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 non-Class 1E (i.e., nonsafety-related) ac power capability (two additional GTGs) to supply the required loads in the event of a loss of all ac emergency onsite power sources as well as offsite power sources (station blackout (SBO)). 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.

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 and non-Class 1E plant loads. 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 nonsafety-related, onsite power system, except for the permanent power system, through the UATs. With the load-break switch open, offsite power is provided to the non safety-related, onsite power system, 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, the “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,” of10 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 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 must 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.

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) both physical and electrical separation are designed between the two (or more) circuits to minimize the chance of simultaneous failure; and (4) there is an interface of the preferred power source with an AAC power source for safe shutdown in the event of an SBO.

Table 8-1 of the SRP lists GDC, RGs, Stds., 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 a SBO is also reviewed with respect to its adequacy and its independence 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

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 standalone 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. The system must be capable of supplying all safety loads independent of the onsite emergency power 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, non-safety-related electric power buses 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 NRC staffs concern is that the requirements placed on generator breakers/load break switches are much more rigorous on those devices if they are used in an immediate-access source of power scheme as opposed to a delayed-access source of power scheme. Immediate-access devices must 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. In Request for Additional Information (**RAI) 4-205, Question 08.02-6,** the NRC staff requested that the applicant demonstrate that the design of the load-break switch complies with the provisions of Appendix A 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 a letter dated May 30, 2008, the applicant points out 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, Question 08.02-15**, as a follow-up to **Question 08.02-6**, the NRC staff requested that this clarification on the use of the load break switch be documented in Section 8.2 of the DCD. In Section 8.2.1.2 of the DCD, Revision 2, the applicant provided the requested documentation. Given this clarification, 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 as closed.

When the normal source is not available through the UATs, offsite power is provided to the non-safety-related onsite electric power buses 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, both safety-related and non 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, 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. In Revision 2 of the DCD, 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 found 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, the applicant committed to add this description to a future revision of 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. These protective relays satisfy the NRC staff's concern that protection is provided. The NRC staff's review of the transfer scheme is documented in Section 8.3.1 of this SE. In its letter, dated September 24, 2009 the applicant also committed to add this response to Section 8.2.1.2 of the DCD. This additional information has not yet been incorporated into the DCD and therefore this remains as a confirmatory item. Therefore, **RAI 4-205, Question 08.02-4** is closed, and **RAI 432-3206, Question 08.02-13**, is **Confirmatory Item 08.02-13**.

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 in Revision 2 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. This acceptably resolves **RAI 4-205, Question 08.02-8**, as 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 full 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. In a March 23, 2009, teleconference, the applicant committed to ensure that the design would provide for all protective features recommended by IEEE Std. 666-1991and would update the DCD to reflect this commitment. As a followup to the conference call, the NRC staff issued **RAI 432-3206, Question 08.02-16,** to formalize the request for the DCD to be revised accordingly. Section 8.2.2.2 in Revision 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)). This change was verified by the NRC staff in Revision 2 of the DCD and therefore, resolves RAI **4-205, Question 08.02-7, and RAI 432, Question 08.02-16** as 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, 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 postulate 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, power supply to the offsite power to Class 1E busses will remain available to accomplish the safety functions indentified in the above criteria. 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 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 non-Class 1E disconnect switches in the selector circuits A and B, 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 perform the isolation between the Class 1E and 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 of meeting the requirements for isolation between AAC sources and 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 the grid is site specific, RG 1.206 calls for the DCD to include interface requirements for the COL application. In addition, the minimum voltage and frequency that must be maintained by the COL applicant's systems for the reactor coolant pump (RCPs) to satisfy DCD Chapter 15 analyses was not provided. 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. In a March 23, 2009, teleconference, the applicant committed to provide the requested information in a future revision to the DCD. In order to assure that these requirements are fully documented in the DCD, the NRC staff issued the followup **RAI 432-3206, Questions 08.02-10** and **08.02-11**, to formally request that this documentation be incorporated into the DCD. In response to these RAIs, the applicant provides a 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 and provides 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, Revision 2, provides a 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. This acceptably resolves **RAI 4-205, Questions 08.02-1** and **08.02-2** and **RAI 432-3206, Questions 08.02-10** and **08.02-11** as closed.

In addition to the missing information discussed above, the DCD 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. During a March 23, 2009, teleconference, the applicant agreed to augment the COL Information Item to conform to RG 1.206. As a follow-up to this discussion, the NRC staff issued **RAI 432-3206, Question 08.02-12,** to reinforce the need to update the DCD accordingly. The applicant provided this interface requirement in Section 8.2.4 (COL 8.2(11)) of DCD Revision 2. This revision to the DCD calls for the following detailed stability and reliability studies of the offsite power system: 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. A failure modes and effects analysis (FMEA) also is required. This list is in full conformance with RG 1.206 and is acceptable. **RAI 4-205, Question 08.02-03**, and **RAI 432-3206, Question 08.02-12**, are 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 SE.

8.2.4.7 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 nonsafety-related buses 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 a letter dated May 30, 2008, 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, and 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, Revision 2, the applicant provided the requested documentation. The NRC staff finds this explanation acceptable 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 plant switchyard including layout, control system and characteristics of circuit breakers and buses.	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 addressed in accordance with BTP 8-3 (Reference 8.2-17). The study is to 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 operating range, for maintaining transient stability. A FMEA is to be provided.	8.2.3
8.2(12)	Deleted	NA

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, Stds. and BTPs committed to by the applicant. The NRC staff also reviewed the COL information items found in Section 8.2.5 of this SE. 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 08.02-1** concerning the applicant's commitment to add additional design details to Section 8.2.1.2 of the DCD with respect to the transfer scheme between the RATs and UATs. 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 SE.

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 ac power system and 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 SE. The Class 1E and non-Class 1E dc power systems are described in Subsection 8.3.2 of this SE.

8.3.1 Alternating Current Power Systems

The US-APWR onsite ac power system includes normal power systems powered from the offsite power sources, emergency power systems backed-up by Class 1E GTGs and permanent power systems 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, performs 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 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 of the Class 1E and non-Class 1E power distribution systems that, in conjunction, 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,” describes the design criteria, features, testing and qualification requirements 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 Criteria, 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 require 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. The Class 1E, 6.9-kV buses each has a dedicated Class 1E GTG for backup emergency power if the preferred sources are not available. The GTGs are required 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 Operating Conditions (LCO) and surveillances related to the ac electrical power sources under plant operating conditions. Section 3.8.2, "AC Sources - Shutdown," contains the LCO 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 50.34(f), "Contents of applications; technical information. Additional TMI-related requirements," as it relates to additional Three Mile Island (TMI)-related requirements including the provision of power to bypassed and inoperable status indication of ac power systems, pressurizer heaters, pressurizer relief valves, block valves, and level indicators.

8. 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).

9. 10 CFR 50.63, as it relates to the establishment of a reliability program for emergency onsite ac power sources and the use of the redundancy and reliability of onsite ac power sources as a factor in limiting the potential for SBO events.

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 (such as envisioned for the reference COL plant, Comanche Peak Nuclear Power Plant, Units 3 and 4); 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. As endorsed by RG 1.153, IEEE Std. 603-1991 provides a method acceptable to the NRC staff to evaluate all aspects of the electrical portions of the safety-related systems, including basic criteria for addressing single failures.

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 SE.

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. 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. Conformance to this SECY paper is addressed in Section 8.2.

15. Branch Technical Position (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.

16. BTP 8-2, "Use of Diesel-Generator Sets for Peaking," which states that emergency diesel generators will not be used for peaking service. Although not stated explicitly in BTP 8-2, this provision is applicable to the GTGs of the US-APWR because the intent of BTP 8-2 was to prohibit the use of the emergency standby/alternate ac power source, of whatever type, for peaking loads.

17. 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.

18. 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.

19. 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, Stds., 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 by 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 shutdown 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. They are also designed to withstand the effects of postulated internal events such as fires and flooding 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 description and value, for the US-APWR design are described in DCD Tier 2, Chapter 2, "Site Characteristics." The US-APWR design criteria for wind, tornado, flood, and seismic design (earthquake) are 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 building and their mounting and installations are seismically designed. The Class 1E ac power systems are designed to withstand the effects of natural phenomena such as design basis earthquake, tornado, hurricane, flood, tsunami, or seiche without losing the capability to perform their intended safety functions. Compliance to 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 on Chapter 3 of this SE. The location of the onsite ac power system inside Seismic Category I structures, the design of the onsite ac power system as Class 1E, and the seismic qualification of that equipment, will provide assurance that the 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.

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.

The NRC staff has reviewed the applicant's onsite Class 1E ac distribution system components. These are located in Seismic Category I structures and rooms constructed in such a manner that any internal hazard only affects their respective train. 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 is located in a separate electrical room. There are no high or moderate energy lines routed through the safety-related electrical rooms containing 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. Each room is also provided with a redundant train 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 provides reasonable assurance 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, "Environmental Qualification of Mechanical and Electrical Equipment." 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 are 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.

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, 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 a response dated July 18, 2008, 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 accepted the applicant's response to the above RAI Question because the RAI explained 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. This redundancy satisfies the requirements of GDC 4 pertaining to the capability of Class 1E equipment to perform its safety function while subjected to environmental conditions such as a fire, and the requirements of GDC 17 pertaining to the redundancy of onsite ac 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** 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. On March 18, 2009, the NRC staff and the applicant discussed the applicant's response to **RAI 10-453, Question 08.03.01-16** via teleconference. During this teleconference, the applicant agreed to include more details concerning the functional capabilities of the RSP in upcoming DCD revisions.

In **RAI 386-2859, 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**, based on discussions with the applicant during the teleconference held on March 18, 2009. **RAI 386-2859, Question 08.03.1-28**, 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.

In a letter dated July 22, 2009, the applicant responded to **RAI 386-2859, Question 08.03.1-28**, 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 4 pertaining to the capability of Class 1E equipment to perform its safety function while subjected to environmental conditions such as a fire, and the requirements of GDC 17 pertaining to the redundancy of onsite ac power sources. 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** 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. 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 addresses, 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 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, and 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 the 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 and IEEE 387 for loading it 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**, dated July 18, 2008, on the testing of the Class-1E GTGs and maximum expected load carrying capability, 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 the DCD Revision 2 to state that the loading test will be performed at 90- 100 percent of the Class 1E GTG rating. This response was acceptable because it provided 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. During the March 18, 2009, teleconference, the NRC staff requested that the loading test PF be included in an upcoming revision of the DCD. The applicant agreed that it would include the PF test values in the DCD, Revision 2. 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** based on discussions with the applicant during the teleconference held on March 18, 2009. **RAI 386-2859, Question 08.03.1-29**, 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, Revision 2, 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. It is not clear from the listing 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 hasn't 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. In a response to **RAI 10-453, Question 08.03.01-18**, dated July 18, 2008, 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 dated July 18, 2008, 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 their 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. The NRC staff informed the applicant during the March 18, 2009, teleconference that the description given in Table 8.3.1-2 in the DCD should be revised 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. MHI agreed that it would revise the description in the upcoming DCD Revision 2. 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** based on discussions with the applicant during the teleconference held on March 18, 2009. **RAI 386-2859, Question 08.03.1-30**, 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, 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 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, follows.

