Chapter 8 Electric Power

8.1 Introduction

8.1.1 General

Power is supplied to the plant from two independent offsite power sources, the “Normal Preferred” power source and the “Alternate Preferred” power source. The loss of both preferred sources may be referred to as a loss of preferred power (LOPP) or a loss of offsite power (LOOP). The terms may be used interchangeably. These power sources are designed to provide reliable power for the plant auxiliary loads, such that any single active failure can affect only one power source and cannot propagate to the alternate power source. The Preferred Power Supply (PPS) consists of the normal preferred and alternate preferred power sources and includes those portions of the offsite power system and the onsite power system required for power flow from the offsite transmission system to the safety-related isolation power centers incoming line breakers.

The onsite alternating current (AC) power system consists of safety-related and nonsafety-related power systems. The two offsite power sources provide the normal preferred and alternate preferred AC power to safety-related and nonsafety-related loads. In the event of total loss of offsite power sources and loss of main generator island mode operation (main generator continues to provide AC power to site loads upon loss of offsite power sources), two onsite independent nonsafety-related standby diesel generators are provided to power the plant investment protection (PIP) nonsafety-related loads and safety-related loads through battery chargers and rectifiers. Two nonsafety-related ancillary diesel generators are capable of supplying power to the ancillary buses when no other sources of AC power are available (see Subsection 8.3.1.1.9). There are four independent safety-related direct current (DC) divisions to provide power for the safety-related loads. Onsite safety-related and nonsafety-related DC systems supply all the DC power requirements of the plant.

8.1.2 Utility Power Grid and Offsite Power System Descriptions

8.1.2.1 Utility Power Grid Description

The utility power grid description is provided in Subsection 8.2.1.

The output of Fermi 3 is delivered to a 345 kV switchyard through the unit main step-up transformers, as described in Section 8.2 and Section 8.3. Fermi 3 is connected to the switchyard by a 345 kV normal preferred transmission line that supplies power to the two unit auxiliary transformers (UAT) and a 345 kV alternate preferred transmission line that supplies power to the two reserve auxiliary transformers (RAT). The switchyard for Fermi 3 serves three 345 kV transmission lines, Fermi-Milan #1, Fermi-Milan #2, and Fermi-Milan #3 which connect this switchyard to the Milan substation. These three transmission lines exit the switchyard and traverse westward from the site as shown in Figure 2.1-204 and Figure 8.2-203. The international

Transmission Company's (ITC *Transmission*) transmission system and connections to Fermi 3 are further described in Section 8.2.

8.1.2.2 **Offsite Power System Description**

The offsite power system consists of the set of electrical circuits and associated equipment that are used to interconnect the offsite transmission system with the plant main generator and the onsite electrical power distribution system.

The system includes the switchyard and the high voltage tie lines to the high-side Motor Operated Disconnects (MODs) of the main generator circuit breaker, the high-side MODs of the Unit Auxiliary Transformers' (UATs) circuit breakers, and the high-side MODs of the Reserve Auxiliary Transformers (RATs).

The Normal PPS interface between the ESBWR certified onsite design and site specific offsite design is at the switchyard side terminals of the high side MOD of the UAT circuit breaker and main generator circuit breaker. The Alternate PPS interface between the ESBWR certified onsite design and the site specific offsite design is at the switchyard side terminals of the RAT high side MODs as indicated on Figure 8.1-1 Sheet 1 of 3, and discussed in Subsection 8.2.1.2.

During plant startup, emergency shutdown, or during plant outages, the offsite power system serves to supply power from the offsite transmission system to the plant auxiliary and service loads. Offsite power sources are as follows:

- "Normal Preferred" source through the UATs
- "Alternate Preferred" source through the RATs

During normal operation, the main generator transmits generated power to the offsite transmission system through the main transformers and to the plant auxiliary and service loads through the UATs.

The onsite power distribution system is powered continuously by the normal preferred power source during shutdown and throughout plant startup. When the onsite main generator breaker is tripped, power to the plant continues to be fed from the normal preferred power source to the UATs or directly to the RATs through the alternate preferred power source line.

A detailed description of the offsite power system is provided in Subsection 8.2.1.

8.1.3 **Onsite Electric Power System**

8.1.3.1 **Onsite AC Power System**

The onsite AC power system includes the main generator, the main transformers, the main generator circuit breaker and high side MODs, the UAT input MODs and circuit breakers, the RAT input MODs, and the unit and reserve auxiliary transformers, as indicated on Figure 8.1-1, Sheet 1 of 3.

The onsite power system is divided into two medium voltage power levels of 13.8 kV and 6.9 kV for operational flexibility of the plant nonsafety-related systems. Each UAT feeds one of the 13.8 kV and 6.9 kV power load groups and a RAT backs up each UAT.

The 13.8 kV medium voltage power level supplies power to nonsafety-related power generation loads required primarily for unit operation.

The 6.9 kV medium voltage power level supplies power to PIP-A and PIP-B (nonsafety-related loads), which, on account of their specific functions, are generally required to remain operational at all times or when the unit is shut down. The 6.9 kV medium voltage power level also supplies power to the safety-related loads through isolation power centers.

Both PIP-A and PIP-B buses have a standby power supply from separate onsite standby diesel generators, in addition to their normal PPS through the UATs, and their alternate PPS from an independent offsite source through the RATs.

The first medium voltage power level distributes power at 60 Hz and voltage levels of 13.8 kV, 480/277V, 240/120V and 208/120V.

The second medium voltage power level distributes power at 60 Hz and voltage levels of 6.9 kV, 480/277V, 240/120V and 208/120V.

A detailed description of the onsite AC power system is provided in Subsection 8.3.1

8.1.3.2 **Onsite DC Power System**

The onsite DC power system includes the plant batteries and battery chargers and their DC loads, including the DC/AC inverters and the inverter loads.

The nonsafety-related 125 VDC power system, Figure 8.1-2, provides power for nonsafety-related DC loads. The nonsafety-related 250V batteries are provided to supply DC power to the inverters that supply 120 VAC to the nonsafety-Related Distributed Control and Information System (Q-DCIS) and DC power to the nonsafety-related DC loads. The 125 VDC power and 250 VDC power are normally supplied through nonsafety-related battery chargers from the nonsafety-related PIP buses. In the event that this power supply is lost, power is supplied from the nonsafety-related batteries for two hours.

The safety-related 250 VDC power distribution system, Figure 8.1-3, provides four independent and redundant onsite sources of power for operation of the safety-related UPS inverters that supply all safety-related AC loads including the Safety-Related Distributed Control and Information System (Q-DCIS). The safety-related 250 VDC bus is normally supplied through the safety-related battery chargers from the isolation power centers, which are powered from the PIP buses. In the event that this power supply is lost, DC power is supplied from the safety-related batteries for 72 hours. The system is physically and electrically separated into four divisions.

A detailed description of the onsite DC power system is provided in Subsection 8.3.2.

8.1.4 Safety-Related Loads

The safety-related loads utilize the four divisions of DC power sources for instrumentation or control power, for systems required for safe shutdown. Multiple divisions of DC power are involved in performing a single safety-related function and ensure that only two divisions of DC power are required for safe shutdown during a design basis accident (DBA). The control and instrumentation systems required for safe shutdown are identified in Section 7.4, which indicate the four separate divisions of power to each system required for safe shutdown, as shown in Figure 8.1-4.

8.1.5 Design Basis

8.1.5.1 Offsite Power

The offsite power system is described in Subsection 8.2.1.

Electric power from the utility grid to the offsite power system is provided by transmission lines designed and located to minimize the likelihood of failure while ensuring grid reliability. The transmission system serves the main offsite power circuit (Normal Preferred Power), and the reserve offsite power circuit (Alternate Preferred Power) through the site switchyard(s).

The switchyard is designed to minimize the likelihood of simultaneous failure of both the normal and alternate preferred power sources.

A single tie line connects the plant main generator circuit breaker MOD and UAT MODs to the switchyard and constitutes the plant's normal preferred offsite power circuit.

A second offsite (alternate preferred) power circuit is connected to the MODs at the high side of the RATs. This power circuit is electrically independent and physically separate from the normal preferred power circuit to minimize the likelihood of simultaneous failure.

The offsite power system is designed to provide a continuous source of power to the onsite power system throughout plant startup, normal operation (including shutdown), and abnormal operations.

8.1.5.2 Onsite Power

8.1.5.2.1 General

The main generator circuit breaker is designed to withstand the maximum root mean square (RMS) and crest currents, and to interrupt the maximum asymmetrical and symmetrical currents determined to be produced by a three-phase bolted fault at its location.

Three single-phase main step-up transformers are provided as part of the onsite power with an additional installed single-phase spare. The installation of the spare transformer permits its connection and energization within 24 hours.

The two UATs are provided to supply power to the plant's auxiliary distribution system. The transformers are equal in size, and each has the capacity required to supply power to their load group of safety-related and nonsafety-related systems under conditions of maximum expected concurrent loads, including all required design margins. UATs supply power to their load group through the main transformer from the main generator during normal plant operation and during island mode operation. When the unit is offline, UATs supply power to their load groups from the normal PPS.

Two RATs serve as backup to the UATs. RATs are provided to supply power to the plant's auxiliary distribution system. The transformers are equal in size, and each has the capacity required to supply power to its load group of safety-related and nonsafety-related systems under conditions of maximum expected concurrent loads, including all required design margins. The RATs supply power to their load groups from the alternate preferred power circuit. The RATs are designed to accept the UAT loads through the auto transfer of incoming circuit breakers at the 13.8 kV and 6.9 kV switchgear.

The onsite nonsafety-related power distribution system is divided into two load groups; each group is fed from separate unit and reserve auxiliary transformers. Redundant loads associated with unit operation are powered from buses of separate power load groups.

Two dedicated buses are provided to feed PIP loads. The dedicated buses have three power supplies:

1. The normal PPS is provided by a UAT connected to the main generator through the main transformer and to the normal preferred offsite power circuit.
2. The alternate PPS is provided by a RAT connected to an independent offsite source.
3. The standby power supply is provided by two independent nonsafety-related standby diesel generators of sufficient capacity such that, in the event of a loss of preferred power, each can supply enough power to achieve cold shutdown.

Additionally, two dedicated nonsafety-related 480 VAC ancillary diesel buses are provided to power the ancillary AC loads. The ancillary diesel buses are normally powered from the PIP buses. On loss of PIP bus power, the ancillary diesel buses are powered by the ancillary diesel generators.

The safety-related loads are powered by four physically separate and electrically independent divisions. Any two out of four divisions can safely shut down the unit and maintain it in a safe shutdown condition.

Each division is fed by a separate 480 VAC isolation power center, which is powered from a PIP nonsafety-related power supply. The nonsafety-related system ends and the safety-related system begins at the input terminals of the normal and alternate main circuit breakers of the isolation power centers. The input power voltage and frequency are monitored and the input breaker tripped if either voltage or frequency is out of the specified limits for a predetermined time. The powering of the isolation power centers with a nonsafety-related power supply does not jeopardize plant safety, since safety-related batteries supply the required power during loss of AC power. The isolation power centers are provided with electrical protection through isolation breakers as shown on Figure

8.1-1 Sheet 2 and Figure 8.1-1 Sheet 3. The battery chargers and AC Power supplied through rectifiers prevent degradation of the safety-related DC power system by the nonsafety-related AC power system through their output diodes as shown in Figure 8.1-3.

The redundant safety-related electrical divisions (Divisions 1, 2, 3 and 4) are provided with separate onsite DC power supplies, electric buses, distribution cables, controls, relays and other redundant electrical devices. Redundant divisions are physically separate and electrically independent so that in a Design Basis Accident with loss of any two divisions, safe plant shutdown for all operating modes can be accomplished with the two remaining divisions of DC power.

Separation criteria are established for preserving the independence of redundant safety-related systems and providing isolation between safety-related and nonsafety-related equipment.

Raceways are not shared by safety-related and nonsafety-related cables, or safety-related cables of a different division. Separate raceways are provided exclusively for each channel group of the Reactor Protection System solenoid wiring.

Special identification criteria, as discussed in Subsection 8.3.1.3, are applied to safety-related equipment, cabling and raceways.

The safety-related 480 VAC and 120 VAC, and 250 VDC power and control systems conform to Seismic Category I requirements and are housed in Seismic Category I structures. Seismic Qualification is in accordance with IEEE Standard 344 (Section 3.10).

Safety-related equipment and systems have been designed with the capability for periodic inspection and testing in accordance with General Design Criteria (GDC) 18.

8.1.5.2.2 **Uninterruptible AC Power Supply**

The Uninterruptible AC Power Supply (UPS) is divided into two subsystems, the safety-related UPS and the nonsafety-related UPS.

8.1.5.2.2.1 **Safety-Related Uninterruptible AC Power Supply**

There is no direct safety-related AC power source required for safety-related loads. The safety-related UPS that support the safety-related logic and control functions during normal, upset, and accident conditions are powered from the four divisions of DC power through DC/AC inverters.

Each safety-related battery charger provides the safety-related AC uninterruptible power through separate and independent safety-related inverters connected to the safety-related DC bus of the same division and backed up by its divisional 480 VAC isolation power center (Figure 8.1-4).

Upon loss of AC power to the isolation power centers, the safety-related UPS is powered by its respective division's safety-related battery, and switching from the AC to DC source is transparent to UPS loads.

8.1.5.2.2.2 **Nonsafety-Related Uninterruptible AC Power Supply**

Each load group of the nonsafety-related uninterruptible AC power supply is powered through separate and independent nonsafety-related inverters connected to the nonsafety-related DC bus and from their 480 VAC power center (Figure 8.1-5). Separate nonsafety-related batteries also power each DC bus.

Upon loss of AC power supply, the nonsafety-related UPS is powered by its respective nonsafety-related battery, and switching from the AC to the DC source is transparent to UPS loads. Provision is made for automatic switching to the alternate bypass supply from a 480 VAC power center, in case of a failure of the inverter power supply. The inverter normal AC power supply is synchronized in both frequency and phase with the alternate AC bypass supply, so that unacceptable voltage spikes are avoided in case of an automatic transfer from normal to alternate supply. The onsite standby diesel generators provide backup for the normal and alternate 6.9 kV AC power sources that supply the 480 VAC power centers from the PIP buses.

8.1.5.2.3 **Nonsafety-Related Instrumentation and Control (I&C) Power Supply System**

System deleted.

8.1.5.2.4 **Regulatory Requirements**

The following list of criteria is addressed in accordance with which is based on Table 8-1 of the standard review plan. In general, the ESBWR is designed in accordance with the following criteria. Any exceptions or clarifications are noted below.

General Design Criteria:

- GDC 2, “Design Bases for Protection Against Natural Phenomena”
- GDC 4, “Environmental and Dynamic Effects Design Bases”
- GDC 5, “Sharing of Structures, Systems, and Components” – The ESBWR does not share any safety-related structure, system or component with any other unit. Therefore, this GDC is not applicable.
- GDC 17, “Electric Power Systems” - Safety-related DC power sources are provided to support passive core cooling and passive containment integrity safety-related functions. No offsite or diesel-generator-derived AC power is required for 72 hours after an abnormal event. However, the ESBWR PPS complies with GDC 17 with respect to two independent and separate offsite power sources, each with the capacity and capability to power equipment during design basis operating modes (plant start-up, normal operation, safe shutdown, accident, and post-accident operation. Subsection 3.1.2.8, “Criterion 17 – Electric Power Systems,” provides ESBWR electric power source availability requirements and conformance with Regulatory Guide 1.93.
- GDC 18, “Inspection and Testing of Electric Power Systems” - Safety-related DC power sources are provided to support passive core cooling and passive containment integrity safety-related

functions. No offsite or diesel-generator-derived AC power is required for 72 hours after an abnormal event. However, the nonsafety-related offsite and onsite AC systems that supply AC power to the isolation power centers are testable and meet GDC 18 requirements.

- GDC 50, “Containment Design Basis.”

NRC Regulatory Guides:

- Regulatory Guide 1.6, “Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems” – The ESBWR Standard Plant does not need or have safety-related standby AC power sources; however, portions pertaining to the safety-related DC system are addressed within Subsection 8.3.2. The ESBWR offsite and onsite nonsafety-related power sources do comply with independence and redundancy between their sources and distribution systems.
- Regulatory Guide 1.9, “Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants”– The ESBWR diesel-generator units are not safety-related, nor is AC power needed for the ESBWR to achieve safe shutdown, therefore this regulatory guide is not applicable to the ESBWR design.
- Regulatory Guide 1.32, “Criteria for Power Systems for Nuclear Power Plants.” Safety-related DC power sources are provided to support passive core cooling and containment integrity safety functions. No offsite or diesel-generator-derived AC power is required for 72 hours after an abnormal event.
- Regulatory Guide 1.47, “Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems.”
- Regulatory Guide 1.53, “Application of the Single-Failure Criterion to Safety Systems.”
- Regulatory Guide 1.63, “Electric Penetration Assemblies in Containment Structures for Nuclear Power Plants.”
- Regulatory Guide 1.75, “Criteria for Independence of Electrical Safety Systems.” Safety-related equipment relies only upon DC-derived power and meets the design requirements for physical independence.
- Regulatory Guide 1.81, “Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants” – The ESBWR Standard Plant is designed as a single-unit plant. Therefore, Regulatory Guide 1.81 is not applicable.
- Regulatory Guide 1.106, “Thermal Overload Protection for Electric Motors on Motor-Operated Valves.” The ESBWR does not require 480 VAC electric motors or motor-operated valves to perform any safety-related function, therefore, this regulatory guide is not applicable.

- Regulatory Guide 1.118, “Periodic Testing of Electric Power and Protection Systems” (see Subsection 13.5.2 for Operating and Maintenance Procedures and Chapter 16 for Technical Specifications).
- Regulatory Guide 1.128, “Installation Design and Installation of Large Lead Storage Batteries for Nuclear Power Plants.”
- Regulatory Guide 1.129, “Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Nuclear Power Plants.”
- Regulatory Guide 1.153, “Criteria for Safety Systems.”
- Regulatory Guide 1.155, “Station Blackout” – The ESBWR does not require AC power to achieve safe shutdown. Thus, the ESBWR meets the intent of Regulatory Guide 1.155. The Station Blackout evaluation is provided in Section 15.5.5.
- Regulatory Guide 1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants” - Maintenance Rule development is addressed in Table 1.9-21 and Subsection 13.5.2 for Operating and Maintenance Procedures.
- Regulatory Guide 1.204, “Guidelines for Lightning Protection of Nuclear Power Plants” Refer to Subsection 8A.1.2.

Branch Technical Positions (BTP):

- 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 ESBWR.
- BTP ICSB 8 (PSB), “Use of Diesel-Generator Sets for Peaking” – The ESBWR can achieve safe shutdown without AC power, and the diesel-generator sets are not safety-related. Therefore, this BTP is not applicable.
- BTP ICSB 11 (PSB), “Stability of Offsite Power Systems” – See Subsection 8.2.2.1.
- BTP ICSB 18 (PSB), “Application of the Single Failure Criterion to Manually-Controlled Electrically-Operated Valves” - There are no safety-related, manually-controlled, electrically operated valves in the ESBWR design. All safety-related valves are automatic and require no manual action for 72 hours. This BTP is not applicable to the ESBWR design.
- BTP ICSB 21, “Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems.”
- BTP PSB 1, “Adequacy of Station Electric Distribution System Voltages” - Degraded Voltage in the offsite power system does not affect the safety-related systems as the 480 VAC isolation power centers do have degraded voltage protection. See Subsection 8.3.1.1.2.

- BTP PSB 2, “Criteria for Alarms and Indications Associated with Diesel-Generator Unit Bypassed and Inoperable Status” - The ESBWR has no safety-related diesel-generator. The ESBWR diesel generator units are nonsafety-related. Therefore this criterion does not apply.

Other Safety Review Plan (SRP) Criteria:

- NUREG/CR 0660, “Enhancement of Onsite Diesel Generator Reliability” – The ESBWR diesel-generator units are not safety-related, nor is AC power needed to achieve safe shutdown; therefore, the NUREG is not directly applicable. However, defense-in-depth principles such as redundancy and diversity are incorporated in the design and integration of ESBWR systems.
- NUREG 0737, “Clarification of TMI Action Plan Requirements.”
- NUREG-0718, Revision 1, “Licensing Requirements for Pending Applications for Construction Permits and Manufacturing License,” relating to TMI Item I.D.3, “Safety System Status Monitoring,” regarding the application of Regulatory Guide 1.47.
- TMI Action Item II.E.3.1, “Emergency Power Supply for Pressurizer Heater” – This criterion is applicable only to PWRs and does not apply to the ESBWR.
- TMI Action Item II.G.1, “Emergency Power for Pressurizer Equipment” – This criteria is applicable only to PWRs and does not apply to the ESBWR.

8.1.6 Compliance to Regulatory Requirements and Guidelines

Table 8.1-1 presents a matrix of regulatory requirements and guidelines, in accordance with Table 8-1 of the Standard Review Plan. Note that several criteria pertaining to safety-related diesel generators and AC power systems are not applicable for the ESBWR, because the ESBWR does not require AC power to achieve safe shutdown or to perform any safety-related function. Therefore, the diesel generators are nonsafety-related. However, defense-in-depth principles such as redundancy and diversity are incorporated in the design and integration of ESBWR systems.

8.1.7 COL Information

None.

8.1.8 Reference

8.1-1 Title 10, Code of Federal Regulations, Part 50 (10 CFR 50) Appendix A, “General Design Criteria for Nuclear Power Plants.”

