

## 8.0 Electric Power

### 8.1 Introduction

#### 8.1.1 Offsite Transmission Network

The description of the offsite transmission network is out of the ABWR Standard Plant scope, however there are interface requirements contained in Section 8.2.3 which must be complied with by the COL applicant.

#### 8.1.2 Electric Power Distribution System

##### 8.1.2.0 Definitions

The definitions used throughout Chapter 8 are consistent with Section 3 of IEEE-308 with the following important clarifications for the ABWR:

**Division**—The designation applied to a given safety-related system or set of components that enables the establishment and maintenance of physical, electrical, and functional independence from other redundant sets of components. (The term “safety-related” is added to the IEEE-308 definition.)

**Load group**—An arrangement of buses, transformers, switching equipment, and loads fed from a common power supply. (The last three words “...within a division” are deleted with respect to the IEEE-308 definition.) A load group may be safety-related or non-safety-related depending on its common power supply.

**Safety-related**—Any Class 1E power or protection system device included in the scope of IEEE-603 or IEEE-308. (This term is explicitly defined in IEEE-100, though not in IEEE-308.) Note that “safety-related” includes both electrical and non-electrical equipment, whereas “Class 1E” pertains only to electrical equipment (i.e., any equipment which has an electrical interface).

##### 8.1.2.1 Description of Offsite Electrical Power System

The scope of the offsite electrical power system includes the entire offsite transmission network and the transmission lines coming into the switchyards to the termination of the bus duct and power cables at the input terminals of the circuit breakers for the medium voltage switchgear. The COL applicant has design responsibility for portions of the offsite power system. The scope split is as defined in the detailed description of the offsite power system in Subsection 8.2.1.1.

The main power transformer is a bank of three single phase transformers. One single phase installed spare transformer is provided.

A main generator circuit breaker capable of interrupting the maximum available fault current is provided. This allows the generator to be taken off line and the offsite transmission network to

be utilized as a power source for the unit auxiliary transformers and their loads, both Class 1E and non-Class 1E. This is also the startup power source for the unit.

There are three unit auxiliary transformers, connected to supply power to three approximately equal load groups of equipment. The “Normal Preferred” power feed is from the unit auxiliary transformers so that there normally are no bus transfers required when the unit is tripped off the line.

There are two (2) three winding reserve auxiliary transformers (RATs), each with one 13.8 kV and one 4.16 kV secondary winding that provide alternate preferred power to connected loads.

A minimum of 20 MW combustion turbine generator is provided as an alternate AC power source. The unit is capable of providing power to non-Class 1E plant investment protection buses and Class 1E buses. The combustion turbine generator is non-safety-related.

#### **8.1.2.2 Description of Onsite AC Power Distribution System**

Unit auxiliary transformers (UATs) A & B each provide power to three non-Class 1E buses and one Class 1E bus. UAT C provides power to one non-Class 1E bus and one Class 1E bus. The 13.8 kV reserve auxiliary transformer (RAT) windings can be used to supply reserve power to non-Class 1E power generation buses. The 4.16 kV RAT windings can be used to supply reserve power to the plant investment protection (PIP) buses and also to the three (3) Class 1E buses.

A combustion turbine generator (CTG) supplies automatic standby power to plant investment protection non-Class 1E loads. These loads are grouped on the three plant investment protection (PIP) buses as shown in Figure 8.3-1. The CTG also has the capability to be manually connected to any of the three Class 1E buses, for mitigation of the station blackout (SBO) event (see Subsection (9) of 8.3.1.1.7).

In general, motors larger than 300 kW are supplied from the medium voltage metal-clad (M/C) bus. Motors 300 kW or smaller but larger than 100 kW are supplied power from 480V power center (P/C) switchgear. Motors 100 kW or smaller are supplied power from 480V motor control centers (MCC). The medium voltage and 480V single line diagrams are shown in Figure 8.3-1.

During normal plant operation all of the non-Class 1E buses and two of the Class 1E buses are supplied with power from the main turbine generator through the unit auxiliary transformers. The remaining Class 1E bus is supplied from a reserve auxiliary transformer. This division is immediately available, without a bus transfer, if the normal preferred power is lost to the other two divisions.

