidance in the following RGs 1.6, 1.32, 1.53, 1.75, 1.128, 1.129, and 1.153, as described below.

8.3.2.4.4.1 Conformance with RG 1.6

DCD Tier 2, Section 8.3.2.2.2 states conformance with RG 1.6., "Independence between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems." RG 1.6 relates, in part, to the independence between redundant onsite dc power sources and between their distribution systems. Conformance to this RG for regulatory positions identified in SRP Subsection 8.3.2 is described below:

- Regulatory position D.1 - This regulatory position states that the electrically powered safety loads (ac and dc) should be separated into redundant load groups such that loss of any one group will not prevent the minimum safety functions from being performed. To address this regulatory provision, the US-APWR electrically powered dc safety loads are separated into four different redundant load groups, powered by four redundant trains of the safety-related dc power system. Since any two of the four redundant trains are adequate to power minimum safety functions, the dc system design conforms to the single failure criterion while one redundant train is out of service.

- Regulatory position D.3 - This regulatory position states that each dc load group should be energized by a battery and battery charger. The battery-charger combination should have no automatic connection to any other redundant dc load group. The US-APWR design adequately addresses this regulatory position because each redundant train of the dc power system is energized by a dedicated battery and a battery charger. In addition, there are two installed spare battery chargers AB and CD. Spare battery charger AB can be connected manually to replace any of the chargers of the two redundant trains A or B, but not in both trains at once. Similarly, the spare battery charger CD can be connected manually to replace any of the chargers of the two redundant trains C or D, but not in both trains at once. The battery-charger combination of one train has no automatic connection to any other redundant dc load group.

- Regulatory Position D.4 - This regulatory position states that when operating from the standby sources, redundant load groups and the redundant standby sources should be independent of each other at least to the following extent:

    a. The standby source of one load group should not be automatically paralleled with the standby source of another load group under accident conditions;

b. No provisions should exist for automatically connecting one load group to another load group;

c. No provisions should exist for automatically transferring loads between redundant power sources;

d. If means exist for manually connecting redundant load groups together, at least one interlock should be provided to prevent an operator error that would parallel their standby power sources.

To address this regulatory position, the applicant has stated that the onsite dc power sources and their distribution systems are redundant and completely independent. The NRC staff has determined that the US-APWR design adequately addresses this regulatory position because the equipment, components and circuits of each safety-related train and non-safety load groups are electrically isolated and physically separated from each other. There is no provision for automatic parallel operation of batteries or battery chargers, and there are no provisions for automatically connecting one load group to another load group. Similarly, no provisions exist for automatically transferring loads between redundant power sources. The installed spare charger can, however, be manually placed in service to replace any one safety-related charger.

Based on the foregoing, the NRC staff finds that the Class 1E onsite dc power sources provide uninterruptible dc power to the redundant safety-related load groups and conform to the guidance of RG 1.6.

8.3.2.4.4.2 Conformance with RG 1.32

DCD Tier 2, Section 8.3.2.2.2 states conformance with RG 1.32. RG 1.32, "Criteria for Power Systems for Nuclear Power Plants," relates, in part, to the design, operation, and testing of the safety-related portions of the onsite dc power system. RG 1.32 endorses IEEE Std. 308-2001, "Criteria for Class 1E Power Systems for Nuclear Power Generating Stations."

This RG has an exception that pertains to sharing of dc power systems at multi-unit nuclear power plants. The exception cited in this RG is not applicable to the US-APWR since it is designed as a single unit plant and the safety-related dc systems and components (i.e., batteries, chargers, or inverters) are not shared between individual nuclear power units.

DCD Tier 2, Section 8.3.2.1.1, states that the I&C power supply system inverters are designed to supply 120 V ac power with dc input less than 140V and more than 108 V. DCD Tier 2, Section 8.3.2.1.1, also stated that the I&C power supply system inverters are powered from the dc switchboard and are capable of operating at the battery minimum terminal voltage of 108 V. Since there will be some voltage drop from the battery terminal to the inverter terminal, in RAI 8-343, Question 08.03.02-9, the NRC staff asked the applicant to explain how the voltage will be maintained over 108 V at the inverter terminal.

In a response to RAI 8-343, Question 08.03.02-9 dated July 10, 2008, the applicant explained that the Class 1E batteries are designed under the condition of 1.8 V as the minimum battery terminal voltage per one cell (108 V per system). The applicant also explained that it will apply the UPS unit, which has more than 100 V as specification of minimum acceptable dc input voltage (125 V +/-20 percent). The applicant also evaluated whether the voltage drop from the battery terminal to the inverter terminal can be kept below 8 V. Table 3 of the applicant's July 10, 2008, RAI response shows the voltage at the battery terminal and at the inverter (UPS) unit:

Table 3

Mode	Class 1E DC System Voltage	DC input voltage of Class 1E UPS unit
1. Period of equalizing charging to battery	140 V; at output terminal of charger	132 V; at input terminal of UPS unit
2. Period of end portion of battery discharging	108 V; at output terminal of battery	100 V; at input terminal of UPS unit

The applicant's July 10, 2008, response to RAI 8-343, Question 08.03.02-9, demonstrated that the Class 1E UPS unit, as procured, will be designed to cope with 108 V as the minimum battery terminal voltage. The NRC staff verified that the DCD has been revised such that DCD Tier 2, Section 8.3.2.1.1 contains the revised statement that shows a 108 V rating corresponding to the battery terminal voltage. Since the DCD has been revised to include the clarification on the assumption of the voltage drop across the inverter terminals in the design of the battery in terms of capacity, the NRC staff considers RAI 8-343, Question 08.03.02-9 closed and the issues it raised have been resolved.

DCD Tier 2, Table 8.3.2-1, "125 V DC Class 1E Load Current Requirement," specifies a current minimum of 438 amps for a UPS. In RAI 8-343, Question 08.03.02-11, the NRC staff asked the applicant to explain why the dc input current for the UPS increases as the battery input voltage to the UPS decreases given that the battery voltage decreases after one minute and reduces to 108 V after two hours.

In response to RAI 8-343, Question 08.03.02-11 (ML081960254), the applicant explained that when the ac input power of a Class 1E charger is lost, the Class 1E battery starts to discharge and supply dc power to dc loads including the Class 1E UPS units. The voltage of a battery decreases gradually during discharge. The applicant explained that the dc input current of the UPS unit increases in accordance with decreasing battery voltage because each UPS unit will maintain the output power against the decreasing input voltage. The applicant evaluated the dc input current of each UPS unit conservatively based on the worst current conditions by using the calculation presented below. The applicant utilized a UPS unit that has more than 100 V as specification of acceptable dc input voltage (125 V +/- 20 percent). The rating of the Class 1E UPS unit is 50 kVA. The applicant evaluated the current by using minimum acceptable voltage as follows:

$$50 \times 0.7 \div 0.8 \times 0.1 = 437.5 \text{ Amps (A)}$$

Where,

50: kVA rating of UPS unit
0.7: Average power factor of digital I&C loads
0.8: Efficiency of UPS unit
0.1: 100 V minimum acceptable voltage of UPS unit

Since the minimum current needed for the UPS unit is 438 A, and the worst current condition (calculated value of 437.5 A) is below this value, the UPS unit's current rating will not be exceeded beyond its capacity. Accordingly, the NRC staff finds that the applicant has adequately addressed this issue, and considers RAI 8-343, Question 08.03.02-11, closed and the issues it raised to have been resolved.

The staff also requested additional information to determine whether there was an adequate margin in the design to provide power to lighting equipment. In RAI 8-343, Question 08.03.02-13, the NRC staff asked the applicant to confirm that the ten amps specified as needed for emergency lighting includes emergency lighting for the MCR as well as the remote shutdown console, as shown in DCD Tier 2, Table 8.3.2-1. In response to RAI 8-343, Question 08.03.02-13 (ML081960254), the applicant explained that based on the preliminary calculations, 10 amperes from each Class 1E dc system is adequate and includes emergency dc lighting in the MCR and Remote Shutdown console (RSC). The applicant presented the following assumptions:

Room Dimensions as per Reference Drawing US-APWR Standard Plant Reactor Building

- MCR dimensions are approximately 63 ft x 36 ft
- RSC room dimensions are approximately 16 ft x 15 ft
- Minimum Emergency lighting in the MCR and RSC is 10FC (100 lumens/m^2).
- Fluorescent lamps are considered for the emergency lighting.

The applicant indicated in response to RAI 8-343, Question 08.03.02-13 (ML081960254), the lighting calculations show a load of 12 fluorescent lamp fixtures (57 W each) for providing emergency lighting in the MCR and RSC. Considering 57 W for each fluorescent fixture, the total load on the dc system is 12 x 57 W = 684 W. The applicant stated that these 12 fixtures are distributed on two trains of the dc system in order to assure the minimum illumination level with a postulated failure of two trains. The applicant therefore concluded that the total emergency lighting load on each dc system is (684/2) = 342 W or 3.1 A at 110 Vac or 2.7 A at 125 Vdc.

Use of ac or dc lighting fixtures will be decided during the detailed design phase. Considering a worst-case inverter efficiency of 70 percent, the load on the dc system is (342 / 0.7 / 125) = 3.9 A at 125 V dc. Because in a worst-case scenario 3.9 A is needed to provide adequate power to lighting equipment, and each US-APWR Class 1E dc system is designed to provide 10 ampere on each train of the emergency dc system, as shown in Table 8.3.2-1 of the DCD, the US-APWR Class 1E dc system is designed to be more than adequate to provide the minimum design basis power credited for the illumination equipment in the MCR, RSC, and the passage in between the MCR and RSC. Accordingly, the NRC staff finds the use of either ac or dc fixtures acceptable as long as the selected fixtures provide the minimum illumination level with a postulated failure of two trains (this is equivalent to the failure one train with another train out of service). If ac fixtures are used, inverters for lighting circuits will be necessary. Since the applicant clarified that the emergency lighting calculations and design include emergency lighting for the MCR as well as the remote shutdown console, RAI 8-343, Question 08.03.02-13 is closed and the issues it raised have been resolved.

DCD Tier 2, Figure 8.1-1 shows that several MOV MCCs are fed from the corresponding train of the MOV inverter, each of which is backed up by the pertinent Class 1E 125V dc bus. It was not clear, however, whether the battery and the battery chargers have sufficient capacity to provide backup power for the additional inverter load while carrying their own design basis loads. In RAI 8-343, Question 08.03.02-7, the NRC staff asked the applicant to confirm that the batteries and battery chargers have sufficient capacity to provide backup power for the additional inverter load while carrying their own design basis loads.

In a letter dated July 10, 2008, submitted in response to RAI 8-343, Question 08.03.02-7, the applicant explained the following:

> Figure 8.3.2-1 of DCD shows the configuration of Class 1 E DC system. A MOV inverter 1 and A MOV inverter 2 are supplied power from A DC switchboard via the AI DC switchboard normally. Also, A MOV inverter 1 and A MOV inverter 2 can be supplied power from B DC switchboard via the AI DC switchboard. B MOV inverter is supplied power from B DC switchboard normally. And also, B MOV inverter can be supplied power from A DC switchboard. Situation of train C and D MOV inverters is similar to train A&B. This means that each train battery supplies power to maximum three MOV inverters. MHI designs that each train battery can supply to loads which includes the three MOV inverters. MHI requires the capacity over 5000AH for all train battery as mentioned in Table 8.3.2-3 in DCD.
>
> Table 8.3.2-1 (sheet 1 of 4) in DCD, current of A MOV inverter 1440A is total current of A MOV inverter 1, A MOV inverter 2 and B MOV inverter. On the other hand, current of B MOV inverter 720A in Table 8.3.2-1 (sheet 2 of 4) is current of only B MOV inverter. MHI will revise the current of MOV inverter of “sheet 2 of 4” and “sheet 3 of 4” to 1440A. MHI provided the detail of battery sizing analysis. MHI will revise the DCD Revision 1 that loads condition of Table 8.3.2-3 replace to condition of Table 8.3.2-B2.

The NRC staff has confirmed that Table 8.3.2-1, “125V DC Class 1E Load Current Requirements,” includes the revised MOV inverter ratings. Since the applicant provided a detailed battery sizing analysis that shows the actual inverter ratings, and these ratings demonstrate each battery and charger combination has the capability to provide power to its assigned loads, the applicant has demonstrated that the battery and the battery chargers have sufficient capacity to provide backup power for the additional inverter load while carrying their own design basis loads in the event of a loss of an inverter. Therefore, the NRC staff considers RAI 8-343, Question 08.03.02-7, closed and the issue it raised, resolved.

In order to assess the adequacy of the safety-related dc power systems, in RAI 8-343, Question 08.03.02-14, the NRC staff asked the applicant to provide the results of battery sizing calculations, battery terminal voltage calculations, SC calculations, and voltage drop calculations for NRC staff review.