Table 8.1-1 Onsite Power System SRP Criteria Applicability Matrix (Sheet 1 of 2)

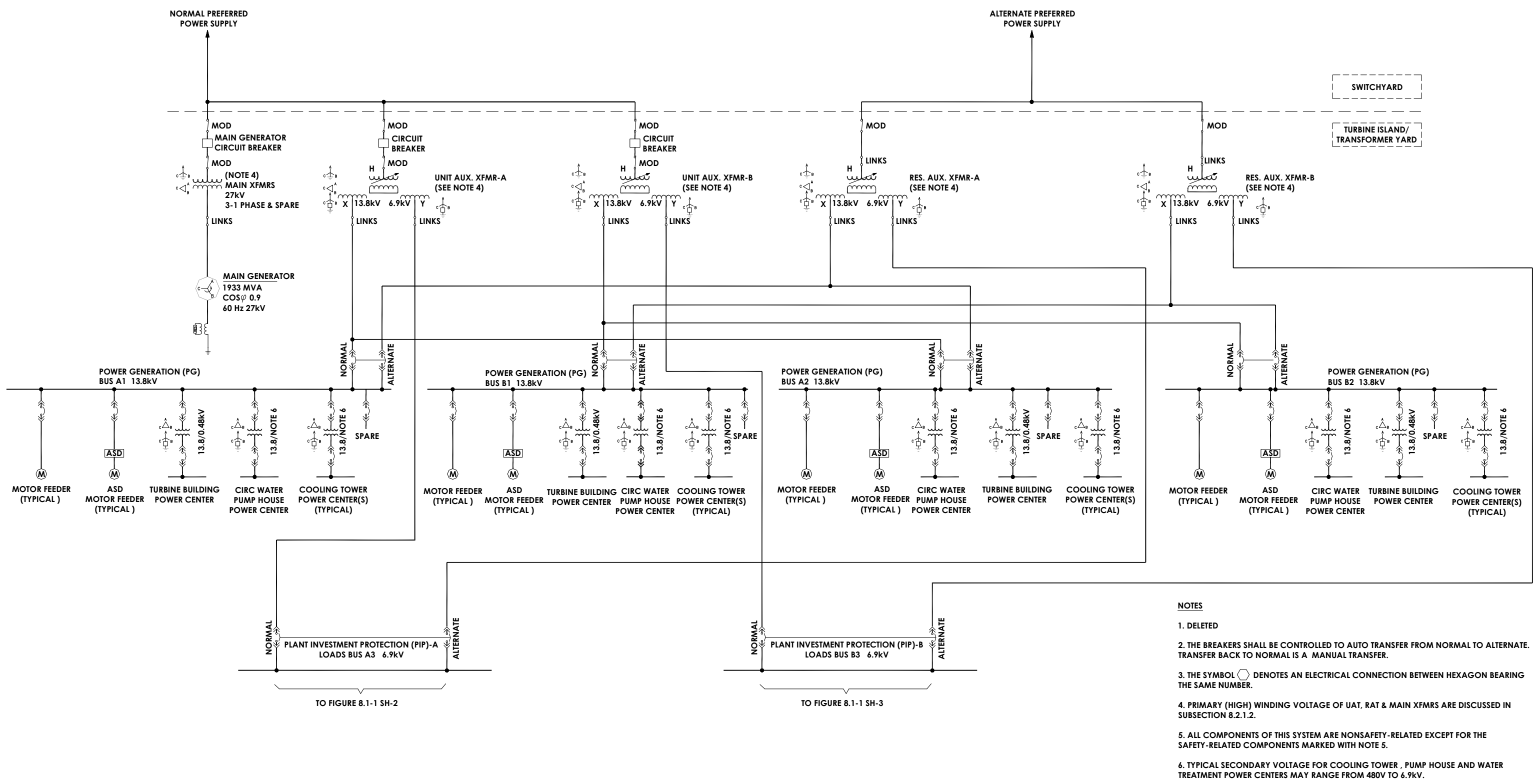
Applicable Criteria		IEEE Standard	Notes	Offsite Power System	AC (Onsite) Power System	DC (Onsite) Power System
GDC	2		7			X
GDC	4		7			X
GDC	5		1			
GDC	17		7, 8	X	X	X
GDC	18		7	X	X	X
GDC	50				X	X
10 CFR	50.34(f)(2)(v)		6			
10 CFR	50.34(f)(2)(xiii)		2			
10 CFR	50.34(f)(2)(xx)		2			
10 CFR	50.63		7			X
RG	1.6			X	X	X
RG	1.9		3			
RG	1.32	308	7			X
RG	1.47		7			X
RG	1.53	379,603	7			X
RG	1.63	242, 317, 741			X	X
RG	1.75	384	7			X
RG	1.81		1			
RG	1.106					
RG	1.118	338, 603	7			X
RG	1.128	485, 344, 323, 484				X
RG	1.129	450				X
RG	1.153	603	7			X
RG	1.155 (NUMARC 8700)		7, 9			X
RG	1.160 (NUMARC 93-01)			X	X	X
RG	1.204	665, 666, 1050, C62.23		X	X	
BTP	ICSB 4		2			
BTP	ICSB 8		3			
BTP	ICSB 11			X		
BTP	ICSB 18					
BTP	ICSB 21		7			X

Table 8.1-1 Onsite Power System SRP Criteria Applicability Matrix (Sheet 2 of 2)

BTP	PSB 1				X	
BTP	PSB 2		3			
NUREG-0718			6			
NUREG-0737			5			
NUREG/CR-0660			3			
TMI Action Item II.E.3.1			2			
TMI Action Item II.G.1			2			

Notes:

1. Noted criteria are applicable to multiple unit plants only, and are not applicable to the single-unit ESBWR.
2. The criterion is only applicable to PWRs, and thus, is not applicable to the ESBWR.
3. The ESBWR Standard Plant does not have safety-related diesel generators, and thus, this criterion is not applicable to the ESBWR.
4. (Deleted)
5. Covered by 10 CFR 50.34(f)(2)(xiii) and 50.34(f)(2)(xx).
6. Not applicable to the ESBWR:
   - 10 CFR 50.34 (f)(2)(v)
   - NUREG 0718 (applied only to the pending applications at February 16, 1982)
7. The safety-related UPS system and the safety-related 480 VAC isolation power centers are included in the DC onsite applicability column.
8. Refer to Subsection 8.1.5.2.4, GDC 17, for electric power source availability requirements.
9. Procedures and training for SBO Response Guidelines, AC Power Restoration, and Severe Weather Guidelines are developed per Sections 13.2 and 13.5.



NORMAL PREFERRED
POWER SUPPLY
ALTERNATE PREFERRED
POWER SUPPLY
SWITCHYARD
TURBINE ISLAND/
TRANSFORMER YARD
MOD
MAIN GENERATOR
CIRCUIT BREAKER
MOD
(NOTE 4)
MAIN XFMRS
27kV
3-1 PHASE & SPARE
LINKS
MAIN GENERATOR
1933 MVA
COS 0.9
60 Hz 27kV
CIRCUIT
BREAKER
UNIT AUX. XFMR-A
(SEE NOTE 4)
UNIT AUX. XFMR-B
(SEE NOTE 4)
RES. AUX. XFMR-A
(SEE NOTE 4)
RES. AUX. XFMR-B
(SEE NOTE 4)
H
X
Y
13.8kV
6.9kV
NORMAL
ALTERNATE
POWER GENERATION (PG)
BUS A1 13.8kV
POWER GENERATION (PG)
BUS B1 13.8kV
POWER GENERATION (PG)
BUS A2 13.8kV
POWER GENERATION (PG)
BUS B2 13.8kV
ASD
13.8/0.48kV
13.8/NOTE 6
SPARE
MOTOR FEEDER
(TYPICAL)
ASD
MOTOR FEEDER
(TYPICAL)
TURBINE BUILDING
POWER CENTER
CIRC WATER
PUMP HOUSE
POWER CENTER
COOLING TOWER
POWER CENTER(S)
(TYPICAL)
PLANT INVESTMENT PROTECTION (PIP)-A
LOADS BUS A3 6.9kV
PLANT INVESTMENT PROTECTION (PIP)-B
LOADS BUS B3 6.9kV
TO FIGURE 8.1-1 SH-2
TO FIGURE 8.1-1 SH-3
NOTES
1. DELETED
2. THE BREAKERS SHALL BE CONTROLLED TO AUTO TRANSFER FROM NORMAL TO ALTERNATE. TRANSFER BACK TO NORMAL IS A MANUAL TRANSFER.
3. THE SYMBOL DENOTES AN ELECTRICAL CONNECTION BETWEEN HEXAGON BEARING THE SAME NUMBER.
4. PRIMARY (HIGH) WINDING VOLTAGE OF UAT, RAT & MAIN XFMRS ARE DISCUSSED IN SUBSECTION 8.2.1.2.
5. ALL COMPONENTS OF THIS SYSTEM ARE NONSAFETY-RELATED EXCEPT FOR THE SAFETY-RELATED COMPONENTS MARKED WITH NOTE 5.
6. TYPICAL SECONDARY VOLTAGE FOR COOLING TOWER , PUMP HOUSE AND WATER TREATMENT POWER CENTERS MAY RANGE FROM 480V TO 6.9kV.

Figure 8.1-1 Electrical Power Distribution System (Sheet 2 of 3)

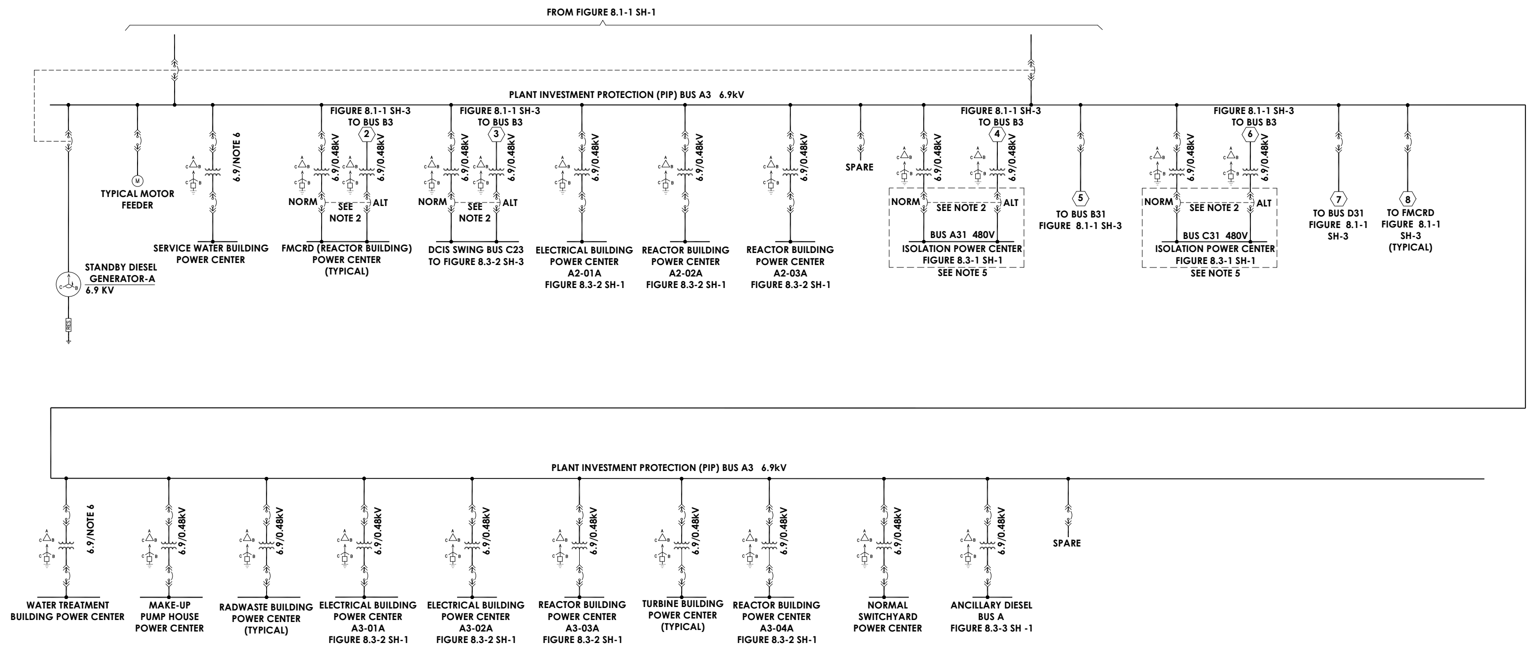
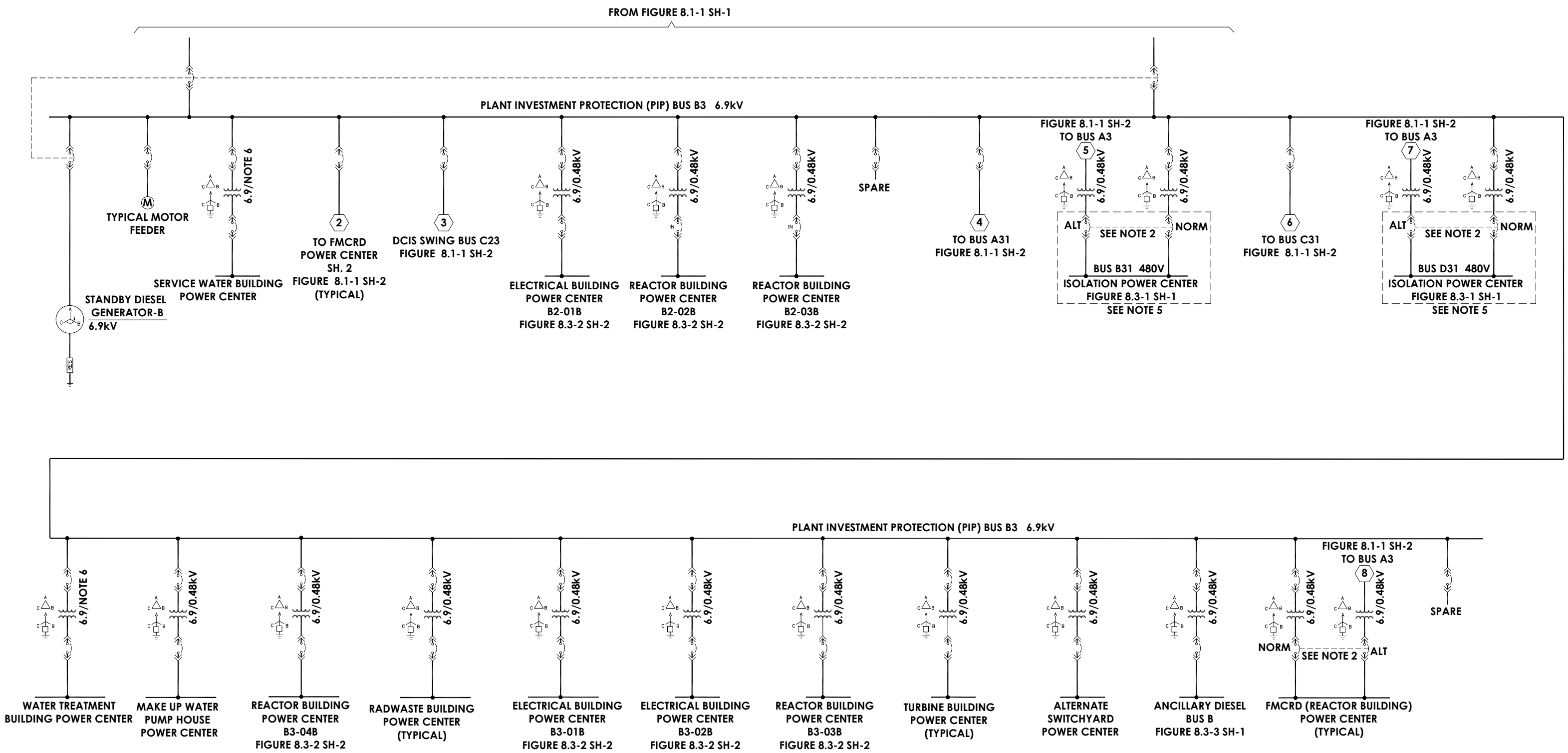
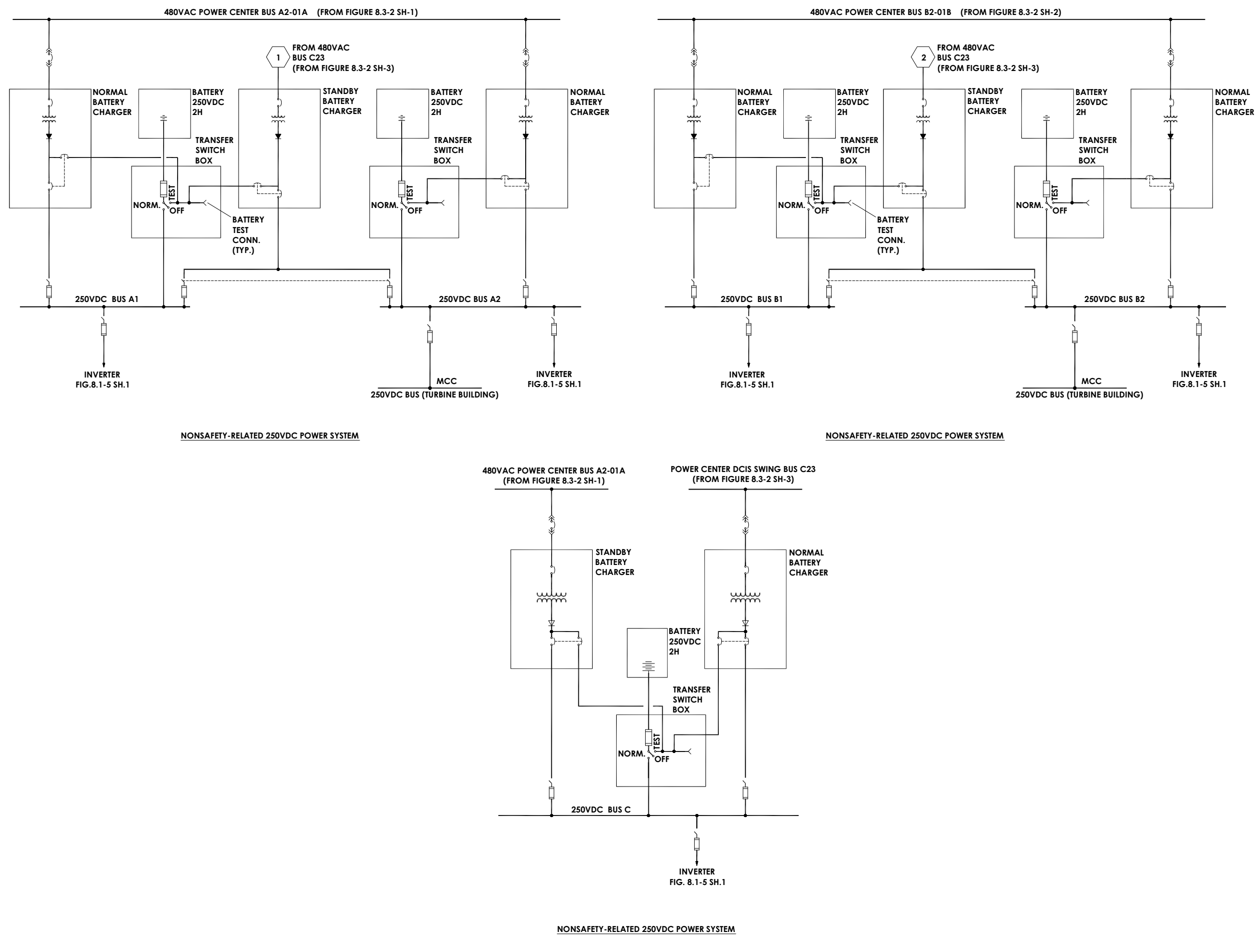
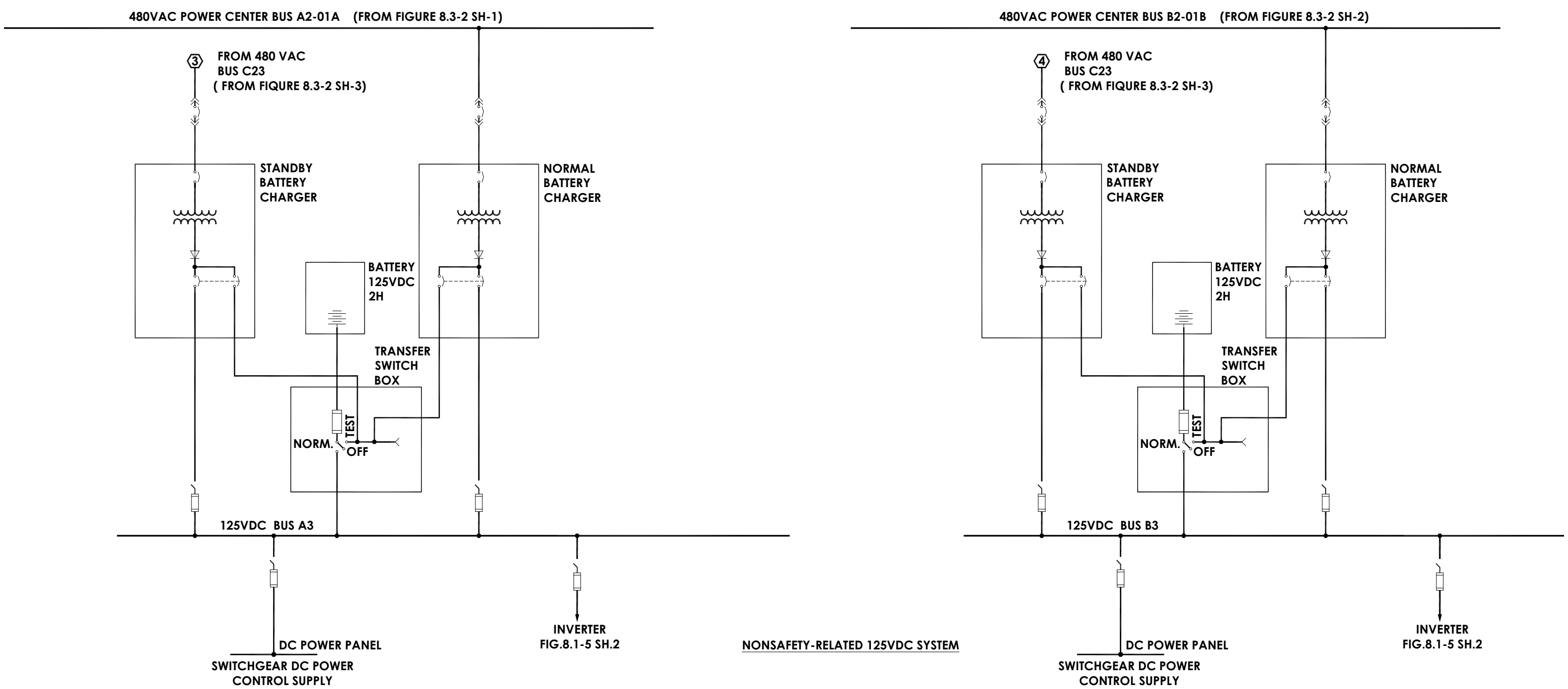