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 required 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 load requirements during all plant operating conditions, AOOs and the DBE. 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 required 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, 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 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 train B load center and train A load center A1, and between 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 this RG for 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 (a-c and d-c) 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. Since any two of the four redundant trains are required 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 a-c 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 a-c load group has two connections to the preferred offsite power sources and to an onsite standby power source. 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 that 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 a-c 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 a-c 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 1 E Gas Turbine Generator System." which is discussed in Section 8.3.1.4.8, "Compliance with 10 CFR 50.63" of this SE.

The DCD states that the incoming circuit breaker from the UAT is closed after one second, 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, describes several scenarios involving the loss of offsite power from RAT and LOCA occurring simultaneously, and the automatic transfer of Class 1E buses from RAT to UAT. In **RAI 10-453, Question 08.03.01-12**, in order to assess the availability of power to Class 1E buses, the NRC staff asked the applicant to answer several questions based on loss of power scenarios. Under a scenario involving the loss of offsite power from RAT and LOCA occurring simultaneously, the NRC staff asked whether it was correct to assume that offsite power would be lost only from the 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 RAT to UAT for this scenario is carried out when an undervoltage signal is initiated, whether or not the power supply from 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 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 ultra violet (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.

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 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 RAT to UAT when offsite power is available from the MT breaker and the GLBS. In a letter dated July 18, 2008, 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. Since the applicant has discussed the outcomes of several scenarios involving the automatic transfer of Class 1E buses from RAT to UAT due to the LOOP and LOCA occurring simultaneously, and has provided an assessment of the availability of power to Class 1E buses as recommended by RG 1.6, 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, and considers the issues it raised to be resolved.

The NRC staff also asked about grid stability. In a letter dated February 8, 2008, the applicant provided a response to the question on grid stability analysis that justifies 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 asked the NRC staff to assume are 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 basically, even if LOCA and LOOP occur concurrently, power supply from offsite transmission system can be expected to be available for a short period, such three seconds. The applicant also stated that power supply from the MG can be expected to remain available during turbine inertia for as long as 15 seconds. The applicant further replied 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. It is assumed 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.

Since MHI has discussed the outcomes of several scenarios involving the automatic transfer of Class 1E buses from RAT to UAT due to the LOOP and LOCA occurring simultaneously, and has provided an assessment of the availability of power to Class 1E buses, 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.

DCD Tier 2, Section 8.3.1.1.2.4.A, "Automatic fast transfer of Class 1E buses from RAT to UAT," fails to describe the time needed to accomplish the fast transfer from RAT to UAT. 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 dated July 18, 2008, the applicant committed to provide a description about transformer protective relay types in Section 8.3.1.1.2.4 of the DCD, Revision 2, 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 150milliseconds to complete a fast transfer would not result in out-of-phase transfer of motor loads. In a teleconference on March 18, 2009, the NRC staff asked about the fast bus transfer during loss of voltage that did not involve a fault and the role of degraded-voltage and loss-of-voltage relays in the fast transfer scheme. The NRC staff also asked the applicant to explain why the 150 millisecond transfer time was appropriate in view of 100 milliseconds being used in US plants for fast bus transfers. The NRC staff asked the applicant to address if it had performed the required analysis to ensure that the motor voltages are not substantially out of phase with bus voltage during the 150 milliseconds fast bus transfer. The applicant indicated that if the MV bus voltage goes down (due to loss-of- or degraded-voltage condition), bus transfer is only controlled as a slow transfer. Also, the applicant agreed to provide additional information to explain the bus transfer on low/loss of voltage, and discuss why 150 milliseconds versus 100 milliseconds will not result in an out-of-phase transfer of motor loads. Further, the applicant agreed to add a description of the protection relays which would initiate the fast bus transfer in DCD Section 8.3.1.1.2.4. 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** based on discussions with the applicant during the teleconference held on March 18, 2009. 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,** dated July 22, 2009, 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 further explained that fast transfer time depends on the time from opening of incoming circuit breaker to closing of back-up circuit breaker. A 100 millisecond transfer (six cycles) is possible in view of actual circuit breaker performance. The 150 millisecond period cited in the previous response to the RAI included conservatively a 100 millisecond interval for closing the circuit breaker and a 50 millisecond interval for operation time for the protective relays. However, protective relays do operate before the opening of the incoming circuit breaker, so there is no need to include operation time of the protective relays. Therefore transfer time will be revised to a 100 millisecond (six cycles) interval. Preliminary analysis about fast transfer will be added in a new technical report. The fast bus transfer is not initiated by protection relay directly. The fast transfer is started by opening of the incoming breaker for normal offsite power. The opening may occur by 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 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 to 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. The NRC staff verified that the DCD has been revised to include this information in the DCD, Revision 2, Section 8.3.1.1.2.4. 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 the each scheme, or the use of the LOOP sequencer. During the March 18, 2009, teleconference, the applicant agreed to revise and clarify the description in the DCD of the bus transfer schemes, the relays associated with each scheme and the use of the LOOP sequencer. 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**, based on discussions with the applicant during the teleconference held on March 18, 2009. 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, MHI submitted a response to **RAI 386-2859, Question 08.03.01-25**, which explained that Class 1E buses of the US-APWR have both fast transfer and slow transfer schemes. 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 required loads reduces operator burden during this condition. 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 8.4.1.3. Since the applicant has revised DCD Tier 2, Section 8.4.1.3 to reflect the commitment made during the March 18, 2009, teleconference, **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.

The NRC staff finds that the design features discussed above conform to RG 1.6, and that the US-APWR onsite power systems have sufficient independence to perform their safety functions assuming a single failure.

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 tornado-generated missiles.

The US-APWR GTGs include the following design features:

- Rating - The Class 1E GTG output rating of 4,500KW at 6.9kV is determined based on the characteristics of each connected load, required duration of operation and maximum combined load demand on the Class 1E GTG during the worst operating conditions. The loading for the Class 1E GTGs during various operating conditions is shown in DCD Tier 2, Table 8.3.1-4. The maximum loading on the Class 1E GTG is determined based on the nameplate rating of the load (pump pressure and flow under runout conditions, or starting horsepower equivalent to motor brake horsepower).

- Starting - The starting system for the Class 1E GTGs is a compressed air system. The Class 1E GTGs are started by the following methods: automatic starting by the ECCS actuation signal, an undervoltage signal on the Class 1E 6.9kV bus to which the Class 1E GTG is connected, or a degraded grid voltage signal on the Class 1E 6.9kV bus to which the Class 1E GTG is connected. Manual starting from the MCR, the Class 1E GTG room in the Power Sources Building, or from remote shutdown room in the R/B. The Class 1E GTGs start and are ready to accept load, in less than 100 seconds after receiving the start signal.

- Tripping Devices - The following trip protective functions are provided during operation of the Class 1E GTG: overspeed, generator differential current, high exhaust gas temperature, failed to start, overcurrent, low pressure lube oil, high temperature lube oil, and anti motoring. Under LOCA conditions, all protective functions are bypassed except the following functions and a Class 1E GTG trouble alarm is initiated in the MCR: overspeed, generator differential current, and high exhaust gas temperature.

- Interlocks - The following interlocks related to GTG and offsite power system are provided for automatic and manual closing of the incoming breakers:

  - The incoming breaker to the Class 1E 6.9kV bus cannot be closed on to a faulted bus during bus transfer.
  - Only one incoming circuit breaker to the 6.9kV bus is closed during all modes of operation except during parallel operation of the Class 1E GTG with offsite power source during periodic testing or for a short duration during parallel transfer from the AAC GTG.
  - During manual transfer of power from UAT to RAT or RAT to UAT, both the incoming circuit breakers from UAT and RAT are momentarily paralleled after synchronizing both the sources. Electrical interlocks are provided to prevent both incoming breakers from the offsite sources remaining paralleled.
  - During periodic testing, the Class 1E GTG is operated in parallel with the offsite power source. The incoming breaker from the GTG is interlocked to close only after synchronization with the offsite power source.
  - During LOOP, bus undervoltage signal trips both incoming circuit breakers on the bus connected to the offsite sources and prevents them from automatic reclosing.
  - When the Class 1E GTG provides power to the 6.9kV buses, the incoming breaker from the offsite power supply can only be closed manually after synchronizing the offsite power source with the Class 1E GTG supplying power to the bus. The incoming breaker from the Class 1E GTG is tripped manually after the incoming breaker from the offsite power source is closed.
  - The tie connection between the Class 1E 6.9kV buses A, B, C and D and the non-Class 1E AAC GTGs is normally open. The tie can only be closed manually by administrative controls and automatic closing interlocks are not provided.

- Permissive - A switch is provided in the Class 1E GTG room in the PS/B for each Class 1E GTG to block automatic start signals when the Class 1E GTG is out for maintenance. When the switch is in local position, annunciation is initiated in the MCR.

- Load Shedding and Sequencing Circuits - The bus undervoltage signal due to loss of voltage or degraded-grid voltage on the Class 1E, 6.9kV buses initiates the following actions:

  - Sheds all motor loads upon a loss-of-voltage signal.
  - Starts the Class 1E GTG associated with the affected Class 1E bus.
  - Trips the incoming breakers from the offsite power supplies through the UAT and/or the RAT and prevents them from reclosing.

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 (104F) without specifying the minimum temperature. In **RAI 5-272, 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 degrees Fahrenheit (F). In its response dated June 6, 2008, 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. During the March 12, 2009, teleconference, the applicant stated that the ambient temperature condition for the GTGs of the US-APWR is set between -40 degrees F and 115 degrees F, and the US-APWR standard design has heating equipment as a countermeasure against low-side ambient temperature. The low -side ambient temperature could adversely impact the quality of the fuel oil, and this is the reason why the fuel oil temperature is maintained above the cloud point. The fuel oil temperature above the cloud point is achieved by an area electric heater. During the March 12, 2009, teleconference, the applicant agreed to incorporate the discussion of the heating equipment as a countermeasure against the effects of low-side ambient temperatures on fuel oil in the description in the appropriate section of the DCD. The NRC staff considered **RAI 5-272, Question 08.03.01-5** closed, but the issue remained unresolved.

In **RAI 394-3048, Question 08.03.01-37**, the NRC staff asked a follow-up question to **RAI 5-272, Question 08.03.01-5**, based on discussions with the applicant during the teleconference held on March 12, 2009. 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, 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, 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 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.

The NRC staff finds that the US-APWR onsite power systems conform to RG 1.9 in regards to the design and testing of 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. 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 the 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 found 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, 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 detailed guidance of IEEE 308, IEEE 338, and IEEE 603 which are endorsed in RG 1.32, RG 1.47, RG 1.118, and RG 1.153. The applicant also committed to revise the description in the DCD, Revision 2 to include detail requirements described in the above-referenced regulatory guidance. Because the applicant revised its DCD to show its conformance to the guidance in IEEE 308, IEEE 338, and IEEE 603, 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, "Criteria for Power Systems for Nuclear Power Plants," with an exception that pertains to sharing of dc power systems at multi-unit nuclear power plants. The US-APWR ac power system design, operation and testing fully conform to the regulatory guidance in RG 1.32 with the exception of the item that pertains to sharing of ac power systems at multi-unit nuclear power plants. 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, so the foregoing exceptions in RG 1.32 are not applicable.