In the response to RAI 8-343, Question 08.03.02-14 (ML081960254), the applicant furnished a summary of its analysis of the Class 1E dc system. The applicant provided a load flow calculation that determined the voltage level at the battery terminals, dc switchboards, and inverters during the largest loading demand, as determined by the battery duty cycle developed in accordance with IEEE Std. 485-1997 (R2003), "IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications," endorsed by RG 1.212, "Sizing of Large Lead-Acid Storage Batteries." The staff determined that these load flow calculations show that adequate voltage is available throughout the two-hour battery duty cycle duration (based on safety analysis assumptions) and that battery charging conditions are within the design rating. The final dc load flow analysis of the dc onsite power system, as constructed, is specified in DCD Tier 1, Table 2.6.2-2, ITAAC Item 3. Also, the applicant provided COL Information Item 8.3(8), which calls for the COL applicant to provide a SC analysis for the dc power system. This COL information item is adequate because it addresses the site-specific characteristics of the plant site and analyzes them in light of the specific conditions the plant would experience throughout its life. Also, the applicant submitted battery charger and battery sizing calculations. The NRC staff determined that these sizing calculations conform to the guidance in IEEE Std. 946, "IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations," and IEEE Std. 485, respectively. These standards are acceptable for battery charger and battery sizing calculations for this application. The NRC has endorsed IEEE Std. 485-1997 in RG 1.212 (November 2008). Accordingly, the NRC staff finds that the applicant has adequately addressed the issue. The NRC staff considers RAI 8-343, Question 08.03.02-14, closed and the issues it raised, resolved.

In RAI 8-343, Question 08.03.2-2, the NRC staff asked the applicant to provide additional information in the following areas: inverter specification, including voltage regulation, frequency variation, and total harmonic distortion (THD); regulating transformer specifications, including voltage regulation; and UPS protective scheme against faults (e.g., overcurrent, fault current, undervoltage, and underfrequency). The applicant submitted the response to RAI 8-343, Question 08.03.02-2 (ML081960254). The NRC staff reviewed the information submitted by the applicant and determined this response acceptable because it provided information related to the adequacy of the Class 1E dc power systems including the Class 1E Inverter specifications (UPS Unit), regulating transformer specifications, and UPS protective scheme against faults. In particular, the staff determined that the information in the response is in conformance with the applicable portion of RG 1.32. However, the NRC staff understood that the information provided by the applicant needed to be part of the DCD.

Accordingly, in RAI 388-2858 (ML091620161), Question 08.03.2-16, the NRC staff asked a follow up RAI to RAI 8-343, Question 08.03.02-2. In this follow-up RAI, the NRC staff asked the applicant to include this information in an upcoming revision of the DCD.

In response to RAI 388-2858, Question 08.03.2-16 (ML091980044), the applicant stated that the specification of Class 1E UPS unit and transformer, and UPS protection scheme against faults would be added in a revision of the DCD. The NRC staff has verified that the applicant has added the following information to DCD, Tier 2, Section 8.3.1.1.6:

> Protection of UPS is provided in accordance with IEEE-446 and recommendation from manufacturers. The fault current, over current, overvoltage and undervoltage are basic protection schemes. In addition, an inverter is also commonly supplied with current limiting capability for protection. Distribution devices are to be coordinated with this inverter's current-limiting capability.

The NRC staff also verified that DCD Tier 2, Table 8.3.1-11, "Electrical Equipment Ratings - Component Data, I&C power source," was revised with detailed specifications for the UPS Unit. The information submitted by the applicant conforms to the guidance in RG 1.32 regarding the principal design criteria and the design features for the safety-related power systems that enable the systems to perform their assigned functions under the conditions produced by the postulated design basis events. Based on the applicant's response and the revision of the DCD, the NRC staff considers RAI 8-343, Question 08.03.02-2 and RAI 388-2858, Question 08.03.2-16 closed and the issue they raised, resolved.

DCD Tier 2, Section 8.3.2.1.1, states that each Class 1E battery charger has the capacity to recharge its battery from the design minimum charge to a 95 percent charged condition within 24 hours and simultaneously supply the normal dc loads of the associated 125 V dc switchboard bus. However, the NRC staff noted that each non-Class 1E battery charger has the capacity to recharge its battery from the design minimum charge to fully charged condition within 24 hours and simultaneously supply the normal dc loads of the associated 125 V dc switchboard bus. In RAI 8-343, Question 08.03.2-3, the NRC staff asked the applicant to provide justification for providing the Class 1E battery chargers enough capacity to recharge their batteries from the design minimum charge to a 95 percent charged condition, but not a fully charged condition. In a response to RAI 8-343, Question 08.03.02-3 (ML081960254**)**, the applicant clarified that both Class 1E and the non-Class 1E chargers are designed to charge the battery to 95 percent capacity within 24 hours. The NRC staff determined this response acceptable because the battery chargers of US-APWR are designed in accordance with IEEE Std. 946, "IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations," which allows the design of the charger to have capability to charge to 95 percent capacity within 8 to 24 hours. This IEEE standard has not been endorsed by the NRC, but it is widely used by the industry as a standard reference document.

Accordingly, in RAI 388-2858, Question 08.03.2-17**,** the NRC staff asked a follow up RAI to RAI 8-343, Question 08.03.02-3. In this RAI, the NRC staff requested that the applicant include the description on the charging of the Class 1E and non-Class-1E batteries from "fully" to "95 percent." In response to RAI 388-2858, Question 08.03.2-17 (ML091980044), the applicant stated it had revised the DCD such that the description of the charging of the non-Class 1E batteries was changed from "fully" to "95 percent." The NRC staff verified that DCD Tier 2, Section 8.3.2.1.2 contains a statement that the battery chargers are sized to carry the normal dc system load and simultaneously recharge a design basis discharged battery to 95 percent of full rated capacity within 24 hours. Based on the applicant's July 13, 2009, response and the revision of the DCD, the NRC staff considers RAI 8-343, Question 08.03.2-3 and RAI 388-2858, Question 08.03.2-17 closed and the issue they raised, resolved.

Section 8.3.2.1.1 of the DCD stated that there are four Class 1E battery chargers, one for each train, connected to the Class 1E 125V dc switchboard bus. In addition, there are two installed non-Class 1E spare battery chargers, one spare battery charger AB for trains A and B, and another spare battery charger CD for trains C and D. The spare battery charger AB can be used to temporarily replace any one of the Class 1E battery chargers A or B, but not both at once. Similarly, the spare battery charger CD can be used to temporarily replace any one of the Class 1E battery chargers C or D, but not both at once. The non-Class 1E spare battery charger is placed in service to temporarily replace an inoperable Class 1E charger. In RAI 8-343, Question 08.03.2-4, the NRC staff asked the applicant to provide the justification for replacing Class 1E battery chargers with non-Class 1E chargers when a Class 1E charger is inoperable during power operation. In addition, the NRC staff asked the applicant to describe the periodic surveillances that will be performed on the non-Class 1E battery chargers. In the response to RAI 8-343, Question 08.03.02-4 (ML081960254), the applicant discussed the replacement scheme to be followed when a Class 1E battery charger is inoperable. The applicant stated that the spare non-safety charger is used to prevent the battery from drying out when the Class 1E charger is inoperable. The applicant also stated in its response that surveillance requirements were not necessary for non-Class 1E chargers. The NRC staff understood the intended use of the spare charger but determined this response inadequate because the applicant failed to clarify the use of non-Class 1E chargers when a Class 1E charger is inoperable, and to describe the interaction between safety-related SSCs and SSCs that are not safety-related. Because the non-Class 1E charger is not necessary to maintain the quality of the Class 1E batteries, the NRC staff agrees that non-Class 1E equipment is not required to undergo periodic surveillances under the TS.

Article 4.11 of IEEE Std. 308, endorsed by RG 1.32, states that connection of non-Class 1E circuits to Class 1E power systems is not recommended. Article 4.11 of IEEE Std. 308 also provides that the non-Class 1E circuits shall meet the independence and isolation requirements as established in IEEE Std. 384-1992, which was endorsed by RG 1.75. In RAI 388-2858, Question 08.03.2-18, which the NRC staff asked a follow up RAI to RAI 8-343, Question 08.03.02-4, the NRC staff asked the applicant, in view of the guidance given in IEEE 308, to provide justification for using non-Class 1E chargers and to explain why the use of non-class 1E chargers should be acceptable for an out-of-service Class 1E charger, and how the design meets the guidance stated above. RAI 388-2858, Question 08.03.2-18, requested, at a minimum, that the applicant provide a failure modes and effect analysis of the interactions of the non-Class 1E system chargers on the safety-related dc train equipment to ensure that a failure of system that is not safety-related does not cause a loss of or a failure in the safety-related system component. Also, the staff asked the applicant to demonstrate that the design included a safety-related isolation device between the non-Class 1E chargers and safety-related dc train equipment.

In the response to RAI 388-2858, Question 08.03.2-18 (ML091980044), the applicant stated that non-Class 1E safety spare battery chargers are not normally connected to the Class 1E dc power system. Spare battery chargers that are not safety-related are connected to the Class 1E dc power system when the Class 1E charger is inoperable due to maintenance. This configuration does not change the condition of the Class 1E battery charger from inoperable to operable. An isolation device (Circuit Breaker Tripped by Fault Currents) is applied to the connection of a non-Class 1E spare battery charger to the Class 1E dc system. The applicant committed to performing a FMEA on the interactions of the non-Class 1E system chargers on the safety-related dc train, and to add the requirement for that analysis as Table 8.3.2-4 in the DCD. The NRC staff verified that the applicant has included the FMEA on the interactions of the non-Class 1E system chargers on the safety-related dc train in Table 8.3.2-4 in the DCD. Because the non-Class 1E spare battery chargers are only connected to the Class 1E dc power system when the Class 1E battery charger is inoperable due to maintenance, a safety-related isolation device is applied between the non-Class 1E chargers and safety-related dc train equipment in this temporary configuration, and the applicant has provided a FMEA to assess whether a failure of a system that is not safety-related will cause a loss of or a failure in the safety-related system component, the NRC staff finds that the IEEE Std. 384 has been met. Therefore, RAI 8-343, Question 08.03.02-4 and RAI 388-2858, Question 08.03.2-18, are closed and the issues have been resolved.

Section 8.3.1.1.6 of the DCD provides that for each safety-related train, in case of a failure of the UPS unit or the inoperability of the UPS unit due to maintenance, buses A, B, C and D are switched to the 50kVA, 480V/120V ac bypass transformer associated with the same train. The DCD explains that switching between each UPS unit and the bypass transformer is done automatically by an undervoltage signal, but did not describe in detail how this circuitry works and where the undervoltage signal is originated. Since switching between each UPS unit and the bypass transformer is done automatically by an undervoltage signal, the NRC staff asked the applicant in RAI 8-343, Question 08.03.2-6 to describe in detail how the circuitry works and to explain where the undervoltage signal is originated. In response to RAI 8-343, Question 08.03.02-6 (ML081980254), the applicant provided a description of the switching scheme between the UPS unit and the transformer. This response is acceptable because the applicant provided a description of the switching scheme between the UPS unit and the transformer as recommended in IEEE Std. 308, which is endorsed by RG 1.32. IEEE Std. 308 specifically recommends that the "…specific design basis shall be provided for the Class 1E power systems of each nuclear power generating station." This includes the minimum equipment or system performance criteria related to under voltage relay accuracy since its protective actions include limit the degradation effects of under voltage. However, the applicant had not committed to revising its DCD to include this information, which is necessary to demonstrate conformance with RG 1.32 in regard to design features for safety-related power systems.

Accordingly, in RAI 388-2858, Question 08.03.2-20, the NRC staff asked a follow up RAI to RAI 8-243, Question 08.03.02-6. The NRC staff requested that the applicant docket its response confirming the above actions to resolve this RAI question.

In response to RAI 388-2858, Question 08.03.2-20 (ML091980044), MHI provided the following clarification regarding the switching scheme between the UPS unit and the transformer.

> Normally 120V ac distribution panels A, B, C and D are fed from the 50kVA, 1 phase UPS units A, B, C and D respectively. In case of failure of the UPS unit or if the UPS unit is out on maintenance, buses A, B, C and D are switched to the 50kVA, 480V/120V ac bypass transformer associated with the same train. Switching circuits are provided with contactors for transfer between the UPS unit power and the transformer power. When the input power of switching circuit from

UPS unit is lost, undervoltage relay actuates. Following the undervoltage signal, a contactor of UPS unit side is opened, and then a contactor of transformer side is closed with time delay, automatically. Administrative controls ensure that no more than one vital ac bus is powered from the bypass transformer at any time during routine preventive maintenance of the associated UPS unit. The transfer from the transformer back to the UPS is performed manually.

The applicant provided a description of the switching scheme between the UPS unit and the transformer, and the staff determined that the design conforms with RG 1.32 in regard to design features for safety-related power systems related to undervoltage relay accuracy and its protective actions, which limit the degradation effects of undervoltage. Accordingly, RAI 8-243, Question 08.03.02-6 and RAI 388-2858, Question 08.03.2-20 are considered closed, and this issue is considered resolved.

DCD Tier 2, Table 8.3.2-1 shows a load current of one Ampere for the Class 1E 480V Load Center. Compared to operating experience data for Class 1E 480V load centers, a load current of one Ampere appears to be too low in terms of current-carrying capacity. Accordingly, in RAI 8-343, Question 08.03.2-12, the NRC staff asked the applicant to provide its basis for assuming a load of one Ampere for each Class 1E 480V Load Center as shown in Table 8.3.2-1 of the DCD. In addition, the NRC staff determined that this table does not include load current for 480V load center items such as the load sequencer, dc solenoids, ground detector, auxiliary relays, and indicating lights. Therefore, the NRC staff also asked the applicant to confirm that all the loads listed above are included in battery load calculations. In response to RAI 8-343, Question 08.03.02-12 (ML081960254), the applicant indicated that the load currents would depend on procurement specifications for the batteries. The NRC staff considered the response to RAI 8-343, Question 08.03.02-12 inadequate because the applicant failed to submit the load current for items such as the load sequencer, dc solenoids, ground detector, auxiliary relays, indicating lights, etc. RAI 8-343, Question 08.03.2-12, is considered closed, but the issues it raised remained open.