Figure 8.1-1 Electrical Power Distribution System (Sheet 3 of 3)




480VAC POWER CENTER BUS A2-01A (FROM FIGURE 8.3-2 SH-1)
FROM 480VAC BUS C23 (FROM FIGURE 8.3-2 SH-3)
NORMAL BATTERY CHARGER
BATTERY 250VDC 2H
STANDBY BATTERY CHARGER
TRANSFER SWITCH BOX
NORM.
TEST
OFF
BATTERY TEST CONN. (TYP.)
250VDC BUS A1
250VDC BUS A2
INVERTER FIG.8.1-5 SH.1
MCC
250VDC BUS (TURBINE BUILDING)
NONSAFETY-RELATED 250VDC POWER SYSTEM
480VAC POWER CENTER BUS B2-01B (FROM FIGURE 8.3-2 SH-2)
250VDC BUS B1
250VDC BUS B2
480VAC POWER CENTER BUS A2-01A (FROM FIGURE 8.3-2 SH-1)
POWER CENTER DCIS SWING BUS C23 (FROM FIGURE 8.3-2 SH-3)
250VDC BUS C
INVERTER FIG. 8.1-5 SH.1


480VAC POWER CENTER BUS A2-01A (FROM FIGURE 8.3-2 SH-1)
3
FROM 480 VAC
BUS C23
(FROM FIQURE 8.3-2 SH-3)
STANDBY
BATTERY
CHARGER
NORMAL
BATTERY
CHARGER
BATTERY
125VDC
2H
TRANSFER
SWITCH
BOX
NORM.
TEST
OFF
125VDC BUS A3
DC POWER PANEL
SWITCHGEAR DC POWER
CONTROL SUPPLY
INVERTER
FIG.8.1-5 SH.2
NONSAFETY-RELATED 125VDC SYSTEM
480VAC POWER CENTER BUS B2-01B (FROM FIGURE 8.3-2 SH-2)
4
FROM 480 VAC
BUS C23
(FROM FIQURE 8.3-2 SH-3)
STANDBY
BATTERY
CHARGER
NORMAL
BATTERY
CHARGER
BATTERY
125VDC
2H
TRANSFER
SWITCH
BOX
NORM.
TEST
OFF
125VDC BUS B3
DC POWER PANEL
SWITCHGEAR DC POWER
CONTROL SUPPLY
INVERTER
FIG.8.1-5 SH.2

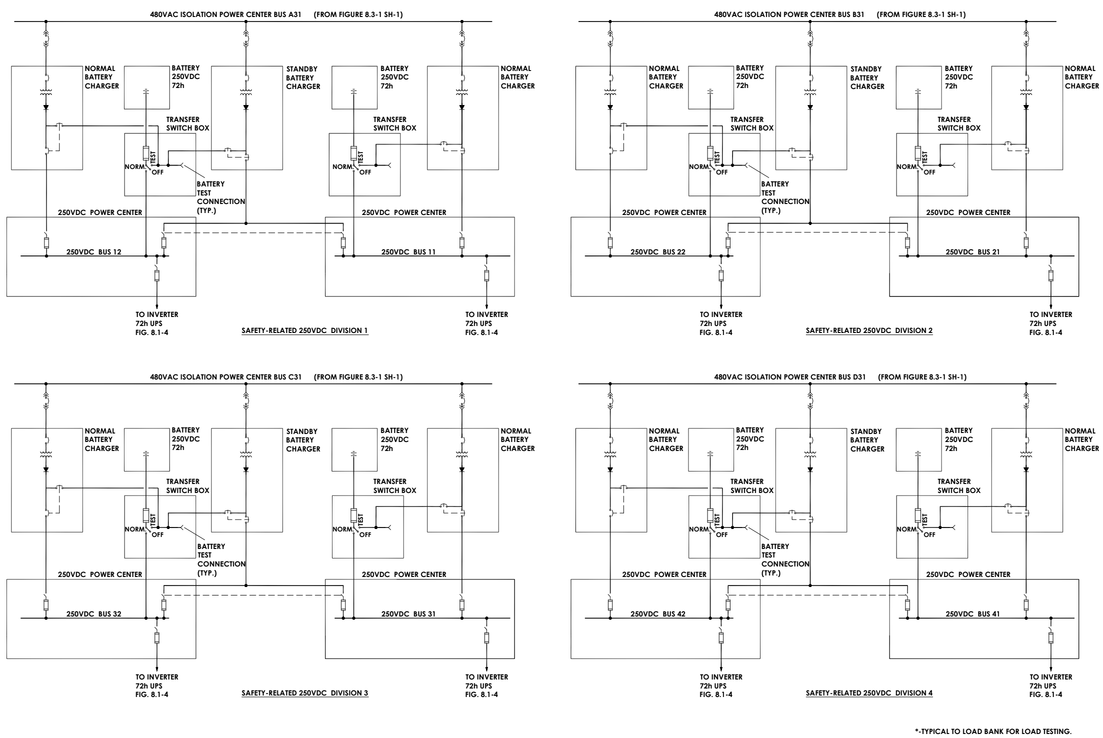

480VAC ISOLATION POWER CENTER BUS A31 (FROM FIGURE 8.3-1 SH-1)
NORMAL BATTERY CHARGER
BATTERY 250VDC 72h
STANDBY BATTERY CHARGER
BATTERY 250VDC 72h
NORMAL BATTERY CHARGER
TRANSFER SWITCH BOX
TRANSFER SWITCH BOX
NORM.
TEST
OFF
BATTERY TEST CONNECTION (TYP.)
250VDC POWER CENTER
250VDC POWER CENTER
250VDC BUS 12
250VDC BUS 11
TO INVERTER 72h UPS FIG. 8.1-4
SAFETY-RELATED 250VDC DIVISION 1
TO INVERTER 72h UPS FIG. 8.1-4
480VAC ISOLATION POWER CENTER BUS B31 (FROM FIGURE 8.3-1 SH-1)
250VDC BUS 22
250VDC BUS 21
SAFETY-RELATED 250VDC DIVISION 2
480VAC ISOLATION POWER CENTER BUS C31 (FROM FIGURE 8.3-1 SH-1)
250VDC BUS 32
250VDC BUS 31
SAFETY-RELATED 250VDC DIVISION 3
480VAC ISOLATION POWER CENTER BUS D31 (FROM FIGURE 8.3-1 SH-1)
250VDC BUS 42
250VDC BUS 41
SAFETY-RELATED 250VDC DIVISION 4
*-TYPICAL TO LOAD BANK FOR LOAD TESTING.

Figure 8.1-4 Uninterruptible AC Power Supply (Safety-Related) (Sheet 1 of 1)

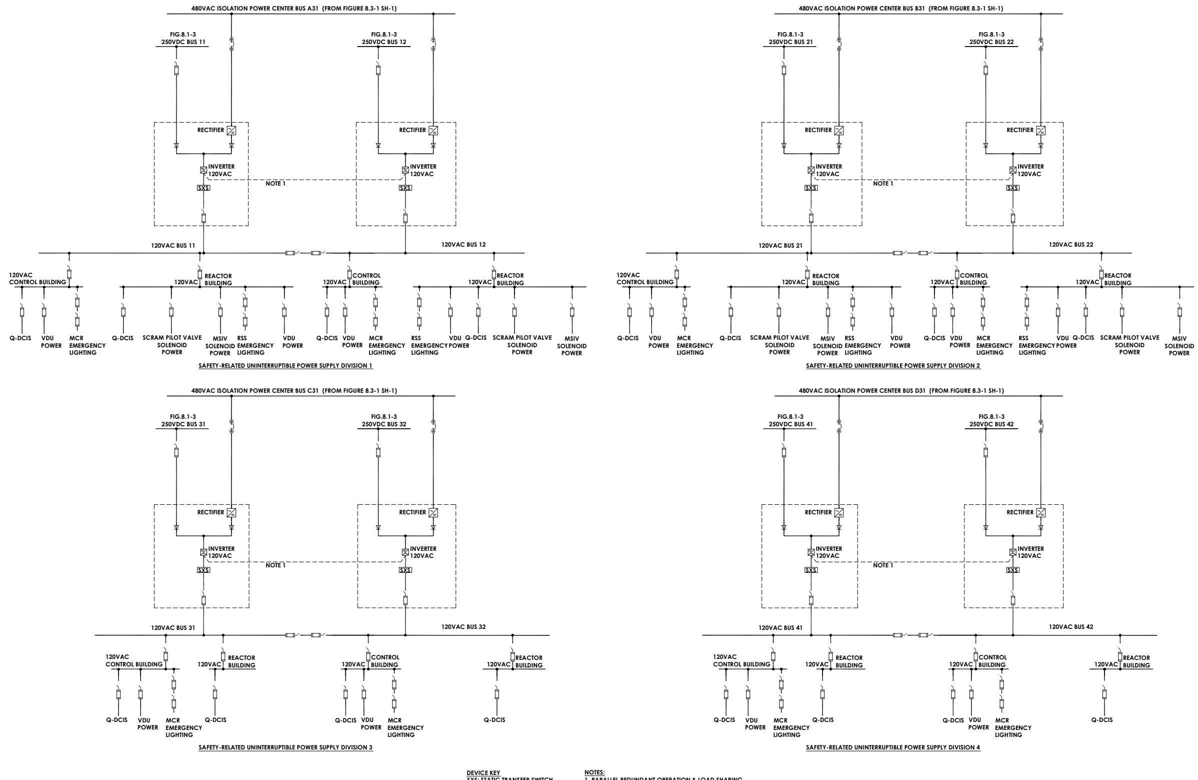


Figure 8.1-5 Uninterruptible AC Power Supply (Nonsafety-Related) (Sheet 1 of 2)

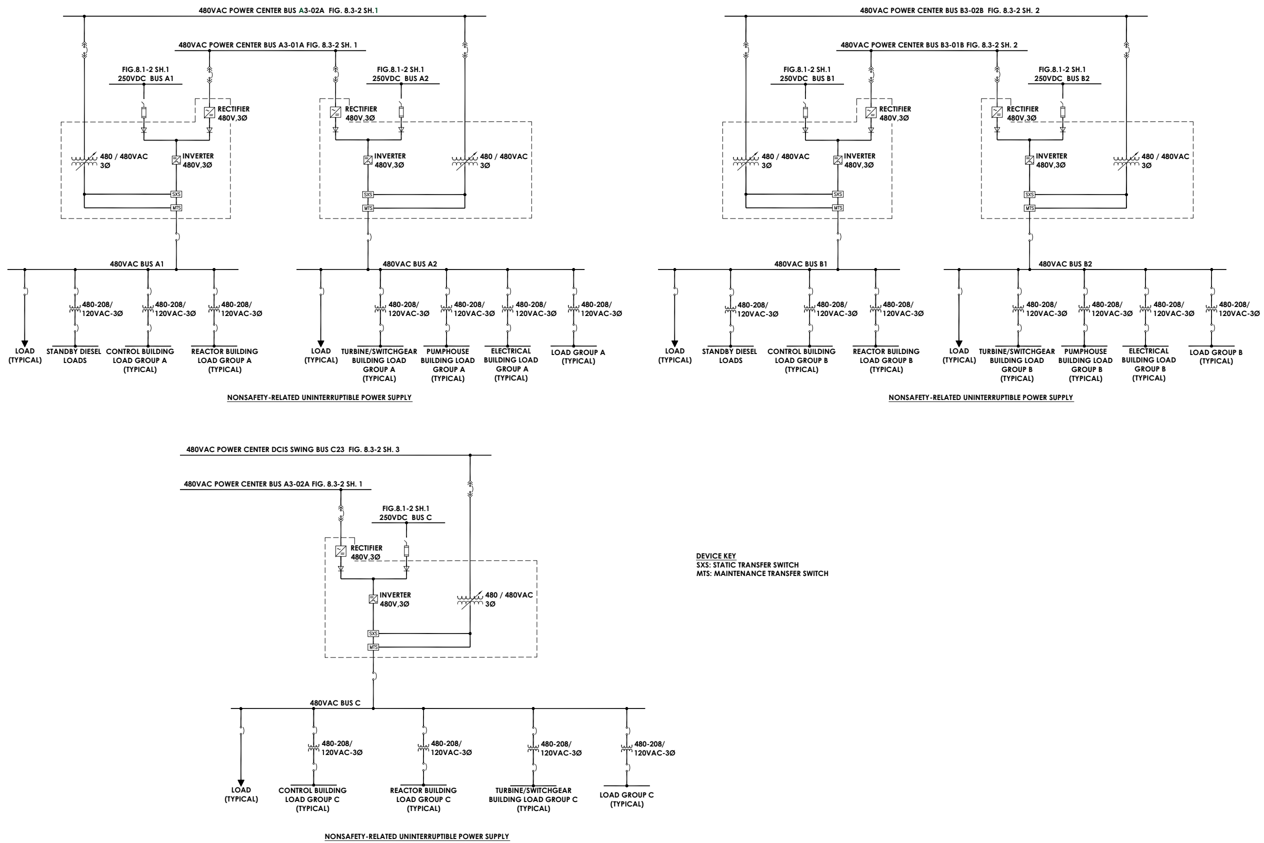
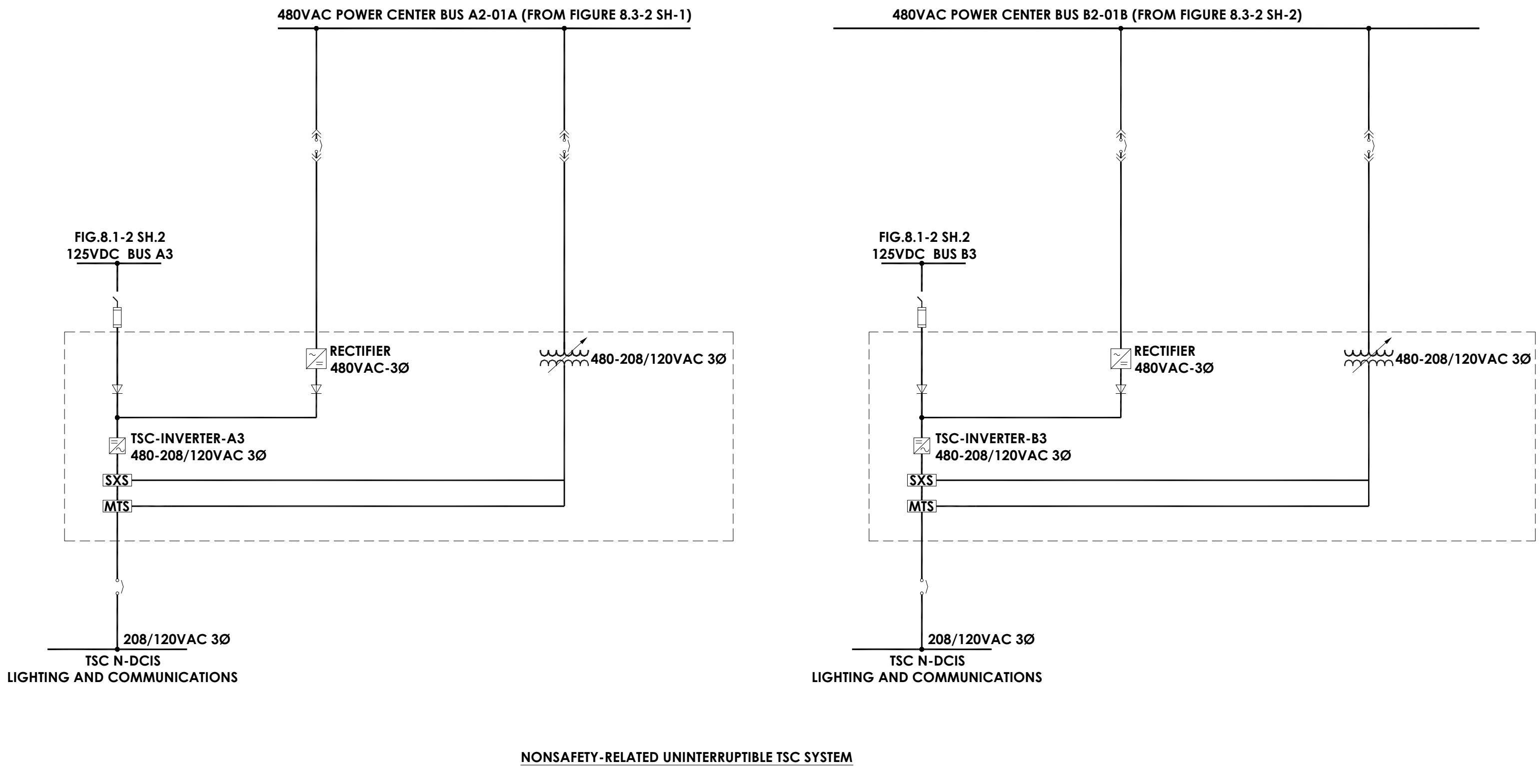


Figure 8.1-5 Uninterruptible AC Power Supply (Nonsafety-Related) (Sheet 2 of 2)



8.2 Offsite Power Systems

8.2.1 Description

8.2.1.1 Transmission System

Fermi 3, is connected to the ITC *Transmission* system by three 345 kV lines. These lines are designed and located to minimize the likelihood of simultaneous failure.

The Fermi 3 main generator feeds electric power through a 27 kV isolated-phase bus to a bank of three single-phase transformers, stepping the generator voltage up to the transmission voltage of 345 kV. Figure 8.2-201 provides a one-line diagram that shows the 345 kV switchyard electrical connections to the onsite power system for Fermi 3. From the Fermi 3 345 kV switchyard the three transmission lines leave the site heading west in a common corridor with the Fermi 2 transmission lines. The corridor is described in more detail below. Figure 8.2-203 maps the offsite transmission lines.

The transmission lines connecting the 345 kV switchyard for Fermi 3 to the transmission system are as follows:

- A 345 kV Fermi-Milan #1 overheard line to the Milan substation (approximately 47.3 km [29.4 mi])
- A 345 kV Fermi-Milan #1 overheard line to the Milan substation (approximately 47.3 km [29.4 mi])
- A 345 kV Fermi-Milan #3 overheard line to the Milan substation (approximately 47.3 km [29.4 mi])

The three 345 kV lines for Fermi 3 run in a common corridor, with transmission lines for Fermi 2, to a point just east of I-75. From the intersection of this Fermi site corridor and I-75, the three Fermi-Milan lines run west and north for approximately 19.3 km (12 mi) in a corridor shared with other non-Fermi lines. From this point, all non-Fermi lines turn north and continue on to their respective destinations and the three Fermi-Milan lines continue west for approximately 16 km (10 mi) to the Milan substation.

Transmission tower and steel pole separation, line installation, and clearances are consistent with applicable regulatory standards, typically the National Electrical Safety Code (NESC), and ITC *Transmission* line structure heights, materials and finish are consistent with ITC *Transmission* line design standards.

8.2.1.2 Offsite Power System

The offsite power system is a nonsafety-related system. Power is supplied to Fermi 3 from three independent and physically separate offsite power sources. The normal preferred power source is any one of the three 345 kV Fermi-Milan transmission lines, and the alternate preferred power source in any other one of the three 345 kV lines.

The normal preferred power source is supplied to the UATs through MODs and isolation circuit breakers, as shown in Figure 8.1-1. The normal preferred power interface with the offsite power system occurs at the high voltage terminals of the main generator circuit breaker MOD and UAT MODs. The MOD feeding a faulted UAT will be opened after the UAT high voltage breaker opens.

The alternate preferred power source is supplied through the RATs. The alternate preferred power source, as an alternate power source to the plant load, may be utilized in the event of unavailability of the normal preferred power source. The alternate preferred power interface between offsite and onsite power occurs at the MODs prior to the high voltage terminals of the RATs. The MOD feeding a faulted RAT will be opened after the switchyard alternate power supply breaker opens. Fully OPEN indication of the MOD for the faulted RAT will allow the switchyard breaker to be re-closed to the unaffected RAT.

Unit synchronization is normally through the onsite main generator circuit breaker with a second offsite switchyard breaker supplying the normal preferred power source that is also designed for unit synchronization during island mode operation. Synchrocheck relays are used to ensure proper synchronization of the unit to the offsite system. Dual trip coils and redundant protective relaying schemes are provided for both the main generator circuit breaker and the normal preferred supply breakers.

Normal and alternate preferred power to the UATs and RATs, respectively, is via overheard conductors. To maintain their independence from each other, the conductors are routed such that they are physically and electrically separate from each other.

8.2.1.2.1 **Switchyard**

The switchyard design bases requirements are contained in Subsection 8.2.3.

Protective relay schemes used for the protection of the offsite power circuits and transformers are redundant and include backup protection features.

Breakers are equipped with dual trip coils. Each redundant protection circuit, which supplies a trip signal, is powered from its redundant load group of DC power and connected to a separate trip coil. Equipment and cabling associated with each redundant system is physically separated from its redundant counterpart.

The DC power needed to operate redundant protection and control equipment of the offsite power system is supplied from two separate, dedicated switchyard batteries, each with a battery charger fed from a separate AC bus. Each battery is capable of supplying the DC power required for normal operation of the switchyard equipment.