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 found that both the safety and non-safety GTGs were of the same manufacture and design. Since there is no diversity among safety and non-safety GTGs, 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 and non-safety GTGs, 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 non-safety loads 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 dated June 6, 2008, the applicant limited the difference between the Class 1E and the non-safety GTGs 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. The NRC staff discussed with the applicant its initial response to this RAI during the March 12, 2009, teleconference. During the April 13, 2009, public meeting, the NRC staff asked the applicant to provide more detailed information on limiting common cause failure potential in the safety and non-safety GTGs, since they are of the same manufacture and design, and the applicant agreed to provide to the NRC staff its final resolution of this issue at a later date. The NRC staff considers **RAI 5-272, Question 08.03.01-6**, closed, but the issues it raised remained unresolved.

As a follow-up to the discussions the NRC staff had with the applicant about potential resolution of these issues, the NRC staff asked RAI **394-3048, Question 08.03.1-38**. In **RAI 394-3048, Question 08.03.1-38**, the NRC staff requested additional information on the diversity between the Class 1E GTGs and the 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. Similar to SECY-90-16, it requires 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, the GTG should be capable of powering one safety division and one division of permanent non-safety loads 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 that AAC GTGs and Class 1E GTGs are diverse because AAC GTGs use battery for starting whereas the Class 1E GTGs use air starting. 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 Class 1E GTGs and AAC GTGs proposed for the US-APWR design are not diverse.

In the applicant's letter dated July 23, 2009, submitted in response to **RAI 394-3048, Question 08.03.1-38** , the applicant acknowledged that during the April 13, 2009, public meeting, the NRC staff presented two acceptable approaches to achieve diversity between Class 1E GTG and AAC GTG: (1) An AAC GTG whose manufacturer differs from Class 1E GTG is adopted, or (2) If the same manufacturer is adopted, the applicant needs to provide verification that probability of common cause failure is minimized by analysis. MHI indicated that it understood that adopting a different AAC GTG manufacturer from the Class 1E GTG manufacturer would ensure diversity between these two GTGs. Therefore, if the applicant elects to use safety and non-safety GTGs from the same manufacturer, the applicant would be required to submit an evaluation report to provide verification that probability of common cause failure is minimized by analysis. During the public meeting that took place on August 6, 2009, the applicant indicated that it would use different GTG manufacturers to ensure diversity. The NRC staff considers the issue pertaining to diversity resolved subject to the verification that the DCD has been updated to include language that clarifies that the applicant will require that the safety and non-safety GTGs be acquired from different manufacturers. This is **Confirmatory Item 08.03.01-1**.

With respect to the issue regarding the capacity of the AAC GTGs to bring and maintain the plant in a safe shutdown condition during a SBO, the applicant has stated that the US-APWR has two AAC GTGs, and both AAC GTGs used together, have the capacity to bring and maintain the plant in a safe shutdown condition during a SBO. Instead of having a configuration where the AAC GTG can supply power to the Class 1E bus while supplying power to the permanent bus under an SBO condition, the applicant will change the configuration to having the AAC GTGs supplying power to the Class 1E bus without supplying to non-safety permanent bus during SBO conditions. Therefore, the AAC GTG design will have enough capacity margins to operate under SBO conditions. Given that the applicant has clarified that, by providing enough capacity margins for the AAC GTGs, the AAC GTGs are capable of bringing and maintaining the plant in a safe shutdown condition during an SBO. The NRC staff has verified that Table 8.3.1-6 has been revised to show the revised values pertaining to the capacity of the GTGs, this issue is resolved. **RAI 394-3048, Question 08.03.1-38**, is closed and, with the exception of **Confirmatory Item 08.03.01-1**, the issues it raised have been resolved.

Since, the applicant has committed to chose different manufacturers for the safety and non-safety GTGs thus providing design diversity for the GTGs, and has provided sufficient information indicating that the AAC GTG design will have enough capacity margins to operate under SBO conditions, the NRC staff finds that the applicant's safety-related systems have the necessary electrical power to perform their safety-related function with the presence of a single failure. The NRC staff finds that the US-APWR design conforms to RG 1.53 given that the applicant has clarified that the possibility of common cause failure is minimized by the selection of safety and non-safety GTGs from different manufacturers.

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 cables of the dc circuits for the US-APWR design that feed dc loads inside the containment vessel go through electrical penetration assemblies. The electrical penetration assemblies used for Class 1E and non-Class 1E ac circuits are qualified for the worst temperature and pressure condition resulting from any LOCA without exceeding the design leakage rate in accordance with IEEE Std. 323, and IEEE Std. 317. The protection system design of the electric penetration assemblies provides both primary and back up protection. The NRC staff finds that the US-APWR onsite ac power systems conform to RG 1.63 in regards 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 that prevents 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 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. The Class 1E equipment and circuits that are designated as A1 or associated with A1 buses are considered part of train A. During normal plant operations, the A1 buses are powered from A train power sources and the Class 1E power systems have four independent trains. 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 A-Class 1E GTG, the A1 buses are powered from train B sources. During maintenance of B-Class 1E GTG, the A1 buses are powered from train A power sources. During this maintenance period of A or B train GTGs, for analysis purposes, the A and B trains are considered as one train, completely independent from trains C and D. Availability of any two of these three trains is sufficient to mitigate any DBE condition.

Similarly, the Class 1E equipment and circuits that are designated as D1 or associated with D1 buses are considered part of train D. During normal plant operation, the D1 buses are powered from D train power sources and the Class 1E power systems have four independent trains. 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 D-Class 1E GTG, the D1 buses are powered from train C sources. During maintenance of C-Class 1E GTG, the D1 buses are powered from train D power sources. During this maintenance period of D or C train GTGs, for analysis purposes, the D and C trains are considered as one train, completely independent from trains A and B. Availability of any two of these three trains is sufficient to mitigate any DBE condition.

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.

Thus, the applicant's safety-related 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, is in compliance with the IEEE Std. 384 as endorsed by RG 1.75. The NRC staff finds that the US-APWR design conforms to 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 requirements 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. Meeting the detailed requirements of IEEE 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations," with respect to independence and separation of the ac power distribution system divisions, will achieve the goals stated in RG 1.153.

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 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 that 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 shutdown the plant following a fire. 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 required 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 adequacy of the starting air requirements for GTGs were different from those adopted for the 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 five air-start attempts are required for the emergency diesel generators per SRP Section 9.5.6. In its response dated June 6, 2008, the applicant stated that in regards 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. During the March 18, 2009, teleconference, 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. The applicant agreed during the teleconference meeting to add wording to Section 8.3.1 in DCD, Revision 2 to explain how safe shutdown will be accomplished with any two trains for all systems (mechanical and fluid) based on the four train system. 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** based on discussions with the applicant during the teleconference held on March 18, 2009. **RAI 394-3048, Question 08.03.1-34** asked the applicant to revise its DCD to include additional language to Section 8.3.1 in Revision 2 to explain how safe shutdown will be accomplished with any two trains for all systems (mechanical and fluid) based on the four train system.

In a letter dated July 23, 2009, the applicant responded to **RAI 394-3048, Question 08.03.01-34**, 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. They 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, each remaining train is designed to perform its safety function for 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 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.

The onsite ac power electrical distribution equipment (switchgear, load centers, MCCs, transformers, breakers) is sized to provide sufficient power to start and operate the connected loads. 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 non-safety related buses, P1 and P2, during a SBO. Therefore, the NRC staff asked the applicant in **RAI 10-453, Question 08.03.01-13** to clarify the required loads on the non-safety related buses, P1 and P2, 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 a SBO event. In its response to **RAI 10-453, Question 08.03.01-13**, dated July 18, 2008, the applicant stated that the only loads retained on the non-safety related P1 and

P2 buses during a SBO are 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. The applicant agreed during the March 18, 2009, teleconference to revise the description in the DCD to show what P1 or P2 loads are not required during a SBO and to discuss the administrative controls and procedures for shedding and locking out the loads that are not required. 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** based on discussions with the applicant during the teleconference held on March 18, 2009. **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 required during a 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, the applicant explained that it would modify the design to state that AAC can supply power to a Class 1E bus without supplying power to the permanent bus in the SBO condition. By not supplying power to the loads that are not required under a SBO, the AAC GTGs have additional capacity margin for the AAC GTGs, and the AAC GTGs are capable of bringing and maintaining the plant in a safe shutdown condition during an SBO. Therefore, during a 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 a SBO. DCD Tier 2, Table 8.3.1-6 was revised accordingly. The NRC staff verified that the above information has been included in Revision 2 of 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 they raised 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 SE.

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 and coordination 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. 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.

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 are grounded through grounding transformers providing high resistance grounding, the MT and station service transformer (SST) low voltage neutrals are grounded solidly, 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 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 the lightning stroke discharge can enter the earth directly. The lightning protection 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 stroke. 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, 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 ground grid and lightning protection. The NRC staff finds the COL information item acceptable because it provides the NRC staff with assurance that the COL applicant is required to provide 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 provided assurance that the ground grid and lightning protection provided through COL Information Item 8.3(2) where 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 transformers, and the operating characteristics of 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 the above RAI dated July 18, 2008, the applicant stated that the detail 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 were responsible for performing the protective devices and coordination studies. During the March 18, 2009, teleconference, the applicant agreed to specify who (DC or COL applicant) will perform the circuit protective devices coordination study. 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** based on discussions with the applicant during the teleconference held on March 18, 2009. **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** dated July 22, 2009, 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.

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 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 requirements such that during the preoperational period and at least once every 24 months after the plant is in operation. Tests such as maximum expected load-carrying capability for 24 hours, functional capability at full load temperature conditions by verifying the Class 1E GTG starts upon receipt of a manual or auto-start signal, test of the loss of the largest single load and of complete loss of load, and verification of ECCS signal overrides the test mode may be performed during any mode of plant operation, as required.

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 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. 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 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 SE Section 7.5.

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 the lack of information regarding a program to monitor and mitigate the degradation of inaccessible cables in accordance with the guidance of 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 maintain a program to monitor and mitigate the degradation of inaccessible cables in accordance with the guidance of GL 2007- 01 after the plant is licensed.

In its response to **RAI 10-453, Question 08.03.01-21** dated July 18, 2008, 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 periodical testing, such as partial discharge testing, time domain reflectometry, dissipation factor testing, and very low frequency AC testing."

The method in which 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. Although the applicant has provided an acceptable method to prevent degradation of underground MV cables, and the NRC staff has verified that the language stated above was added to the DCD, Revision 2, in Section 8.2.1.2, the applicant failed to provide a COL information item identifying the responsibility of the COL applicant to maintain a program to monitor and mitigate the degradation of inaccessible cables in accordance with the guidance of GL 2007- 01 after the plant is licensed. The issue related to the COL information item is unresolved, and **RAI 10-453, Question 08.03.01-21** is open. This is **Open Item 08.03.01-1.**

With the exception of the open item discussed above, the NRC staff finds that the applicant's onsite ac power system will be designed to be testable during operation of the nuclear power generating station, as well as during those intervals when the station is shut down. Therefore, with the exception of the open item discussed above, the NRC staff finds that this design conforms to the positions of RG 1.118.

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 single random failures of circuit protective devices.

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 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. 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.

Grouping of circuits in the containment vessel penetration is the same as raceway voltage groupings. 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, 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.

Based upon 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.

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 outlined in RG 1.153, "Criteria for Safety Systems," which endorses IEEE Std. 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations."