In RAI 388-2858, Question 08.03.2-22, the NRC staff asked a follow up RAI to RAI 8-343, Question 08.03.02-12. In RAI 388-2858, Question 08.03.02-22, the NRC staff requested that the applicant provide a brief discussion on the conservatism used in sizing of the loads and the associated protection of the loads, provide a more in-depth explanation of this issue, and incorporate this information in the upcoming DCD revisions.

In its response to RAI 388-2858, Question 08.03.02-22 (ML12114A327), the applicant stated that the load current in DCD, Revision 1 included Japanese experience and the product baseline loads will be revised to include US products. The applicant also indicated that the load current of the Reactor Building DC Distribution Panel included load current for the Class 1E solenoid valves. The load current for solenoid valves will be described separately from the Reactor Building DC Distribution Panel. Also, the applicant committed to add the assumed current for any load (i.e., auxiliary relay etc.) in Table 8.3.2-1 and its notes. In addition, the load sequencer and ground detector are not assumed in the dc power load. The applicant's supplemental response, dated April 20, 2012, provided detailed information regarding current for loads included in the battery sizing calculations. The calculations factored US manufacturers' information and differences from the Japanese manufacturers. The staff has reviewed the calculations and, since they reflect US information, among other things, finds them adequate as they pertain to design basis scenarios. The NRC staff considers this issue resolved since the DCD has been revised to incorporate the changes provided in the applicant's response.

Based on the foregoing, the NRC staff finds that the US-APWR onsite dc power system conforms to the guidance of RG 1.32. Furthermore, the NRC staff finds that the batteries, battery chargers, inverters, and distribution equipment are designed to: (1) operate with sufficient power at the quality necessary for the safety systems to perform their functions, and (2) conform to the restrictions on sharing of the safety-related dc power system between multiple units. The aspect related to the periodic inspection and testing of important parameters and features is discussed and analyzed in Section 8.3.1.4.5 of this SER**.**

8.3.2.4.4.3 Conformance with RG 1.47

DCD Tier 2, Section 8.3.2.2.2 states that the onsite dc power systems have been designed to conform to RG 1.47, "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems," which provides supplemental guidance for implementing IEEE Std. 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," to satisfy the NRC regulatory requirements.

RG 1.47 describes an acceptable method of complying with the requirements to indicate the inoperable or bypassed status of Class 1E systems or portions of such systems. The applicant's DCD states that indication of a bypassed component is automatically annunciated in the MCR to indicate the system or component condition. Since two Class 1E power sources provide power to the PSMS for the I&C equipment status, the plant operator can identify systems actuated or controlled by the PS in accordance with RG 1.47. DCD Tier 2, Section 7.5.1.2.1, "Design of Bypassed and Inoperable Status Indication," provides information on testability of bypassed or inoperable status indicators that are displayed. The NRC staff's evaluation of this information is in Section 7.5 of this SER.

Since the onsite power systems provide power for I&C equipment status, and bypassed or inoperable Class 1E systems or portions of such systems are automatically annunciated in the MCR, the plant operator can identify systems actuated or controlled using the indications that are displayed as the SDCV information on LDP in the MCR. The system-level Bypass and Inoperable Status Indication is discussed in detail in Topical Report MUAP-07007. Given the above, the NRC staff finds that this design conforms to the guidance in RG 1.47.

8.3.2.4.4.4 Conformance with RG 1.53

The applicant has stated in DCD Tier 2, Section 8.3.2.2.2, that the US-APWR has been designed based on the guidance of RG 1.53, "Application of the Single-Failure Criterion to Safety Systems," which provides that safety-related systems will have the power to perform their safety-related function in the presence of a single failure. DCD Tier 2, Section 8.3.2.2.2 states that the US-APWR has been designed so that safety-related systems will have the power to perform their safety-related function in the presence of a single detectable failure, all failures caused by the single failure, and all failures caused by a DBE. Local alarms are provided for "battery charger high dc voltage," "battery charger low dc voltage," "battery charger output breaker open," "failure of battery charger ac input," and "failure of battery charger dc output." These local alarms are combined to generate a 'battery charger trouble alarm' for indication in the MCR. The Class 1E dc power system is comprised of four trains of completely independent systems, each with its own battery, battery charger, and power distribution equipment. The components and equipment of each train are electrically isolated and located in separate rooms in a seismic Category I building with a minimum three-hour rated fire barrier between rooms. The HVAC systems that support operation of the Class 1E dc power system are powered from the redundant Class 1E ac power system. Any two of the four trains are sufficient to provide power for the minimum safety functions under any postulated design event. Hence, the Class 1E dc power system complies with the single failure criterion, even when one train is out of service. Based upon the above, the NRC staff finds that the US-APWR onsite dc power system conforms to the guidance in RG 1.53.

8.3.2.4.4.5 Conformance with RG 1.75

DCD Tier 2, Section 8.3.2.2.2 states conformance with RG 1.75. RG 1.75, "Criteria for Independence of Electrical Safety Systems," addresses the physical independence of the circuits and electrical equipment that compose or are associated with the onsite dc power system. The design's conformance with the guidance in this RG in regard to the physical independence of circuits and electrical equipment that comprise or are associated with safety systems is discussed in DCD Tier 2, Subsection 8.3.2.2.2.

Separation criteria, which establish the independence of redundant Class 1E electric systems, are applied among any redundant Class 1E systems and between any Class 1E system and non-Class 1E systems. Raceways are not shared by Class 1E and non-Class 1E cables. Cables of each train are run in separate raceways and are physically separated from cables of the other trains. Separation of different trains is in accordance with IEEE Std. 384, as endorsed by RG 1.75. Raceways for non-Class 1E are separated from each Class 1E train (A, B, C and D). Raceways for non-Class 1E are routed in the same areas as raceways of Class 1E while maintaining separation in accordance with IEEE Std. 384, as endorsed by RG 1.75. The DCD describes raceway and cable routing criteria for the applicant's onsite power systems and includes information on cable conductor size, cable tray fill, cable independence, and necessary separation. All components in each UPS train for the US-APWR are located in separate seismic Category I structures. This arrangement provides physical separation through the use of safety class structures for the majority of the electrical equipment and circuits. RG 1.75 does not distinguish between ac and dc power system cables. The function and voltage class of the cables includes 125 Vdc control and low voltage power cables. The NRC staff finds that the physical independence of the circuits and electrical equipment for the onsite dc power system, as described above, satisfies RG 1.75.

The applicant has provided information that demonstrates that the physical independence of the circuits and electrical equipment that compose or are associated with the onsite dc power system. Based on the above, the NRC staff finds that the US-APWR onsite dc power system conforms to the guidance in RG 1.75.

8.3.2.4.4.6 Conformance with RG 1.128

DCD Tier 2, Section 8.3.2.2.2 states conformance with RG 1.128. RG 1.128, "Installation Design and Installation of Vented Lead-Acid Storage Batteries for Nuclear Power Plants," relates to the installation of vented lead-acid batteries. This RG endorses IEEE Std. 484, "IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications," with some stipulations as indicated in regulatory positions C.1 through C.10. The IEEE Std. 484 provides the criteria that should be used for storage, location, mounting, ventilation, instrumentation, preassembly, assembly, and charging of vented lead-acid batteries. The regulatory positions and the manner in which MHI proposed to demonstrate conformance with them is described in Section 8.3.2.2.2 of DCD Tier 2.

IEEE Std. 485 recommends a 10-15 percent capacity margin to allow for unforeseen additions to the dc system and less-than-optimum operating conditions of the battery due to improper maintenance, recent discharge, ambient temperature lower than anticipated, or a combination of these factors. In RAI 8-343, Question 08.03.02-8, the NRC staff noted that the battery sizing included only a ten percent design margin. The battery chargers are sized to carry the normal dc system load and simultaneously recharge a battery discharged to the level specified in the design-basis to 95 percent of full rated capacity. Accordingly, it appeared that when a battery is declared operable at 95 percent of the full rated capacity, it will have only 5 percent margin available for load growth. As a result, the NRC staff asked the applicant to justify a 10 percent design margin instead of 15 percent margin for load growth, and demonstrate that the 10 percent design margin is adequate when a battery is supplying power at 95 percent of the full rated capacity.

In a letter dated July 10, 2008, submitted in response to RAI 8-343, Question 08.03.02-8, the applicant explained that the Class 1E battery size and charger size are designed in accordance with IEEE Std. 485 and IEEE Std. 946, "IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations." IEEE Std. 485-1997 was endorsed by the NRC in RG 1.212 (November 2008). The applicant explained that it designs each Class 1E battery with minimum ten percent margin. The Class 1E charger is designed with a capability to recharge the battery to 95 percent capacity within 24 hours. The detail of the applicant's evaluation was provided in Attachment B to the letter. For example, each Class 1E battery is evaluated 4560AH as minimum rating including 10 percent margin, 25 percent aging factor and 95 percent initial capacity. The typical battery rating is determined in accordance with manufacturer's standard. The applicant selected and applied 5100AH battery, demonstrating sufficient margins to adjust to load growth. Additionally, charger size is calculated by using this battery rating 5100AH. Since the applicant has demonstrated that the Class 1E battery size and charger size have been designed in accordance with IEEE Std. 485 and IEEE Std. 946 with the recommended capacity margin, the NRC staff agrees with the applicant's clarification and considers RAI 8-343, Question 08.03.02-8 closed and the issues it raised, resolved.

RG 1.128 recommends a one percent maximum hydrogen concentration in the battery room. The National Fire Protection Association (NFPA) Standard 70E, "Standard for Electrical Safety in the Workplace- 2004," Article 320.4(C)(2) and 320.4(D)(1) states that ventilation shall be provided so as to prevent liberated hydrogen gas from exceeding one percent concentration. The NFPA-70E requirement is similar to the guidance given in RG 1.128, which states that "…the ventilation system shall limit hydrogen accumulation to one percent of the total volume of the battery area." DCD Tier 2, Section 8.3.2.1.1, originally stated that the US-APWR design has a limit of two percent maximum hydrogen concentration in the battery room. In RAI 8-343, Question 08.03.02-1, the NRC staff asked the applicant to provide the justification for using a two percent maximum hydrogen concentration instead of the one percent maximum hydrogen concentration as recommended in RG 1.128. In a response to RAI 8-343, Question 08.03.02-1 (ML081550236), the applicant responded that "…the 2% limits described in RG 1.189 was appropriate for the fire protection scenario." The NRC staff determined that this response unacceptable because while a two percent limit in hydrogen concentration in the battery room may be acceptable for the fire protection scenario, it may not be acceptable for workers' protection.

Accordingly, in RAI 388-2858, Question 08.03.02-15, the NRC staff asked a follow up RAI to RAI 8-343, Question 08.03.02-1. In RAI 388-2858, Question 08.03.02-15, the NRC staff requested that the applicant confirm that the battery room ventilation fans have sufficient capacity to maintain the hydrogen concentration below one percent in the battery rooms, which will be verified with hydrogen detectors, and requested the applicant to revise the DCD to incorporate the new information.

In response to RAI 388-2858, Question 08.03.02-15 (ML091980044), the applicant stated that the DCD would be revised to state that the maximum hydrogen concentration in the battery room would be 1 percent, in conformance with the guidance in RG 1.128. The NRC staff determined that this response is acceptable because the hydrogen concentration in the battery room will conform to NFPA-70E. The NRC staff also verified that DCD Tier 2, Sections 8.3.2.1.1, 8.3.2.1.2, 8.3.2.2.2, 9.4.3.1.2.2, 9.4.3.2.2, 9.4.3.3.2, 9.4.4.1.2, 9.4.4.2.2, 9.4.5.1.1.2, 9.4.5.2.2, 9.4.5.3.2, and 9.5.1.2.1 state that the battery rooms are ventilated to the outside to preclude hydrogen concentration of more than 1 percent. Given that the DCD revision conforms to the guidance in RG 1.128, the NRC staff considers RAI 8-343, Question 08.03.02-1 and RAI 388-2858, Question 08.03.02-15, closed and the issue they raised, resolved.

Similarly, before the applicant revised its DCD to correct the hydrogen concentration in the battery room to 1 percent, DCD Tier 2, Section 8.3.2.1.1, stated that that the battery rooms are ventilated to the outside air to preclude a hydrogen concentration of more than two percent, and that a safety-related ventilation system is not directly required when the batteries perform their safety function. In RAI 8-343, Question 08.03.02-10, the NRC staff asked the applicant to clarify why operability of the safety-related ventilation system is not required when the batteries perform their safety function. In its response to RAI 8-343, Question 08.03.02-10 (ML081960254), the applicant explained that the US-APWR design does not include a safety-related ventilation system for the Class 1E battery room. The NRC staff determined that this explanation was inadequate because the applicant did not address whether and how the battery rooms would be ventilated in the case of a DBE.

As a follow-up to RAI 8-343, Question 08.03.02-10, the NRC staff asked RAI 388-2858, Question 08.03.2-21. By this RAI, the NRC staff requested the applicant to indicate whether the battery rooms have a safety-related ventilation system, and to update its DCD to reflect this information.