Two redundant PIP AC power supply systems supply AC power to the switchyard auxiliary loads as shown in Figure 8.1-1 Sheet 2 and Figure 8.1-1 Sheet 3. Each system is supplied from separate, independent AC buses. The capacity of each system is adequate to meet the AC power requirements for normal operation of the switchyard equipment.

The Fermi 3 switchyard, prior to the point of interconnection with Fermi 3, is a 345 kV, air insulated, breaker-and-a-half bus arrangement. Fermi 3 is connected to this switchyard by overhead conductors, the normal preferred and alternate preferred power conductors.

The anticipated physical location and electrical interconnection of the 345 kV switchyard for Fermi 3 is shown on Figure 2.1-204 and Figure 8.2-201.

The 345 kV switchyard for Fermi 3 receives two sources of AC auxiliary power from the 6.9 kV Plant Investment Protection (PIP) buses for the normal preferred switchyard power center and alternate preferred switchyard power center, as shown on Figure 8.1-1. The switchyard auxiliary power system is designed with adequate equipment, standby power, and protection to provide maximum continuity of service for operation of the essential switchyard equipment during both normal and abnormal conditions. There are two independent sets of 125 V DC batteries, chargers, and DC panels for the switchyard relay and control systems DC supply requirements. Each charger is powered from a separate AC source with an automatic switchover to the alternate source, in the event the preferred sources is lost. The distribution systems for the two battery systems are physically separated.

Control and relay protection systems are provided. Support systems, such as grounding, raceway, lighting, AC/DC station service, and switchyard lightning protection, are also provided.

Periodic monitoring of cable insulation for underground cable will be conducted to detect potential cable degradation from moisture intrusion. This program is described in Subsection 17.6.4.

Fermi 3 switchyard lightening protection system is designed in accordance with IEEE Standard 998-1996 (R2002), “IEEE Guide for Direct Lightening Stroke Shielding of Substations,” using the Rolling Sphere Method. Periodic monitoring, maintenance and testing of the switchyard lightening protection system includes the following activities.

- Lightning surge arresters are thermally scanned using infrared technology annually.
- Lightning surge arresters are power factor tested during bus inspections and/or relay control scheme testing on a 10 year cycle.

The 345 kV switchyard for Fermi 3 does not require any transformers for Fermi 3. Therefore, Fermi 3 switchyard transformer protection is not required.

The anticipated capacity and electrical characteristics for switchyard equipment are as follows:

Breakers	Max Design (kV)	Rated Current (A)	Interrupting Current at Max kV
345 kV	379.5	3250	63 kA
Transmission Lines		**Rated Current at 86 F**	
345 kV		2940 A	
Bus Work		**Rater Current**	
345 kV		3660A	

8.2.1.2.2 **Monitoring of Transformers for Open Circuit**

An open phase condition, whether one, two or three phases, with or without accompanying ground faults, located on the high-voltage side of a transformer connecting a GDC 17 offsite power circuit to the plant electrical system could result in a degraded condition in the onsite power system see Reference 8.2-3. Monitoring of the normal and alternate preferred power supply feeds through the UAT and RAT is done by the digital protective relays used for transformer protection. Specifically, the potential and current transformers on the high-voltage side of the UAT and RAT transformers used by the digital protective relays are also used to detect open phase conditions, with or without accompanying ground faults. Upon detection of an open circuit in any combination of the three phases, the protective relay initiates an alarm for each phase or combination of the three phases in the Main Control Room through the DCIS monitoring system. Operator actions are addressed in procedures, as described in Section 13.5. Analysis and testing of the monitoring system are performed through inspections, tests, analyses, and acceptance criteria to determine set points to verify proper functionality.

[START COM 8.2-001] Plant operating procedures, including off-normal operating procedures, associated with the monitoring systems will be developed in accordance with Subsection 13.5.2.1 at least six months prior to fuel load. **[END COM 8.2-001]**

[START COM 8.2-002]Maintenance and testing procedures, including calibration, setpoint determination and troubleshooting procedures, associated with the monitoring system will be developed in accordance with Subsection 13.5.2.2.6.1 prior to fuel loading. **[END COM 8.2-002]**

[START COM 8.2-003]Control Room operator and maintenance technician training associated with the operation and maintenance of the monitoring system will be developed in accordance Subsection 13.2.1 for Reactor Operators and Subsection 13.2.2 for Non Licensed Plant Staff. Training will be completed prior to fuel loading. **[END COM 8.2-003]**

8.2.1.2.3 **Protective Relaying**

The 345 kV transmission lines are protected with redundant high-speed communications-assisted relay schemes and include automatic breaker reclosing. The 345 kV switchyard buses have redundant differential protection using separate and independent current and control circuits. Normal and alternate preferred power conductors located between the Fermi 3 UATs and RATs and the 345 kV switchyard buses are protected by dual high-speed current differential schemes.

The 345 kV switchyard circuit breakers are equipped with breaker failure protection. All of these breakers have dual trip coils. There are two independent DC supply systems, each with a 125 V battery and battery charger. Each redundant protection scheme that supplies a trip signal is powered from its redundant DC power supply and connected to a separate trip coil.

The 345 kV switchyard for Fermi 3 does not require any transformers for Fermi 3. Therefore, Fermi 3 switchyard transformer protection is not required.

8.2.1.2.4 **Testing and Inspection**

Transmission lines are periodically inspected via an aerial inspection program in accordance with the ITC *Transmission* inspection plan. The inspection focuses on such items as right-of-way encroachment, vegetation management, conductor and line hardware condition, and the condition of supporting structures.

Routine switchyard testing and inspection activities include, but are not necessarily limited to, the following:

- Circuit Breaker Inspections - Every 6 years or after 10 automatic operations.
- Station Infrared (IR) scans - Annually.
- Switchyard Inspection - Monthly manual walk through of substation mat to visually inspect all equipment, including but not limited to; locks, fencing, control houses.
- Station Batteries and Chargers - Tested annually. Battery load tested every 5 years.
- Relays:
  - Electromechanical Type - Calibrated on 5 year cycle
  - Microprocessor Type - Calibrated on a 10 year cycle
  - Control Schemes - Tested for operation and insulation integrity on a 10 year cycle
- Current Transformers (CTs), Potential Transformers (PTs), and Coupling Capacitive Voltage Transformer (CCVTs) – Tested concurrently with control schemes on a 10 year cycle.
- Communication Equipment (including Line Tuners and Wave Traps) – Tested concurrently with control schemes on a 10 year cycle.
- Bus Inspection/Disconnect Switches – Tested concurrently with control schemes on a 10 year cycle.

- Backup AC Generators – Biannual inspections, includes annual load testing.
- Ground Mat Integrity – Tested every 15 years.
- Lighting Surge Arresters - Infrared thermal scan annually. Power factor tested during bus inspections and/or relay control scheme testing on a 10 year cycle.

Monitoring, maintenance and testing of the switchyard protection will be performed under North American Electric Reliability Corporation (NERC) Standard PRC-005-1, "Transmission and Generation Protection System Maintenance and Testing."

8.2.2 Analysis

8.2.2.1 Reliability and Stability Analysis

A system impact study performed by ITC *Transmission* analyzed loadflow, transient stability and fault analysis for the addition of Fermi 3. (Reference 8.2-201) The base case for this analysis represented the expected system configuration and loading in 2017 and included planned transmission projects that had budgetary approval at the time the analysis was performed. The sub-transmission system used for the analysis represented the summer for 2007 case and did not include any planned upgrades beyond that time. Stability analysis was performed on both the 2017 summer peak base model and the 2017 eighty percent model with Fermi 3 and projected network upgrades included.

The ITC *Transmission* system was analyzed for thermal and voltage limitations for normal and post contingency conditions via power flow analysis using Power Technology International Software PSS/E and MUST power flow and contingency analysis simulation tools. The analysis examined potential constraints such as thermal equipment overloads, voltage criteria violations, breakers that exceed their rated capabilities as well as constraints related to maintaining system stability and the sudden loss of single critical generation.

The equipment considered is from the point of interconnection of Fermi 3 to the switchyard out to the 345 kV transmission system. Maximum and minimum switchyard voltage limits established by ITC *Transmission* will be applied to the 345 kV switchyard. Normal operating and abnormal procedures exist to maintain the switchyard voltage schedule and address challenges to the maximum and minimum limits. Upon approaching or exceeding a limit, these procedures verify the availability of required and contingency equipment and materials, and direct notifications to outside agencies until the normal voltage schedule can be maintained. Detroit Edison will establish a Generator Interconnection and Operation Agreement with ITC *Transmission* and protocols for maintenance, communications, switchyard control, and system analysis sufficient to safely operate and maintain the powerstation interconnection to the transmission system.

ITC *Transmission* in conjunction with the Midwest ISO provides analysis capabilities for both Long Term Planning and Real Time Operations. System conditions are evaluated to ensure a bounding analysis and model parameters are selected that are influential in determining the system's ability to provide offsite power adequacy. Elements included in the analysis are system load forecasts (including sufficient margin to ensure a bounding analysis over the life of the study), system generator dispatch (including outages of generators known to be particularly influential in offsite power adequacy of affected nuclear units), outage schedules for transmission elements that have significant influence on offsite power adequacy, cross-system power transfers and power imports/exports, and system modification plans and schedules. A Real Time State Estimator is used to assist in the evaluation of actual system conditions.

The study concluded that with the additional generating capacity of Fermi 3, the transmission system remains stable under the analyzed conditions, preserving the grid connection and supporting the normal and shutdown power requirements of Fermi 3.

The reliability of the overall system design is indicated by the fact that there have been no widespread system interruptions. Failure rates of individual facilities are low. Most lightning-caused outages are momentary, with few instances of line damage. Other facilities do fail occasionally, but these are random occurrences, and experience has shown that equipment specifications are adequate.

Grid availability in the region over the past 20 years has been highly reliable with minimal outages due to equipment failures.

Grid stability is evaluated on an ongoing basis based on load growth, the addition of new transmission lines, or new generation capacity.

8.2.2.2 Regulatory Analysis

In accordance with the Nuclear Regulatory Commission (NRC) Standard Review Plan (NUREG-0800), Table 8-1 and Section , the preferred offsite power distribution system is designed consistent with the following criteria, so far as it applies to nonsafety-related equipment. Any exceptions or clarifications are so noted.

Applicable Criteria:

- GDC 5, "Sharing of Structures, Systems, and Components," and Regulatory Guide 1.81, "Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants" – The ESBWR Reference Plant is designed as a single-unit plant. Therefore, GDC 5 and Regulatory Guide 1.81 are not applicable.
- GDC 17, "Electric Power Systems" – The ESBWR Reference Plant design does not require an offsite or diesel-generated AC source of power for 72 hours after an abnormal event. Safety-related DC power sources are provided to support passive core cooling and containment safety-related functions. However, the ESBWR PPS complies with GDC 17 with respect to two independent and separate offsite power sources, each with the capacity and capability to power equipment during design basis operating modes (plant start-up, normal operation, safe shutdown, accident, and post-accident operation). Subsection 3.1.2.8, "Criterion 17 - Electric

Power Systems," provides ESBWR electric power source availability requirements and conformance with Regulatory Guide 1.93. See Subsection 8.2.1.2.2 for discussion on GDC 17 as related to Reference 8.2-3.

- GDC 18, "Inspection and Testing of Electric Power Systems" – Safety-related DC power sources are provided to support passive core cooling and containment safety-related functions. No offsite or diesel-generator-derived AC power is required for 72 hours after an abnormal event. However, the nonsafety-related offsite and onsite AC systems that supply AC power to the isolation power centers are testable.
- 10 CFR 50.63, "Loss of All Alternating Current Power" – The ESBWR Design Bases do not rely upon any offsite power system to achieve and maintain safe shutdown. See the Station Blackout evaluation in Subsection 15.5.5.
- Regulatory Guide 1.32, "Criteria for Power Systems for Nuclear Power Plants" – The offsite power system is nonsafety-related. Therefore, Regulatory Guide 1.32 is not applicable to the ESBWR offsite power system.
- Regulatory Guide 1.47, "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems," and BTP ICSB 21, "Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems" – The offsite power system is nonsafety-related. Therefore, Regulatory Guide 1.47 and BTP ICSB 21 are not applicable to the ESBWR offsite power system.
- BTP ICSB 11, "Stability of Offsite Power Systems" – This topic is addressed in Subsection 8.2.2.1.

8.2.2.3 Failure Modes and Effects Analysis

8.2.2.3.1 Introduction

There are no single failures that can prevent the Fermi offsite power system from performing its function to provide power to Fermi 3 Reference 8.2-201.

8.2.2.3.2 Transmission System Evaluation

Fermi 3 is connected to the ITC *Transmission* system via three 345 kV overhead transmission lines. The normal preferred power is any one of the three 345 kV lines (See Subsection 8.2.1.1 and Subsection 8.2.1.2).

Each 345 kV transmission line occupies a common right-of-way and traverses from the Fermi site within an anticipated 91 m (300 ft) right-of-way. The 345 kV towers and poles provide clearances consistent with applicable regulatory standards. The towers and poles are grounded to achieve 15 ohms or less per structure. Failure of any one 345 kV tower or pole due to structural failure can at most disrupt and cause a loss of power distribution to itself and the adjacent line, if one is present.

Failure of a line conductor would cause the loss of one of the three 345 kV lines, with the other two lines remaining available as normal and alternate preferred power sources.

8.2.2.3.3 Switchyard Evaluation

A breaker-and-a-half scheme is incorporated in the design of the 345 kV switchyard for Fermi 3. The equipment in the switchyard is rated and positioned within the bus configuration according to the following criteria in order to maintain incoming and outgoing load flow for Fermi 3.

- Equipment continuous current ratings are such that no single contingency in the switchyard (e.g., a breaker being out of service for maintenance) results in current exceeding 100 percent of the continuous current rating of the equipment.
- Interrupting duties are such that no faults occurring on the system exceed the equipment rating.
- Momentary ratings are such that no faults occurring on the system exceed the equipment momentary rating.
- Voltage ratings for the equipment are specified to be greater than the maximum expected operating voltage.

The breaker-and-a-half switchyard arrangement offers the following flexibility to control a failed condition within the switchyard:

- Any faulted transmission line into the switchyard can be isolated without affecting any other transmission line.
- Either bus can be isolated without interruption of any transmission line or other bus.
- All relay schemes used for protection of the offsite power circuits and the switchyard equipment include primary and backup protection features. All breakers are equipped with dual trip coils. Each protection circuit that supplies a trip signal is connected to a separate trip coil.

The normal preferred and alternate preferred power supplies are electrically independent and physically separate from each other, as indicated in Section 8.2.3. This power source independence and physical separation along with the isolation flexibility described above to control failed conditions ensures that a minimum of one preferred source of power remains available to supply the load during all plant conditions.

8.2.3 Design Bases Requirements

The offsite power system of the ESBWR Reference Plant is based on certain design bases requirements. These design requirements are as follows:

- In case of failure of the normal PPS circuit, the alternate PPS circuit remains available.
- The normal preferred circuit and the alternate preferred circuit are electrically independent and are physically separated from each other. The normal preferred and the alternate preferred

circuits are fed from separate transmission lines, each capable of supplying the shutdown loads. Both circuits may share a common switchyard but adequate separation exists.

- The switchyard to which the main offsite circuits are connected have two full capacity main buses arranged such that:
  - Any incoming or outgoing transmission line can be switched without affecting another line.
  - Any circuit breaker can be isolated for maintenance without interrupting service to any circuit.
  - Faults of a single main bus are isolated without interrupting service to any circuit.
- Circuit breakers are sized and designed in accordance with IEEE Standard C37.06 (Reference 8.2-1). Disconnecting switches are sized and designed in accordance with IEEE Standard C37.32 (Reference 8.2-2.)
- Conductors associated with the normal preferred and alternate preferred circuits are routed separately and in separate raceways apart from each other and from onsite power system cables. However, they may share a common underground duct bank as indicated below.
- Associated control, instrumentation, and miscellaneous power cables of the alternate preferred circuit, if located underground in the same duct bank as cables associated with the normal preferred circuit between the switchyard and the power block, are routed in separate raceways.
- Interface protocols will be established between the control room and the transmission operator, in accordance with the interconnection service agreement.
- Conductors associated with the alternate preferred circuit are routed in trenches within the switchyard separate from cables associated with the normal preferred circuit.
- A transmission system reliability and stability review of the site specific configuration to which the plant is connected will be performed to determine the reliability of the offsite power system and verify that it is consistent with the probability risk analysis of Chapter 19.
- Provisions are made to auto-disconnect the high side of a failed UAT or RAT through protective relaying to the UAT input circuit breakers and the RAT offsite switchyard breaker.
- A station ground grid is provided consisting of a ground mat below grade at the switchyard that is connected to the foundation embedded loop grounding system provided for the entire power block and associated buildings. (See Subsection 8A.1.1 for the description of the electrical grounding and surge protection system.)

8.2.4 COL Information

8.2.4-1-A Transmission System Description

This COL item is addressed in Subsection 8.2.1.1.

8.2.4-2-A Switchyard Description

This COL item is addressed in Subsection 8.2.1.2.1.

8.2.4-3-A **Normal Preferred Power**

This COL item is addressed in Subsection 8.2.1.2.

8.2.4-4-A **Alternate Preferred Power**

This COL item is addressed in Subsection 8.2.1.2.

8.2.4-5-A **Protective Relaying**

This COL item is addressed in Subsection 8.2.1.2.3.

8.2.4-6-A **Switchyard DC Power**

This COL item is addressed in Subsection 8.2.1.2.1.

8.2.4-7-A **Switchyard AC Power**

This COL item is addressed in Subsection 8.2.1.2.1.

8.2.4-8-A **Switchyard Transformer Protection**

This COL item is addressed in Subsection 8.2.1.2.1.

8.2.4-9-A **Stability and Reliability of the Offsite Transmission Power Systems**

This COL item is addressed in Subsection 8.2.2.1.

8.2.4-10-A**Interface Requirements**

This COL item is addressed in Subsection 8.2.2.1.

8.2.5 References

8.2-1 IEEE Standard C37.06, "AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis - Preferred Ratings and Related Required Capabilities."

8.2-2 IEEE Standard C37.32, "High-Voltage Switches, Bus Supports, and Accessories Schedules of Preferred Ratings, Construction Guidelines, and Specifications."

8.2-3 NRC Bulletin 2012-01, "Design Vulnerability in Electric Power System," July 27, 2012.

8.2-201ITC *Transmission*, System Impact Study Report (MISO G867), "Generation Interconnection in Monroe County, MI", July 21, 2008.