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 conforms to RG 1.153, which endorses the applicable guidance of IEEE Std. 603, and will be confirmed by the electrical distribution system protection and coordination studies, and verified via ITAAC (See DCD Tier 1, Table 2.6.4-1, "Emergency Power Systems ITAAC"). Accordingly, the NRC staff finds that the US-APWR onsite ac power system design will meet 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 SE.

8.3.1.4.8 Compliance with 10 CFR 50.63

US-APWR compliance with 10 CFR 50.63 relates to 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 source (i.e., GTG) as a factor in determining the coping duration for a SBO and establishing of a reliability program for attaining and maintaining source target reliability levels. There is no operating experience on GTG operation in the US nuclear fleet, therefore, the applicant must 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 1 E 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 Gas GTG system report complies with the requirement of 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** submitted June 6, 2008, the applicant furnished reliability data of commercial-grade GTGs and the component reliability data given in NUREG /CR6928 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 was based on limited samples and it 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 /CR6928 was not applicable to the commercial components to be used in the GTGs. The applicant agreed during a public meeting on April 13, 2009, to perform 100 initial type tests without any failures to achieve 0.95 reliability target with 95 percent confidence. This reliability target of 0.95 for the Class 1E GTGs would be achieved by actual initial type testing. Based on the applicant’s commitment to perform additional testing and achieve a 0.95 reliability target with a 95 percent confidence, the NRC staff considers **RAI 5-272, Questions 08.03.01-2 and 08.03.01-3** closed, but the issues were unresolved. 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**, based on discussions with the applicant during the public meeting held on April 13, 2009.

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 requirement for reliability of emergency power source. Technical Report MUAP-07024-P will provide the reliability analysis in conjunction with the reporting type test data. Because the testing for this first-of-a-kind application is not yet available, the NRC staff considers **RAI 394-3048, Question 08.03.1-35** as **Open Item 08.03.01-2**.

In **RAI 5-272, Question 08.03.1-4**, the NRC staff asked the applicant to justify and provide a basis for why the qualification tests for the GTG should be less than 300 tests (with no more than three failures) that were originally required for EDG qualification, with the understanding that the GTGs are a first-of-a-kind application as a Class 1E power source. In its response dated June 6, 2008, the applicant stated that it was following IEEE Std 387-1995, which requires 100 starts with no failures, but that if NRC required 300 tests with no more than three failures to qualify the GTG, the applicant would consider performing such tests. The NRC staff finds this response inadequate because the basis for the 100-start requirement for the EDGs was operational experience gathered from the nuclear industry. Since this is a first-of-a-kind application and there is no operational experience with GTGs in the nuclear industry in the US, the NRC staff's position is that GTGs should be subjected to 300 starts (with no more than three failures) just as the EDGs were subjected to 300 starts when there was insufficient operational experience regarding their performance. The NRC staff would, however, consider alternate approaches with an equivalent statistical basis. The NRC staff held a public meeting with the applicant on April 13, 2009, in which the applicant committed to revise its Technical Report MUAP-07024-P, "Qualification and Test Plan of Class 1E Gas Turbine Generator System," to show the number of times of valid start and load tests. Based on the applicant's response, the NRC staff considers **RAI 5-272, Question 08.03.1-4** closed, but the issue it raises remains unresolved. To resolve this issue, the NRC staff asked follow-up **RAI 394-3048, Question 08.03.1-36**, based on discussions with the applicant during the public meeting held on April 13, 2009, to request additional information to justify the applicant's basis for the qualification tests for the proposed Class 1E GTGs.

In a letter dated July 23, 2009, submitted in response to **RAI 394-3048, Question 08.03.1-36**, the applicant committed to perform over 100 starting tests without any failure as initial type tests. The NRC staff has verified that the applicant has revised its Technical Report MUAP-07024-P, "Qualification and Test Plan of Class 1E Gas Turbine Generator System," to show the number of times of valid start and load tests. The NRC staff verified that the number of tests will exceed the 95 percent reliability target with a 95 percent confidence level. Therefore, the NRC staff considers **RAI 394-3048, Question 08.03.1-36** resolved as closed.

Based upon the above, the NRC staff finds that the applicant's approach to demonstrating GTG reliability does not meet the requirements of 10 CFR 50.63. Resolution of the issues concerning GTG reliability is being tracked as **Open Item 08.03.01-35**.

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 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 Section 1.9.

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 10CFR 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 (DRAP) (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.

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 has addressed adequately the issue of compliance with 10 CFR 50.65(a)(4).

8.3.1.4.10 Compliance with 10 CFR 50.34(f) on Three Mile Island (TMI) Action Plan Requirements

DCD Tier 2, Table 8.1-1, "Design Criteria and Guidelines for Electric Power Systems," captures the applicant's commitment to conform to the requirements of 10 CFR 50.34(f) regarding the following three items:

- 10 CFR 50.34(f)(2)(v) [TMI Action Item I.D.3]: Bypassed and inoperable status indication of ac power systems is displayed as the spatially dedicated continuously visible (SDCV) information on large display panel (LDP) in the MCR following the guidance in RG 1.47 (Reference 8.3.1-23) as described in Section 7.5.1.2. This satisfies the recommendation of TMI Item I.D.3 for safety-related system status monitoring.

- 10 CFR 50.34(f)(2)(xiii) [TMI Action Item II.E.3.1]: the GTG provides standby power to a number of pressurizer heaters, one in each train. During a LOOP concurrent with a turbine trip, selected backup heaters powered from the onsite emergency power sources (GTGs) are capable of being manually energized for pressure control purposes. Offsite power or the power supplied by the emergency power sources (GTGs) is sufficient to establish and maintain natural circulation in hot standby condition in conformance with the requirement of 10 CFR 50.34 (f)(2)(xiii) (as described in DCD Section 5.4.10.3). This satisfies the redundancy recommended by TMI Action Item II.E.3.1.

- 10 CFR 50.34(f)(2)(xx) [TMI Action Item II.G.1]: the GTGs provide power for pressurizer relief valves, block valves, and level indicators such that: (a) Level indicators are powered from vital buses; (b) motive and control power connections to the emergency power sources are through devices qualified in accordance with requirements applicable to systems important to safety and (c) electric power is provided from emergency power sources, as recommended by TMI Action Item II.G.1.

Based on the above information, the NRC staff finds that the US-APWR design complies with the requirements of 10 CFR 50.34(f) that apply to the onsite ac emergency power sources.

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), is 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 valves 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 will be provided in Chapter 7 of this SE.

8.3.1.4.12 Conformance with BTP 8-2

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 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.

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 and 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 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. 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. 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 voltage levels required 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 an 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** dated July 18, 2008, the applicant failed to provide voltage boundary conditions for the onsite power distribution systems. During a March 18, 2009, teleconference, the applicant agreed to revise Attachment A to the response for **Question 08.03.01-14** to define the voltage boundary conditions for the onsite power distribution systems in accordance with the guidance given in BTP 8.6. Also, the applicant agreed to include in an upcoming revision of the DCD the onsite voltage boundary conditions as COL interface action items, and to clearly specify who will be responsible (DC or COL applicant) for load flow, short circuit (SC) analysis, protective trip device coordination studies, etc. Based on the applicant's responses during the teleconference, the NRC staff considers **RAI 10-453, Question 08.03.01-14** closed, but the issue it raised remains unresolved. 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**, based on discussions with the applicant during the teleconference held on March 18, 2009. 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, 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, titled "Onsite AC Power System Calculation." 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 and startup/shutdown. The report presents all of the assumptions per the acceptance criteria as described for each equipment, properly analyzes three conditions for each operational mode, and will protect safety-related equipment on Class 1E buses from degraded voltage conditions. These three conditions are the normal condition when Class 1E buses are powered from RAT and Non-Class 1E buses are powered from the UAT, the condition where the UAT is unavailable so all buses are powered from the RAT and 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 the compliance with BTP-6 is indicated as the COL information in the DCD. The applicant has identified COL Information Item, COL 16.1_3.3.1 (1), for confirmation of the trip setpoints and allowable values in 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 and its adequacy will be reviewed in Chapter 16 of this SE, 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. .

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 verification will be performed by COL holders during the initial testing program, 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 is consistent with positions 1.6 through 1.9 of RG 1.9, "Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants." 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
- SC 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 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 per the acceptance criteria as described for each equipment, and properly analyzes three conditions for each operational mode,

DCD Tier 2, Figure 8.3.1-1 shows the possibility that non-safety buses 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 the applicant a three-part question regarding the 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, if the applicant had performed a voltage drop and load flow analysis for this limiting condition. Then, 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 to discuss the impact on the safety buses assuming a stuck breaker in the non-safety system that fails to clear a fault in the non-safety system, and to discuss and provide a rationale showing how the proposed 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-safety bus. In response to the **RAI 10-453, Question 08.03.01-8**, 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. The NRC staff considered **RAI 10-453, Question 08.03.01-8** closed, but the issues it raised remained unresolved.

In **RAI 386-2859, Question 08.03.1-23**, the NRC staff asked a follow up RAI to **RAI 10-453, Question 08.03.01-8** based on discussions with the applicant during a teleconference held on March 18, 2009. Regarding the motor starting transient graphs in Attachment A that the applicant had submitted, 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). During the March 18, 2009, teleconference, the applicant agreed to revise the ETAP motor transient analysis and the Attachment A. Also, the applicant agreed to add a report with assumptions to support its analysis documented in Attachment A for the NRC staff review, and submit the revised Attachment A as part of the DCD or technical report. The NRC staff requested that the applicant docket its response confirming the above actions to resolve this RAI question. In its response to **RAI 386-2859, Question 08.03.1-23** dated July 22, 2009, MHI committed to submit a new Technical Report MUAP-09023-P, "Onsite Power System Calculation" as revision of Attachment A of response to **Question 08.03.01-8** by the end of August 2009, 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, during the March 18, 2009, teleconference, the NRC staff discussed with the applicant its concern that a failure (stuck breaker) of the main breaker in the non-safety bus (P1 or P2) that fails to open, would then require 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 expressed its concern that a failure in the non-safety bus (main breaker failed) in P1 (or P2 bus) would cause a failure in the respective safety buses, and indicated that in this respect, the US-APWR electrical design did not adhere to the guidance provided by the NRC on offsite power systems for evolutionary plants. During the March 18, 2009, teleconference, the applicant agreed to change the electrical design for supplying the non-safety MV buses P1 and P2 from the RAT to UAT s and the corresponding Schematics and DCD description to address the NRC staff's concerns. In **RAI 386-2859, Question 08.03.1-23**, NRC staff requested that the applicant change the electrical design for supplying the non-safety MV buses P1 and P2 from the RAT to 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-safety bus. During the March 18, 2009, teleconference, the applicant agreed to supply power to the non-safety buses P1 and P2 from UATs normally. The applicant agreed that it will revise the electrical design, appropriate drawings and DCD to ensure that the power to the safety buses is supplied directly from the offsite (RAT) with no intervening non-safety buses. The NRC staff requests 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, the applicant stated that the normal and alternate power of permanent buses will be changed. Normal offsite power of permanent buses is changed from RAT to UAT. Alternate offsite power of permanent buses is changed from UAT to RAT. As agreed in a teleconference held on March 18, 2009, the applicant also committed to provide the following additional language in the DCD:

The eighth and ninth sentence of the first paragraph of DCD Subsection 8.1.1 will be revised as following:

> When the GLBS is open, offsite power to the onsite non safety-related electric power system is provided through the MT and the UATs. With the GLBS either open or closed, offsite power to the onsite safety-related electric power system is provided through the RATs.