In its response to RAI 388-2858, Question 08.03.2-21 (ML091980044), the applicant stated that the safety-related ventilation system is provided for the associated Class 1E battery room as described in DCD Tier 2, Subsection 9.4.5.2.2. The NRC staff verified that DCD Tier 2, Revision 2, Section 8.3.2.1.1 had been revised to mention that a safety-related ventilation system is provided for the associated Class 1E battery room. The NRC staff also verified that DCD Tier 2, Section 9.4.5.2.2, contains detailed information about the safety-related ventilation system including its major components: A Class 1E electrical room air handling unit, a Class 1E electrical room return air fan, a Class 1E battery room exhaust fan, an outside air intake and exhaust outlets with a tornado missile protection grid and a tornado depressurization protection damper. Chapter 9 of this SER sets forth the staff evaluation of the information in Section 9.4.5.2.2 of the DCD. Given the DCD revisions, the NRC staff considers RAI 388-2858, Question 08.03.2-21, closed, and the issue it raised resolved.

Based on the foregoing, the NRC staff finds that the design of the batteries for the onsite power system of the US-APWR conforms to the guidance in RG 1.128.

8.3.2.4.4.7 Conformance with RG 1.129

DCD Tier 2, Section 8.3.2.2.2 states conformance with RG 1.129. RG 1.129, "Maintenance, Testing, and Replacement of Vented Lead-Acid Storage Batteries for Nuclear Power Plants," provides information and recommendations concerning the maintenance, testing, and replacement of vented lead-acid batteries used in stationary application in the onsite power system. RG 1.129 endorses IEEE Std. 450-2002, "Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications." Detailed battery surveillance testing is in the TS in DCD Tier 2, Chapter 16, Sections 3.8.4 and 3.8.5. In addition, testing related to initial design and installation of batteries for the US-APWR will be performed by COL applicants under DCD Tier 1, Table 2.6.2-2, "DC Power Systems ITAAC." This conformance provides an adequate basis for complying with the requirements set forth in GDC 17 and 18 of Appendix A to 10 CFR Part 50 as they relate to testing the operability and functional performance of safety-related batteries. Based upon the above, the NRC staff finds that the design of the batteries for the US-APWR onsite dc power system conforms to the guidance in RG 1.129.

8.3.2.4.4.8 Conformance with RG 1.153

RG 1.153, "Criteria for Safety Systems," 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. This RG provides supplemental guidance for implementing IEEE Std. 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," to satisfy the NRC regulatory requirements and provides minimum functional and design requirements for the power, instrumentation, and control portions of safety systems for nuclear power generating stations.

DCD Tier 2, Section 8.3.2.2.2 states conformance with RG 1.153. The NRC staff has reviewed the applicant's onsite dc electrical distribution safety-related configuration and its functions to determine whether functional independence and physical separation of each division is in accordance with RG 1.153 and IEEE Std. 603-1991. The IEEE standard addresses independence between redundant portions of a safety system and effects of a design basis event. In the US-APWR design, this is accomplished by the separation of safety-related components among divisions. The physical separation assures that a single failure or an internal hazard, or both, in one division can only affect that division. Therefore, during design basis accidents coincident with a single failure to any electrical component in a division, the remaining divisions will support safety-related function completion. In addition, the onsite dc power electrical distribution equipment (i.e., batteries, battery chargers, MCCs, switchboards, inverters, and panel boards) is sized to provide sufficient power to start and operate the connected loads. Specifically, the onsite dc system design features include: (1) four independent and redundant dc divisions, (2) the capacity and capability to perform their associated safety functions during all normal and emergency modes of plant operation including DBEs, (3) physical separation and electrical isolation among divisions, and (4) the system is located within seismic Category I buildings, which can withstand seismic design loads without loss of safety-related functions. Accordingly, the NRC staff finds that the US-APWR DCD satisfies the regulatory guidance with respect to a reliable dc power source for all facility operating modes, including AOOs and design-basis accidents, to support the performance of safety functions and other vital functions, even in the event of a concurrent single failure.

The batteries are sized for the worst-case duty cycle for a period of two hours, considering loss of associated battery charger and plant conditions that include normal plant operation, LOOP, and coincident LOOP and LOCA. The battery cells are flooded lead-acid cells. Each train has 60 cells rated at 125Vdc, 5000Ah, with a float voltage 2.25V/cell, equalize voltage 2.33V/cell, and an 8 hour rating (see DCD Tier 2, Table 8.3.2-3, “Electrical Equipment Ratings - Component Data Class 1E DC Power System (Nominal Values).” The battery chargers are sized to carry the normal dc system load and simultaneously recharge a design basis discharged battery to 95 percent of full rated capacity within 24 hours. Each battery charger is provided with a “high dc voltage shutdown relay” that opens the main ac supply breaker to the charger and provides a local alarm. Local alarms are provided for ”battery charger high dc voltage”, “battery charger low dc voltage”, “battery charger output breaker open”, “failure of battery charger ac input” and “failure of battery charger dc output”. These local alarms are combined to generate a ‘battery charger trouble alarm’ for indication in the MCR.

Based upon the above, the NRC staff finds that the US-APWR onsite dc power supply has the capacity and capability to provide power to all safety loads needed to assure that fuel design limits and RCS pressure boundary design conditions are not exceeded and the core is cooled and containment integrity and other vital functions are maintained during all facility operating modes, including AOOs and design-basis accidents, even in the event of a single failure. Accordingly, the US-APWR dc power supply, including station batteries, meets the requirements of GDC 17 and is designed in accordance with the separation and independence guidance of RG 1.153.

8.3.2.4.4.8 Conformance with RG 1.155

DCD Tier 2, Section 8.3.2.2.2 states conformance with RG 1.155. RG 1.155 relates to the capability and the capacity of a nuclear power plant’s onsite dc power system for an SBO, including batteries associated with the operation of the AAC power source(s). This RG provides guidance for complying with 10 CFR 50.63.

The US-APWR onsite dc power system is designed such that power supplies to all electrical loads that are required to be operable is restored within one hour from the onset of an SBO event. Under normal plant operating conditions, both safety-related dc power systems and dc power systems that are not safety-related derive power from the battery chargers, which are fed from the safety-related 480V MCCs and the 480V MCCs that are not safety-related, respectively. Safety-related batteries and batteries that are not safety-related will provide power to the dc power system during the first hour of an SBO event. Within one hour of an SBO event, power from one of the AAC sources would be available to a required Class 1E battery charger and its associated train of the dc system will be powered from that battery charger. Hence, for an SBO condition, the batteries are sized to provide their duty cycle current for a period of one hour. In addition, all batteries are sized for the worst-case duty cycle for a period of two hours, considering loss of associated battery charger and plant conditions that include normal plant operation, LOOP, and coincident LOOP and LOCA.

Based on the above, the NRC staff finds that the US-APWR onsite dc power system batteries conform to the guidance in RG 1.155. Furthermore, the staff finds that the capacity of any onsite dc sources used for SBO response is adequate to address the worst-case SBO load profile and specified duration to meet the requirements of 10 CFR 50.63.

8.3.2.4.5 Compliance with GDC 18

GDC 18 requires that electric power systems important to safety, which include the onsite dc power system, be designed to permit appropriate periodic inspection and testing of important areas and features to assess the continuity of the systems and the condition of their components. These systems shall be designed with a capability to test periodically: (1) the operability and functional performance of the components of the systems, such as onsite dc power sources, inverters, battery chargers, switchboards, and buses, and (2) the operability of the systems as a whole and under conditions as close to design as practical.

For the US-APWR, all dc system components are periodically tested in accordance with the TS as detailed in DCD Tier 2, Chapter 16. Local alarms are provided for “battery charger high dc voltage”, ”battery charger low dc voltage”, “battery charger output breaker open”, ‘failure of battery charger ac input” and “failure of battery charger dc output”. These local alarms are combined to generate a ‘battery charger trouble alarm’ for indication in the MCR. DCD Tier 1, Table 2.6.2-2, “DC Power Systems ITAAC,” verifies the design of electrical display parameters that will be monitored in the MCR. The safety-related dc power system has been designed to permit periodic inspection and testing of key areas and features in order to assess system continuity and availability, and to verify the condition of system components. The safety-related dc power system is designed to provide the capability to perform integral periodic testing of the system. TS outlined in Chapter 16, Section 3.8, describe surveillance requirements for electrical power systems. The system design conforms to the NRC guidance provided in RGs 1.32, 1.47, and 1.153, as described above, and RG 1.118 and BTP 8-5 (see below).

Based on the above, the NRC staff finds that the US-APWR onsite dc power system can be appropriately accessed for required periodic inspection and testing, enabling verification of important system parameters, performance characteristics, and features, as well as detection of degradation and/or impending failure under controlled conditions. Therefore, the NRC staff finds that the US-APWR onsite dc power system meets the requirements of GDC 18.

8.3.2.4.5.1 Conformance with RG 1.118

RG 1.118, "Periodic Testing of Electric Power and Protection Systems," endorses IEEE Std. 338 with some exceptions and clarifications indicated in regulatory positions C(1) through C(3). The applicant's commitment to conform to RG 1.118 is captured in Table 1.9.2-8 of the DCD Tier 2.

Battery and battery charger capacities of the US-APWR are periodically tested in accordance with TS detailed in DCD Tier 2, Chapter 16, in accordance with RG 1.118. Periodic dc system component testing in accordance with RG 1.129 is performed based on the component manufacturer recommendations and IEEE Std. 450-2002. There are four Class 1E safety-related battery chargers: one for each train, connected to the Class 1E 125V dc switchboard bus for that train. In addition, there are two installed non-Class 1E spare battery chargers, one spare battery charger AB for trains A and B, and another spare battery charger CD for trains C and D. Any two of the four trains are capable of mitigating any abnormal or design-basis accident conditions. Hence, the system is capable of performing its safety functions assuming a single failure and one train being out of service for maintenance. Testing that could cause perturbations to the dc electrical distribution systems or challenge continued steady-state operation of safety-related systems is normally performed during plant shutdown. Testing performed during plant shutdown includes battery performance or modified performance discharge tests. Inverter maintenance that involves removing the inverter from service is also performed during plant shutdown. Additional specific testing of the UPS components during shutdown is detailed in DCD Tier 2, Chapter 16.

Based on the above, the NRC staff finds that the applicant's onsite dc power system can be appropriately accessed for required periodic inspection and testing, enabling verification of important system parameters, performance characteristics, and features, as well as detection of degradation and/or impending failure under controlled conditions. The US-APWR UPS has been designed to permit periodic inspection and testing to assess the operability and functionality of the systems and the condition of their components. Therefore, the NRC staff finds that the US-APWR onsite dc power system meets the recommendations of RG 1.118.

8.3.2.4.6 Compliance with GDC 50

GDC 50 requires, in part, that the design of containment penetrations, including electrical penetrations containing circuits of the dc power system in containment structures, must withstand a LOCA without loss of mechanical integrity. In order to satisfy this requirement, the penetration assemblies in containment structures must be capable to withstand all ranges of overload and short circuit currents up to the maximum fault current versus time conditions that could occur given single random failures of circuit protective devices. The compliance of containment electrical penetration assembly design, qualification, and protection has been reviewed and evaluated under Section 8.3.1 of this SER. The design provisions described in that section apply to the onsite dc power circuits. Since all US-APWR containment electrical penetration assemblies for onsite Class 1E ac and dc systems are designed, constructed, and qualified in accordance with IEEE Std. 317-2003, "IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations," as endorsed by RG 1.63, the NRC staff finds that this provides assurance that a LOCA will not cause the electrical penetrations of a containment structure to exceed the design leakage rate, thus limiting the consequences of a LOCA as prescribed by GDC 50.

8.3.2.4.8 Compliance with 10 CFR 50.63

The applicant has met the requirements of 10 CFR 50.63 with respect to the onsite dc power system. The dc power systems have adequate capability and capacity to enable the plant to withstand and recover from an SBO event of duration specified in the application. See Section 8.4 of this SE for the NRC staff's evaluation of this matter, with the exception of battery capacity and capability, which is discussed in Section 8.3.2.4.4.8 of this SER.

8.3.2.4.9 Compliance with 10 CFR 50.65(a)(4)

Under 10 CFR 50.65(a)(4), COL applicants assess and manage the increase in risk that may result from proposed maintenance activities for onsite ac power equipment before performing the maintenance activities. These activities include 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 Chapter 17 of NUREG-0800. Programs for incorporation of requirements into appropriate procedures are reviewed under Chapter 13 of NUREG-0800.

The US-APWR DCD states that compliance and acceptability with the maintenance rule in conformance with the following RGs: RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," and RG 1.182, "Assessing and Managing Risk before Maintenance Activities at Nuclear Power Plants," is generically addressed in DCD Tier 2, Section 1.9.

To address the development of the program for implementation of 10 CFR 50.65, the Maintenance Rule, the applicant has provided COL Item 17.6(1) described in Section 17.6 of the DCD. COL Item 17.6(1) states that the COL applicant that references the US-APWR DC must provide in its DCD a description of the maintenance rule program, and its implementation, for monitoring the effectiveness of maintenance necessary to meet the requirements of 10 CFR 50.65(a)(4). Since the removal of multiple SSCs from service can lead to a loss of Maintenance Rule functions, the COL applicant must provide a program description that will address how removing SSCs from service will be affected. For qualitative risk assessments, the program description must explain how the risk assessment and management program will preserve plant specific key safety functions. Because the description of a Maintenance Rule program is the COL applicant's responsibility and the DCD applicant provides a mechanism to implement the

Maintenance Rule requirements, the NRC staff finds that the US-APWR DCD applicant has adequately addressed 10 CFR 50.65(a)(4).