Figure 8.2-201 345 kV Switchyard Single-Line Diagram

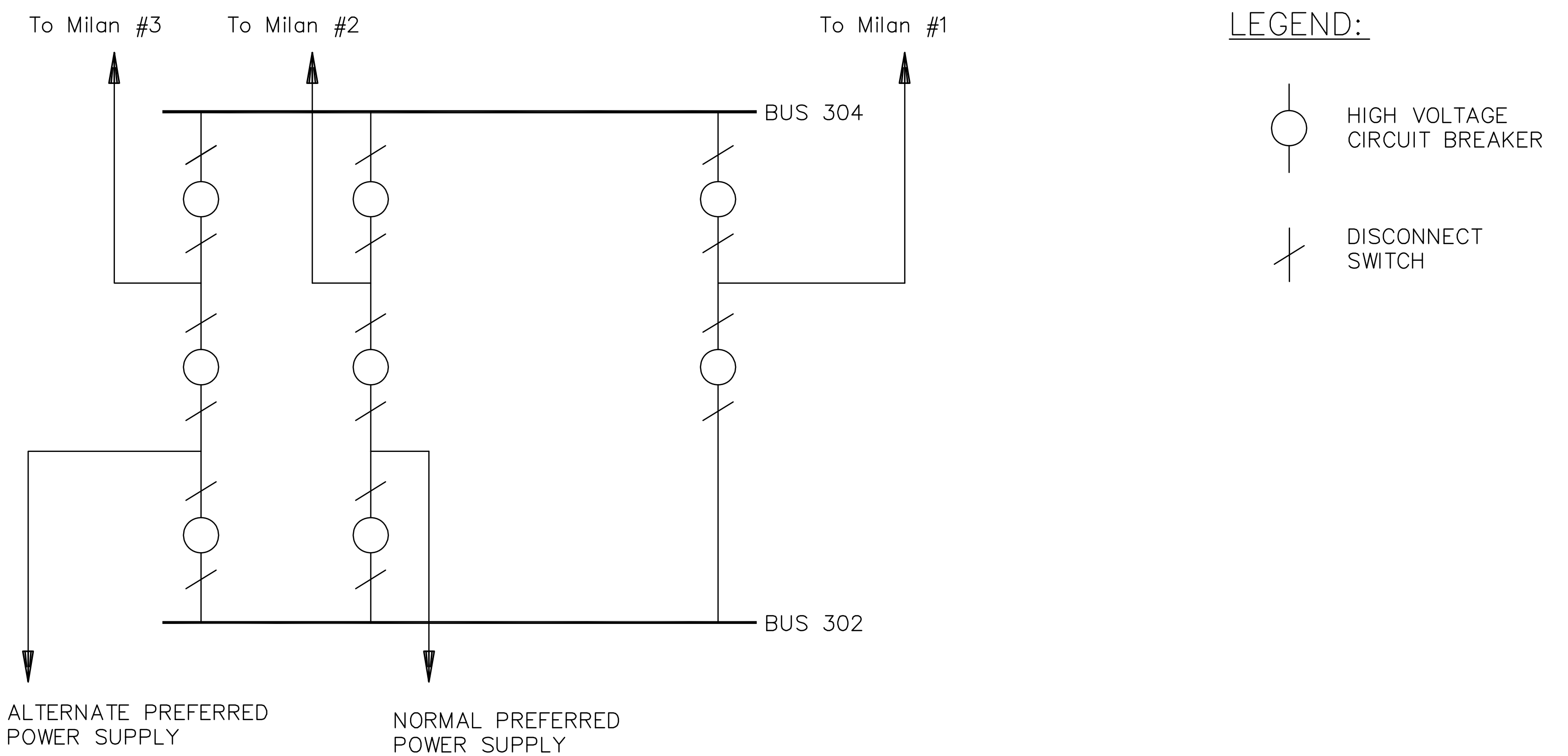


Figure 8.2-202 This page is intentionally left blank

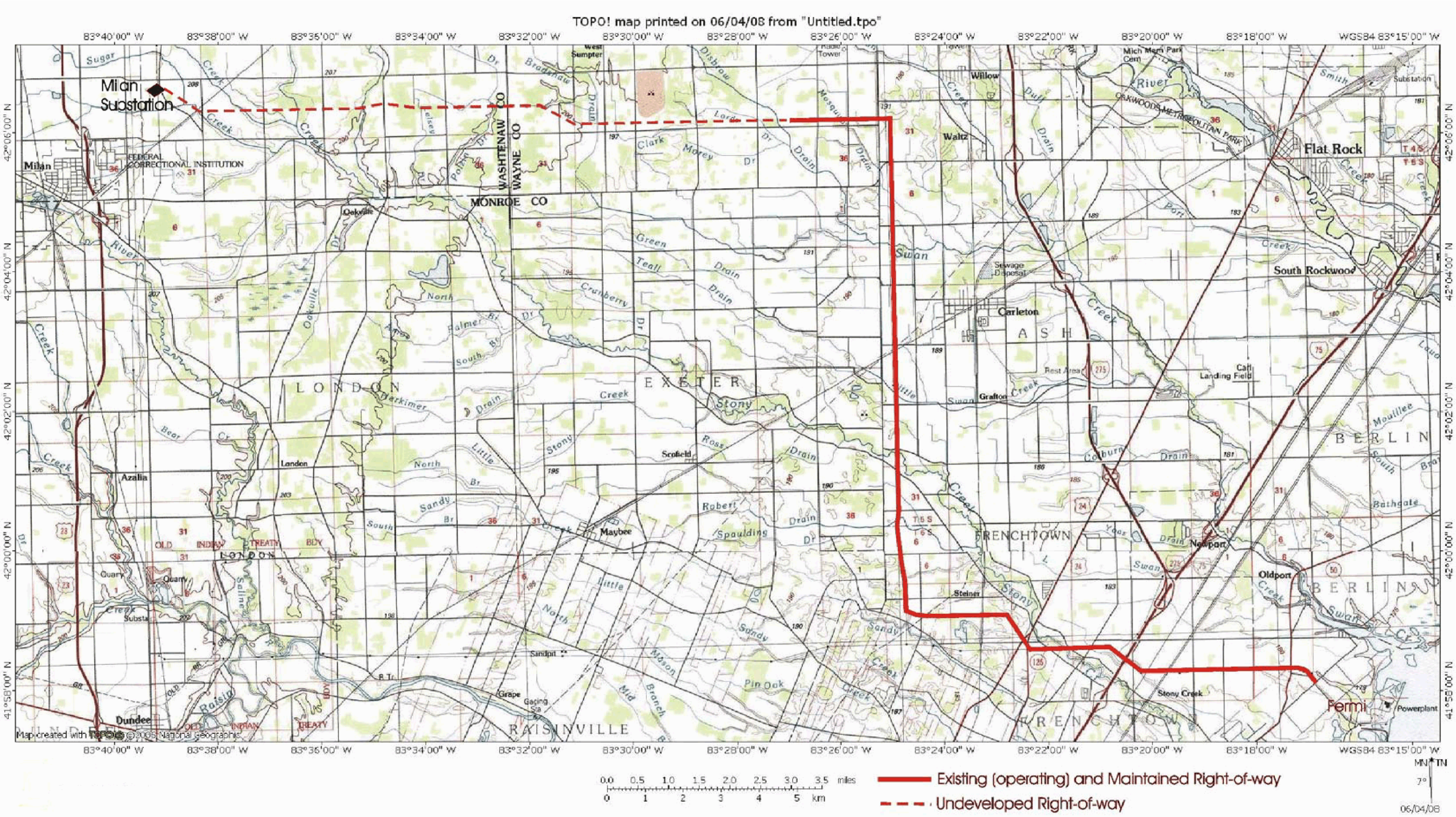


Figure 8.2-203 Transmission Line Map

8.3 Onsite Power Systems

8.3.1 AC Power Systems

8.3.1.1 Description

The main power transformer is within the onsite power system and consists of three single-phase transformers and an installed spare.

The UATs consist of two, three-phase transformers. The UATs provide normal preferred offsite power or main generator island mode power to each of the plant's two power generation and PIP load groups.

The RATs consist of two, three-phase transformers fed from the alternate preferred offsite power source. The RATs provide alternate preferred power to the plant's two power generation and PIP load groups.

The RATs are of the same size as the UATs, and each functions as a backup power source in the event of a UAT failure.

The UAT and RAT are physically separated by distance or physical barriers so as to minimize to the extent practical the likelihood of simultaneous failure under design basis conditions.

The main power transformers, UATs and RATs, are designed and constructed to withstand the mechanical and thermal stresses produced by external short circuits, and meet the corresponding requirements of IEEE Standard C57.12.00 (Reference 8.3-12).The main power transformers, UATs, and RATs have protective devices for overcurrent, differential current, ground overcurrent, and sudden overpressure.

An onsite main generator circuit breaker is provided with capability of interrupting the maximum available fault current. The main generator circuit breaker is sized and designed in accordance with IEEE Standard C37.010 (Reference 8.3-28). The main generator circuit breaker allows the generator to be taken off line and the main grid to be utilized as an immediate access power source for the onsite AC power system. Start-up power is normally provided through the UATs from the offsite power system.

Disconnect links are also provided for the main transformers so that a failed transformer may be taken out of service and the installed spare connected.

The onsite isolated phase bus duct provides the electrical interconnection between the main generator output terminals and the low voltage terminals of the main transformers. The isolated phase bus duct is protected against overcurrent and bus differential current.

Onsite non-segregated phase bus duct provide for the electrical interconnection between the RATs and the 13.8 kV and 6.9 kV switchgear buses and are physically separated from the bus ducts provided for the interconnection of the UATs and the switchgear buses to minimize to the extent practical the likelihood of simultaneous failure under design basis conditions. The non-segregated phase bus duct is protected against overcurrent and bus differential current.

Input isolation breakers (IEEE C37.06 [Reference 8.3-26]), MODs, and disconnect links are provided for the UATs so that a failed transformer may be taken out of service. On loss of power from the UATs, 13.8 kV and 6.9 kV switchgear buses are automatically transferred to the RATs, which are connected to the alternate preferred power source.

Disconnect links in addition to MODs are provided for the RATs so that a failed transformer may be taken out of service. Each of the connected RATs has the capability to replace one UAT.

The PPS consists of the normal preferred and alternate preferred power sources and includes those portions of the offsite power system and the onsite power system required for power flow from the offsite transmission system to the safety-related isolation power centers' incoming line breakers.

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

The onsite AC power system consists of a 60 Hz standby onsite AC power supply system and various pieces of electrical distribution equipment. Figure 8.1-1 shows the plant main one line diagram. The onsite power distribution system has multiple nominal bus voltage ratings. Throughout the discussion and on all the design drawings the equipment utilization voltages are designated as 13.8 kV, 6.9 kV, 480/277V, 208/120V and 240/120V.

The onsite AC power system is configured into two separate power load groups. Each power load group is fed by a separate UAT, each with a redundant RAT for backup, and consists of two types of buses:

- **Power Generation (PG) nonsafety-related buses** - are those buses that are not directly backed by standby onsite AC power sources and have connections to the normal preferred or alternate preferred offsite source through the UATs or RATs, respectively. The PG nonsafety-related buses are the 13.8 kV unit auxiliary switchgear and associated lower voltage load buses.
- **PIP nonsafety-related buses** - are those buses that are backed by the standby onsite AC power supply system and have connections to the normal preferred and alternate preferred offsite sources through the UATs and RATs, respectively. Backfeed to the standby onsite AC power source is prevented by reverse power relaying. The PIP nonsafety-related buses are the 6.9 kV PIP buses and associated lower voltage load buses exclusive of the safety-related isolation power center buses.

The PG nonsafety-related buses feed nonsafety-related loads required exclusively for unit operation and are normally powered from the normal preferred power source through the UATs. These buses are also capable of being powered from the alternate preferred power source (RATs), through an auto bus transfer, in the event that the normal preferred power source is unavailable. On restoration of UAT power, transfer back to the normal PPS may be performed by a manually selected bus transfer or the bus may be placed in the automatic transfer mode and remain powered from the alternate preferred power source (RATs).

The PIP nonsafety-related buses feed nonsafety-related loads generally required to remain operational at all times, including when the unit is shut down. In addition, the PIP nonsafety-related buses supply AC power to the safety-related buses. The PIP nonsafety-related buses are backed up by a separate standby onsite AC power supply system connected to each PIP bus. These buses are also capable of being powered from the alternate preferred power source (RATs), through an auto bus transfer, in the event that the normal preferred power source is unavailable. On restoration of UAT power, transfer back to the normal PPS may be performed by a manually selected bus transfer or the bus may be placed in the automatic transfer mode and remain powered from the alternate preferred power source (RATs).

8.3.1.1.1 **Medium Voltage AC Power Distribution System**

The medium voltage AC power distribution system consists of the onsite electric power distribution circuits that operate at 13.8 kV and 6.9 kV. The system begins at the connection of the input terminals of the 13.8 kV and 6.9 kV feeder circuit breakers that are supplied power from the UATs and RATs, and at the output terminals of the plant onsite standby AC power sources. The system ends at the input terminals of medium voltage load breakers. The system includes switchgear buses and circuit breakers as well as their associated local instrumentation, controls, and protective relays.

Power is supplied from the UATs and RATs at 13.8 kV and 6.9 kV to the PG and PIP buses. There are four PG buses, each being powered from one of the two UATs, or if the UATs are unavailable, from one of the two RATs. The source breakers for each PG bus are electrically interlocked to prevent simultaneous connection of UATs and RATs to the PG buses under a faulted condition.

Two 6.9 kV PIP buses (PIP-A and PIP-B) provide power for the nonsafety-related PIP loads. Each PIP bus is normally powered from the normal preferred power source through the UAT of the same load group. In the event the normal preferred power source is unavailable, each PIP bus has connections to and can be powered from the alternate preferred power source through the RAT of the same load group. The source breakers of the normal and alternate preferred power sources are electrically interlocked to prevent simultaneous connection of UATs and RATs to the PIP buses under a faulted condition.

Standby AC power for the PIP nonsafety-related buses is supplied by standby diesel generators at 6.9 kV and distributed by the nonsafety-related power distribution system. The 6.9 kV PIP buses are automatically transferred to the standby diesel generators when the normal and alternate preferred power supplies to these buses are lost.

Each 13.8 kV and 6.9 kV bus has a safety grounding circuit breaker, not shown on the one line diagram, designed to protect personnel during maintenance operations. (See Subsection 13.5.2.)

8.3.1.1.2 **Low Voltage AC Power Distribution System**

The low voltage AC power distribution system consists of the onsite electric power distribution circuits that operate at 480V through 120V, exclusive of plant lighting. For a discussion of the plant 120V systems refer to Subsection 8.3.1.1.3. The low voltage system begins at the input terminals of the medium voltage feeder breakers to the power center transformers. The system ends at the input terminals of load breakers.

The low voltage AC power distribution system includes power centers, motor control centers (MCCs), distribution transformers, and distribution panels as well as the associated overcurrent protective devices, protective relaying, and local instrumentation and controls. It also includes all cables interconnecting the buses to their sources and loads.

13.8 kV PG and 6.9 kV PIP power is supplied from the respective switchgear buses with designated secondary voltage as shown in Figure 8.1-1 Sheet 1, Figure 8.1-1 Sheet 2, and Figure 8.1-1 Sheet 3. The power centers supply power to motor loads, MCCs, and the ancillary diesel generator buses (see Figure 8.1-1 Sheet 2, Figure 8.1-1 Sheet 3, and Figure 8.3-3). The power centers are of the single-fed or double-ended type depending on the redundancy requirements of the loads powered by a given power center. The power supplies to the double-ended power center transformers of the PIP nonsafety-related buses are supplied from different buses. Each double-ended power center is normally powered by its normal power source through its normal source main breaker, with the alternate source main breaker open. The power center normal and alternate source main breakers are electrically interlocked to prevent simultaneous powering of the power center by normal and alternate sources.

Isolation Power Centers

The isolation power centers are powered from the PPS via the PIP nonsafety-related buses, which are backed up by the standby diesel generators. There are four isolation power centers, one each for Divisions 1, 2, 3 and 4. Each isolation power center is double-ended and can be powered from either of the PIP load group buses.

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

The normal and alternate source main breakers of each isolation power center are electrically interlocked to prevent powering the isolation power center from the normal and alternate sources simultaneously. The isolation power centers are shown in Figure 8.3-1.

The isolation power centers supply power to safety-related loads of their respective division. These loads consist of the safety-related battery chargers or rectifiers as discussed in Subsections 8.3.2 and 8.3.1.1.3. There is no safety-related lighting that operates directly from the 480 VAC in the ESBWR design. The lighting system is discussed in Chapter 9.

Isolation power centers are protected against degraded voltage and frequency conditions by way of voltage and frequency relays installed in each isolation power center to provide alarms and facilitate isolation power center bus isolation and transfer functions using two-out-of-three logic to prevent spurious actuation. The four safety-related isolation power centers are located in the Seismic Category I Reactor Building in their respective divisional areas.

Motor Control Centers

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

8.3.1.1.3 Uninterruptible AC Power Supply System

Safety-Related Uninterruptible AC Power Supply System

Figure 8.1-4 shows the overall safety-related Uninterruptible AC Power Supply (UPS) system. The safety-related UPS for each of the four divisions is supplied from a 480V isolation power center in the same division. The isolation power centers are connected to PIP nonsafety-related buses, which are backed by standby diesel generators. Divisions 1, 2, 3 and 4 each have three battery chargers, including one standby per division, two batteries and two UPS rectifiers. Each rectifier (battery charger and UPS rectifier) receives 480 VAC normal power from the isolation power center of that division, see Figure 8.3-1, and converts it to 250 VDC. The 480 VAC/250 VDC UPS rectifiers and the safety-related 72-hour batteries of that division, maintained fully charged by the 480 VAC/250 VDC battery chargers, supply 250 VDC power through diodes to two parallel output 120 VAC single phase UPS inverters.

The safety-related UPS inverter high DC input voltage trip setpoint and time delay are greater than the associated battery charger and UPS rectifier high DC output voltage trip setpoint and time delay. This arrangement prevents safety-related UPS inverter trips as a result of fast transients on the AC supply that may occur during the ESBWR islanding transient or as a result of generator voltage regulator failures, for which protective relaying and breaker operations may not otherwise prevent safety-related UPS inverter trips.

Power is distributed to the individual safety-related loads from associated 120 VAC distribution panels, which supply power to the Reactor Building and the Control Building.

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

Refer to Subsection 8.3.1.1.5 for a discussion of physical separation and independence.

Four divisions of safety-related UPS provide 120 VAC power for the Q-DCIS loads/logic components (reference Section 7.1 for Q-DCIS description) and other safety-related loads requiring uninterruptible power (see Figure 8.1-3). Two divisions (1 and 2) of safety-related power supply the Reactor Protection System (RPS) scram pilot valve solenoids and the same two divisions supply power to the Main Steam Isolation Valve (MSIV) solenoids (see Figure 7.2-1 and Figure 8.1-4).

The four divisions of safety-related UPS are shown in Figure 8.1-4. The safety-related UPS buses are each supplied independently from their divisional safety-related inverters, which, in turn, are powered from one of the independent and redundant DC buses of the same division and from their isolation power center. The divisional DC bus is powered through a battery charger connected to its divisional isolation power center, and backed by the division's safety-related batteries. The two inverters in each safety-related division will be configured for parallel redundant operation to allow load sharing and the equal discharge of the division's safety-related batteries.

Routine maintenance can be conducted on equipment associated with the safety-related UPS power supply. Inverters, rectifiers, and solid state switches can be inspected, serviced and tested channel by channel without tripping the RPS logic.

UPS Components - Each of the four safety-related divisions includes the following safety-related UPS components:

- Two solid-state UPS rectifiers, to convert 480 VAC to 250 VDC.
- Two solid-state UPS inverters, to convert 250 VDC to 120 VAC power.
- Two solid-state transfer switches to sense failure of each of the division's inverters.
- Power distribution panel boards to provide power to all safety-related loads requiring uninterruptible 120 VAC power.

Operating Configuration - The four divisions of safety-related UPS operate independently, providing power to all safety-related loads within their division requiring uninterruptible AC power.

The normal power source for each division's inverters is the same division's isolation power center, which provides AC power to the rectifiers. Transfer from the 480 VAC power supply to the 250 VDC buses is done automatically and passively in case of loss of the normal power source. Each inverter normally carries approximately 50% of the load. If one inverter fails, 100% of the load is picked up by the remaining inverter for a period of time greater than 36 hours but less than 72 hours. If both inverters in a division are lost, the associated 120 VAC UPS buses are de-energized. An alarm is provided in the main control room for any of the alternate operating lineups.

Nonsafety-Related Uninterruptible Power Supply System

The nonsafety-related UPS provides reliable, uninterruptible AC power for nonsafety-related equipment needed for continuity of power plant operation. UPS loads are divided into five load groups (load groups A, B, C, Technical Support Center [TSC]-A, and TSC-B). UPS load groups A and B each include two solid-state inverters, two solid-state rectifiers, two solid-state transfer switches, two manual transfer switches, and two regulating transformers with associated distribution panels (Figure 8.1-5). UPS load group C includes one solid-state inverter, one solid-state rectifier, one solid-state transfer switch, one manual transfer switch, and one regulating transformer with associated distribution panels.

The normal power supply for the A and B load groups of the nonsafety-related UPS is through a nonsafety-related 480 VAC power center fed from the A and B PIP buses, respectively. In case of failure of the 480 VAC power supply, transfer from the 480 VAC power center to the nonsafety-related 250 VDC bus is automatic and passive. Transfer from the normal AC power source through the inverter to the alternate AC power source occurs by automatic static transfer should an inverter failure occur. An alarm in the main control room sets off when an alternate lineup of the nonsafety-related UPS occurs.

A third nonsafety-related UPS is provided to supply additional nonsafety-related loads (load group C) that require uninterruptible power. This UPS is normally powered from 480 VAC power centers, which receive power from the diesel-backed PIP-A bus. Should a failure of the normal power supply occur, the alternate power supply to the UPS is from the 250 VDC bus. During loss of normal and alternate power supply or inverter failure, loads continue to get power from the 480 VAC DCIS double-ended (PIP-A or PIP-B) Swing Bus through the 480/480 VAC regulating transformer, which also supplies power during maintenance of the inverter and its associated components.

Two dedicated nonsafety-related UPS (Figure 8.1-5) are provided for the TSC, also in a two-load group configuration. Power for each TSC nonsafety-related UPS is normally supplied from a 480 VAC power center. In case of failure of the 480 VAC power supply, transfer from the 480 VAC power center to the nonsafety-related 125 VDC bus is automatic and passive. Transfer from the normal AC power source through the inverter to the alternate AC power source occurs by automatic static transfer should an inverter failure occur.

The 480 VAC power centers, which provide power to the nonsafety-related battery chargers, are connected to PIP nonsafety-related buses that are backed up by standby diesel generators.

8.3.1.1.4 **Instrumentation and Control Power Supply System**

System deleted.

8.3.1.1.5 **Safety-Related Electric Equipment Considerations**

The following guidelines are utilized for safety-related equipment.

Physical Separation and Independence:

- Electrical equipment is separated in accordance with IEEE Standard 384 (Reference 8.3-10), Regulatory Guide 1.75 and General Design Criterion 17.
- To meet the provisions of Policy Issue SECY-89-013, which relates to fire tolerance, 3 hour rated fire barriers are provided between areas of different safety-related divisions throughout the plant except in the reinforced concrete containment vessel (RCCV) and the control room complex. Refer to Subsection 9.5.1 for a description of how the provisions of the policy issue are met.
- The overall design objective is to locate the divisional equipment and its associated control, instrumentation, electrical supporting systems, and interconnecting cabling such that separation is maintained between all divisions. Redundant divisions of electric equipment and cabling are located in separate rooms or fire areas wherever possible.
- Electric equipment and wiring for the safety-related systems which are segregated into separate divisions are separated so that no design basis event is capable of disabling more than one division of any Engineered Safety Feature (ESF).
- The safety-related electrical equipment (batteries, distribution panels, etc.) are located in separate seismic Category I rooms in the reactor building to ensure electrical and physical separation among the divisions. Separation is provided between divisional cables being routed between various equipment rooms, the main control room, RCCV, and other processing areas. Separation of safety-related equipment in these areas is achieved by separate safety-related structures, barriers, or a combination thereof. The equipment is located to facilitate divisional separation of cable trays and to provide access to electrical penetration assemblies. Exceptions to this separation objective are identified and analyzed as to equivalency and acceptability in the fire hazard analysis. (See Section 9A.6 Special Cases.) For separation requirements relating to the main control room and relay panels, refer to "Main Control Room Panels" in Subsection 8.3.1.4.
- For separation requirements relating to the wiring and components within control, relay, and instrument panels/racks, refer to "Main Control Room Panels" in Subsection 8.3.1.4.
- For additional separation requirements relating to RPS and ESF systems refer to "System Separation Requirements" in Subsection 8.3.1.4. RCCV electrical penetrations are dispersed

around the periphery of the RCCV and are physically separated in accordance with the requirements of Section 6.5 of IEEE 384 (Reference 8.3-10). Each penetration carries circuits of a single voltage class and division. Penetrations serving safety-related loads are not used for nonsafety-related circuits and are only used for circuits belonging to the same safety-related division.

- Wiring for all safety-related equipment indicating lights is an integral part of the safety-related cables used for control of the same equipment and are considered to be safety-related circuits.