The third sentence of the third paragraph of DCD Subsection 8.1.3 will be revised as following:

> During normal power operation of the plant with the GLBS closed, the MG provides power to the plant MV buses N1, N2, N3, N4, N5 and N6, and MV permanent buses P1 and P2 through the UATs.

The last sentence of the third paragraph of DCD Subsection 8.1.3 will be revised as following:

> During all modes of plant operation including startup, normal and emergency shutdown and postulated accident (PA), the MV Class 1E buses A, B, C and D are powered through the RATs from offsite power sources.

The second sentence of the fifth paragraph of DCD Subsection 8.1.3 will be revised as following:

> For all Class 1E (A, B, C and D) MV buses, power from the RAT is the normal preferred source and power from the UAT is the alternate preferred source.

The fourth sentence of the fourth paragraph of DCD Subsection 8.1.5.1 will be revised as following:

> During all modes of plant operation, including startup, normal and emergency shutdown and postulated accident conditions, the Class 1E MV buses A, B, C and D, are fed from the normal preferred offsite power source through the RATs.

The ninth sentence of the second paragraph of DCD Subsection 8.2.1.2 will be revised as following:

> With GLBS either open or closed, offsite power to the onsite safety-related electric power system is provided through the RATs.

The fifth sentence of the fifth paragraph of DCD Subsection 8.2.1.2 will be revised as following:

> During all modes of plant operation including startup, normal and emergency shutdown and PAs, the MV Class 1E buses A, B, C and D, are powered through the RATs from offsite power sources.

The second sentence of the seventh paragraph of DCD Subsection 8.2.1.2 will be revised as following:

> For all Class 1 E (A, B, C and D) MV buses, power from the RAT is the normal preferred source and power from the UAT is the alternate preferred source.

The eighth and last sentence of the second paragraph of DCD Subsection 8.3.1.1 will be revised as following:

> The MV Class 1E buses and are normally fed from the RATs. MV non-Class 1 E buses are normally fed from the UATs.

Figure 8.3.1-1 will be revised as shown in Attachment 1.

Figure 8.3.1-2 will be revised as shown in Attachment 2.

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 for each operational mode, the NRC staff considers this response adequate. The NRC staff also verified that all the changes stated above were incorporated in Revision 2 of the DCD. The applicant's revision of the DCD is adequate to resolve these issues because the applicant changed the electrical design for supplying the non-safety MV buses P1 and P2 from the RAT to UAT therefore meeting 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. 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 COLA Action Items in the DCD. In a response dated July 18, 2008, the applicant submitted the analyses in their response but the NRC staff had concerns about several aspects presented in the response. The NRC staff considered **RAI 10-453, Question 08.03.01-19**, closed, but the issues it raised remained open.

In a teleconference held on March 18, 2009, the NRC staff discussed with the applicant issues regarding the analysis of the ETAP results for the SC analysis of the Class 1E onsite distribution system, including the effect on the analysis presented if GTGs are not running, the lack of a conservative assumed voltage, discrepancies in the interrupting ratings of breakers, and the lack of analysis on steady-state load flow. Based on this discussion, 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** based on the issues listed below regarding the analysis of the ETAP results for the SC analysis of the Class 1E onsite distribution system:

- 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 breakers in the each safety buses (A, B,C and D) are shown to be 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 required by BTP 8-6 of the SRP.

In a letter dated July 22, 2009, the applicant submitted a response **RAI 386-2859, Question 08.03.01-31** 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 the each safety buses (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, titled “Onsite AC Power System Calculation.” 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 provide 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 the 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 required for the ac power system in accordance with Section C.1.8.3.1.3 of RG 1.206. In a response dated July 18, 2008, the applicant directed the NRC staff to information contained in Attachment A to the applicant’s response to RAI 10-453. The NRC staff deemed this response inadequate because Appendix 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. The NRC staff considers **RAI 10-453, Question 08.03.01-22** closed, but the issue it raised remains unresolved.

The NRC discussed this RAI with the applicant during a teleconference held on March 18, 2009. During the March 18, 2009, teleconference, the applicant agreed to incorporate in Attachment A, the six studies needed to support the design and submit the appropriate documents for the NRC staff's review. Further, the applicant will also 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. Based on these discussions, 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**.

In a letter dated July 22, 2009, submitted in response to **RAI 386-2859, Question 08.03.01-33,** the applicant indicated that it would submit a new technical report that includes analysis regarding the onsite ac power systems information required in accordance with 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 on **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, titled, “Onsite AC Power System Calculation.” 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 devise 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.

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.

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

Table 8.3.1-1
US-APWR Combined License Information Items

Item No.	Description	Section
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

8.3.1.6 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, Stds., 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 the open and 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 SE.

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 that 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 non-safety-related portions are described only in sufficient detail to permit an understanding of their interactions with the safety-related portions. This section of the DCD clearly identifies the safety loads and states the length of time they would be operable 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 required for the plant instrumentation, control, monitoring, and other vital functions needed for shutdown of 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 2.6.2and 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 require 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 non safety-related dc loads and to the non Class 1E I&C power supply system. Operation of the non Class 1E dc power system is not required 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 ac electrical power sources under plant operating conditions. Section 3.8.5, "DC Sources - Shutdown," states the LCO and surveillances related to ac 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 ac electrical power sources under plant operating conditions. Section 3.8.10, "Distribution Systems- Shutdown," states the LCO and surveillances related to ac 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. GDCs 33, 34, 35, 38, 41, and 44, as they relate to the operation of the onsite dc electric power system, encompassed in GDC 17, to ensure that the safety functions of the systems described in GDCs 33, 34, 35, 38, 41, and 44 are accomplished.

7. 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.

8. 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..

9. 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. 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.

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

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. As endorsed by RG 1.153, IEEE Std. 603 provides a method acceptable to the NRC staff to evaluate all aspects of the electrical portions of the safety-related systems, including basic criteria for addressing single failures. However, as stated in 10 CFR 50.55a(h), not all plants are required to comply with IEEE Std. 603.

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 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 Stds., 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 earthquake, tornado, hurricane, flood, tsunami, or seiche without losing its capability to perform their intended safety functions. The applicant's discussion in regards 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 flood. 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 will be 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 regards 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 found 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 found 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 provides reasonable assurance 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 SSCs important to safety (i.e., dc power system) and should 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. 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 require 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 non safety-related dc loads and to the non Class 1E I&C power supply system. Operation of the non-Class 1E dc power system is not required 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 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," 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**, **Question 08.03.02-14**. The safety batteries and the dc power system distribution equipment and components including all cables and circuits have sufficient capacity and capability to perform their 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 and one 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. 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 (a-c and d-c) 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 required for 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 d-c load group should be energized by a battery and battery charger. The battery-charger combination should have no automatic connection to any other redundant d-c load group. The US-APWR design adequately addresses this regulatory position because each redundant train of the dc power system is energized by a 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. Similarly, the spare battery charger CD can be connected manually to replace any of the chargers of the two redundant trains C or D. 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 found 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 information provided by the applicant and reviewed by the NRC staff, 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 108V 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 1 E batteries are designed under the condition of 1.8V as the minimum battery terminal voltage per one cell (108V per system). The applicant also explained that it will apply the UPS unit which has more than 100V as specification of minimum acceptable dc input voltage (125V +/-20 percent). The applicant also evaluated whether the voltage drop from the battery terminal to the inverter terminal can be kept below 8V. 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	DC input voltage of Class

	Voltage	1E UPS unit
1. Period of equalizing charging to battery	140V; at output terminal of charger	132V; at input terminal of UPS unit
2. Period of end portion of battery discharging	108V;at output terminal of battery	100V; 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 is to be designed to cope with 108V 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 108V 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," provides a current requirement 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 108V after two hours.

In a letter dated July 10, 2008, in response to **RAI 8-343, Question 08.03.02-11**, 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 1 E 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 of battery voltage because each UPS unit will maintain the output power against the decreasing of 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 which has more than 100V as specification of acceptable dc input voltage (125V +/- 20 percent). The rating of Class 1E UPS unit is 50kVA. 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: 100V minimum acceptable voltage of UPS unit

Since the current requirement 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. 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. 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 requirement of ten amps 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 a letter dated July 10, 2008, in response to **RAI 8-343, Question 08.03.02-13,** the applicant explained that based on the preliminary calculations, 10-Ampere 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 required in the MCR and RSC is 10FC (100 lumens/ m2).
- Fluorescent lamps are considered for the emergency lighting.

The lighting calculations show the load requirement of 12 - 57W for the fluorescent lamp fixtures or providing emergency lighting in the MCR and RSC. Considering 57W for each fluorescent fixture, the total load requirement is 12 x 57W = 684W on the dc system. These 12 fixtures are distributed on two trains of the dc system in order to assure the minimum required illumination level with a postulated failure of the other two trains. Hence, the total emergency lighting load on each dc system is (684/2) = 342W or 3.1A at 110Vac or 2.7A at 125Vdc.

Use of ac or dc lighting fixtures will be decided during the detail 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 3.9A 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 required for the illumination equipment in the MCR, RSC and the passage in between the MCR and RSC. 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 other two trains. If ac fixtures are used, inverters for lighting circuits will be required. 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 which shows the actual inverter ratings, and these ratings demonstrate enough 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 the NRC staff review.

In the response to **RAI 8-343, Question 08.03.02-14** dated July 10, 2008; the applicant furnished a summary of the evaluation and analysis of the Class 1E dc system. The applicant provided the load flow calculation that determines 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." Load flow calculations show that adequate voltage is available throughout the two hour battery duty cycle duration (based on safety analysis assumptions) and battery charging conditions are within the design rating. The final dc load flow analysis that supports the adequacy of the dc onsite power system will be provided in

DCD Tier 1, Table 2.6.2-2, ITAAC Item 3. Also, the applicant provided COL Information Item 8.3(8) which required 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 analyses 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 finds 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. 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). In a letter dated July 10, 2008, the applicant submitted the response to **RAI 8-343, Question 08.03.02-2**. The NRC staff reviewed the information submitted by the applicant and found 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 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. During the March 23, 2009, teleconference, the NRC staff indicated that the response was acceptable but that the information needed to be included in the next revision of the DCD. The NRC staff considers **RAI 8-343, Question 08.03.02-2** closed, but the issue it raised remained open.

In **RAI 388-2858, Question 08.03.2-16**, the NRC staff asked a follow up **RAI to RAI 8-343, Question 08.03.02-2**. This follow-up RAI was based on the NRC staff's discussions with the applicant during the teleconference held on March 23, 2009, 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 this follow-up RAI, the NRC staff asked the applicant to include this information in an upcoming revision of the DCD.

In a letter dated July 13, 2009, in response to **RAI 388-2858, Question 08.03.2-16**, 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 meet their functional requirements 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 388-2858, Question 08.03.2-16** closed and the issue it 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 125V dc switchboard bus. However, the NRC staff notes that the 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 125V 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**, dated July 10, 2008, 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 found 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. During the March 23, 2009, teleconference, the NRC staff indicated that the response was acceptable and requested that the applicant include it in the next revision of the DCD. In the subject teleconference, the applicant committed to revising the description on the charging of the Class 1E and non Class-1E batteries (page 8.3-44 in Section 8.3.2.1.2 of the DCD Tier 2, Revision 1) from "fully" to "95 percent." Based on the applicant's response and the discussion during the teleconference on March 23, 2009, the NRC staff considers **RAI 8-343, Question 08.03.2-3** closed, but the issue it raised remained unresolved.