Three safety related, Class 1E diesel generator standby AC power supplies provide a separate onsite source of power for each Class 1E division when normal or alternate preferred power supplies are not available. The transfer from the normal preferred or alternate preferred power

supplies to the diesel generator is automatic. The transfer back to the normal preferred or the alternate preferred power source is a manual transfer.

The Division I, II, and III standby AC power supplies consist of an independent 4.16 kV Class 1E diesel generator (D/G), one for each division. Each D/G may be connected to its respective 4.16 kV Class 1E switchgear bus through a circuit breaker located in the switchgear.

The standby AC power system is capable of providing the required power to safely shut down the reactor after loss of preferred power (LOPP) and/or loss of coolant accident (LOCA) and to maintain the safe shutdown condition and operate the Class 1E auxiliaries necessary for plant safety after shutdown.

The plant 480 VAC power system distributes sufficient power for normal auxiliary and Class 1E 480 volt plant loads. All Class 1E elements of the 480V power distribution system are supplied via the 4.16 kV Class 1E switchgear and, therefore, are capable of being fed by the normal preferred, alternate preferred, standby diesel generator, or combustion turbine generator power supplies.

The 120 VAC non-Class 1E instrumentation power system, Figure 8.3-2, provides power for non-Class 1E control and instrumentation loads.

The Class 1E 120 VAC instrument power system, Figure 8.3-2, provides for Class 1E plant controls and instrumentation. The system is separated into Divisions I, II, III, and IV with distribution panels and local control panels fed from their respective divisional sources, except Division IV is fed from the Division II source.

The 125 VDC power distribution system provides four independent and redundant onsite battery sources of power for operation of Class 1E DC power, control, and instrument loads. The 125 VDC non-Class 1E power control and instrument loads are supplied from three 125 VDC batteries located in the turbine building. A separate non-Class 1E 250V battery is provided to supply uninterruptible power to the plant computers and non-Class 1E DC motors (Figure 8.3-4).

The safety system and logic control (SSLC) for the Reactor Protection System (RPS) and Main Steamline Isolation Valves (MSIV) derives its power from four uninterruptible 120 VAC divisional buses (See Figure 8.3-3). The SSLC for the Emergency Core Cooling System (ECCS) derives its power from the four divisions of 125 VDC buses. The four buses provide the redundancy for various instrumentation, logic and trip circuits and solenoid valves. The SSLC power supply is further described in Subsection 8.1.3.1.1.2.

### **8.1.2.3 Safety Loads**

The safety loads utilize various Class 1E AC and/or DC sources for instrumentation and motive or control power or both for all systems required for safety. Combinations of power sources may be involved in performing a single safety function. For example, low voltage DC power in

the control logic may provide an actuation signal to control a 4.16 kV circuit breaker to drive a large AC-powered pump motor. The systems required for safety are listed below:

- (1) Safety System Logic and Control Power Supplies including the Reactor Protection System
- (2) Core and Containment Cooling Systems
  - (a) Residual Heat Removal (RHR) System
  - (b) High Pressure Core Flooder (HPCF) System
  - (c) Automatic Depressurization System (ADS)
  - (d) Reactor Core Isolation Cooling (RCIC) System
- (3) ESF Support Systems
  - (a) Diesel generator Sets and Class 1E AC/DC power distribution systems
  - (b) HVAC Emergency Cooling Water (HECW) System
  - (c) Reactor Building Cooling Water (RCW) System
  - (d) Reactor Service Water System (RSW)
  - (e) Standby Gas Treatment System (SGTS)
  - (f) Reactor Building Emergency HVAC System
  - (g) Control Building HVAC System
  - (h) High Pressure Nitrogen Gas Supply (HPIN) System
  - (i) Leak Detection and Isolation System (LDS)
- (4) Safe Shutdown Systems
  - (a) Standby Liquid Control System (SLCS)
  - (b) Nuclear Boiler System (NBS)
    - (i) Safety/Relief Valves (SRVs)
    - (ii) Steam Supply Shutoff Portion
  - (c) Residual Heat Removal (RHR) System decay heat removal
- (5) Class 1E Monitoring Systems
  - (a) Neutron Monitoring System (NMS)
  - (b) Process Radiation Monitoring System (PRMS)

- (c) Containment Atmosphere Monitoring System (CAMS)
- (d) Suppression Pool Temperature Monitoring System (SPTM)

For detailed listings of Division I, II and III loads, see Tables 8.3-1 and 8.3-2.