Safety-Related Electric Equipment Design Bases and Criteria:

- Plant design specifications for electrical equipment require such equipment be capable of continuous operation with equipment terminal voltage fluctuations of plus or minus 10% of rated voltage.
- Power sources, distribution systems, and branch circuits are designed to maintain voltage and frequency within acceptable limits.
- Interrupting capacity of distribution panels is at least equal to the maximum available fault current to which it is exposed under all modes of operation. Circuit breaker and applications are in accordance with ANSI C37.50 (Reference 8.3-22).
- Refurbished circuit breakers are not used in either safety-related or nonsafety-related circuitry of the ESBWR design. New circuit breakers are specified in all ESBWR purchase specifications. (NRC Bulletin No. 88-10 and NRC Information Notice No. 88-46 identify problems with defective refurbished circuit breakers.)

Testing:

The design provides for periodically testing the chain of system elements from sensing devices through actuated equipment to ensure that safety-related equipment is functioning in accordance with design requirements, and to ensure that the requirements of Regulatory Guide 1.118 and IEEE 338 (Reference 8.3-37) are met.

8.3.1.1.6 **Circuit Protection**

Philosophy of Protection

Simplicity of load grouping facilitates the use of conventional, protective relaying practices for isolation of faults. Emphasis has been placed on preserving function and limiting loss of safety-related equipment function in situations of power loss or equipment failure.

Protective relay schemes and direct acting trip devices are provided throughout the onsite power system to:

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

Grounding

The ESBWR grounding complies with guidelines provided in Section 8A.1.

Bus Protection

Bus protection for nonsafety-related and safety-related buses are as follows:

- The 13.8 kV and 6.9 kV bus incoming circuit breakers have inverse-time overload, ground fault, undervoltage, and degraded voltage protection.
- The 13.8 kV and 6.9 kV feeder breakers for power centers have instantaneous, inverse-time overload and ground fault protection.
- The 13.8 kV and 6.9 kV motor feeder breakers have instantaneous, inverse-time overload and ground fault protection.
- The 13.8 kV and 6.9 kV buses have bus differential protection.
- The 480V feeder breakers for MCC buses have long-time and short-time overload and ground fault protection.
- The 480V isolation power center buses have inverse-time overload and ground fault protection. In addition, loss of voltage, degraded voltage and under-frequency relay protective functions are provided which isolate these buses from the nonsafety-related system upon degraded source conditions.
- The 480V MCC loads (nonsafety-related only, there are no safety-related 480 VAC MCC loads) have instantaneous and inverse-time overload protection.
- The 480V power center motor feeder breakers have instantaneous, inverse-time overload and ground fault protection.

Protection Requirements

When the standby onsite AC power sources are called upon to operate, all the protective relay functions identified in "Protection Systems" (Subsection 8.3.1.1.8) are available.

8.3.1.1.7 **Load Shedding and Sequencing on PIP Buses**

Load shedding, bus transfer and sequencing on the 6.9 kV PIP buses is initiated on loss of bus voltage. Loss of normal preferred power may cause load shedding and sequencing with an auto transfer to alternate preferred power. If alternate preferred power is not sensed by protective relaying, power is supplied by the appropriate onsite standby diesel power source.

PIP bus ready-to-load signals are generated by the diesel generator protective relaying logic and control system for the medium voltage distribution system.

Diesel generators are sized conservatively to accommodate expected loads to be served by them with an acceptable starting sequence.

LOPP

The 6.9 kV PIP buses are normally energized from the normal PPS. When the normal PPS is lost, an auto transfer from the normal PPS to the alternate PPS is initiated.

Should the normal and alternate preferred power supplies protective relaying sense loss of power, the incoming PIP buses feeder breakers trip. Medium voltage motor breakers are tripped and low voltage motor starters are opened due to undervoltage. A standard dead bus transfer is automatically initiated to the standby onsite AC power source. The signal starts the standby onsite AC power source, and closes the standby power supply breaker after the standby onsite AC power source has returned a ready to load signal (that is, voltage and frequency are within normal limits and no lockout exists, and the normal and alternate preferred supply breakers are open). After bus voltage has been reestablished, loads are sequentially energized as required. Transfer back to the preferred power source is a synchronized closure of the feeder breaker by manual action to the selected source.

Loss-of-Coolant-Accident (LOCA)

When a LOCA occurs without a LOPP there is no effect on the electrical distribution system. The plant remains on either source of preferred power and the onsite diesel generator is not started. The load shed and sequence timers are not activated.

LOPP Following LOCA

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

LOCA Following LOPP

If a LOCA occurs following loss of both the normal and alternate preferred power supplies, the standby onsite AC power source should have already started from low bus voltage. Automatic load sequencing will have started as described in LOPP above.

LOCA When the Standby Onsite AC Power Source is Parallel to the Power Source During Testing

If a LOCA occurs when the standby diesel generator is paralleled with either the normal preferred power or the alternate preferred power source, the standby diesel generator automatically disconnects from the 6.9 kV PIP bus regardless of whether the test is being conducted from the local control panel or the main control room.

Loss of Normal Preferred Power Source During Standby Onsite Power Source Paralleling Test

If the normal PPS is lost during the standby onsite AC power source paralleling test, the normal PPS breaker and diesel generator breaker are automatically tripped and the alternate preferred power source accepts loads to re-energize the selected bus loads. Transfer back to the normal PPS may then be accomplished manually or the bus may be placed in the automatic transfer mode and remain powered from the alternate preferred power source, the RATs.

Loss of Alternate Preferred Power Source During Standby Onsite Power Source Paralleling Test

If the alternate preferred supply is used for load testing the standby onsite AC power source, and the alternate preferred source is lost, the alternate PPS breaker and diesel-generator breaker are automatically tripped. The affected bus may then be transferred back to the normal PPS manually or the normal preferred power source automatically accepts the selected bus loads, if the bus was placed in the automatic transfer mode.

Restoration of Offsite Power

Upon restoration of offsite power, the 6.9 kV PIP buses can be transferred back to the offsite source by manual operation only, as described above in LOPP.

8.3.1.1.8 **Standby Onsite AC Power Supply System**

The standby AC power supply system is not within the ESBWR Design Bases, is not relied upon to perform any safety-related function or achieve safe shutdown, and thus, is classified as nonsafety-related. It includes the standby onsite AC power sources and associated power supply circuits up to the source breakers of the onsite PIP buses to which they are connected.

The standby onsite AC power sources consist of the prime movers and AC generators, the auxiliary systems (starting, lubrication, cooling, fuel supply, excitation, etc.), the fuel storage and transfer systems and the associated local instrumentation and control systems. (Refer to Subsections 9.5.4, 9.5.5, 9.5.6, 9.5.7, 9.5.8, and 9.4.7.)

The onsite standby AC power supply system is designed to supply backup AC power to the PIP nonsafety-related buses when the normal and alternate preferred power supplies are not available.

The PIP buses provide power for various auxiliary and investment protection load groups, and isolation power centers. Operation of the system is not required to ensure safe shutdown.

Figure 8.1-1 shows the interface between the normal preferred power sources, alternate preferred power sources, and the standby onsite AC power sources.

Redundant (non-safety) Standby AC Power Supplies

Each standby power system load group, including the standby diesel generator, its auxiliary systems, and the distribution of power through the 6.9 kV and lower voltage PIP buses to various investment protection load groups, is segregated and separated from the redundant load group. No interconnection is provided between the redundant standby power system load groups. Each standby onsite AC power source is operated independently of the other standby onsite AC power source and is connected to the utility power system by manual control during testing.

Ratings and Capability

Each of the standby onsite AC power sources is sized to serve its nonsafety-related load and conforms to the following criteria:

- Each standby onsite AC power source is capable of starting, accelerating, and supplying its loads in the sequence necessary for PIP.
- Each standby onsite AC power source is capable of starting, accelerating, and supplying its loads in their proper sequence without exceeding an acceptable voltage limit at its output terminals.
- Each standby onsite AC power source is capable of reaching full speed and voltage within 2 minutes after receiving a signal to start, and is capable of being fully loaded within an acceptable time that does not challenge the diesel generator capacity.
- Each standby onsite AC power source has a continuous power rating greater than the sum of its PIP loads and battery chargers that could be powered concurrently during hot standby, normal plant cool down, or plant outages.
- The generator exciter and voltage regulator systems are capable of providing full voltage control during operating conditions including expected transients.

Starting Circuits and Systems

The standby onsite AC power sources start automatically upon loss of AC power. Undervoltage relays initiate the sequence used to start each standby onsite AC power source.

Upon loss of preferred AC power (normal and alternate) to the PIP buses, the transfer of these buses to the standby onsite AC power sources is automatic. After the breakers connecting the buses to the normal PPS (or alternate PPS, depending upon system configuration) are opened and when the required standby onsite AC power source generator voltage and frequency are established, the standby onsite AC power source breaker is closed.

Automatic Shedding, Loading and Isolation

The standby onsite AC power source is connected to its PIP bus only when the incoming normal preferred and alternate preferred source breakers have been tripped, except during parallel load testing using the normal or alternate preferred power sources. (See Subsection 8.3.1.1.7.)

Protection Systems For Diesel Generators

The onsite standby generator is shut down and the generator breaker tripped under the following conditions during all modes of operation and testing:

- Generator overspeed trip
- Reverse power relay trip
- Field relay trip
- Overcurrent relay trip
- Overvoltage relay trip
- Ground relay trip
- Over temperature relay trip
- Undervoltage relay trip
- Frequency relay trip
- Generator differential relay trip

These protective functions of the standby onsite AC power source or the generator breaker and other off-normal conditions are alarmed and/or indicated in the main control room. (See Table 8.3-1.)

Local and Remote Control

Each standby onsite AC power source is capable of being started or stopped manually from the main control room. Start/stop control and bus transfer control may be transferred to a local control station in the standby onsite AC power source room by operator action.

Engine Mechanical Systems and Accessories

Descriptions of these systems and accessories are given in Section 9.5.

Interlocks and Testability

Each standby onsite AC power source, when operating other than in parallel loading, is totally independent of the PPS. Additional interlocks to the LOPP sensing circuits terminate parallel operation testing as described in Subsection 8.3.1.1.7. A lockout or maintenance mode removes the standby onsite AC power source from service. The inoperable status is indicated in the control room.

8.3.1.1.9 **Ancillary AC Diesel Generators**

Two nonsafety-related ancillary diesel generators provide post accident power to the loads designated on Figure 8.3-3 when no other sources of power are available. Refer to Appendix 19A for further discussion of the ancillary diesel generator augmented design requirements. The ancillary diesel generators are Seismic Category II, as are their associated auxiliaries, controls, electrical buses, and fuel oil tanks. (See Subsection 9.5.4 for discussion of fuel oil tanks.) The diesels and associated equipment are housed in a Seismic Category II structure. The ancillary power is not required to support safety-related loads for the first 72 hours following the loss of all other AC power sources. See Figure 8.3-1 Sheet 1 for the isolated ancillary power connection to safety-related loads.

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

The ancillary diesel generators and associated buses are rated at 480 VAC. These buses are normally powered by offsite power or the onsite standby diesel generators through the PIP buses (see Figure 8.1-1 Sheet 2 and Figure 8.1-1 Sheet 3). On sensing undervoltage AC power to their buses or on the sensing of low ancillary diesel room temperature, the 480 VAC ancillary diesel bus feeder breaker will trip and send a start signal to the ancillary diesel generator. The signal starts the ancillary diesel generator and closes the ancillary generator power supply breaker.

8.3.1.2 **Analysis**

8.3.1.2.1 **General Design Criteria and Regulatory Guidance Compliance**

The following paragraphs analyze compliance with NRC General Design Criteria, NRC Regulatory Guides and other criteria consistent with the Standard Review Plan (SRP).

Table 8.1-1 identifies the onsite power system and applicability of the associated codes and standards applied in accordance with Table 8-1 of the SRP. All regulatory guides, BTPs and NUREGs are discussed in Subsection 8.1.5.2.4, where GDC compliance is evaluated.

GDC 2, Design Basis for Protection Against Natural Phenomena

GDC 4, Environmental and Dynamic Effects Design Bases

The requirements of the GDC 2 and 4 are met, in that all components of the safety-related power system are housed in seismic Category I structures designed to protect them from natural phenomena. These components have been qualified to the appropriate seismic, hydrodynamic, and environmental conditions as described in Chapter 3.

GDC 17, Electric Power Systems

Safety-related DC power sources are provided to support passive core cooling and RCCV safety-related functions. No offsite or diesel-generator-derived AC power is required for 72 hours after an abnormal event. However, the ESBWR PPS complies with GDC 17 with respect to two independent and separate offsite power sources, each with the capacity and capability to power equipment during design basis operating modes (plant start-up, normal operation, safe shutdown, accident, and post-accident operation). Subsection 3.1.2.8, "Criterion 17 – Electric Power Systems," provides ESBWR electric power source availability requirements and conformance with Regulatory Guide 1.93.

GDC 18, Inspection and Testing of Electric Power Systems

Safety-related DC power sources are provided to support passive core cooling and RCCV safety-related functions. No offsite or diesel-generator-derived AC power is required for 72 hours after an abnormal event. However, the nonsafety-related offsite and onsite AC systems that supply AC power to the isolation power centers are testable and meet GDC 18 requirements.

The safety-related DC power system (including safety-related UPS and 480 VAC isolation power centers) is designed to permit the following:

- During divisional equipment shutdown occurring during plant operation, periodic inspection and testing of wiring, insulation, connections, and the condition of components.
- During normal plant operation, periodic testing of the operability and functional performance of onsite power supplies, circuit breakers, and their associated control circuits, relays, and buses.
- During plant shutdown, testing of the operability of the safety-related system as a whole. The full operational sequence that brings the system into operation, including operation of signals of the safety-related systems and the transfer of power between offsite and onsite power system, are able to be tested, under conditions as close to design as practicable.

GDC 50, Containment Design Basis

GDC 50, as it relates to the design of circuits using RCCV electrical penetration assemblies, is met as indicated in Subsection 8.1.5.2.4.

8.3.1.2.2 **Quality Assurance Requirements**

The Quality Assurance program is provided in Chapter 17. This program includes a comprehensive system to ensure that the purchased material, manufacture, fabrication, testing, and quality control of the equipment conforms to the GE Quality Assurance program. The administrative responsibility and control provided are also described in Chapter 17.

These Quality Assurance requirements include an appropriate vendor quality assurance program and organization, purchaser surveillance as required, vendor preparation and maintenance of appropriate test and inspection records, certificates and other quality assurance documentation, and vendor submittal of quality control records considered necessary for purchaser retention to verify quality of completed work.

A necessary condition for receipt, installation and placing of equipment in service is the citing and auditing of Quality Assurance/Quality Control (QA/QC) verification data and the placing of this data in permanent onsite storage files.

8.3.1.2.3 **Environmental Considerations**

In addition to the effects of operation in a normal service environment, all safety-related equipment is designed to operate during and after any design basis event, in the area in which it is located. All safety-related electric equipment in a harsh environment is qualified to IEEE 323 (Reference 8.3-13). Detailed information on all safety-related equipment that must operate in a harsh environment during and subsequent to an accident is provided in Section 3.11.

8.3.1.3 **Physical Identification of Safety-Related Equipment**

8.3.1.3.1 **Power, Instrumentation and Control Systems**

Electrical and control equipment, panels and racks, and cables and raceways grouped into separate divisions are identified so that their electrical divisional assignment is apparent, and so that an observer can visually differentiate between safety-related equipment and wiring of different divisions, and between safety-related and nonsafety-related equipment and wiring. The identification method is color-coding. All markers within a division have the same color. The ESBWR standard plant design eliminates safety-related associated circuits as defined by IEEE 384 (Reference 8.3-10) and in accordance with RG 1.75. Divisional separation requirements of individual pieces of hardware are shown in the system elementary diagrams. Identification of raceways, cables, etc., is compatible with the identification of the safety-related equipment with which it interfaces. Location of the identification is such that points of change of circuit classification (at isolation devices, etc.) are readily apparent.

Equipment Identification

Equipment (panels, racks, junction or pull boxes) of each division of the safety-related electric system are identified as follows:

- The background nameplate for the equipment of a division has the same color as the cable jacket markers and raceway markers associated with that division.
- Power system distribution equipment (for example, power centers, transformers, distribution panels, batteries, chargers) is tagged with an equipment number the same as indicated on the single-line diagrams.

Cable Identification

All cables are tagged at their terminations with a unique identifying number (cable number), in addition to the marking characteristics shown below.

All safety-related cables are marked with sufficient durability to be legible to facilitate initial verification that the installation is in conformance with the separation criteria.

Such markings are colored to uniquely identify the division (or non-division) of the cable. Within cabinets or panels with circuits of more than one division, individual conductors are color-coded or color-tagged so that the division they belong to is clearly discernible. Any non-divisional cable within such cabinets is appropriately marked to distinguish it from the divisional cables.

To distinguish the neutron monitoring and scram solenoid cables from other cable types, unique voltage class designations are used in the cable routing program.

Raceway Identification

All conduit is similarly tagged with a unique conduit number, at discontinuities, at pull boxes, at points of entrance and exit to rooms, and at origin and destination of equipment. Conduits containing cables operating at voltages above 600V (that is, 6.9 kV) are also tagged to indicate the operating voltage. These markings are applied prior to the installation of the cables.

All safety-related cable trays are marked with the division color, and with their raceway identification on straight sections, at turning points and at points of entry and exit of enclosed areas. Cable trays are marked prior to the installation of cables.

Neutron monitoring cables, local power range monitor cables and startup range neutron monitor cables are run in their own divisional conduits and cable trays, separate from all other power, instrumentation and control cables. Scram solenoid cables are run in a separate conduit for each rod scram group.

Redundant safety-related equipment and circuits, assigned to redundant safety-related divisions, are readily distinguishable from each other and nonsafety-related system equipment and circuits without consulting reference materials. This is accomplished by color-coding of equipment, nameplates, cables, and raceways, as described above.

8.3.1.4 Independence of Redundant Systems

8.3.1.4.1 Power Systems

The safety-related onsite electric power systems and major components of the separate power divisions are shown in Figures 8.1-3 and 8.1-4.

Independence of the electric equipment and raceway systems, between the different divisions, is maintained primarily by firewall-type separation, where feasible, and by spatial separation, in accordance with criteria given within this subsection, "Safety-Related Electric Equipment Arrangement." Exceptions are analyzed in Appendix9A.6.4, "Fire Separation for Divisional Electrical Systems".

Where spatial separation cannot be maintained in hazardous areas (for example, potential missile areas), physical isolation between electrical equipment of different divisions is achieved by use of a protective barrier designed to withstand the effects of postulated hazards.

The physical independence of electric power systems complies with the requirements of IEEE Standard 384, GDC 17, and NRC Regulatory Guide 1.75.

Safety-Related Electric Equipment Arrangement

Safety-related electric equipment and wiring are segregated into separate divisions so that no single credible event is capable of disabling enough equipment to hinder reactor shutdown, removal of decay heat from the core, or isolation of the RCCV in the event of an accident. Separation requirements are applied to control power and motive power for all systems involved.

Equipment arrangement and/or protective barriers are provided such that no locally generated force or missile can destroy any redundant RPS, Nuclear Steam Supply Systems (NSSS), ESF, or ECCS functions.

Routing of wiring/cabling is arranged such as to eliminate, to the extent practical, all potential for fire damage to cables and to separate the redundant divisions so that fire in one division does not propagate to another division.

An independent raceway system is provided for each division of the safety-related electric system. The raceways are arranged, physically, top to bottom based on the function and the voltage class of the cables.

Electric Cable Installation

Cable derating and cable tray fill — Base ampacity rating of cables is established as described in Subsection 8.3.3.2. Cables are installed in trays in accordance with their voltage ratings and as described in this subsection. Tray fill is as established in Subsection 8.3.3.2.

Cable routing in potentially harsh environmental areas — Circuits of different safety-related divisions that are routed through the same potentially harsh environmental area are protected through separation by conduit and by qualifications described in Subsection 8.3.3.2.

Sharing of cable trays — Each division of safety-related AC and DC system cables is provided with its own independent and separate raceway system.

Cable fire protection and detection — For details of cable fire protection and detection, refer to Section 9A.5, Subsections 8.3.3 and 9.5.1.

Cable and raceway markings — All cables are tagged at their terminations with a unique identifying number. The marking of cables and raceways for divisional identification is discussed in Subsection 8.3.1.3.

Spacing of wiring and components in control boards, panels and relay racks — Separation is accomplished by mounting the redundant devices or other components on physically separated control boards. When human factors engineering dictates that redundant equipment be in close proximity, separation is achieved by a barrier or enclosure to retard internal fire or by a maintained air space in accordance with criteria given in this subsection, "Safety-Related Electric Equipment Arrangement."

In this case, redundant circuits, which serve the same safety-related function, enter the control panel through separated apertures and terminate on separate and separated terminal blocks. Where redundant circuits unavoidably terminate on the same device, barriers are provided between the device terminations to ensure circuit separation.

RCCV electrical penetration assemblies — Electric penetration assemblies of different safety-related divisions are separated by 3-hour rated fire barriers, separate rooms and/or locations on separate floor levels. Separation by distance without barriers is allowed only in the inerted RCCV. Separation between divisional and non-divisional penetrations is in accordance with IEEE 384. Grouping of circuits in penetration assemblies follows the same raceway voltage groupings as described in this subsection.

Redundant overcurrent interrupting devices are provided for electrical circuits routed through RCCV penetrations if the maximum available fault current is greater than the continuous rating of the penetration. This avoids penetration damage in the event of failure of any single overcurrent device to clear a fault within the penetration or beyond it.

Control of Compliance with Separation Criteria During Design and Installation

The equipment nomenclature used on the ESBWR standard design is one of the primary mechanisms for ensuring proper separation. Each equipment and/or assembly of equipment carries a single number (e.g., the item numbers for motor drivers are the same as the machinery driven). Based on these identification numbers, each item can be identified as safety-related or nonsafety-related, and each safety-related item can further be identified to its division. This is carried through and dictates appropriate treatment at the design level during preparation of the detailed design drawings. Nonsafety-related equipment is separated where desired to enhance power generation reliability and availability.