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** based on discussions with the applicant during the teleconference held on March 23, 2009. 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 (Page 8.3-44 in Section 8.3.2.1.2 of the DCD, Revision 1) from "fully" to "95 percent." In a letter dated July 13, 2009, submitted in response to **RAI 388-2858, Question 08.03.2-17,** the applicant stated it had revised the DCD such that the description of the charging of the non-Class 1 E 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 388-2858, Question 08.03.2-17** closed and the issue it raised, resolved.

Section 8.3.2.1.1 of the DCD stated that there are four Class 1 E safety battery chargers, one for each train, connected to the Class 1E 125V dc switchboard bus. In addition, there are two installed non-Class 1 E 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. Similarly, the spare battery charger CD can be used to temporarily replace any one of the Class 1 E battery chargers C or D. The non-Class 1E spare battery charger is placed in service to temporarily replace any one of the four inoperable Class 1 E chargers. 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 Class 1E chargers are 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 1 E battery chargers. In the response to **RAI 8-343, Question 08.03.02-4**, dated July 10, 2008, 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 required for non-Class 1E chargers. The NRC staff understood the intended use of the spare charger but found this response inadequate because the applicant failed to clarify the use of non-safety chargers when Class 1E charges are inoperable, and to describe the interaction between non-safety and safety-related equipment. The NRC staff agrees that non-Class 1E equipment is not required to undergo periodic surveillances under the TS. The NRC staff considered **RAI 8-343, Question 08.03.2-4,** closed, but the issues it raised remained open.

Article 4.11 of IEEE 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 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-safety 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-safety system chargers on the safety-related dc train equipment to ensure that a failure of non-safety system does not cause a loss of or a failure in the safety-related system component. Also, the applicant should demonstrate that the design included a safety-related isolation device between the non-safety chargers and safety-related dc train equipment.

In the response to **RAI 388-2858, Question 08.03.2-18** dated July 13, 2009, the applicant stated that non-safety spare battery chargers are not normally connected to the Class 1E dc power system. Non-safety spare battery chargers 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 non-safety spare battery charger to the Class 1E dc system. The applicant committed to performing a FMEA on the interactions of the non-safety 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-safety system chargers on the safety-related dc train in Table 8.3.2-4 in Revision 2 of the DCD. Because the non-safety 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-safety chargers and safety-related dc train equipment in this temporary configuration, and the applicant has provided a FMEA requirement to assess whether a failure of non-safety system will cause a loss of or a failure in the safety-related system component, the NRC staff finds that the IEEE 384 standard 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/1 20V 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**, dated July 10, 2008, the applicant provided a description of the switching scheme between the UPS unit and the transformer. In a teleconference on March 23, 2009, the NRC staff asked the applicant to explain whether the transfer from the transformer back to the UPS was made, and if the transfer was automatic or manual. The applicant explained that both automatic and manual transfer was possible, but that the US-APWR design would use a manual transfer. 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: "…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. The applicant had not committed to revising its DCD to include this information, which is necessary to demonstrate conformance with RG 1.32 in regards to design features for safety-related power systems. The NRC staff considered **RAI 8-343, Question 08.03.2-6,** closed, but the issues it raised remained open.

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** based on discussions with the applicant (MHI) during the teleconference held on March 23, 2009. The NRC staff requested that the applicant docket its response confirming the above actions on part of the applicant to resolve this RAI question.

In a letter dated July 13, 2009, submitted in response to **RAI 388-2858, Question 08.03.2-20**, MHI committed to provide the following language in the DCD to clarify 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 NRC staff verified that the applicant provided the following information in Section 8.3.1.1.6 of the DCD, Revision 2. Since the applicant provided a description of the switching scheme between the UPS unit and the transformer, and revised its DCD to conform with RG 1.32 in regards to design features for safety-related power systems related to undervoltage relay accuracy and its protective actions which limit the degradation effects of undervoltage, **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 current requirement of 1 Ampere for the Class 1E 480V Load Center. Compared to operating experience data for Class 1E 480V load centers, a current requirement of one Ampere appears to be too low in terms of current-carrying capacity. 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 found that this table does not include load current requirements 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 the response to **RAI 8-343, Question 08.03.02-12**, dated July 10, 2008, the applicant indicated that the load currents would depend on procurement specifications for the batteries. During the teleconference held on March 23, 2009, the NRC staff asked the applicant to explain the load current requirements for these types of loads and to confirm that all the loads listed above are included in battery load calculations. The applicant provided a brief discussion on the conservatism used in sizing of the loads and the associated protection of the loads. The applicant indicated that its assumptions for these types of loads were made based on Japanese experience and products. The applicant agreed to provide a more in-depth explanation of this issue which will be incorporated in the upcoming DCD revisions (Revision 3 or later). The response to **RAI 8-343, Question 08.03.02-12** was considered inadequate because the applicant failed to submit the load current requirements 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** based on discussions with the applicant during the teleconference held on March 23, 2009. In RAI 388-2858, Question 08.03.02-22, the NRC staff requested that the applicant docket its response confirming the above actions on part of MHI to resolve this RAI question.

In its response to **RAI 388-2858, Question 08.03.02-22** dated July 13, 2009, the applicant stated that the current requirements in DCD, Revision1 included Japanese experience and the product baseline requirements will be revised to include US products. The current requirement of Reactor Building DC Distribution Panel included current requirement for Class 1E solenoid valves. The load current requirements for solenoid valves will be described separately from the Reactor Building DC Distribution Panel. Also, the applicant committed to add the assumed current requirement included in 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. Since the applicant has committed to tender more detailed information regarding current requirements for loads included in the battery sizing calculations in future revisions of the DCD, **RAI 388-2858, Question 08.03.02-22** remains open because the issue raised has not been resolved. The NRC staff considers this **Open Item 08.03.02-1**.

With the exception of the open item discussed above, 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 meet their functional requirements, 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 SE. Therefore, with the exception of the open item discussed above, the NRC staff finds that the US-APWR onsite dc power system conforms to the guidance of RG 1.32.

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

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 SE.

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 ‘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 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 required to be operational to provide minimum safety function 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 with regards 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 requirements for preserving 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 RG1.75. 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 or 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 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 demonstrated conformance with them is described below:

a) Regulatory position C.1 – The RG states that Subsection 2, “References,” which stipulates that this standard should be used in conjunction with other IEEE standards, should be supplemented as follows:

> “For nuclear power generating stations, the recommended practice should also be used in conjunction with other pertinent publications. (In some cases, the specific applicability or acceptability of these documents may be covered separately in other RGs.) The pertinent publications include the following IEEE standards:
>
> 1. IEEE Std. 308, “Criteria for Class 1E Power Systems for Nuclear Power Generating Stations,” as endorsed by RG 1.32.
> 2. IEEE Std. 336-2005, “Installation, Inspection, and Testing Requirements for Power, Instrumentation, and Control at Nuclear Facilities.”
> 3. IEEE Std. 344, “Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations,” as endorsed by RG 1.100.
> 4. IEEE Std. 450, “Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications,” as endorsed by RG 1.129.
> 5. IEEE Std. 384, “Standard Criteria for Independence of Class 1E Equipment and Circuits,” as endorsed by RG 1.75.

The applicant stated that the recommended practice of IEEE Std. 484 is used in conjunction with IEEE Std. 308 (as endorsed by RG 1.32), IEEE Std. 336, IEEE Std. 344 (as endorsed by RG 1.100), IEEE Std. 450 (as endorsed by RG 1.129) and IEEE Std. 384 (as endorsed by RG 1.75).

b) Regulatory position C.2 – The RG states that Subsection 5.1, “Location, ” item (d) should be supplemented to add the following:

> "…(d) For nuclear power generating stations, the general requirement that the battery should be protected against fires should be supplemented with the applicable recommendations for battery rooms in Regulatory Guide 1.189, 'Fire Protection for Operating Nuclear Power Plants."

The applicant stated that the Class 1E battery rooms are protected against fires and explosions in accordance with the guidance provided in RG 1.189 for battery rooms. The battery rooms, including all penetrations and openings, of redundant trains are separated by minimum three-hour rated fire barriers. DC switchgear, switchboards, MCCs, UPS or inverters are not located in the Class 1E battery rooms. The Class 1E battery rooms are provided with automatic fire detection systems with provision for local alarm and alarm and annunciation in the MCR. The Class 1E battery room ventilation systems are designed to maintain a hydrogen concentration of less than one percent, and loss of ventilation is alarmed in the MCR. Standpipes and hose stations are readily available outside the Class 1E battery rooms. Portable extinguishers are provided in the Class 1E battery rooms.

c) Regulatory position C.3 – The RG states that Subsection 5.1, "Location," should be supplemented to add item (k), as follows:

> "…(k) For nuclear power generating station Class 1E batteries, where batteries are required in redundant systems, the batteries shall be separated as specified by IEEE Std 384, 'Standard Criteria for Independence of Class 1E Equipment and Circuits,' and as recommended for battery rooms in Regulatory Guide 1.189, 'Fire Protection for Operating Nuclear Power Plants.'"

The applicant stated that the Class 1E batteries of redundant trains are located in separate safety class structures conforming to the requirements of IEEE Std. 384 and RG 1.189.

d) Regulatory position C.4 - The RG states that Subsection 5.2, "Mounting," item (c), should be supplemented to add the following:

> "…(c) For nuclear power generating stations, battery cells must be arranged on racks to provide for the ability for cell plates to be inspected."

The applicant stated that the Class 1E batteries are installed on Seismic Category I racks and their arrangement on the racks provides the ability for cell plate inspection.

e) Regulatory position C.5 - The RG states that Subsection 5.3, "Seismic," criteria should be supplemented to add the following:

"…(d) For nuclear power generating station Class 1E batteries, the racks, anchors, and installation thereof shall be able to withstand the force calculated for a safe shutdown earthquake to allow continuous battery service during and following the event in accordance with IEEE Std 344, 'Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations,' and the associated Regulatory Guide 1.100, 'Seismic Qualification of Electric Equipment for Nuclear Power Plants."

The applicant stated that the Class 1E batteries and their installation including racks and anchors are designed and qualified as Seismic Category I in accordance with IEEE Std. 344 as endorsed by RG 1.100. The installation is able to withstand the forces of a safe shutdown earthquake event while maintaining battery service during and following the event.

f) Regulatory position C.6 – The RG states that in Subsection 5.4, "Ventilation," revise the second sentence to be consistent with RG 1.189, as follows:

"The ventilation system shall limit hydrogen accumulation to one percent of the total volume of the battery area."

The applicant stated that the Class 1E battery room ventilation systems are designed to limit hydrogen accumulation to one percent of the total volume of the battery room.

g) Regulatory position C.7 - The RG states that in Subsection 6.3.1, "Freshening Charge Sequence," item (a) should be supplemented as follows:

"…(a) The pilot cell determined by sampling shall not be used to support maintenance and test measurements in IEEE Std 450 as endorsed by Regulatory Guide 1.129, unless that pilot cell has been verified through measurement of each cell's specific gravity and float voltage to be representative of the average of the entire battery."