8.3.2.4.10 Compliance with 10 CFR 50.55a(h)

10 CFR 50.55a(h) requires compliance with the relevant positions for plant protection and safety systems regarding design, reliability, qualification, and testability of the power and I&C portions of safety systems outlined in RG 1.153, "Criteria for Safety Systems," which provides supplemental guidance for implementing IEEE Std. 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," to satisfy the NRC regulatory requirements. The IEEE standard requires evaluation of all aspects of the electrical portions of the safety-related systems, including the basic criteria for addressing single failures.

Section 8.3.2.1.1 of the DCD states that the Class 1E switchboards employ molded case circuit breakers and/or fusible disconnect switches as input and output circuit protection devices. It was not clear to the NRC staff whether molded circuit breakers or fusible disconnect switches will be employed as input and output circuit protection devices. In RAI 8-343, Question 08.03.02-5, the NRC staff asked the applicant to confirm whether the US-APWR will use molded case circuit breakers or fusible disconnect switches as input and output circuit protection devices. The NRC staff requested that the applicant describe how the molded case circuit breakers will be coordinated with the downstream protective devices if molded case circuit breakers are used. In addition, the staff requested the applicant to provide results of the coordination studies performed on the dc system. In a response to RAI 8-343, Question 08.03.02-5, the applicant provided a brief discussion stating that both MCCBs and fuses are accepted as protective devices. However, it was not clear from the applicant's response whether the US-APWR will employ MCCBs or fusible disconnect switches as input and output circuit protection devices.

As a followup to RAI 8-343, Question 08.03.02-5, the NRC staff issued RAI 388-2858, Question 08.03.2-19, in which the NRC staff asked the applicant to clarify which of those devices are going to be used, and to discuss the coordination of the feeder breakers and downstream protective devices (MCCB) of the loads, if the main fuse can be coordinated with the feeder MCCBs, and if its statements are based on actual studies. In response to RAI 388-2858, Question 08.03.2-19 (ML091980044), the applicant stated that fusible disconnect switches are used as protective device of dc main switchboard. The applicant also stated that descriptions for the coordination of the feeder fusible disconnect switches and downstream protective device would be added to an upcoming revision of the DCD. This information clarified what protective devices would be used for each function. The NRC staff verified that DCD Tier 2, Section 8.3.2.1.1 was revised to include the following information:

> The Class 1E switchboards employ fusible disconnect switches as input and output circuit protection devices.
>
> The main circuit protection devices located in the switchboards have selective coordination with all downstream protective devices in accordance with IEEE Std. 242, "IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems."

Also, the NRC staff verified that DCD Tier 2, Section 8.3.2.1.2 was revised to include the following information:

> The non-Class 1E switchboards employ fusible disconnect switches as input and output circuit protection devices.
>
> The main circuit protection devices and feeder circuit protection devices located in the switchboards have selective coordination with all downstream protective devices in accordance with IEEE Std. 242.

The NRC staff also verified that DCD Tier 2, Figure 8.3.2-1 was revised to indicate fusible disconnect switches as protective device for dc main switchboards. Since the applicant accurately described that the Class 1E switchboards employ fusible disconnect switches as input and output circuit protection devices, and commit to using the method described in IEEE Std. 242 which has not been endorsed by the NRC but is an acceptance standard widely used in the industry, the NRC staff considers RAI 8-343, Question 08.03.02-5, and RAI 388-2858, Question 08.03.2-19, closed and the issues they raised, resolved.

In view of the above, the NRC staff finds that the safety and protection systems of the US-APWR onsite dc power system design are based on RG 1.153 and IEEE Std. 603, and the compliance of the systems as constructed will be confirmed by the electrical distribution system protection and coordination studies and verified through the ITAAC Item 12 in Table 2.6.2-2 in Tier 1 of the DCD. Accordingly, the NRC staff finds that the US-APWR onsite dc power system design meets the requirements of 10 CFR 50.55a(h). The aspects of IEEE Std. 603 that apply to the adequacy of I&C are evaluated in Chapter 7 of this SER.

8.3.2.4.11 Conformance with BTP 8-5

In addition to conforming to RG 1.47, DCD Tier 2, Section 8.1.5.3.3, states that the guidelines of BTP 8-5, "Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems," have been incorporated into the design of the bypassed and inoperable status indicators. The system level Bypass and Inoperable Status Indication is discussed in detail in Topical Report MUAP-07007. Because the onsite power systems provide power for I&C equipment status, the plant operator can identify systems actuated or controlled using the indications that are displayed as the SDCV information on LDP in the MCR, in accordance with RG 1.47. All bypassed or inoperable status indicators that are displayed are indicated in DCD Tier 2, Chapter 7, and this portion of the design is acceptable for the reasons stated in Chapter 7 of this SER. Therefore, the NRC staff finds US-APWR design is in conformance with BTP 8-5 in this regard.

8.3.2.4.12 Conformance with RG 1.206

Section 8.3.2.3 of the DCD describes the dc system electrical power system calculations and distribution system studies for the US-APWR consistent with Section C.I.8.3.2.3 of RG 1.206. The applicant has performed the following electrical power system calculations and distribution system studies for onsite dc power systems on a preliminary basis for the standard plant design:

- Load Flow/Voltage Regulation Studies and Under/Overvoltage Protection
- SC Studies
- Equipment Sizing Studies
- Equipment Protection and Coordination Studies
- Power Quality Limits

The electrical power system calculations and distribution system studies utilized ETAP to analyze the ac distribution system for load flow, voltage regulation, motor starting, and SC studies. The applicant stated that ETAP conforms to the requirements of 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," and ASME NQA-1, "Quality Assurance Program Requirements for Nuclear Facility Applications." Onsite ac power system calculations are presented in Technical Report MUAP-09023-P. The NRC staff has determined that this technical report adequately addresses this subject because it includes steady state load flow, motor starting, SC, transfer of MV switchgear and harmonic analysis, and presents all of the assumptions per the acceptance criteria as described for each SSC, and properly analyzes three conditions for each operational mode. This technical report is acceptable for the reasons discussed in the staff evaluation in Section 8.3.1.4.15 of this SER.

Therefore, the NRC staff finds that the DCD conforms to the guidance in RG 1.206 in this regard.

8.3.2.5 Combined License Information Items

The following is a list of item numbers and descriptions from Table 1.8-2 of the DCD:

Table 8.3.2-1
US-APWR Combined License Information Items

Item No.	Description	Section
8.3(1)	The COL applicant is to provide transmission voltages. This includes MT and RAT voltage ratings.	8.3.1.4.4.9
8.3(2)	The COL applicant is to provide ground grid and lightning protection.	8.3.1.4.17
8.3(3)	The COL applicant is to provide SC analysis for the ac power system, since the system contribution is site-specific.	NA
8.3(4)	Deleted	NA
8.3(5)	Deleted	NA
8.3(6)	Deleted	NA
8.3(7)	Deleted	8.3.2.4.4.2
8.3(8)	The COL applicant is to provide SC analysis for the dc power system.	NA
8.3(9)	Deleted	8.3.1.4.17

Table 8.3.2-1
US-APWR Combined License Information Items

Item No.	Description	Section
8.3(10)	The COL applicant is to provide protective devices coordination.	8.3.1.4.17
8.3(11)	The COL applicant is to provide insulation coordination (surge and lightning).	8.3.1.4.4.9
8.3(12)	The COL Applicant is to provide the cable monitoring program for underground and inaccessible cables with the scope of the maintenance rule (10 CFR 50.65).	8.3.1.4.5.2

8.3.2.6 Conclusions

As set forth above, the NRC staff has reviewed all of the relevant information that is applicable to the US-APWR onsite dc power system design and evaluated its compliance with GDC 17, 18, and 50, and conformance to RGs, industry codes and standards, and BTPs committed to by the applicant. The NRC staff also reviewed the COL information items in DCD Tier 2, Table 1.8-2. The NRC staff concludes the design of the US-APWR onsite dc power system meets the appropriate regulatory requirements listed in Section 8.3.2.3, and shown in the NRC staff technical evaluations in Sections 8.3.2.4 and 8.3.2.5 of this SER.

8.4 Station Blackout

8.4.1 Introduction

Station blackout (SBO) refers to the complete loss of ac power to the essential (safety-related) and nonessential (not safety-related) electrical buses in a nuclear power plant (NPP). That is, an SBO involves the loss of the offsite electric power system (PPS) concurrent with a turbine trip and failure of the onsite emergency ac power system. For the US-APWR design, during an SBO, all offsite ac power sources and the onsite safety-related GTGs are assumed to be lost and unavailable to perform their intended safety function. An SBO does not include the loss of available ac power to safety buses served by station batteries through inverters or by AAC power sources. 10 CFR 50.63 identifies the factors that must be considered in determining the SBO duration and requires that each NPP be able to withstand and recover from an SBO for a specified duration. Because many safety systems for reactor core decay heat removal and containment heat removal rely on ac power, an SBO could result in a severe core damage accident. An SBO does not assume a concurrent single failure or DBA.

As described below, the US-APWR reactor design uses natural circulation and the turbine-driven emergency feedwater pump for cooling. An AAC power source is established to power a shutdown bus within one hour to power SBO loads for the remaining period of a specified duration to cope with an SBO and recover from it. The AAC power source is designed to provide reliable electric power to safely shut down and maintain the reactor in a safe condition during an SBO event.

8.4.2 Summary of Application

DCD Tier 1: The Tier 1 information associated with a SBO is found in DCD Tier 1, Section 2.6.5 and Table 2.6.5-1. The applicant states that the two GTGs that are not safety-related are provided as the AAC power sources to provide power to station loads necessary to bring the plant to and maintain it in a safe shutdown condition during a SBO event.

DCD Tier 2: The applicant has provided a Tier 2 system description in Section 8.4 summarized here in part, as follows:

8.4.2.1 Station Blackout Coping Duration

The applicant states that the offsite power system and its interconnections to the generating stations are site-specific and therefore not covered in the DCD. However the applicant states that each site will have a minimum of two physically independent transmission lines from the offsite grid systems to the onsite transformer yard and to the plant safety buses to fully conform to 10 CFR Part 50, Appendix A, GDCs 17 and 18. Since the offsite power design characteristics are site-specific, and are not specifically known to the DCD applicant, the applicant has selected a bounding offsite power characteristic group which is "P3" in accordance with Table 4 of RG 1.155. The onsite emergency ac power supply system design comprises four redundant and independent emergency Class 1E onsite GTGs. The applicant states that any two of the four emergency Class 1E GTGs are adequate to operate the ac powered decay heat removal systems. Therefore, onsite emergency power configuration group is classified as "B" in accordance with Table 3 of RG 1.155. The applicant has chosen the minimum target reliability of the Emergency Class 1E GTGs to be 0.95 in accordance with Section C.1.1 of RG 1.155.

Based on the offsite power characteristic group "P3," onsite emergency power configuration group as "B" and the Class 1E GTG reliability of 0.95, the applicant has calculated the acceptable SBO coping duration of 8 hours in accordance with Table 2 of RG 1.155 for the US-APWR design described in the DCD.

8.4.2.2 Alternate AC Power Sources

The applicant states that two AAC GTGs are provided for reliability and operational flexibility, but only one is necessary for achieving safe shutdown of the NPP under SBO conditions. The applicant states that power to the buses needed for safe shutdown can be restored from the AAC power source within 60 minutes, and provides a coping analysis for the first 60 minutes of SBO duration. The applicant states that the GTGs achieve rated voltage and frequency within 100 seconds after receiving a start signal. The applicant implements diversity between the Class 1E GTGs and the AAC GTGs by using different ratings and starting mechanisms; locating the AAC sources in separate rooms from the Class 1E GTGs; using independent auxiliaries; and providing interconnections to the offsite and onsite emergency ac power systems, such that no single point of vulnerability would cause AAC failure and prevent it from performing its intended safety function. The ac power from the AAC GTG to one Class 1E 6.9-kV bus will be verified by actual field testing to show that it is available within 60 minutes after an SBO. The applicant states that a weather-related event or a single failure could not disable all the onsite emergency ac sources and offsite ac power supplies simultaneously along with all of the AAC sources.

8.4.2.3 Station Blackout Coping Analysis

The applicant states as follows: The AAC GTGs are not normally connected to the Class 1E 6.9-kV buses A or B, or C or D. The AAC GTGs are automatically started by the undervoltage signal on the 6.9-kV permanent buses P1 or P2. Once the AAC GTGs have reached rated voltage and frequency, they will be connected to their respective 6.9kV permanent bus P1 or P2 during an SBO or LOOP. All of the major loads on both buses P1 and P2 are tripped on undervoltage, so there is minimal residual load on these buses when the AAC GTGs are connected. The power supply from an AAC GTG can be restored to one of the Class 1E buses within 60 minutes by closing disconnect switches and circuit breakers connecting the AAC GTGs to the Class 1E buses. The AAC GTGs reach the rated frequency and voltage within 100 seconds after they are started. Since the power supply from the AAC GTG to the Class 1E buses is not restored within 10 minutes, a coping analysis is performed for first one hour (60 minutes) as required by 10 CFR 50.63(c)(2) and in accordance with the guidance of Regulatory Position C.3.2 of RG 1.155. The one-hour coping analysis is performed to show that the plant is kept safe by taking the following action:

- The RCP seals can maintain integrity for at least one hour without water cooling.