Once the safety-related equipment has been identified within a safety-related division, the divisional assignment dictates a characteristic color (Subsection 8.3.1.3) for positive visual identification. Likewise, the divisional identification of all equipment, cable and raceways matches the divisional assignment of the system it supports.

Independence of Redundant Safety-Related Instrumentation and Control Systems

This subsection defines independence criteria applied to safety-related electrical systems and instrumentation and control equipment. Safety-related systems to which the criteria apply are those necessary to mitigate the effects of anticipated and abnormal operational transients or Design Basis Accidents. This includes safety-related systems and functions enumerated in Chapter 7. The term "systems" includes the overall complex of actuated equipment, actuation devices (actuators), logic, instrument channels, controls, and interconnecting cables that are required to perform system safety-related functions. The criteria outline the separation requirements necessary to achieve independence of safety-related functions compatible with the redundant and/or diverse equipment provided and postulated events.

General

Separation of the equipment for the safety-related systems referred to in Chapter 7 is accomplished so that they are in compliance with IEEE 603 (Reference 8.3-33), 10 CFR 50 Appendix A, GDC 17, and NRC Regulatory Guides 1.75 (IEEE 384) and 1.53 (IEEE 379).

Independence of mutually redundant and/or diverse safety-related equipment, devices, and cables is achieved by spatial separation, barriers, and electrical isolation. This protection is provided to maintain the independence of safety-related circuits and equipment so that the protective function required during and following a design basis event, including a single fire anywhere in the plant or a single active failure in any circuit or equipment, with one unaffected division out of service, can be accomplished with the remaining two divisions.

Separation Techniques

The methods used to protect redundant safety-related systems from results of single active failures or events are utilization of safety-related structures, spatial separation, 3-hour rated fire barriers, and isolation devices.

Safety-Related Structures — The basic design consideration in plant layout is that redundant circuits and equipment are located in separate safety-related areas and fire areas to the extent possible. The separation of safety-related circuits and equipment is such that the required independence is not compromised by the failure of mechanical systems served by the safety-related electrical system. For example, safety-related circuits are routed or protected so that failure of related mechanical equipment of one system cannot disable safety-related circuits or equipment essential to the operation of a redundant system.

Spatial Separation and/or Protective Barriers — Spatial (distance) separation and/or protective barriers are such that no locally generated force or missile resulting from a Design Basis Accident (DBA) or from random failure of equipment can disable a redundant safety-related function. Separation in all safety-related equipment and cable areas meets or exceeds the requirements of IEEE 384.

Main Control Room Panels — The protection system and safety-related control, logic, and instrument panels/racks are located in a safety-related structure in which there are no potential sources of missiles or pipe breaks that could jeopardize redundant cabinets and raceways.

Control, relay, and instrument panels/racks are designed in accordance with the following general criteria to preclude failure of nonsafety-related circuits causing failure of any safety-related circuit, and to preclude failure of any safety-related circuit causing failure of its redundant safety-related circuit. Single panels or instrument racks do not contain circuits or devices of the redundant safety-related protection system or nonsafety-related systems except:

1. Human factors engineering may require certain operator interface control panels to have human factors considerations that dictate that redundant protection system or safety-related system circuits or devices be located in a single panel. These circuits and devices are separated horizontally and vertically by the minimum distance required in IEEE 384 Subsection 6.6.2, or by steel barriers or enclosures.
2. Safety-related circuits and devices are also separated from the nonsafety-related circuits and devices that are present inside a panel. These circuits and devices are separated from each other horizontally and vertically by the minimum distance required in IEEE 384 Subsection 6.6.2, or by steel barriers or enclosures.
3. Where electrical interfaces between safety-related and nonsafety-related circuits or between safety-related circuits of different divisions cannot be avoided, safety-related isolation devices are used (see "Isolation Devices," below).
4. If two panels containing circuits of different safety-related divisions are less than 91.5 cm (3 ft) apart, there is a steel barrier between the two panels. Panel ends closed by steel end plates are considered to be acceptable barriers provided that terminal boards and wireways are spaced a minimum of 2.5 cm (1 inch) from the end plate.
5. Penetration of separation barriers within a subdivided panel is permitted, provided such penetrations are sealed or otherwise treated so that fire generated by an electrical fault could not reasonably propagate from one section to the other and disable a protective function.

6. If two or more safety-related divisions of fiber optic cable are brought to a fiber bypass switch, separation is not necessary in the immediate vicinity of the switch.

Isolation Devices — Where electrical interfaces between safety-related and nonsafety-related circuits or between safety-related circuits of different divisions cannot be avoided, safety-related isolation devices are used. Isolation is provided by the isolation devices defined in IEEE 384 Section 7.

Wiring from safety-related equipment or circuits which interface with nonsafety-related equipment circuits (that is, annunciators or data loggers) is safety-related and retains its divisional identification and separation up to and including its isolation device (usually fiber optic). The output circuits from this isolation device are classified as nonsafety-related and are physically separated from the safety-related wiring.

System Separation Requirements

The separation requirements pertaining to the RPS and other safety-related systems are given in the following subsections.

Reactor Protection (Trip) System (RPS) — The following separation requirements apply to the RPS wiring:

1. RPS sensors, sensor input circuit wiring, trip channels, and trip logic equipment are arranged in four functionally independent and divisionally separate groups designated Divisions 1, 2, 3 and 4. The trip channel wiring associated with the sensor input signals for each of the four divisions provides inputs to divisional logic cabinets which are in the same divisional group as the sensors and trip channels and which are functionally independent and physically separated from the logic cabinets of the redundant divisions.
2. Where trip channel data originating from sensors of one division are required for coincident trip logic circuits in other divisions, safety-related isolation devices are used as interface elements for signals sent from one division to another such as to maintain electrical isolation between divisions.
3. Sensor wiring for several trip variables associated with the trip channels of one division may be run together in the same conduits or in the same raceways of that division. Sensor wiring associated with one division is not routed with, or in close proximity to, any wiring or cabling associated with a redundant division.
4. The scram solenoid circuits, from the actuation devices to the solenoids of the scram pilot valves of the control rod drive (CRD) hydraulic control units, are run in grounded steel conduits, with no other wiring contained within the conduits, so that each scram group is protected against a hot short to any other wiring by a grounded enclosure. Short sections of flexible metallic conduit are permitted for making connections within panels and the connections to the solenoids.

5. Separate grounded steel conduits are provided for the scram solenoid wiring for each of four scram groups. Separate grounded steel conduits are also provided for both the A solenoid wiring circuits and for the B solenoid wiring circuits of the same scram group.
6. Scram solenoid conduits have a unique identification and are separately routed as Division 1 and 2 conduits for the A and B solenoids of the scram pilot valves, respectively. This corresponds to the divisional assignment of their power sources. The conduits containing the scram solenoid group wiring of any one scram group are also physically separated by a minimum separation distance of 2.5 cm (1 in.) from the conduits of any other scram group, and from raceways which contain either divisional or nonsafety-related circuits. The RPS conduits containing the scram group wiring for the A and B solenoids of the scram pilot valves (associated with Divisions 1 and 2, respectively) are separated from non-enclosed raceways associated with any of the four electrical divisions or non-divisional cables in accordance with IEEE 384 and Regulatory Guide 1.75.
7. Any scram group conduit may be routed alongside any cable or raceway containing either safety-related circuits (of any division), or any cable or raceway containing nonsafety-related circuits, as long as the conduit itself is not within the boundary of any raceway which contains either the divisional or the nonsafety-related circuits and is physically separated from said cables and raceway boundaries as stated in item (6) above.
8. The Startup Range Neutron Monitoring (SRNM) and Local Power Range Monitor (LPRM) subsystem cabling of the Neutron Monitoring System (NMS) cabling under the vessel is treated as divisional. The SRNM and LPRM cables are assigned to Divisions 1, 2, 3 and 4. Under the vessel, cables are enclosed as described in Subsection 9A.6.4.

Other Safety-Related Systems

1. Separation of redundant systems or portions of a system is such that no single active failure can prevent initiation and completion of a safety-related function.
2. The Standby Liquid Control system redundant safety-related controls are run so that no failure of standby liquid control function results from any single electrical failure.
3. Inboard and outboard isolation valves are redundant to each other so they are made independent of and protected from each other to the extent that no single active failure can prevent the operation of at least one of an inboard/outboard pair.
4. Isolation valve circuits require special attention because of their function in limiting the consequences of a pipe break outside the RCCV. Isolation valve control and power circuits are required to be protected from the pipe lines that they are responsible for isolating. Safety-related isolation valve wiring in the vicinity of the outboard (downstream) valve is installed in conduits and routed to take advantage of the mechanical protection afforded by the valve operator or other available structural barriers not susceptible to disabling damage

from the pipe line break. Additional mechanical protection (barriers) is placed as necessary between wiring and potential sources of disabling mechanical damage consequential to a break downstream of the outboard valve.

5. Automatic Depressurization System (ADS) and Gravity Driven Cooling System (GDCS) comprising the ECCS have their various sensors, logics, actuating devices and power supplies assigned to safety-related divisions, so that no single active failure can disable a redundant ECCS function.
   a. The wiring to the ADS solenoid valves within the drywell is run in rigid conduits. The conduits for ADS solenoids are divisionally separated from other ADS solenoid conduits and contain no other cable. Short lengths of flexible conduit are used to make the final raceway connection to the ADS valve solenoids.
   b. The wiring for ADS depressurization valve squibs is run in rigid conduits. The conduits are divisionally separated and contain only cable(s) associated with one division of power. Short lengths of flexible conduit are used to make the final raceway connection to the depressurization valve squibs.
   c. The wiring to the GDCS valve squibs is run in rigid conduits. The conduits are divisionally separated and contain only cable(s) associated with the valve squibs. Short lengths of flexible conduit are used to make the final raceway connection to the GDCS valve squibs.
6. Electrical equipment and raceways for safety-related systems are either not located in close proximity to primary steam piping (steam leakage zone), or designed for short-term exposure to the high temperature and humidity associated with a steam leak.
7. Safety-related electrical equipment located in the suppression pool level swell zone is limited to the suppression pool temperature monitors, which have their terminations sealed such that operation would not be impaired by submersion caused by pool swell or LOCA. These devices are qualified to the requirements of IEEE 323 for the environment in which they are located.
8. RCCV penetrations are arranged so that no design basis event can disable cabling in more than one division. Penetrations do not contain cables of more than one divisional assignment.
9. Inputs from safety-related equipment or circuits are safety-related and retain their divisional identification up through their safety-related isolation device. The output circuit from this isolation device supports a nonsafety-related function.

8.3.2 DC Power Systems

8.3.2.1 Description

Completely independent safety-related and nonsafety-related DC power systems are provided. The safety-related DC system is shown in Figure 8.1-3. The nonsafety-related DC system is shown in Figure 8.1-2.

Eight independent safety-related 250 VDC batteries are provided, two each for Divisions 1, 2, 3 and 4. They provide four divisions of independent and redundant onsite sources of power for operation of safety-related loads, monitoring and Main Control Room (MCR) emergency lighting.

Seven independent nonsafety-related DC batteries are provided consisting of five 250 VDC batteries and two 125 VDC batteries. The nonsafety-related DC systems supply power for control and switching, switchgear control, TSC, instrumentation, and station auxiliaries.

Battery cycle times are shown in Table 8.3-2.

8.3.2.1.1 Safety-Related Station Batteries and Battery Chargers

250V Safety-Related DC Systems Configuration

Figure 8.1-3 shows the overall 250 VDC system provided for safety-related Divisions 1, 2, 3 and 4. Divisions 1, 2, 3 and 4 consist of two separate batteries in each division. Each battery supplies power to its safety-related inverter for at least 72 hours following a design basis accident. The DC systems are operated ungrounded for increased reliability. Each of the safety-related battery systems has a 250 VDC battery, a battery charger, a main distribution bus, and a ground detection panel. One divisional battery charger is used to supply each group DC distribution panel bus and its associated battery. The divisional battery charger is fed from its divisional 480V isolation power center. The main DC distribution bus feeds the UPS inverter. Each division has a standby charger to act as a backup to either of the batteries of that division.

The four safety-related divisions are supplied power from four independent isolation power centers. The 250 VDC systems supply DC power to Divisions 1, 2, 3 and 4, and are designed as safety-related equipment in accordance with IEEE 308 (Reference 8.3-38) and IEEE 946 (Reference 8.3-1). The safety-related DC system is designed so that no single active failure in any division of the 250 VDC system results in conditions that prevent safe shutdown of the plant while a separate division has been taken out of service for maintenance.

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

Safety-Related Batteries

In Divisions 1, 2, 3, and 4, the two 250 volt safety-related batteries per division are sized together so that their total rated capacity will exceed the required battery capacity per division for 72-hour station blackout conditions. The DC system minimum battery terminal voltage at the end of the discharge period is 210 VDC (1.75 volts per cell). The maximum equalizing charge voltage for safety-related batteries is specified by the battery vendor and is as allowed by the voltage rating of the connected loads (UPS inverters). The UPS inverters are designed to supply 120 VAC power with DC input less than the minimum discharge voltage (210 VDC) and greater than the maximum equalizing charge voltage. The safety-related battery float voltage and maximum equalizing charge voltage values are included in Table 8.3-4.

The safety-related batteries have sufficient stored capacity without their chargers to independently supply the safety-related loads continuously for 72 hours. Each distribution circuit is capable of transmitting sufficient energy to operate all required loads in that circuit. Batteries are sized for the DC load in accordance with IEEE Standard 485 (Reference 8.3-2) with an expected 20-year service life and include margin to compensate for uncertainty in determining the battery state of charge. The battery banks are designed to permit the replacement of individual cells.

The safety-related batteries meet the qualification requirements of Section 3.11.

Safety-Related Battery Chargers

The safety-related battery chargers are full wave rectifiers. The housings are freestanding, NEMA Type 1, and are ventilated. The chargers are suitable for float charging the batteries. The chargers operate from a 480 volt, 3 phase, 60 Hz supply. The power for each divisional battery charger is supplied by that division's dedicated isolation power center. The standby battery charger is used to equalize either of its associated divisional batteries, or as a replacement to the normal charger associated with that battery.

Standby chargers are supplied from the same isolation power center as the normal charger.

Each battery charger is capable of restoring its battery after a bounding design basis event discharge within 24 hours to a state that the battery can perform its design basis function for subsequent postulated operational and design basis functions, while at the same time supplying the largest combined demands associated with the individual battery.

The battery chargers are the constant voltage type, adjustable between 240 and 290 volts, with the capability of operating as battery eliminators. The battery eliminator feature is incorporated as a precautionary measure to protect against the effects of inadvertent disconnection of the battery. The battery chargers are designed to function properly and remain stable on the disconnection of the battery. Variation of the charger output voltage is less than ± 1 percent with or without the battery connected. The maximum output ripple for the charger is 30 millivolts RMS with the battery, and less than 2% RMS without the battery.

The battery charger's output is of a current limiting design. The battery chargers are designed to prevent their AC source from becoming a load on the batteries because of power feedback from loss of AC power. The battery charger's output voltage is protected against overvoltage by a high voltage shutdown circuit. The overvoltage protection feature is incorporated to protect equipment from damage caused by high voltage. When high voltage occurs, the unit disconnects the auxiliary voltage transformer, which results in charger shutdown. Loss of charger input voltage or charger shutdown is alarmed in the control room.

Ventilation

A safety-related ventilation system is not required for the batteries to perform their safety-related functions. However, battery rooms are ventilated by a system designed to remove the hydrogen gas produced during the charging of batteries. The system is designed to preclude the possibility of hydrogen accumulation. (See Subsection 9.4.6).

Inspection, Maintenance, and Testing

An initial composite test of the onsite DC power systems is a prerequisite to initial fuel loading. This test verifies that each division's total battery capacity is sufficient to satisfy a design basis load demand profile under the conditions of a LOCA and loss of preferred power. Battery capacity tests are conducted in accordance with IEEE 450 (Reference 8.3-42). These tests ensure that the batteries have the capacity to meet safety-related load demands.

In-service tests, inspections, and resulting maintenance of the DC power systems including the batteries, chargers, and auxiliaries are specified in the ESBWR Technical Specifications that are based on IEEE 450 and manufacturer recommendations (see Reference 8.3-42).

Station Blackout

The station blackout scenario (defined in 10 CFR 50.63, Regulatory Guide 1.155 and Appendix B to SRP 8.2) includes the complete loss of all offsite and onsite AC power, but not the loss of available AC power buses fed by station batteries through inverters, as with the ESBWR. The ESBWR Design Bases rely upon battery power to achieve and maintain safe shutdown for 72 hours. The batteries are adequately sized for the station blackout loads. The station blackout safety analysis is provided in Subsection 15.5.5.

Training and procedures to mitigate an SBO event are implemented in accordance with Section 13.2 and Section 13.5. As recommended by NUMARC 87-00 (Reference 8.3-201), SBO event mitigation procedures address SBO response (e.g., restoration of onsite standby power sources), AC power restoration (e.g., coordination with transmission system load dispatcher), and severe weather guidance (e.g., identification of site specific actions to prepare for the onset of severe weather such as an impending tornado), as applicable.The ESBWR is a passive design and does not rely on offsite or onsite AC sources of power for at least 72 hours after an SBO event, as described in Section 15.5.5, Station Blackout. In addition, there are no nearby large power sources, such as a gas turbine or black start fossil fuel plant, that can directly connect to the station to mitigate the SBO event. Restoration from an SBO event will be contingent upon power being made available from any one of the following sources:

- Any of the standby or ancillary diesel generators
- Restoration of any one of the three 345 kV transmission lines described in Section

8.3.2.1.2 Nonsafety-Related Station Batteries and Battery Chargers

125V and 250V Nonsafety-Related DC Systems Configuration

Figure 8.1-2 shows the overall 125V and 250V nonsafety-related DC systems. The DC systems are operated ungrounded for increased reliability. Each of the DC systems has a battery, a battery charger, a standby battery charger, main DC distribution bus, and ground detection panel, except the 250 VDC load groups A and B. The A and B load groups each have two normal battery chargers, one standby battery charger, two batteries, a ground detection panel, and two DC distribution buses. The main DC distribution buses feed the local DC distribution panels, UPS inverter and/or DC motor control center.

The plant design and circuit layout of the nonsafety-related DC systems provide physical separation of the equipment, cabling and instrumentation associated with the load groups of nonsafety-related equipment. Each 125V and 250 VDC battery is separately housed in a ventilated room apart from its charger, distribution, and ground detection panels. Equipment of each load group of the DC distribution system is located in an area separated physically from the other load groups.

The nonsafety-related DC power is required for control and switching functions such as the control of the main generator circuit breaker, 13.8 kV, 6.9 kV and 480V switchgear, DC motors, control relays, meters and indicators.

Nonsafety-Related Batteries

The 125 volt nonsafety-related batteries are sized for 2-hour duty cycles at a discharge rate of 2 hours, based on a terminal voltage of 1.75 volts per cell. The DC system minimum battery terminal voltage at the end of the discharge period is 105 volts. The maximum equalizing charge voltage for 125V batteries is specified by the battery vendor.

The 250 volt nonsafety-related batteries are sized for 2-hour duty cycles at a discharge rate of 2 hours, based on a terminal voltage of 1.75 volts per cell. The DC system minimum battery terminal voltage at the end of the discharge period is 210 volts. The maximum equalizing charge voltage for 250V batteries is specified by the battery vendor.

The nonsafety-related batteries have sufficient stored capacity without their chargers to independently supply their loads continuously for at least 2 hours. Each distribution circuit is capable of transmitting sufficient energy to start and operate all required loads in that circuit.

The batteries are sized so that the sum of the required loads does not exceed the battery ampere-hour rating, or warranted capacity at end-of-installed-life with 100% design demand. The battery banks are designed to permit replacement of individual cells

Nonsafety-Related Battery Chargers

The nonsafety-related battery chargers are full wave rectifiers or an acceptable alternate design. The housings are freestanding, NEMA Type 1, and are ventilated. The chargers are suitable for float charging the batteries. The chargers operate from a 480 volt, 3 phase, 60 Hz supply. Each normal charger is supplied from a separate power center than its standby charger, and is backed by the standby diesel-generator.

Standby chargers are used to equalize battery charging. Standby chargers are supplied from a different power center than the normal charger.

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

The battery charger’s output is of a current limiting design. The battery chargers are designed to prevent their AC source from becoming a load on the batteries caused by power feedback from a loss of AC power. The battery charger’s output voltage is protected against overvoltage by a high voltage shutdown circuit. The overvoltage protection feature is incorporated to protect equipment from damage caused by high voltage. When high voltage occurs, the unit disconnects the auxiliary voltage transformer, which results in charger shutdown. Loss of charger input voltage and charger shutdown is alarmed in the control room.

Ventilation

Battery rooms are ventilated by a system designed to remove the hydrogen gas produced during the charging of batteries. The system is designed to preclude the possibility of hydrogen accumulation. Refer to Subsection 9.4.7.

8.3.2.2 **Analysis**

8.3.2.2.1 **Safety-Related DC Power Systems**

The 480 VAC power supplies for the divisional battery chargers are from the individual isolation power centers to which the particular 250 VDC system belongs (Figure 8.1-3). These isolation power centers are fed directly from the PIP nonsafety-related buses, which are backed up by the standby diesel generators. In this way, separation between the independent systems is maintained and the AC power provided to the chargers can be from either preferred or standby AC power sources.

The DC system is arranged so that the probability of an internal system failure resulting in loss of that DC power system is extremely low. A ground detection system is employed for prompt detection of grounds. Important system components are either self-alarming on failure, or capable of clearing faults, or being tested during service to detect faults. Each battery set is located in its own ventilated battery room. All abnormal conditions of important system parameters such as system grounds, charger failure and low bus voltage are alarmed in the main control room and/or locally.