The applicant stated that for maintenance and test measurements of Class 1E batteries, the pilot cell is not determined by any sampling process. The pilot cell is representative of the average of the entire battery that is obtained by measurement of each cell's specific gravity and float voltage.

h) Regulatory position C.8 - The RG states that Subsection 6.3.4, "Acceptance test," should be revised to specify capability and capacity tests upon initial installation, as follows:

"Upon initial installation, the battery's capability shall be demonstrated by completing a service test or modified performance test in accordance with IEEE Std. 450, as endorsed by Regulatory Guide 1.129. If factory tests did not include capacity tests, the battery's capacity shall also be demonstrated by completing a performance test or modified performance test in accordance with IEEE Std. 450, as endorsed by Regulatory Guide 1.129."

The applicant stated that upon initial installation of Class 1E batteries, each battery's capability is demonstrated by a performance test or a modified performance test in accordance with IEEE Std. 450 as endorsed by RG 1.129.

i) Regulatory position C.9 - All activities that pertain to Class 1E batteries are performed in accordance with plant quality assurance program.

j) Regulatory position C.10 - The RG stated that in addition to the requirements of IEEE Std 484-2002, the recommendations (indicated by the verb "should") contained in the following sections of that standard have sufficient safety importance to be treated the same as the requirements of the standard:

(a) Subsection 5.1, "Location," item (c) recommends that the battery area be clean, dry, and well-ventilated and provide adequate space and illumination for inspection, maintenance, testing, and cell/battery replacement.

(b) Subsection 5.1, "Location," item (d) recommends that the battery be protected against natural phenomena, such as earthquakes, winds, and flooding, as well as induced phenomena, such as fire, explosion, missiles, pipe whips, discharging fluids, and carbon dioxide. In addition, the examples of induced phenomena are revised to add the following:

> "radiation"

(c) Subsection 5.1, "Location," item (g), which recommends providing stationary water facilities for rinsing spillage, should be supplemented with the following:

> "Where portable or stationary water facilities are provided within the battery room, their design should preclude any inadvertent spilling of water from these facilities onto the battery itself."

(d) In Subsection 5.5, "Instrumentation and Alarms," the four listed items should be supplemented with two recommended items, as follows:

> "…(e) Ventilation air flow sensor(s) and alarm(s) in the control room"
>
> "…(f) Fire detection sensor(s), instrumentation, and alarm(s), as recommended for battery rooms in Regulatory Guide 1.189, 'Fire Protection for Operating Nuclear Power Plants'"

(e) Subsection 6.1.3, “Storage,” item (a) recommends avoiding extremely low or high ambient temperatures or localized sources of heat.

(f) Subsection 6.3.2, “Data collection,” is supplemented with the following:

> “…(e) At the completion of the freshening charge, a hydrogen survey shall be performed to verify that the design criteria required by Subsection 5.4, ‘Ventilation,’ are met (see Section 7, ‘Records’).”

(g) Subsection 7, “Records,” is supplemented with the following:

> “…(f) Initial hydrogen survey data”

The applicant stated that the Class 1E battery rooms are kept clean, dry and well ventilated; and they are provided with adequate space and illumination for inspection, maintenance, testing, and cell/battery replacement. The Class 1E batteries are protected against natural phenomena, such as earthquake, winds, and flooding, as well as induced phenomena, such as radiation, fire, explosion, missiles, pipe whip, discharging fluids, and carbon dioxide discharge. The design of the portable and stationary water in Class 1E battery rooms precludes any inadvertent spilling of water from these facilities onto the battery itself. Each Class 1E battery installation includes the following instrumentation and alarms:

i. Voltmeter
ii. High and low battery voltage alarm
iii. Ground detector
iv. Instrumentation to measure current through the battery
v. Ventilation air flow sensor and alarm in the MCR
vi. Fire detection sensor, instrumentation and alarm as recommended in RG 1.189

The applicant also stated that when storage is required for Class 1E cells, they are stored indoors in a clean, level, dry, and cool location, avoiding extreme low or high temperatures or localized sources of heat. Upon completion of a freshening charge, a hydrogen survey is performed to verify hydrogen concentration is less than one percent. This concentration conforms to RG 1.189. In addition to the items listed in Section 7 of IEEE Std. 484, records of initial hydrogen survey data are maintained for record purposes and future reference.

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, or 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. Since 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, the NRC staff is concerned 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-485 was endorsed by the NRC. 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 1 E 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-485 and IEEE-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 70 E 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, states 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 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**, dated May 30, 2008, the applicant responded that "…the 2% limits described in RG 1.189 was appropriate for the fire protection scenario". The NRC staff found this response unacceptable, and explained during a teleconference with the applicant on March 23, 2009, that 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. During the teleconference, the applicant stated in its response that the ventilation fans have sufficient capacity to maintain the hydrogen concentration below one percent which will be verified with hydrogen detectors. This response is acceptable because the hydrogen concentration in the battery room will conform to NFPA-70E. However, the applicant must revise its DCD to incorporate the new maximum allowable hydrogen concentration of one percent. As a result, the NRC staff considers **RAI 8-343, Question 08.03.02-1** closed, but the issue it raised remained open.

In **RAI 388-2858, Question 08.03.2-15**, the NRC staff asked a follow up RAI to **RAI 8-343, Question 08.03.02-1** based on discussions with the applicant during the teleconference held on March 18, 2009. In **RAI 388-2858, Question 08.03.2-15**, the NRC staff requested that the applicant docket its response confirming the above actions on part of the applicant to resolve this RAI question.

In a letter dated July 13, 2009, submitted in response to **RAI 388-2858, Question 08.03.2-15**, the applicant stated that the DCD would be revised to state that the maximum hydrogen concentration in the battery room would be 1 %, in conformance with the guidance in RG 1.128. The NRC staff verified that DCD Tier 2, Revision 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 388-2858, Question 08.03.2-15,** closed and the issue it 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 **Question 08.03.02-10,** dated July 10, 2008, the applicant explained that the US-APWR design includes a safety-related ventilation system for the Class 1E battery room. The NRC staff found this explanation inadequate because the applicant did not address whether the battery rooms have safety-related ventilation systems. The NRC staff considers **RAI 8-343, Question 08.03.02-10,** closed but the issue it raised remained open.

In a March 23, 2009, teleconference, the NRC staff asked the applicant to address whether the battery rooms have safety-related ventilation systems. The applicant clarified that safety-related ventilations systems are provided for the Class 1E battery rooms and committed to update its DCD to mention that safety-related ventilations systems are provided for the Class 1E battery rooms. 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**, based on discussions with the applicant during the teleconference held on March 23, 2009. 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 a letter dated July 13, 2009, submitted in its response to **RAI 388-2858, Question 08.03.2-21**, 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. The information in Section 9.4.5.2.2 of the DCD will be reviewed on Chapter 9 of the SE of this application. 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 its review of the information submitted by the applicant, 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 would be required in the TS 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 well as Criterion III of Appendix B 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 endorses IEEE Std. 603-1991, "Criteria for Safety Systems of Nuclear Power Generating Stations," which 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 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. 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. Accordingly, the NRC staff finds that the US-APWR onsite dc electrical distribution system is designed in accordance with the separation and independence requirements described in RG 1.153.

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. 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 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 requirements 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 a 60 cells rated at 125Vdc, 5000Ah, with a float voltage 2.25V/cell, equalize voltage 2.33V/cell, and 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 is capable of providing 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 conforms to the guidance in 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 supply to all electrical loads that are required to be operational is restored within one hour from the onset of an SBO event. Under normal plant operating conditions, both safety-related and non safety-related dc power systems derive power from the battery chargers that are fed from the safety-related and non safety-related 480V MCCs. Safety-related and non safety-related batteries 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 the required Class 1E battery charger and that train of the dc system will be powered from the associated battery charger. Hence, for an SBO condition, the batteries are required to be 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 requirements 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 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. Therefore, the NRC staff finds that the US-APWR onsite dc power system batteries conform to the guidance in RG 1.155.

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, 1.118, and 1.153 and BTP 8-5.

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. In addition, there are two installed non-Class 1E spare battery chargers, one spare battery charger AB for trains A and B, and other spare battery charger CD for trains C and D. Any two of the four trains are required to be operable to mitigate 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 SE. 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 specified duration. 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 SE.

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. The US-APWR DCD stated 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 endorses IEEE Std. 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations." The IEEE standard provides a method acceptable for the NRC staff to evaluate 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. If molded case circuit breakers are used, the NRC staff requested that the applicant describe how the molded case circuit breakers will be coordinated with the downstream protective devices. In addition, the applicant must provide results of the coordination studies performed on the dc system. In a response to **RAI 8-343, Question 08.03.02-5**, dated July 10, 2008, the applicant provided a brief discussion stating that both MCCBs and fuses are accepted as protective devices. As the NRC staff indicated in a March 23, 2009, teleconference with the applicant, it is 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 result, the NRC staff considers **RAI 8-343, Question 08.03.02-5** closed, but the issues it raised remained open.

As a followup to **Question 08.03.02-5** based on the March 23, 2009, teleconference discussion, the NRC staff issued **RAI 388-2858, Question 08.03.2-19** for the applicant to docket its response. In **Question 08.03.2-19** , 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 a letter dated July 13, 2009, submitted in response to **RAI 388-2858, Question 08.03.2-19,** 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. The NRC staff verified that DCD Tier 2, Section 8.3.2.1.1 was revised in Revision 2 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 in Revision 2 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 hasn't been endorsed by the NRC but is an acceptance standard widely used in the industry, the NRC staff considers **RAI 388-2858, Question 08.03.2-19,** closed and the issues it raised, resolved.

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 this finding 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 will meet 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 SE.

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. Therefore, the NRC staff finds US-APWR design is in conformance with BTP 8-5.

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 equipment, and properly analyzes three conditions for each operational mode. The analysis of this technical report is discussed in Section 8.3.1.4.15 of this SE.

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
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

8.3.2.6 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, Stds., and BTP 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 the open item discussed above, 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 SE.

8.4 Station Blackout

8.4.1 Introduction

A SBO refers to the complete loss of ac power to the essential (safety) and nonessential (non-safety) electrical buses in a nuclear power plant (NPP). A SBO, therefore, 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 a 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. A SBO does not include the loss of available ac power to safety buses served by station batteries through inverters or by AAC power sources. The SBO rule (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 a SBO for a specified duration. Because many safety systems for reactor core decay heat removal and containment heat removal rely on ac power, a SBO could result in a severe core damage accident. A SBO does not assume a concurrent single failure or design-basis accident (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 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 a 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 nonsafety-related GTGs 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 design control document (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 required for achieving safe shutdown of the NPP under SBO conditions. The applicant states that power to the buses required 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 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; using independent auxiliaries; and providing interconnections to the offsite and onsite emergency ac power systems, such that no single point of vulnerability would cause its 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. 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 that the AAC GTGs are not normally connected 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 applicant states that 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 turbine driven (T/D) emergency feedwater (EFW) pump and main steam relief valve remove the decay heat of the core through natural circulation of the reactor coolant within the core and the RCS, which maintains a safe mode of operation.

- 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.

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 by using the T/D EFW pump and steam relieved by using 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

It is expected 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 a 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 a 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. However, RG 1.155 takes precedence as noted in Table 1 of RG 1.155.