- All Class 1E electrical cabinets and I&C cabinets are rated to keep their integrity up to 50°C ambient temperature. The temperature of Class 1E electrical room and I&C room will not reach 50°C within one hour even without HVAC.

- Turbine driven (T/D) emergency feedwater (EFW) system mechanical and electrical equipment, including EFW turbine control system components, are rated to keep their integrity up to 175°F temperature. The temperature of the T/D EFW pump room will not reach 175°F within one hour even without HVAC.

The applicant indicated further that at the end of one hour when power to the Class 1E bus is restored from an AAC GTG, the following operations will be performed to keep the plant in a safe shutdown condition for the long term:

- Reactivity control will be maintained by supplying borated water from the boric acid tank via a charging pump;

- RCS inventory will be maintained by supplying water from the refueling water auxiliary tank by using a charging pump;

- RCS pressure control will be maintained by using the pressurizer backup heater bank and depressurizing by using the safety depressurization valve (SDV);

- Decay heat will be removed by supplying EFW pit water to the steam generators by using the T/D EFW pump and relieving steam through a main steam relief valve;

- RCP seal cooling will be provided by a charging pump using the refueling water auxiliary tank as the water source.

The applicant states that the plant can be kept in the safe shutdown condition (hot shutdown) by performing the above actions with power from only one Class 1E train, which would be supplied from one AAC GTG.

8.4.2.4 Recovery from SBO

The applicant's coping analysis shows that at the end of 8 hours, the ac power supply would be restored to the Class 1E buses from the offsite power system or from the onsite Class 1E GTGs. The recovery from an SBO with an available offsite source would be accomplished by paralleling the AAC GTG power supply with the offsite power system. After the two sources are paralleled, the AAC GTG would be unloaded and the Class 1E loads transferred to the offsite power system. If the power from the onsite Class 1E GTGs becomes available before the power supply from the offsite system, then the Class 1E loads will be transferred to the onsite Class 1E GTGs in a similar manner as for the offsite power system.

ITAAC: The ITAAC associated with Tier 2, Section 8.4 are given in Tier 1, Section 2.6.5 and Table 2.6.5-1.

TS: There are no TS identified for this area of review.

8.4.3 Regulatory Basis

The relevant requirements of the Commission's regulations for this area of review, and the associated acceptance criteria, are given in Section 8.4 of NUREG-0800, the SRP, and are summarized below. Review interfaces with other SRP sections also can be found in Section 8.4 of NUREG-0800.

1. 10 CFR 50.63, it relates to the capability to withstand and recover from an SBO of specified duration as defined in 10 CFR 50.2.

Acceptance criteria adequate to meet the above requirements include:

1. The guidance of RG 1.155, which provides guidance for compliance with 10 CFR 50.63.

2. The guidelines and criteria of SECY-90-016 and SECY-94-084, as they relate to the use of AAC power sources for coping with an SBO for evolutionary designs.

3. The guidelines of RG 1.155 and RG 1.9, as they relate to the reliability program implemented to ensure that the target reliability goals for onsite emergency power sources are adequately maintained.

4. Nuclear Energy Institute (formerly the Nuclear Utility Management and Resources Council (NUMARC)) publication NUMARC 87-00, Revision 0, November 1987,

"Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," is endorsed by RG 1.155, and provides guidance acceptable to the NRC staff for meeting SBO rule requirements.

8.4.4 Technical Evaluation

The NRC staff reviewed whether the applicant's design complies with 10 CFR 50.63, which establishes the requirement for the design to have the capability to withstand and recover from an SBO. The primary guidance for acceptably meeting these requirements is found in RG 1.155. The following sub-sections provide the NRC staff's review with respect to the major elements of RG 1.155 and are supplemented by the acceptance criteria of the other guidance documents listed in Section 8.2.3 above.

8.4.4.1 Station Blackout Coping Duration

The SBO rule requires each plant to justify its specified coping duration by an analysis of site- and plant-specific factors that contribute to the likelihood and duration of an SBO. Section C.3.1 of RG 1.155 presents an acceptable method for determining the specified duration for which a plant should be able to withstand an SBO.

In accordance with 10 CFR 50.63 and the guidance given in RG 1.155 for meeting 10 CFR 50.63, the applicant evaluated the onsite and plant-specific factors to withstand and recover from an SBO lasting a specified minimum duration. The specified duration of an SBO for the US-APWR is based on the following factors given in Regulatory Position C.3.1 of RG 1.155:

1. The redundancy of the onsite emergency ac power system (i.e., the number of power sources available minus the number needed for decay heat removal – emergency ac configuration (EAC) group),

2. The reliability of each of the onsite power sources (4500-kW GTGs),

3. The expected frequency of loss of offsite power, and

4. The probable time needed to restore offsite power.

The US-APWR onsite Class 1E electrical distribution system design consists of four physically separate and electrically isolated divisions (trains) A, B, C, and D. Each train comprises 6.9-kV, 480-Vac, 120-Vac, and 125-Vdc electrical power distribution systems. Each train is supplied by a 6.9-kV, 4500-kW Class 1E GTG connected to the Class 1E 6.9-kV bus. The availability of any two trains is adequate to meet the electrical load for a LOOP, and LOOP and LOCA occurring simultaneously. Therefore, the onsite EAC group is two out of four, and in accordance with RG 1.155, Table 3, it is designated as EAC Group "B." Accordingly, the NRC staff finds that the US-APWR DC applicant has appropriately evaluated the EAC as "Group B" per guidelines of RG 1.155 and SRP Section 8.4.

Each GTG provided for the US-APWR plant has a minimum target reliability of 0.95 per demand and that is consistent with the guidelines in Regulatory Position C.1.1 of RG 1.155; therefore, it is acceptable to the NRC staff.

The transmission system (grid) and switchyard, and its interconnections to the US-APWR station are site-specific and not within the scope of the DCD. However, in accordance with GDC 17, the COL applicant will provide at least two physically independent power circuits between the offsite grid systems and the US-APWR plant high-voltage switchyard. Per the US-APWR design, there are two physically independent transmission tie lines from the plant high voltage switchyard to the plant onsite transformer yard. The NRC staff review of the DCD determined that it did not contain information on the offsite power system design with respect to severe weather, severe weather recovery, and extremely severe weather because they are site-specific and cannot be assessed by the DCD applicant. Therefore, the applicant has elected to classify the Offsite Power Design Characteristic Group as “P3” in accordance with Table 4 of RG 1.155. The P3 group is the most conservative group allowed in the Table 4 of RG 1.155, and thus results in the longest SBO coping duration in accordance with RG 1.155, Table 2, “Acceptable Station Blackout Duration Capability (Hours).” Therefore, this characterization provides for a coping duration of 8 hours in accordance with RG 1.155, Table 2. Since the coping duration for the US-APWR is also 8 hours, the staff finds this acceptable.

8.4.4.2 Alternate AC Power Sources

The NRC staff reviewed the US-APWR DCD sections on SBO against the requirements of 10 CFR 50.63, and the guidance given in RG 1.155, SRP Section 8.4, SECY-94-084, and SECY-90-016 to ensure that the applicant had provided sufficient information to demonstrate how the AAC power source meets the regulatory requirements and guidance.

1. Capacity and Capability

In accordance with Section C.3.3.5 of RG 1.155, the AAC power source should be capable of supplying power to all loads that are necessary for the safe shutdown of the plant in the event of an SBO. However, for new ALWR designs, the Commission established a policy in SECY-90-016, “Evolutionary Light Water Reactor (LWR) Certification Issues and Their Relationship to Current Regulatory Requirements,” dated January 12, 1990, which it approved in the NRC staff requirements memorandum dated June 26, 1990 (ML003707885), that such plants should have an AAC power source of diverse design and capable of powering at least one complete set of normal shutdown loads. The Commission’s policy on AAC power sources (SECY-90-016) for new reactor designs is described in SRP Section 8.4. SRP Section 8.4 states that the AAC source should be of diverse design (with respect to onsite power sources); have adequate capacity, independence, and reliability; and have capability for powering at least one complete set of normal safe-shutdown loads. The AAC power source should have sufficient capacity to operate the systems necessary for coping with an SBO for the time necessary to bring and maintain the plant in a safe-shutdown condition including cold shutdown.

To demonstrate that the AAC source for the US-APWR is of diverse design (with respect to onsite power sources); has adequate capacity, independence, and reliability; and has capability for powering at least one complete set of normal safe-shutdown loads, the applicant, in Section 8.4 of the DCD, has provided two 4000-kW, 6.9-kV, non-Class 1E GTGs as AAC sources that can power the P1 and P2 buses, which are not safety-related, during normal and LOOP conditions. Each of the AAC power sources has the capacity and capability to power SBO loads to keep the plant in a safe (hot shutdown) condition for the eight-hour coping duration. The applicant intends to use one of the AAC power sources for powering SBO loads while the other will be used to supply loads that are not safety-related for asset management. The applicant states that two 100 percent-capacity AAC sources are incorporated into the overall design in order to provide greater reliability for coping with an SBO event. The staff's evaluation of diversity is set forth below.

DCD Table 8.3.1-6, "Electrical Load Distribution-AAC GTG Loading (SBO Condition)," did not include the RHR pump in the SBO loads that are powered by the AAC GTG during an SBO event, even though the RHR pump is necessary to keep the plant in hot shutdown condition for the long term. This approach is contrary to the guidance provided in the SECY-90-016, SECY-94-084, and SRP Section 8.4, which states that the preferred method of demonstrating compliance with an SBO (10 CFR 50.63) for evolutionary designs is to have a full-capacity AAC power source of a diverse design that can power a larger complement of shutdown equipment than needed to bring the plant to cold shutdown. It was not clear to the NRC staff how the applicant could assert operational flexibility and enhanced reliability for two AAC power sources for an SBO when one of the AAC power source is used to power loads that are not safety-related for asset management. In RAI 11-456 (ML082040270), Questions 08.04-3 and 08.04-04 the NRC staff asked for clarification on how a single AAC power source would meet the guidance given in SECY-90-016 and SRP Section 8.4; on how greater US-APWR reliability for coping is achieved when only one AAC GTG is used to cope with an SBO event; and why an RHR pump was not included in the SBO loads that are powered by the AAC GTG. Therefore, the NRC staff finds that, since the applicant has committed to use both AAC-GTGs to achieve cold shutdown, the US-APWR design conforms to the guidance set forth in SECY-90-016, SECY-94-084 and SRP Section 8.4.

The NRC staff then asked a followup RAI 419-3126 (ML091940164), Question 08.04-09 formally requesting that the applicant document the description on how US-APWR design meets the guidance provided on an SBO in the SECY-90-016, SECY-94-084 and SRP Section 8.4 for evolutionary designs. In a letter dated August 21, 2009, submitted in response to RAI 419-3126, Question 08.04-09, the applicant explained that the US-APWR design can achieve the cold shutdown condition by using only one AAC-GTG and one train of the Class 1E system. Also, the applicant stated that the second AAC-GTG can be used as an additional back-up source to power Class 1E system loads to achieve and maintain the plant in a cold shutdown condition if necessary, instead of using it for asset management. The applicant indicated that the loads shown in the DCD are the minimum loads needed for hot shutdown under SBO conditions. The applicant also indicated that when the plant is transitioned to cold shutdown, two AAC GTGs will be used to operate any two-out-of-four safety trains' loads, including the RHR pump, for keeping the plant in a safe condition. The applicant committed to add the description of the manner in which both AAC GTGs would be used for SBO purposes to achieve safe shutdown and go to cold shutdown, if necessary, using the two AAC GTGs in Section 8.4 of the DCD. The applicant also agreed to add a separate Table in Section 8.4 to show the loads which are needed for cold shutdown, including the RHR pump. The applicant agreed to add a detailed description to the DCD how both of the AAC GTGs will be used for SBO purposes. The applicant also agreed to revise DCD Table 8.3.1-6 to show the loads for hot- sutdown and cold shutdown to keep the plant in safe condition during an SBO.

The NRC staff finds the applicant's response acceptable since it states that the US-APWR will be capable of achieving cold shutdown using only AAC sources, therefore meeting the Commission's policy on the use of AAC power sources (SECY-90-016) and SRP Section 8.4 for meeting the SBO rule for new reactor designs. The NRC staff has verified that the applicant revised DCD Tier 2, Subsection 8.4.1.3, to add a description of how to achieve and keep cold shutdown. Additionally, the applicant revised Table 8.3.1-6, to show which load will achieve and keep cold shutdown during an SBO. Therefore, the staff finds the applicant's response acceptable, and RAI 11-456, Questions 08.04-3 and 08.04-04 and RAI 419-3126, Question 08.04-09, are resolved.

2. Diversity

The guidelines on diversity of the AAC power sources are described in Appendix B to RG 1.155, SRP Section 8.4, and SECY-90-016, which states that the AAC power sources should be diverse from the onsite Class 1E power sources. The AAC GTGs are rated at 4000 kW and the onsite Class 1E GTGs are rated at 4500 kW. The application originally the following regarding the design of Class 1E GTGs. One manufacturer supplies both the AAC GTGs and the Class 1E GTGs, but the GTG designs differ in some minor respects. For example, the AAC GTGs have a battery (electric) starting system whereas the Class 1E GTGs have an air starting system. The applicant had considered the different rating (4000 kW versus 4500 kW) and the diverse starting systems to be sufficient for meeting the guidance given in RG 1.155, SRP Section 8.4, and SECY-90-016 on diversity between the AAC power sources and the onsite Class 1E emergency power sources. The NRC staff did not consider the difference in kW rating of the Class 1E and AAC GTGs to be of great significance when classifying them as diverse GTGs because the difference in their real power rating is small. Although the AAC GTGs have different starting systems, the GTGs proposed for an SBO and onsite Class 1E emergency power sources are identical in all other aspects. The SBO and onsite Class 1E emergency GTGs are to be made by the same manufacturer and are to use identical components. The NRC staff concluded that the applicant did not sufficiently demonstrate that it had met the Commission guidance on diversity as documented in SECY-90-016 in regard to the AAC power sources.