### **8.1.3 Design Bases**

#### **8.1.3.1 Safety Design Bases—Onsite Power**

##### **8.1.3.1.1 General Functional Requirements**

###### **8.1.3.1.1.1 Onsite Power Systems—General**

The unit's total Class 1E power load is divided into three divisions. Each division is fed by an independent 4.16 kV Class 1E bus, and each division has access to one onsite and two offsite power sources. An additional power source is provided by the combustion turbine generator (CTG). A description of the CTG is provided in Subsection 9.5.11.

Each of the two normally energized offsite power feeders (i.e., normal preferred and alternate preferred power) are provided for the Divisions I, II and III Class 1E systems. Normally two divisions are fed from the normal preferred power source and the remaining division is fed from the alternate preferred power source. Both feeders are used during normal plant operation to prevent simultaneous de-energization of all divisional buses on the loss of only one of the offsite power supplies. The transfer to the other preferred feeder is manual. During the interim, power is automatically supplied by the diesel generators.

The redundant Class 1E electrical divisions (Divisions I, II, and III) are provided with separate onsite standby AC power supplies, electrical buses, distribution cables, controls, relays and other electrical devices. Redundant parts of the system are physically separated and electrically independent to the extent that in any design basis event with any resulting loss of equipment, the plant can still be shut down with the remaining two divisions. Independent raceway systems are provided to meet cable separation requirements for Divisions I, II, and III.

Divisions I, II, and III standby AC power supplies have sufficient capacity to provide power to all their respective loads. Loss of the preferred power supply, as detected by 4.16 kV Class 1E bus under-voltage relays, will cause the standby power supplies to start and connect automatically, in sufficient time to safely shut down the reactor or limit the consequences of a design basis accident (DBA) to acceptable limits and maintain the reactor in a safe condition. The standby power supplies are capable of being started and stopped manually and are not stopped automatically during emergency operation unless required to preserve integrity. Automatic start will also occur on receipt of a Level 1 1/2 signal (HPCF initiate for Divisions II and III), Level 1 signal (RHR initiate for Division I) and high drywell pressure.

The Class 1E 4.16 kV Divisions I, II, and III switchgear buses, and associated 4.16 kV diesel generators, the safety-related 13.8 kV breakers (to trip condensate pumps in case of feedwater

pipe break), 480 VAC distribution systems, and Divisions I, II, III and IV, 120 VAC and 125 VDC power and control systems conform to Seismic Category I requirements. This equipment is housed in Seismic Category I structures except for some control sensors associated with the Reactor Protection System [Subsection 9A.5.5.1], and the Leak Detection System [Subsection 9A.5.5.7, and the safety-related 13.8 kV breakers (Subsection 8.3.1.1.1)]. Seismic Qualification is in accordance with IEEE-344 (Section 3.10).

In addition, non-safety-related equipment are designed to resist failure that could prevent any safety-related equipment from performing its nuclear safety-related function [Subsection 3.2.5.1, item (5)].

#### **8.1.3.1.1.2 Safety System Logic and Control Power Supply System Design Bases**

In order to provide redundant, reliable power of acceptable quality and availability to support the safety logic and control functions during normal, abnormal and accident conditions, the following design bases apply:

- (1) SSLC power has four separate and independent Class 1E inverter uninterruptible constant voltage constant frequency (CVCF) power supplies each backed by separate Class 1E batteries.
- (2) Provision is made for automatic switching to the alternate bypass supply from its respective division in case of a failure of the inverter power supply. The inverter power supply is synchronized in both frequency and phase with the alternate bypass supply, so that unacceptable voltage spikes will be avoided in case of an automatic transfer from normal to alternate supply. The SSLC uninterruptible power supply complies with IEEE-944 (Reference 8.1-1).