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 a 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 a 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 a 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 a SBO lasting a specified minimum duration. The specified duration of a 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, and 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 requirements for a LOOP, and LOOP and LOCA occurring simultaneously. Therefore, the onsite EAC group is two out of four, and in accordance with the RG 1.155, Table 3, it is designated as EAC Group "B." On the basis of the NRC staff's review and evaluation of the information given in the DCD, 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 does 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 for the US-APWR design 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 requiring the longest SBO coping duration in accordance with RG 1.155, Table 2, "Acceptable Station Blackout Duration Capability (Hours)." On the basis of the NRC staff's detailed review and evaluation of the information given in the DCD, the NRC staff finds that the US-APWR applicant has conservatively chosen the Offsite Power Design Characteristic Group as "P3" in accordance with Table 4 of RG 1.155 and SRP Section 8.4. Therefore, this characterization provides for a coping duration of 8 hours per 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 Revision 2 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 a 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, 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 a 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 which can power the non-safety buses P1 and P2 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 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 non-safety loads 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 a SBO event.

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 a SBO event, thereby keeping 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 to bring the plant to cold shutdown if required. It was not clear to the NRC staff how the applicant could assert operational flexibility and enhanced reliability for two AAC power sources for a SBO when one of the AAC power source is used to power non-safety loads for asset management. In **RAI 11-456, 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; of how greater US-APWR reliability for coping is achieved when only one AAC GTG is used to cope with a SBO event and why an RHR pump was not included in the SBO loads that are powered by the AAC GTG during a SBO event. A teleconference with the applicant was held on March 12, 2009, to further clarify the NRC staff's questions on the use of the second AAC-GTG during SBO conditions. 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 required, instead of using it for asset-management. The applicant indicated that the loads shown in the DCD, Revision 0 are the loads needed for hot shutdown as a minimum requirement under SBO conditions. The applicant indicated during the March 12, 2009, teleconference call 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 agreed to add a detailed description to the DCD in a future revision on the use of both AAC-GTGs for SBO purposes. The applicant also agreed to revise DCD Table 8.3.1-6 to show the loads for Hot-Shutdown and Cold-Shutdown to keep the plant in safe condition during an SBO. 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 considered **RAI 11-456, Questions 08.04-3 and 08.04-04**, closed, but the issues they raised remained open.

The NRC staff then asked a followup **RAI 419-3126, Question 08.04-09** formally requesting that the applicant document the above discussion and description on how US-APWR design meets the guidance provided on a 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 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 required using the two AAC GTGs in Section 8.4 of future revisions 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 NRC staff finds the applicant's response on the use of the two GTGs as AAC power sources for 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 acceptable as this allows the plant to be brought all the way to cold shutdown using only AAC sources. This is being tracked as **Confirmatory Item 08.04-2**.

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 design and the manufacturer of the AAC and the Class 1E GTGs are the same with some minor differences. 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 a 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 with regard to the AAC power sources.

In **RAI 11-456, Question 08.04-3**, the NRC staff also requested that the applicant to provide additional information on how the US-APWR designs meets the Commission's guidance on diversity of AAC power sources. During the March 12, 2009, teleconference noted above, the applicant made a commitment to use different manufacturers for Class 1E GTGs and non-safety 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 since it uses different manufacturers, design and components for the AAC GTGs and the onsite Class 1E GTGs. The issue of diversity of the AAC power sources is being tracked as **Confirmatory Item 08.04-1.**

3. Independence

The requirements for independence of AAC power sources are specified in 10 CFR 50.2 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 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 non-safety buses P1 and P2 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 a SBO but has provisions to be manually connected to the safety buses as needed. AAC GTG A can be manually connected to Class 1E buses A or B, and AAC GTG B can be manually connected to the Class 1E buses C or D. 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. The AAC sources are not connected to either of the other two power systems as discussed above. 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 could not disable all of the onsite emergency ac sources and offsite ac power supplies simultaneously along with all the AAC power sources. The auxiliary and support systems for the AAC GTGs are independent and separate from the Class 1E GTGs to minimize the potential for common cause failure. 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 reviewed the DCD information, as summarized above, to assess the adequacy of the independence of the AAC power sources 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 requirements of 10 CFR 50.2 concerning the independence of the AAC sources have been met 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 operability and reliability. The reliability of the AAC power system should meet or exceed 95 percent as determined in accordance with 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 requirements as a COL information item. The NRC staff in **RAI 5251, Question 08.04-14,** requested that the applicant add COL information item in a future revision of 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. This is being tracked as **Open Item 08.04-2.**

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 a SBO. In accordance with the above stated policy, the applicant for the US-APWR DC has provided two AAC GTGs for mitigating a SBO event. The guidance given in RG 1.155, Regulatory Position C 3.3.5.3, states that the AAC power source should be available in a timely manner after the onset of a SBO and with provisions to be manually connected to any of the redundant safety buses as required. The time required 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 a SBO, no coping analysis is required.

The AAC power sources provided in the design of US-APWR for a 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 LOOP, both GTGs are automatically started by an undervoltage signal on 6.9-kV buses P1 and P2 respectively. Also during a SBO, the AAC GTG is 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 the requirements of Regulatory Position C.3.2 of RG 1.155. 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 a SBO given in DCD Tier 2, Section 8.4, to determine the US-APWR's capability to withstand and recover from a SBO with an eight-hour coping duration. When determining a plant's capability to cope with a 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 a 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 its letter dated July 18, 2008, submitted in response to **RAI 11-456, Question 08.04-7,** 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 a SBO condition. In a teleconference held on March 12, 2009, the NRC staff asked the applicant to explain how pump seal leakage does not occur in the US-APWR design. During this teleconference, MHI stated that the wording "leakage of pump will not occur" stated in its July 18, 2008, response was not appropriate. The applicant stated that its RAI response should be revised to state that "leakage of pump will be limited". The applicant explained that there is small leakage through RCP No.2 seal, which is expected to be approximately 0.2 gpm (40 litters) per hour under SBO conditions. This leakage is very small compared to RCS inventory, therefore while there will be some leakage, no significant inventory loss will occur during a SBO. The NRC staff considered **RAI 11-456, Question 08.04-7**, closed, but the issues it raised remained open.

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 a SBO event.

- Perform a 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 in item 1 above.

In response to RAI **419-3126, Question 08.04-12**, dated September 2, 2009, the applicant provided the following:

> The leakage of reactor coolant through the seals of each RCP is assumed to be 0.2 gpm as described in the response to question (1) above. 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 ft3 at standard condition. This amount is small compared to RCS coolant inventory. The normal operating water volume of the pressurizer is approximately 1,300 ft3 (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.

The NRC staff's review shows that the applicant justifies the assumed seal leakage of 0.2 gpm per pump based on closing the isolation valves on the No. 1 seal leak-off line of each RCP by an undervoltage signal. The applicant asserts that No. 2 seal leak-off is the only pathway for reactor coolant leakage through the RCPs and it is expected to be approximately 0.2 gpm per RCP under SBO conditions. The assumed 25-gpm seal leakage per RCP in all PWRs was established as industry guidance in NUMARC-8700 for SBO coping analyses during a SBO rule implementation because of the uncertainty of pump seal leakage. The NRC staff does not accept MHI response of using 0.2-gpm-per-pump leakage in view of the industry guidance of 25 gpm, and finds that MHI should not deviate from this industry position unless the applicant can justify the deviation from industry standards through its RCP design by actual test results. The issue of whether there is sufficient RCS inventory using 25-gpm seal leakage per pump to ensure the core is cooled and remains covered is being tracked as **Open Item 08.04-1**.

(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 a 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 a SBO. The capacity of the EFW pit is designed to maintain eight hours of hot standby condition and six hours cooldown as normal safe shutdown function, and thus has sufficient capacity to cope with a 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 necessary loads required for a SBO, is acceptable. ,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 required for decay heat removal have sufficient reserve air and maintain appropriate containment integrity for a 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 MOV and therefore does not rely on compressed air. The non-safety-related air-operated valves are not operated during a 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 non-safety air-operated valves are not operated during a 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 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 required 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 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 required loads 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 required dc loads 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 a SBO in DCD Tier 2, Section

8.4.2.1.2.3 (page 8.4-8). However, the applicant did not discuss and provide information on effects of the loss of ventilation to other equipment, such as T/D EFW pump, valves, battery room and other equipment credited in mitigating a SBO event. In **RAI 11-456, Question 08.04-7 (e)**, the NRC staff requested additional information on the effects of loss of ventilation in all dominant areas of concern and on the equipment credited during a 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 a SBO, is located in the areas shown in the table below. The equipment credited for a SBO can perform its SBO coping function for one hour from the onset of a 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 their integrity up to 175°F (80°C). Ambient temperature of corridor does not rise than 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 a 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 a SBO condition.
Battery Room	Battery	Heat generation from the battery in discharge mode does not rise 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 a SBO is acceptable. The NRC staff considers **RAI 11-456, Question 08.04-7 (e)**, closed, and the issue it raised, resolved.

8.4.4.5 Recovery from a SBO

In DCD Tier 2, Section 8.4.2, the applicant states that AC power supply to the Class 1E buses would be restored either from the onsite Class 1E GTGs or from the offsite ac power at the end of 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 it becomes available during or at the end of eight hour coping duration. After 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. 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 a 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 C.F.R. Part 50, for guidance on quality assurance (QA) and specifications respectively for non-safety equipment 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 non-safety-related equipment 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 (Revision 0 and Revision 1), did not address the QA activities for non-safety-related equipment 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. In this RAI, 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 the **RAI Question 08.04-6** dated July 18, 2008, stated that the AAC-GTG system is an important system from view point of plant safety. In its response, the applicant elaborated that the design of the AAC-GTG system complies with the 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 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 a letter dated August 21, 2009, in response to **RAI 419-3126, Question 08.04-11**, 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 SE. **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 a SBO. It states that procedures and training should include all operator actions necessary to cope with a 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 a 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 a 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 a letter dated July 18, 2008, submitted in response to **RAI 11-456, Question 08.04.05**, 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 a 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 a SBO for at least the 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 (Revision 2) includes the additions that the applicant committed to in its August 21, 2009, response to **RAI 419-3126, Question 08.04-10,** 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), and will be reviewed in Chapter 13 of this SE. **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 additional information is required to be provided by a COL applicant in connection with this section on a SBO. The NRC staff disagrees with the applicant's position. There are a number of COL applicant interface action items discussed in the NRC staff's technical evaluation above that the COL applicant must provide to satisfy the requirements of 10 CFR 50.63 and the guidance of RG 1.155. All but one of these interface items can be found in either Section 13 or 17 of the DCD and they are evaluated in the corresponding sections of the staff's SE. The one remaining item that belongs in Section 8.4.3 of the DCD is as follows:

> COL applicants that reference the US-APWR design certification are required to provide the below listed information on plant-related interfaces for meeting the SBO rule (10 CFR 50.63). The COL applicant interface action item that is to be included in a future revision of the DCD is:
>
> > AAC power system will be inspected and tested periodically to demonstrate operability and reliability in accordance with RG 1.155, Regulatory Position C3.3.5.

This is being tracked as **Open item 08.04-2** as discussed in Section 8.4.4.2 above.

8.4.6 Conclusion

On the basis of the NRC staff's review and evaluation of the SBO information in the DCD, the NRC staff concludes that, with the exception of the open and confirmatory items described above**,** the applicant has provided sufficient information in the DCD, together with the responses to the NRC staff's RAIs, to support the conclusion that the plant systems credited for coping with a 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, except as noted, 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 SBO coping duration of eight hours and recover from it.