Accordingly, in RAI 11-456, Question 08.04-3, the NRC staff also requested that the applicant provide additional information on how the US-APWR designs meets the Commission's guidance on diversity of AAC power sources. In response, the applicant made a commitment to use different manufacturers for Class 1E GTGs and the AAC GTGs, with each manufacturer having a different GTG design and using different components. The NRC staff finds this approach acceptable because it will minimize common cause failures in view of the different GTG manufacturers and their use of differing designs and components for the AAC GTGs and the onsite Class 1E GTGs. The NRC staff has verified that the applicant revised DCD Tier 2, Subsection 8.4.2.2, to state that two AAC GTGs, which are independent and of different manufacturer from the Class 1E ac power sources, are provided as AAC sources to minimize common mode failures. Therefore, the staff finds the applicant's response acceptable, and this RAI is resolved.

3. Independence

NRC regulations in 10 CFR 50.2 define an AAC power source, in part, as follows: 1) the AAC is connectable to but not normally connected to the offsite or onsite emergency ac power system, and 2) the AAC has minimum potential for common cause failure with offsite power or the onsite emergency ac power sources.

In terms of connectability, the AAC GTGs are not normally connected to the Class 1E buses. The AAC GTGs A and B are aligned, but not normally connected, to the non-Class 1E 6.9-kV permanent buses P1 and P2, respectively, through two separate selector circuits. Each selector circuit consists of one circuit breaker connected to the AAC source and three disconnect switches. The disconnect switches in the respective selector circuits are connected to the 6.9-kV P1 and P2 buses, which are not safety-related, through tie lines. The AAC GTG circuit breakers in the selector circuits are normally open and the AAC power source is not automatically loaded for an SBO but has provisions to be manually connected to the safety-related buses as needed. AAC GTG A can be manually connected to Class 1E buses A or B (but not both simultaneously), and AAC GTG B can be manually connected to Class 1E buses C or D (but not both simultaneously). Accordingly, the NRC staff concludes that the design is in full compliance with the connectability requirements of 10 CFR 50.2.

With respect to providing minimum potential for a common cause failure between the AAC sources and the offsite and onsite emergency power systems, the design has a number of specific provisions. First, the AAC sources are not connected to either of the other two power systems as discussed above. Second, the selector circuits and the non-Class 1E 6.9-kV buses are located in the PS/B, which is separate from the Class-1E switchgear Building. Therefore, weather-related events or a single failure in either system could not disable all of the onsite emergency ac sources and offsite ac power supplies simultaneously along with all the AAC power sources. Third, the auxiliary and support systems for the AAC GTGs are otherwise independent and separate from the Class 1E GTGs to minimize the potential for common cause failure. For example, completely separate and independent fuel supply systems and onsite fuel storage tanks are provided for the Class 1E GTGs and for the non-Class 1E AAC GTGs.

The NRC staff assessed the adequacy of the independence of the AAC power sources as described above and finds the following: the independence between the AAC power source for the SBO and the PPS and onsite power system, electrical ties between these systems, and the physical arrangement of the interface/support equipment should minimize the potential for the loss of any system (i.e., preferred, onsite, or AAC) given the loss of one of the other systems. Therefore, the NRC staff finds that the AAC sources meet the requirements of 10 CFR 50.2 concerning common mode failure and that this aspect of the design is acceptable.

4. Inspection, Testing, and Maintenance

In accordance with RG 1.155, Regulatory Position C3.3.5, the AAC power system should be inspected, maintained, and tested periodically to demonstrate availability and reliability. The reliability of the AAC power system should meet or exceed 95 percent as determined in accordance with Nuclear Science Advisory Committee (NSAC)-108 or equivalent methodology. DCD Tier 2, Section 8.4.2.2 states that the AAC power system will be inspected and tested periodically to demonstrate operability and reliability. The DCD states that reliability of the AAC power system will meet or exceed 95 percent as determined in accordance with NSAC-108 or equivalent methodology to meet the Criterion 5 of Regulatory Position C.3.3.5 in RG 1.155. Because the inspection and testing to demonstrate operability and reliability will be conducted by the COL applicant over the lifetime of the NPP, the DCD should include these inspection and testing measures as a COL information item. The NRC staff in RAI 683-5251 (ML1102006333), Question 08.04-14, requested that the applicant add a COL information item in the DCD to ensure that the AAC power system will be inspected and tested periodically to demonstrate operability and reliability in accordance with RG 1.155, and Criterion 5 of Regulatory Position C.3.3.5. In response to RAI 683-5251, Question 08.04-14, dated February 18, 2011, the applicant revised Section 8.4.2.2 of the DCD to state that the AAC power system will be inspected and tested periodically based on manufactures' recommendations and RG 1.155 to demonstrate operability and reliability. The applicant described this testing as follows: During the quarterly surveillance test, the AAC is started and brought to operating conditions. Additionally, during every refueling outage, the AAC generator is tested by performing a timed start and rated load capacity test. The applicant states that testing and maintenance of the AAC is evaluated under the reliability assurance program and the maintenance rule program as described in the DCD Section 8.4.2.2. The NRC staff finds that the applicant's response acceptable in that a COL item is not needed since the DCD describes that the AAC power system will be inspected and tested periodically to demonstrate operability and reliability in accordance with RG 1.155, and Criterion 5 of Regulatory Position C.3.3.5. Therefore, the staff finds the applicant's response acceptable, and this issue resolved.

8.4.4.3 Station Blackout Coping Analysis

For new ALWR plants, the Commission approved the policy stated in the SECY-90-016 in the Staff Requirements Memorandum dated June 26, 1990, that such plants should have an AAC power source of diverse design which is capable of powering at least one complete set of normal shutdown loads for an SBO. In accordance with the above stated policy, the applicant for the US-APWR DC has provided two AAC GTGs for mitigating an SBO event. The guidance given in RG 1.155, Regulatory Position C 3.3.5.3, indicates that the AAC power source should be available in a timely manner after the onset of an SBO and with provisions to be manually connected to any of the redundant safety buses as necessary. The maximum time for making this equipment available should not be more than one hour as demonstrated by test. If the AAC power source can be demonstrated by test to be available to power the shutdown buses within ten minutes of the onset of an SBO, no coping analysis is required.

The AAC power sources provided in the design of US-APWR for an SBO are 6.9-kV, 4000-kW GTGs. The two AAC GTGs are permanently connected to 6.9-kV buses P1 and P2, respectively. During a LOOP, both AAC GTGs are automatically started by an undervoltage signal on 6.9-kV buses P1 and P2, respectively. Also, during an SBO, the AAC GTGs are automatically started from an undervoltage signal, but will be manually connected to one of the four Class 1E emergency buses within 60 minutes. Since the power supply from the AAC GTG to one of the Class 1E buses cannot be accomplished within ten minutes, a coping analysis for one-hour is required to be performed for the US-APWR standard design in accordance with Regulatory Position C.3.2 of RG 1.155 and the requirements of 10 CFR 50.63(a). The coping analysis must show that with no ac power available to the safety buses, the plant can be kept in safe condition for one hour until one of the AAC GTGs is manually connected to restore ac power to one of the safety buses.

The NRC staff reviewed the information on an SBO given in DCD Tier 2, Section 8.4, to determine the US-APWR's capability to withstand and recover from an SBO with an eight-hour coping duration. When determining a plant's capability to cope with an SBO, the NRC staff evaluates the capability of all systems and components necessary to provide core cooling and decay heat removal, including station battery capacity, condensate storage tank (CST) capacity, compressed air capacity, RCS inventory, and effects of loss of ventilation in all dominant areas of concern and instrumentation and controls. The NRC staff's evaluation of the proposed coping analysis follows.

(1) Core and reactor coolant system (RCS) Inventory:

In DCD Tier 2, Section 8.4.2.1.2, the applicant states that during the first hour of an SBO, the plant is kept in a hot shutdown condition, and the turbine-driven (T/D) emergency feed water (EFW) pump and a main steam relief valve are used to remove the decay heat of the core through natural circulation of the reactor coolant. The applicant did not provide information on the ability to maintain adequate RCS inventory to ensure that the core is cooled and remains covered during the first hour. In RAI 11-456, Question 08.04-7, the NRC staff requested additional information on RCS inventory, taking into consideration any shrinkage, leakage from pump seals, and inventory loss from letdown or other normally open lines. The applicant, in response to RAI 11-456, Question 08.04-7 (ML082040270), explained that RCS inventory shrinkage will not cause pump seal leakage because the seal return line is closed and pump seal leakage will not occur. Also, the letdown line and any other lines from the RCS are closed, so no RCS inventory loss will occur during an SBO condition

The NRC staff questioned how pump seal leakage would not occur in the US-APWR design. Accordingly, in supplemental RAI 419-3126, Question 08.04-12, the NRC staff requested that the applicant provide additional information and clarification on the RCS inventory and core coverage taking into consideration the following:

- Provide a detailed description of the RCP seal return system and explain how the RCP seal leak flow at lower pressure could return to the reactor at higher pressure to avoid loss of reactor coolant inventory during an SBO event.

- Perform an SBO coping analysis to demonstrate that reactor core will remain covered during the SBO time period assuming loss of coolant inventory by: (a) steaming from the reactor through safety relief valves to carry out decay heat from the core, (b) assuming maximum RCS unidentified leakage defined in TS, and (c) appropriate amount of RCP seal leakage (at 25 gpm per pump per NUMARC 87-00, 2.5.2), unless justified as requested above.

In response to RAI 419-3126, Question 08.04-12 (ML11332A119), the applicant provided the following:

> (a) By steaming through the main steam relief valves, the decay heat of the core is removed, and the plant is kept in a condition similar to hot shutdown. This steaming is performed in the secondary system and relief through the valves around the pressurizer in the RCS will not occur. Therefore, it does not result in the loss of coolant inventory in the RCS.
>
> (b) The maximum RCS unidentified leakage defined in the technical specifications is 0.5 gpm and the loss of coolant inventory within 1 hour is expected not to exceed 30 gallons.
>
> (c) The leakage of reactor coolant through the seals of each RCP is assumed to be 0.2 gpm. Therefore, the total loss of coolant inventory within 1 hour from the seals on all four RCPs is expected to be 48 gallons. Based on these assumptions, the total amount of the inventory loss during the first hour after SBO is assumed to be 78 gallons, which corresponds to approximately 10.4 ft^3 at standard conditions. This amount is small compared to RCS coolant inventory. The normal operating water volume of the pressurizer is approximately 1,300 ft^3 (which is 45% of the free internal vessel volume of the pressurizer). Thus, the water in the pressurizer is maintained and the reactor core will remain covered during the SBO time period.

Industry guidance NUMARC-8700 states that the RCP seal leakage is assumed not to exceed 25 gpm per pump for the duration of the SBO event. In response to RAI 419-3126, Question 08.04-12, the applicant states that after an SBO occurs, the seal injection to the RCPs stops, and the isolation valves on the No. 1 seal leak-off line of each RCP are closed by the undervoltage signal. Thus, the No. 2 seal leak-off line is the only pathway for reactor coolant leakage through the RCPs. The leakage through the No. 2 seal is limited and is expected to be approximately 0.2 gpm per RCP under SBO condition. Because the isolation valve stops the leakage in No. 1 seal and the leakage from the No. 2 seal is limited, the NRC staff finds that the 0.2 gpm seal leakage per RCP from the No. 2 seal is acceptable and this issue is resolved.

(2) Condensate Inventory

The applicant did not provide information on condensate inventory in the DCD. In RAI 11-456, Question 08.04-7(b), the NRC staff requested that the applicant discuss and provide additional information on the capacity of the condensate storage tank to ensure that there will be sufficient water inventory to remove decay heat during the first hour of an SBO.

In a letter dated July 18, 2008, submitted in response to RAI 11-456, Question 08.04-7(b), the applicant stated that the emergency feed water pit supplies water to cool the RCS during an SBO. The capacity of the EFW pit is designed to maintain eight hours of a hot standby condition and six hours cooldown as a normal safe shutdown function, and thus has sufficient capacity to cope with an SBO for over eight hours. The NRC staff finds that the applicant's response indicating that there is sufficient water inventory for the first one hour, after which time the AAC power will be connected to power the loads necessary for an SBO, is acceptable because the volume of water in the EFW pit is much larger than that need to cope with an SBO for one hour. Therefore, the NRC staff considers RAI 11-456, Question 08.04-7 (b), closed and the issue it raised, resolved.

(3) Compressed Air Capacity

The applicant did not provide information on compressed air capacity in the DCD. In RAI 11-456, Question 08.04-7(c), the NRC staff requested that the applicant discuss and provide additional information on the compressed air capacity to ensure that air-operated valves relied on for decay heat removal have sufficient reserve air and maintain appropriate containment integrity for an SBO duration of one hour.