#### **8.1.3.1.1.3 Controls and Indication**

The ABWR electrical system design provides controls and indicators in accordance with IEEE-308 guidelines. The specific design bases are described as follows:

- (1) The ABWR electrical system provides controls and indicators in the main control room.
  - (a) Displays provided for the Plant Main Generator (PMG) consist of PMG output voltage, amperes, watts, VARS, and frequency. Displays provided for the Electrical Power Distribution (EPD) System consists of medium voltage M/C switchgear bus voltages, feeder and load amperes, and circuit breaker positions. Controls are provided for the PMG output circuit breaker, medium voltage M/C Switchgear feeder circuit breakers, load circuit breakers from the medium voltage M/C switchgear to their respective low voltage P/C switchgear, and the low voltage feeder circuit breakers to the low voltage P/C switchgear.

- (2) The design provides for control and indication outside the main control room for:
  - (a) Circuit breakers that switch Class 1E buses between the preferred and standby power supply
  - (b) The standby power supply
  - (c) Circuit breakers and other equipment as required for safety systems that must function to bring the plant to a safe shutdown condition
  - (d) EPD System displays and controls are provided at the Remote Shutdown System (RSS). Displays provided consist of bus voltages for the Class 1E Divisions I and II medium voltage M/C switchgear. Controls are provided for the UAT, RAT, CTG, and EDG Class 1E feeder circuit breakers to the Class 1E Divisions I and II medium voltage M/C switchgear and the load circuit breakers from the Class 1E Division I and II medium voltage M/C switchgear to their respective low voltage P/C Switchgear, and the low voltage feeder circuit breakers to the Class 1E Division I and II low voltage P/C switchgear.
- (3) Operational status information is provided for Class 1E power systems.
- (4) Class 1E power systems required to be controlled from outside the main control room also have operational status information provided outside the central control room at the equipment itself, or at its power supply, or at an alternate central location.
- (5) The operator is provided with accurate, complete, and timely information pertinent to the status of the execute features in the control room.
- (6) Indication is provided in the control room of protective actions and execute features unavailability.
- (7) Electric power systems and equipment have the capability of being periodically tested.
- (8) Testability of electrical systems and equipment is not so burdensome operationally that required testing intervals cannot be included.

#### **8.1.3.1.2 Regulatory Requirements**

The following list of criteria is addressed in accordance with Table 8.1-1 which is based on Table 8-1 of the Standard Review Plan. In general, the ABWR is designed in accordance with all criteria. Any exceptions or clarifications are so noted.

##### **8.1.3.1.2.1 General Design Criteria**

- (1) GDC 2—Design Bases for Protection against Natural Phenomena

(2) GDC 4—Environmental and Dynamic Effects Design Bases

(3) GDC 5—Sharing of Structures, Systems and Components

The ABWR is a single-unit plant design. Therefore, this GDC is not applicable.

(4) GDC 17—Electric Power Systems

(5) GDC 18—Inspection and Testing of Electrical Power Systems

(6) GDC 50—Containment Design Bases

#### **8.1.3.1.2.2 NRC Regulatory Guides**

(1) RG 1.6—Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems

(2) RG 1.9—Selection, Design, Qualification and Testing of Emergency Diesel Generator Units Used as Class 1E Electric Power Systems at Nuclear Power Plants

(3) RG 1.32—Criteria for Safety-Related Electric Power Systems for Nuclear Power Plants

Functional operation of fuses can not be periodically tested to verified setpoints, and are exempt from such requirements per Section 4.1.7 of IEEE-741. However, periodic inspection for continuity, correct size, etc, shall be performed.

(4) RG 1.47—Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems

(5) RG 1.63—Electric Penetration Assemblies in Containment Structures for Light-Water-Cooled Nuclear Power Plants

(6) RG 1.75—Physical Independence of Electric Systems

Isolation between Class 1E power supplies and non-Class 1E loads is discussed in Subsection 8.3.1.1.1.

(7) RG 1.81—Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants

The ABWR is designed as a single-unit plant. Therefore, this Regulatory Guide is not applicable.



- (8) RG 1.106—Thermal Overload Protection for Electric Motors on Motor-Operated Valves
- (9) Not Used
- (10) RG 1.118—Periodic Testing of Electric Power and Protection Systems
- (11) RG 1.128—Installation Design and Installation of Large Lead Storage Batteries for Nuclear Power Plants
- (12) RG 1.129—Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Nuclear Power Plants
- (13) RG 1.153—Criteria for Power, Instrumentation, and Control Portions of Safety Systems

Functional operation of fuses cannot be periodically tested to verified setpoints, and are exempt from such requirements per Section 4.1.7 of IEEE-741. However, periodic inspection for continuity, correct size, etc., shall be performed.