In a letter dated July 18, 2008, submitted in response to RAI 11-456, Question 08.04-7(c), the applicant stated the US-APWR design uses MOVs for safety-related valves and therefore does not rely on compressed air. In addition, the air-operated valves that are not safety-related are not operated during an SBO. The NRC staff finds that the applicant's response which states that compressed air is not relied upon for safety-related valves and the air-operated valves that are not safety-related are not operated during an SBO is acceptable. RAI 11-456, Question 08.04-7 (c), is closed and the issue it raised has been resolved.

(4) Battery Capacity

The applicant did not provide information on battery capacity in the DCD specifically for SBO. In RAI 11-456, Question 08.04-7(d), the NRC staff requested that the applicant discuss and provide additional information on the adequacy of battery capacity to support loads necessary for decay removal for the SBO duration of 1 hour as well as the Class 1E GTG field flashing for recovering onsite power sources.

In a letter dated July 18, 2008, submitted in response to RAI 11-456, Question 08.04-7(d), the applicant stated the Class 1E batteries furnished for the US-APWR design have sufficient capacity to supply power to all of the loads necessary to cope with an SBO described in DCD Section 8.3.2 for two hours. In the case of SBO, within the first hour, the AAC GTGs are started and connected so that ac power is restored to the Class 1E buses. Powered by the AAC GTG, the Class 1E battery charger will then supply power to the dc loads necessary to cope with an SBO during the remaining SBO coping duration and at that point will also begin to recharge the battery. Therefore, the batteries with their two-hour capacity are capable of supplying the SBO loads for up to one hour as well as providing dc power for field flashing the Class 1E GTGs if they become available within the first hour. Given this clarification, the applicant's response addressed the NRC staff's concern and is acceptable, therefore the NRC staff considers RAI 11-456, Question 08.04-7 (d), closed and the issue it raised, resolved.

(5) Effects of Loss of Ventilation

The applicant provided information on the effects of loss of ventilation and the integrity of electrical cabinets housing equipment credited for mitigating an SBO in DCD Tier 2, Section 8.4.2.1.2. However, the applicant did not discuss and provide information on effects of the loss of ventilation to other equipment, such as the T/D EFW pump, valves, battery room, and other equipment credited in mitigating an SBO event. In RAI 11-456, Question 08.04-7(e), the NRC staff requested additional information on the effects of a loss of ventilation in all dominant areas of concern and on the equipment credited during an SBO event.

In a letter dated July 18, 2008, submitted in response to RAI 11-456, Question 08.04-7(e), the applicant explained that other equipment except for electrical equipment credited in mitigating an SBO, is located in the areas shown in the table below. The equipment credited for mitigating an SBO can perform its SBO coping function for one hour from the onset of an SBO without ventilation, as presented in the following table:

Table – SBO Equipment Performance without Ventilation

Emergency Feedwater	Pump, Transmitter	The pump and transmitter are rated to Pump (T/D) Area keeps their integrity up to approx. 175°F (80°C). The temperature of this area will not reach 175°F (80°C) during loss of ventilation.
Corridor	Transmitter	Transmitter is rated to keep its integrity up to 175°F (80°C). Ambient temperature of corridor does not rise higher than the temperature of the Emergency Feedwater pump (T/D) area.
Containment Vessel	Transmitter	The transmitters are qualified to keep their integrity in postulated accident condition. Therefore, their integrity is kept in an SBO condition.
Main Steam/Feedwater Piping Area	Valve, Transmitter	The valves and transmitters are qualified to keep their integrity in postulated accident condition. Therefore, their integrity is kept in an SBO condition.
Battery Room	Battery	Heat generation from the battery in discharge mode does not raise the temperature significantly in the battery room.

The NRC staff finds that the applicant has identified and addressed all dominant areas of concern and the effects of loss of ventilation on the equipment credited for an SBO is acceptable. The NRC staff considers RAI 11-456, Question 08.04-7 (e), closed, and the issue it raised, resolved.

Under SRP Section 8.4, the NRC staff performed a review of the transient heat-up analysis of the US-APWR Turbine-Driven Emergency Feed-Water (TDEFW) pump room due to a complete loss of cooling under Station Blackout (SBO) conditions. The staff issued RAI 938-6535 (ML12159A410), Question 08.04-16, in the light of its May 9, 2012 audit (ML12115A205) of the applicant's transient heat-up calculation report, which was mainly conducted to address the concerns expressed by the Advisory Committee for Reactor Safeguards (ACRS) in its September 22, 2011 letter (ML11256A206). The ACRS letter asked that the applicant justify stable operation of the TDEFW pumps for at least one hour without active room cooling; and estimate when the turbine controls are expected to fail if the room heat-up continued for longer than one hour.

A follow-up RAI 991-7026 (ML130980180), Question 08.04-17, was issued to obtain additional details to address the staff's concerns about the potential non-conservatisms and the numerical stability of the transient heat-up analysis scheme, which were not resolved through the December 20, 2012 applicant's response to RAI 938-6535, Question 08.04-16 (ML123610042). The staff questioned the values of the natural convection heat transfer coefficient used between the air and the heat sinks; concrete thermo-physical properties; room outside temperature boundary conditions; and whether the numerical stability criteria were satisfied for the discretized 1-D transient conduction scheme that the applicant implemented in the Excel model for the heat sink heat-up. In response to RAI 991-7026, Question 08.04-17 (ML13100A004), the applicant revised the analysis to use conservative natural convection heat transfer coefficients and concrete thermophysical properties, and demonstrated through the use of Biot and Fourier numbers that the numerical scheme was stable for various heat sinks. The NRC staff confirmed that the heat-up analysis is based on conservative assumptions and uses a numerically stable calculation method. Accordingly, the staff finds that the TDEFW pump room air temperature remains below the 175 °F acceptance criterion up to 24 hours after a complete loss of cooling under SBO, which covers the coping period. Therefore, the NRC staff considers RAI 938-6535 (ML16076A030), Question 08.04-16, and RAI 991-7026, Question 08.04-17, closed, and the issue they raised, resolved.

8.4.4.5 Recovery from an SBO

In DCD Tier 2, Section 8.4.2, the applicant states that the ac power supply to the Class 1E buses would be restored either from the onsite Class 1E GTGs or from the offsite ac power source at the end of the coping duration of eight hours. The applicant has described procedures for the recovery of ac power to Class 1E buses by paralleling either the offsite or onsite Class 1E GTGs with the ACC GTGs once either of those sources becomes available during or at the end of eight-hour coping duration. After one of the two sources are paralleled, the AAC GTG would be unloaded and the Class 1E loads transferred to the offsite or the onsite power system. The staff has concluded that the applicant provided information sufficient to justify an eight-hour coping duration, and that either the onsite Class 1E or the offsite ac power source will become available by the end of that coping duration. Based upon the above information, the NRC staff finds that the applicant has adequately addressed the recovery of offsite or onsite AC power at the end of an SBO coping duration in accordance with the guidance of RG 1.155.

8.4.4.6 Quality Assurance and Specification for SBO Equipment

RG 1.155, Section 3.5, "Quality Assurance and Specification Guidance for Station Blackout Equipment That Is Not Safety Related," refers to Appendices A and B of 10 CFR Part 50 for guidance on quality assurance (QA) and specifications respectively for equipment that is not safety-related proposed to meet the SBO rule. The specific QA guidance is described in DCD Tier 2, Chapter 17, "Quality Assurance and Reliability Assurance," and related Topical Report PQD-HD-19005, "Quality Assurance Program Description," Revision 1. In addition, equipment installed to meet the SBO rule should not degrade the existing safety-related systems. This is accomplished by making the equipment that is not safety-related as independent as practical from existing safety-related systems. SBO equipment is separated from safety-related equipment by isolation devices in accordance with the guidance of RG 1.75. The SBO equipment such as AAC GTG and associated switchgear and equipment is procured and installed in accordance with RG 1.155 Position C.3.5, and Appendix B to RG 1.155.

DCD Tier 2, Section 8.4, did not address the QA activities for equipment that is not safety-related and is used to meet the requirements of 10 CFR 50.63. In RAI 11-456, Question 08.04-06, the NRC staff requested information on how the US-APWR design meets the RG 1.155 Position C3.5 on QA and specifications for SBO equipment that is not safety-related, such as AAC GTG power sources. Additionally, the NRC staff requested that the applicant provide an interface requirement in the US-APWR DCD for a COL applicant that references the US-APWR DC to address the RG1.155 position C.3.5 related to QA and specifications for SBO equipment that is not safety-related.

The applicant's response to RAI 11-456, Question 08.04-6 dated (ML082040270), stated that the AAC GTG system is an important system from the view point of plant safety. In its response, the applicant elaborated that the design of the AAC GTG system complies with position C3.5 of R.G 1.155 and the QA of the AAC GTG will be controlled in accordance with DCD Chapter 17 and related Topical Report PQD-HD-19005, Revision 1. This response resolves the technical aspects of RAI 11-456, Question 08.04-6 in that the topic is fully addressed in DCD Chapter 17 and this RAI is closed. However, in a follow-up RAI, RAI 419-3126, Question 08.04-11, the NRC staff requested that the response to the former RAI be incorporated into DCD Section 8.4 for completeness.

In response to RAI 419-3126, Question 08.04-11 (ML092370430), the applicant stated that it will revise Subsection 8.4.2.2 of the DCD to note its conformance with Regulatory Position C.3.5 of RG 1.155 and Subsection 8.4.4, and to add the reference to Topical Report PQD-HD-19005, Revision 1. The NRC staff has verified that the applicant revised DCD Tier 2, Subsection 8.4.2.2, and added a reference in Subsection 8.4.2.2 of the DCD, which refers the reader to Chapter 17 of the DCD and Topical Report PQD-HD-19005, Revision 1 addressing QA for SBO equipment and systems. The QA program will be reviewed in Chapter 17 of this SER. RAI 419-3126, Question 08.04-11, is closed and the issue it raised has been resolved.

8.4.4.7 Procedures and Training to Cope with SBO

Position C3.4 of RG 1.155 addresses procedures and training to cope with an SBO. It states that procedures and training should include all operator actions necessary to cope with an SBO and to restore normal long-term cooling and decay heat removal. In DCD Tier 2, Section 8.4, the applicant described a sequence of switching operations for connecting and restoring ac power from one of the two AAC GTG power source for mitigating an SBO. The description in DCD Section 8.4 did not describe how Position C3.4 of RG 1.155 is met.

In RAI 11-456, Question 08.04.05, the NRC staff requested that the applicant provide information on how the US-APWR design meets Position C3.4 of RG 1.155. Also, the NRC staff requested that MHI add a requirement for a COL applicant that references the US-APWR DC to address the RG1.155 position C.3.4 related to procedures and training to cope with an SBO, as well as an interface requirement in US-APWR DCD for a COL applicant to develop and submit a summary of SBO coping procedures and training guidelines for NRC staff review.

In response to RAI 11-456, Question 08.04-5 (ML082040270), the applicant stated that a brief overview of SBO actions and operation is described in DCD Tier 2, Sections 8.4.1.3 and 8.4.1.4, and that Position C.3.4 of RG 1.155 is addressed in Section 13.2, “Training,” and 13.5, “Plant Procedures.” Also, in its response to RAI 419-3126, Question 08.04-10 dated August 21, 2009, the applicant stated that it will revise Subsection 8.4.2.2 of the DCD to: (1) ensure conformance with Regulatory Position C.3.4 of RG 1.155; (2) state that procedures to cope with an SBO are addressed in Section 13.5; and (3) ensure that training is addressed in Section 13.2. These revisions of the DCD will also include all operator actions necessary to cope with an SBO for at least the coping duration in accordance with DCD Tier 2, Subsection 8.4.2.1.1, and to restore normal long-term core cooling/decay heat removal once ac power is restored. The DCD will be revised to provide that the COL applicant will submit the detailed procedures and training program. These are addressed as COL information items 13.4(1) and 13.4(2) on training program and procedures respectively. The NRC staff has verified that DCD Tier 2, Section 8.4 includes the additions that the applicant committed to in its response to RAI 419-3126, Question 08.04-10 (ML092370430), and the procedures and training program are now addressed in DCD Tier 2, Chapter 13, as COL Information Items 13.4(1) and 13.4(2). The NRC staff evaluation of these matters is set forth in Chapter 13 of this SER. The NRC staff also determined that the matters addressed in the RAI, if adequately addressed in a COL application, would not significantly affect the design of the US-APWR in regard to compliance with 10 CFR 50.63, and an interface requirement was therefore unnecessary. RAI 11-456, Question 08.04-05 and RAI 419-3126, Question 08.04-10 are closed and the issues they raised have been resolved.

8.4.5 Combined License Information Items

The applicant stated in DCD Tier 2, Section 8.4.3 that no information in addition to that described above is required to be provided by a COL applicant in connection with this section on an SBO.

8.4.6 Conclusion

On the basis of the NRC staff's review and evaluation of the SBO information in the DCD set forth above, the NRC staff concludes that the applicant has provided sufficient information in the DCD, to support the conclusion that the plant systems credited for coping with an SBO meet the applicable regulatory requirements. Also, the NRC staff concluded, based on the information provided in responses to the RAIs as discussed in the technical evaluation above, that the AAC power source design meets the guidance given in SECY-90-016 and SRP Section 8.4 on AAC power sources. Accordingly, the NRC staff finds that the applicant has furnished sufficient information to demonstrate that the plant design is in compliance with the provisions of 10 CFR 50.63 and the guidance of RG 1.155 as it relates to the capability to achieve and maintain safe shutdown for the specified SBO coping duration of eight hours and recover from an SBO.