- (14) RG 1.155—Station Blackout

See Appendix 1C.

#### **8.1.3.1.2.3 Branch Technical Positions**

- (1) BTP ICSB 4 (PSB)—Requirements on Motor-Operated Valves in the ECCS Accumulator Lines

This BTP is written for Pressurized Water Reactor (PWR) plants only and is therefore not applicable to the ABWR.

- (2) BTP ICSB 8 (PSB)—Use of Diesel Generator Sets for Peaking

The diesel generator sets are not used for peaking in the ABWR design. Therefore, this criteria is satisfied.

- (3) BTP ICSB 11 (PSB)—Stability of Offsite Power Systems

- (4) BTP ICSB 18 (PSB)—Application of the Single Failure Criterion to Manually-Controlled Electrically-Operated Valves

- (5) BTP ICSB 21—Guidance for Application of Regulatory Guide 1.47

- (6) BTP PSB 1—Adequacy of Station Electric Distribution System Voltages (Subsection 8.3.1.1.7 (8))

- (7) BTP PSB 2—Criteria for Alarms and Indications Associated with Diesel-Generator Unit Bypassed and Inoperable Status

#### **8.1.3.1.2.4 Other SRP Criteria**

- (1) NUREG/CR 0660—Enhancement of Onsite Diesel Generator Reliability

Operating procedures and the training of personnel are outside the scope of the ABWR Standard Plant. NUREG/CR 0660 is therefore imposed as COL license information. (Subsection 8.1.4.1).

- (2) TMI Action Item II.E.3.1.—Emergency Power Supply for Pressurizer Heater

This criteria is applicable only to PWRs and does not apply to the ABWR.

- (3) TMI Action Item II.G.1—Emergency Power for Pressurizer Equipment

This criteria is applicable only to PWRs and does not apply to the ABWR.

### **8.1.4 COL License Information**

#### **8.1.4.1 Diesel Generator Reliability**

NUREG/CR 0660 pertaining to the enhancement of onsite diesel generator reliability through operating procedures and training of personnel will be addressed by the COL applicant (Subsection 8.1.3.1.2.4(1)).

### **8.1.5 References**

- 8.1-1 IEEE-944, Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations.

**Table 8.1-1 Onsite Power System SRP Criteria Applicable Matrix**

<b>Applicable Criteria</b>	<b>Ref. IEEE Std</b>	<b>Offsite Power System</b>	<b>AC Power Systems (Onsite)</b>	<b>DC Power System (Onsite)</b>
GDC 2			X	X
GDC 4			X	X
GDC 5*				
GDC 17		X	X	X
GDC 18		X	X	X
GDC 50			X	X
RG 1.6			X	X
RG 1.9	387		X	
RG 1.32	308	X	X	X
RG 1.47		X	X	X
RG 1.63	317		X	X
RG 1.75	384		X	X
RG 1.81*				
RG 1.106			X	X
RG 1.118	338		X	X
RG 1.128	484			X
RG 1.129	450			X
RG 1.153	603		X	X
RG 1.155†	NUMARC 8700		X	X
RG 1.204	IEEE-665 IEEE-666 IEEE-1050 IEEE-C62.23		X	X
BTP ICSB 4‡	279			
BTP ICSB 8	308		X	
BTP ICSB 11		X		
BTP ICSB 18			X	
BTP ICSB 21		X	X	X
BTP PSB 1			X	
BTP PSB 2			X	

**Table 8.1-1 Onsite Power System SRP Criteria Applicable Matrix (Continued)**

<b>Applicable Criteria</b>	<b>Ref. IEEE Std</b>	<b>Offsite Power System</b>	<b>AC Power Systems (Onsite)</b>	<b>DC Power System (Onsite)</b>
NUREG CR0060			X	
II. E. 3.1 <sup>‡</sup>				
II. G. 1 <sup>‡</sup>				

\* Multi-unit plants only; not applicable to single-unit ABWR

† See Appendix 1C

‡ PWR only; not applicable to ABWR