8.3.2.2.2 **Regulatory Requirements and Guides**

The following analyses demonstrate compliance of the safety-related Divisions 1, 2, 3 and 4 DC power systems to NRC GDC, NRC Regulatory Guides, and other criteria consistent with the SRP. The analyses establish the ability of the system to sustain credible single active failure with one division already out of service and the remaining two divisions retain their capacity to function for 72 hours before requiring recharge.

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

GDC:

- GDC 2, 4, 17, 18 and 50 - The DC power system complies with these GDC, which are generically addressed in Subsection 8.1.5.2.4.

Regulatory Guides:

- Regulatory Guide 1.6, "Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems." The ESBWR Standard Plant does not need or have any safety-related standby AC power sources; however, portions pertaining to the safety-related DC system are addressed within Subsection 8.3.2.1.1. The ESBWR offsite and onsite nonsafety-related power sources do comply with independence and redundancy between their sources and distribution systems.
- Regulatory Guide 1.32, "Criteria for Power Systems for Nuclear Power Plants." Safety-related DC power sources are provided to support passive core cooling and containment integrity safety functions. No offsite or diesel-generator-derived AC power is required for 72 hours.
- Regulatory Guide 1.47, "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems."
- Regulatory Guide 1.53, "Application of the Single Failure Criteria to Safety Systems."

- Regulatory Guide 1.63, "Electric Penetration Assemblies in Containment Structures for Nuclear Power Plants."
- Regulatory Guide 1.75, "Criteria for Independence of Electrical Safety Systems." Safe shutdown relies only upon DC-derived power and meets the design requirements for physical independence.
- Regulatory Guide 1.106, "Thermal Overload Protection for Electrical Motors and Motor Operated Valves." The ESBWR does not require electric motors or motor operated valves to perform any safety-related function, therefore this regulatory guide is not applicable.
- Regulatory Guide 1.118, "Periodic Testing of Electric Power and Protection Systems." (See Subsection 13.5.2 for Operating and Maintenance Procedures and Chapter 16 for Technical Specifications.)
- Regulatory Guide 1.128, "Installation Designs and Installation of Large Lead Storage Batteries for Nuclear Power Plants."
- Regulatory Guide 1.129, "Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Nuclear Power Plants."
- Regulatory Guide 1.153, "Criteria for Safety Systems."
- Regulatory Guide 1.155, "Station Blackout," The ESBWR uses battery power to achieve and maintain safe shutdown. Thus, the ESBWR meets the intent of Regulatory Guide 1.155. The Station Blackout evaluation is provided in Subsection 15.5.5.

Branch Technical Positions (BTPs):

- BTP ICSB 21, "Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems."

The DC power system is designed consistent with this criterion.

Other SRP Criteria:

Consistent with Table 8-1 of the SRP, there are no other criteria applicable to DC power systems.

8.3.3 **Fire Protection of Cable Systems**

The basic concept of fire protection for the cable system in the ESBWR design is that it is incorporated into the design and installation rather than added onto the systems. Fire protection is built into the system by cable separation; by limiting cable tray fill; by limiting cable ampacity to levels that prevent overheating and insulation failures (and resultant possibility of fire); and by use of fire resistant and non-propagating cable insulation. Fire suppression systems (for example, automatic sprinkler systems) are provided as defined in Subsection 9.5.1.2. Further circuit analysis is provided in Section 9A.6.

8.3.3.1 **Resistance of Cables to Combustion**

The electrical cable insulation is designed to resist the onset of combustion by choice of insulation and jacket materials, which have flame-resistive and self-extinguishing characteristics. Polyvinyl chloride and neoprene cable insulation are not used in the ESBWR. Each power, control, and instrumentation cable is specified to pass the vertical tray flame test in accordance with IEEE 1202 (Reference 8.3-11). All cable trays are fabricated from noncombustible material.

8.3.3.2 **Cables and Raceways**

Power and control cables are specified for continuous operation at conductor temperature not exceeding 90°C (194°F) and to withstand an emergency overload temperature of up to 130°C (266°F) in accordance with ICEA S-95-658/NEMA WC-70 (Reference 8.3-5). The base ampacity rating of the cables is established as published in IEEE 835 (Reference 8.3-6) and ICEA P-54-440/NEMA WC-51 (Reference 8.3-7).

Cables are specified to continue to operate at 100% relative humidity with a service life expectancy of 60 years. Safety-related cables are designed to survive the LOCA ambient condition at the end of the 60-year life span. A water-tree formation retardant is specified when polyethylene cable insulation is selected for medium voltage use. A dry cure process is specified for cable insulation. Certified proof tests are performed on cables to demonstrate 60-year life, and resistance to radiation, flame, and the environment. Refer to IEEE 383 (Reference 8.3-4) and ICEA S-95-658/NEMA WC-70 (Reference 8.3-5). The testing methodology ensures such attributes are acceptable for the 60-year life.

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

- Certify 60-year life by thermal aging.
- Prove the radiation resistance by exposure of aged specimens to integrated dosage.
- Prove mechanical/electrical tests of cable for environmental conditions specified.
- Prove flame resistance by the vertical tray, 70,000 Btu/hr flame test for 20 minutes (minimum).
- Show acceptable levels of gas evolution by an acid gas generation test.

Cable tray fill is limited to 40% of the cross-sectional area for trays containing power cables (600V or less); and 50% cross-sectional area for trays containing control and instrumentation cables. If tray fill exceeds the above maximum fills, the tray fill is justified and documented. Medium voltage cable tray fill is single layer maintained.

Cable splices in raceways are prohibited. Cable splices are only made in manholes, boxes or suitable fittings. Splices in cables passing through the containment penetration assemblies are made in terminal boxes located adjacent to the penetration assembly. (See Regulatory Guide 1.75 for splice exception.)

The cable installation is such that direct impingement of fire suppressant does not prevent safe reactor shutdown.

ESBWR standard plant design cables are routed in tunnels and raceway designed to remain dry and not be susceptible to flooding and moisture intrusion.

[START COM 8.3-001] The COL Holder will verify that owner yard scope site specific underground or inaccessible power and control cable runs to the PSWS and DG Fuel Oil Transfer System that have accident mitigating functions and are susceptible to protracted exposure to wetted environments or submergence as a result of tidal, seasonal, or weather event water intrusion are adequately identified and monitored for appropriate corrective actions under the Maintenance Rule (MR) program described in Section 17.6.4. **[END COM 8.3-001]**

8.3.3.3 Localization of Fires

In the event of a fire, the installation design localizes the physical effects of the fire by preventing its spread to adjacent areas or to adjacent raceways of different divisions. Floors and walls are effectively used to provide vertical and horizontal fire-resistive separations between redundant cable divisions. Localization of the effect of fires on the electric system is accomplished by independence and separation of redundant cable/raceway systems and equipment as described in Subsection 8.3.1.4.

Three hour fire rated concrete barriers are used between the RATs, the UATs and the main transformers and spare main transformer as described in Subsection 9A.4.7, “Yard", and include containment/collection of transformer oil.

In any given fire area, equipment is typically from only one safety-related division. This design objective is not always met due to other overriding design requirements. However, ESBWR always complies to Regulatory Guide 1.75 which endorses IEEE 384 Reference 8.3-10 as described in Subsection 8.1.5.2.4 and Table 8.1-1. In addition, an analysis is made and documented in Appendix 9A to ascertain that the requirement of being able to safely shut down the plant with complete burnout of the fire area without recovery of the equipment is met. The fire detection, fire suppression, and fire containment systems provided, as described in Appendix 9A, assure that a fire of this magnitude does not occur.

8.3.4 COL Information

8.3.4-1-A Safety-Related Battery Float and Equalizing Voltage values

This COL item is addressed in Subsection 8.3.2.1.1.

8.3.4-2-A Identification and Monitoring of Underground or Inaccessible Power and Control Cables to the PSWS and DG Fuel Oil Transfer System Equipment That Have Accident

Mitigating Functions.

This COL item is addressed in Subsection 8.3.3.2.

8.3.5 References

8.3-1 IEEE 946, "Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations."

8.3-2 IEEE 485, "Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications."

8.3-3 (Deleted)

8.3-4 IEEE 383, "Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations."

8.3-5 ICEA S-95-658/NEMA WC-70, "Nonshielded 0-2kV Cables."

8.3-6 IEEE 835, "Standard Power Cable Ampacity Tables."

8.3-7 ICEA P-54-440/NEMA WC-51, "Ampacities of Cables Installed in Cable Trays."

8.3-8 (Deleted)

8.3-9 (Deleted)

8.3-10 IEEE 384, "Standard Criteria for Independence of Class 1E Equipment and Circuits."

8.3-11 IEEE 1202, "Standard for Flame-Propagation Testing of Wire and Cable."

8.3-12 IEEE Standard C57.12.00, "Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers."

8.3-13 IEEE 323, "Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations."

8.3-14 IEEE 344, "Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations."

8.3-15 IEEE 519, "Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems."

8.3-16 IEEE 379, "Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems."

8.3-17 NEMA ICS-2, "Industrial Control and Systems: Controllers, Contactors, and Overload Relays Rated 600 Volts."

8.3-18 Underwriter's Laboratories Standard No. 845, "UL Standard for Safety for Motor Control Centers, 4TH Edition."

8.3-19 IEEE C37.13, "Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures."

8.3-20 IEEE C37.16, "Low Voltage Power Circuit Breakers and AC Power Circuit Protectors - Preferred Ratings, Related Requirements, and Application Recommendations."

8.3-21 IEEE C37.17, "American National Standard for Trip Devices for AC and General Purpose DC Low Voltage Power Circuit Breakers."

8.3-22 ANSI C37.50, "Switchgear Low Voltage AC Power Circuit Breakers Used in Enclosures - Test Procedures."

8.3-23 Underwriter's Laboratories Standard No. 489, "UL Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures."

8.3-24 NEMA AB-1, "Molded Case Circuit Breakers and Molded Case Switches."

8.3-25 IEEE C37.04, "Standard Rating Structure for AC High-Voltage Circuit Breakers."

8.3-26 IEEE C37.06, "AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis - Preferred Ratings and Related Required Capabilities."

8.3-27 IEEE C37.09, "Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis."

8.3-28 EEE C37.010, "Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis."

8.3-29 IEEE C37.11, "Standard Requirements for Electrical Control for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis."

8.3-30 IEEE 741, "Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations."

8.3-31 IEEE C37.20.2, "Standard for Metal-Clad Switchgear."

8.3-32 IEEE C37.100, "Standard Definitions for Power Switchgear."

8.3-33 IEEE 603, "Standard Criteria for Safety Systems for Nuclear Power Generating Stations."

8.3-34 IEEE C57.12.80, "Standard Terminology for Power and Distribution Transformers."

8.3-35 IEEE C57.12.90, "Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers."

8.3-36 IEEE C57.93, "Guide for Installation of Liquid-Immersed Power Transformers."

8.3-37 IEEE 338, "Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems."

8.3-38 IEEE 308, "Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations."

8.3-39 IEEE 100, "The Authoritative Dictionary of IEEE Standards Terms."

8.3-40 IEEE C37.32, "High-Voltage Air Disconnect Switches Interrupter Switches, Fault Initiating Switches, Grounding Switches, Bus Supports and Accessories Control Voltage Ranges-Schedules of Preferred Ratings, Construction Guidelines and Specifications."

8.3-41 IEEE 484, “Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications.”

8.3-42 IEEE 450, “Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.”

8.3-201 Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors, NUMARC87-00, Revision 1, August 1991.

Table 8.3-1 Diesel-Generator Alarms

DESCRIPTION	ALARM	
	LOCAL	REMOTE
Diesel engine running	X	X
D/G trouble		X
D/G controls not in Auto	X	X
D/G main breaker trip	X	X
D/G in maintenance mode	X	X
D/G in parallel mode	X	X
D/G overspeed	X	X
Engine failed to start	X	X
Generator Differential relay	X	X
Reverse power relay	X	X
Field relay	X	X
Overcurrent relay	X	X
Lock-out relay operated	X	X
Overvoltage relay	X	X
Ground relay	X	X
Over temperature relay	X	X
Undervoltage relay	X	X
Frequency relay	X	X
	INDICATION	
DESCRIPTION	LOCAL	REMOTE
Engine speed	X	X
Engine hour meter	X	X
Generator output voltage	X	X
Current	X	X
Active power output	X	X
Reactive power output	X	X

Table 8.3-2 Battery Cycle Times

Safety-Related	Division/Train	Rated Voltage (V)	Cycle Time (h)
Y	1	250	72
Y	1	250	72
Y	2	250	72
Y	2	250	72
Y	3	250	72
Y	3	250	72
Y	4	250	72
Y	4	250	72
N	A	250	2
N	A	250	2
N	B	250	2
N	B	250	2
N	C	250	2
N	A	125	2
N	B	125	2

Table 8.3-3 250VDC Safety-Related Battery Nominal Load Requirements

	DC Power (Watts)							
	Normal	**0-1 min DBA**	**1-5 min**	**5-7 min**	**7-15 min**	**15-17 min**	**17-60 min**	**1-72 hours**
Division 1	24697	26259	19618	22118	20501	20618	20501	20501
Division 2	24697	26259	19618	22118	20501	20618	20501	20501
Division 3	22040	23604	23993	26180	24563	24680	24563	24563
Division 4	22040	23604	23993	25805	24188	24305	24188	24188

Notes:

1. The loads assumed for each divisional battery are estimated nominal values. These nominal loads are based on assumed equipment vendor information, best engineering load estimates, and preliminary Q-DCIS load values.
2. The loads for RMUs powering solenoid valves and squib valves are based on the assumption that the solenoid valves would be operable (energized) for 72 hours. The Q-DCIS design limits the energized state of the squib valves to 2 minutes (time intervals 5-7 minutes and 15-17 minutes). This will conservatively encompass all design basis scenarios.
3. 60°F is the minimum operable temperature used in the sizing calculation for the safety-related batteries in the four divisions shown above.
4. The sizing calculation used for ESBWR safety-related lead acid batteries is the methodology of IEEE 485, which includes an overall margin that is conservative and bounding. The final margins of safety are factors greater than the IEEE standard required, based on the industry uncertainties of deep cycle discharge batteries. Aging factor, temperature factor, design margin factor, state of charge, and the ability to recharge in 24 hours (IEEE 946) were all employed in this calculation.
5. The margins listed above in Notes 2, 3 and 4 ensure that a single 6000 Ah battery has the capacity to power a total division for a period of time greater than 36 hours but less than 72 hours at the end of a 20 year life.

Table 8.3-4 Safety-Related DC and UPS Nominal Component Data

a. Batteries
Two 250 VDC batteries per division, (two parallel strings of 120 lead acid cells per string and 240 cells per battery) 6000 Ah. per battery, 12,000 Ah per division (8 hour rate to 1.75 V/cell @77°F) and qualified to a 72 hour duty cycle.
b. Charger
AC input- 480 VAC, 3-phase, 60 Hz DC output 250 VDC, 500 A continuous - float voltage @77°F-267.6 VDC at the battery terminals - maximum equalizing charge voltage @77°F -288 VDC at the battery terminals
c. Uninterruptible Power Supply (UPS)
i) Inverter - 40 kVA with 250 VDC input and 120 VAC, 60 Hz output - AC output voltage regulation of ±1% steady state - output frequency variation within ±0.1% of nominal 60 Hz - total harmonic distortion <5% (Deleted) (Deleted)

Note:

1. See Figures 8.1-3 and 8.1-4 for the configurations of the safety-related DC and UPS systems.

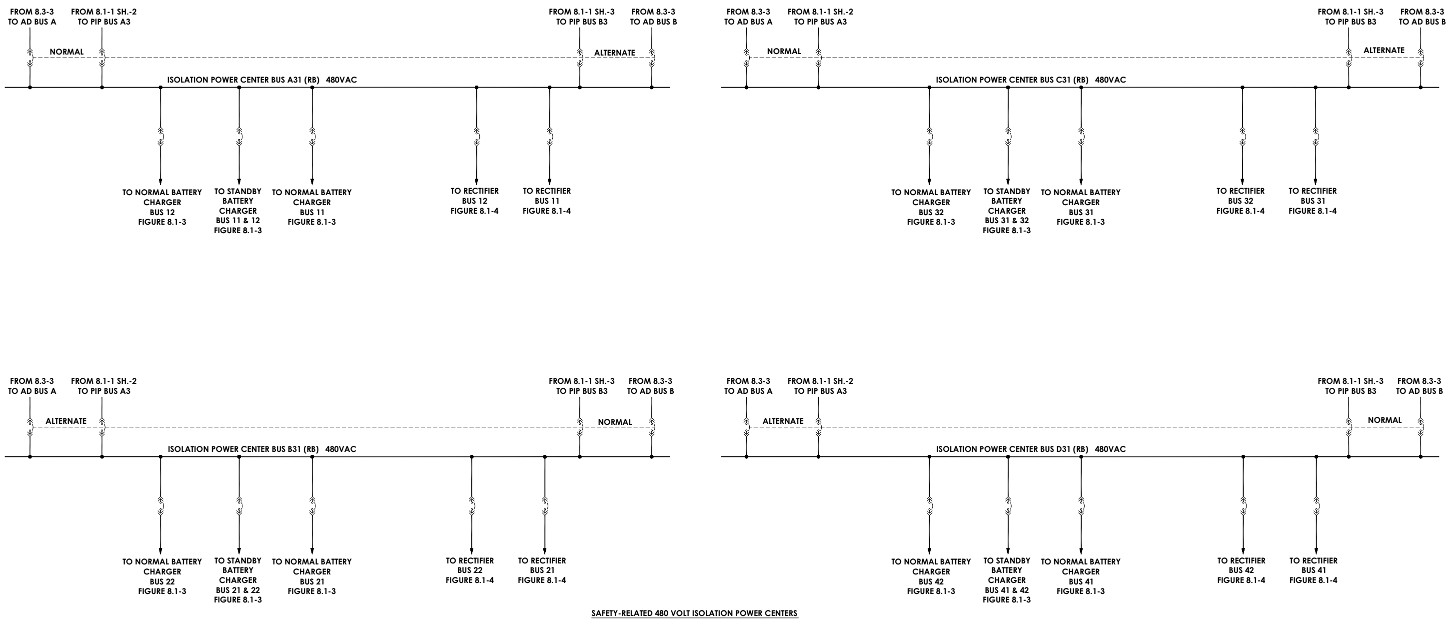
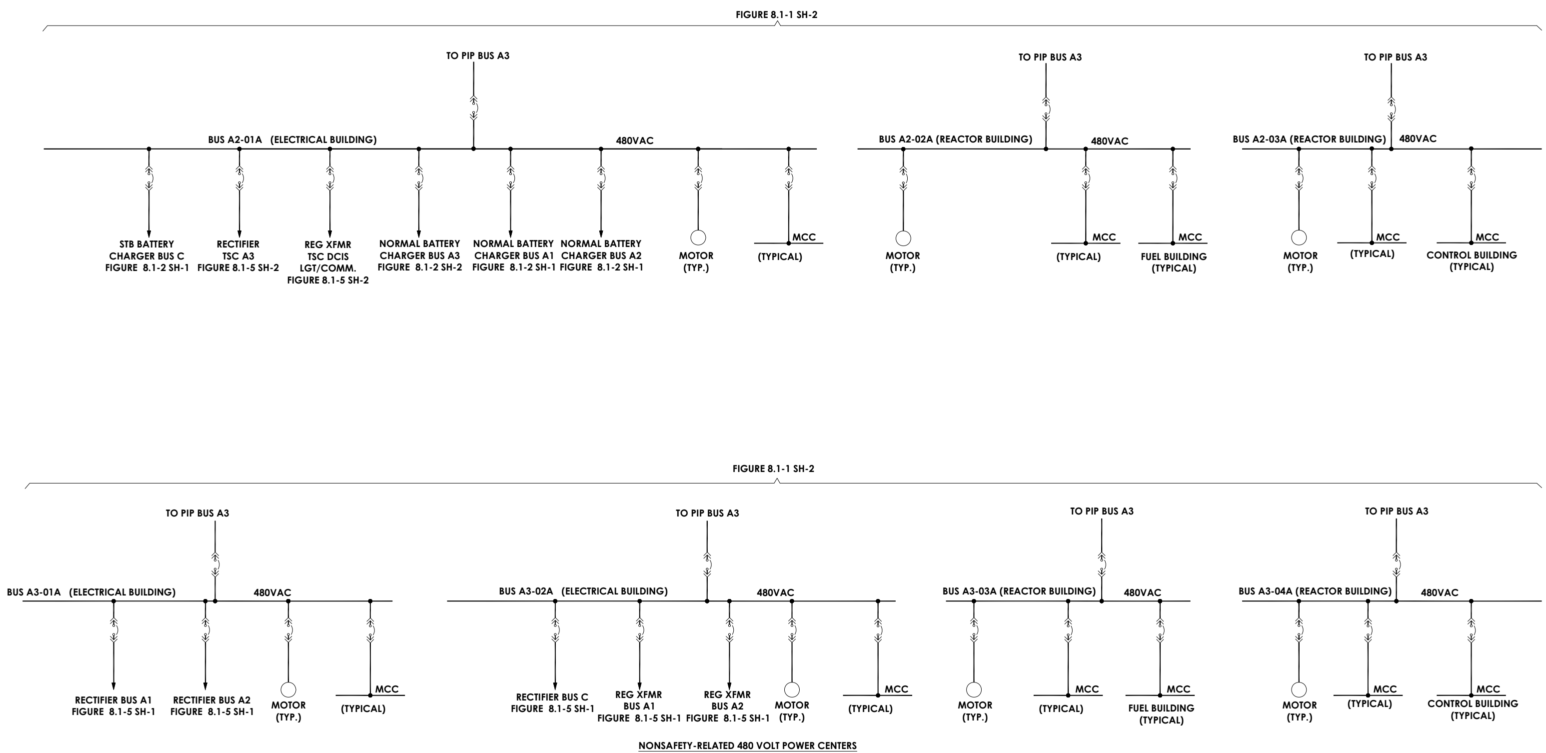
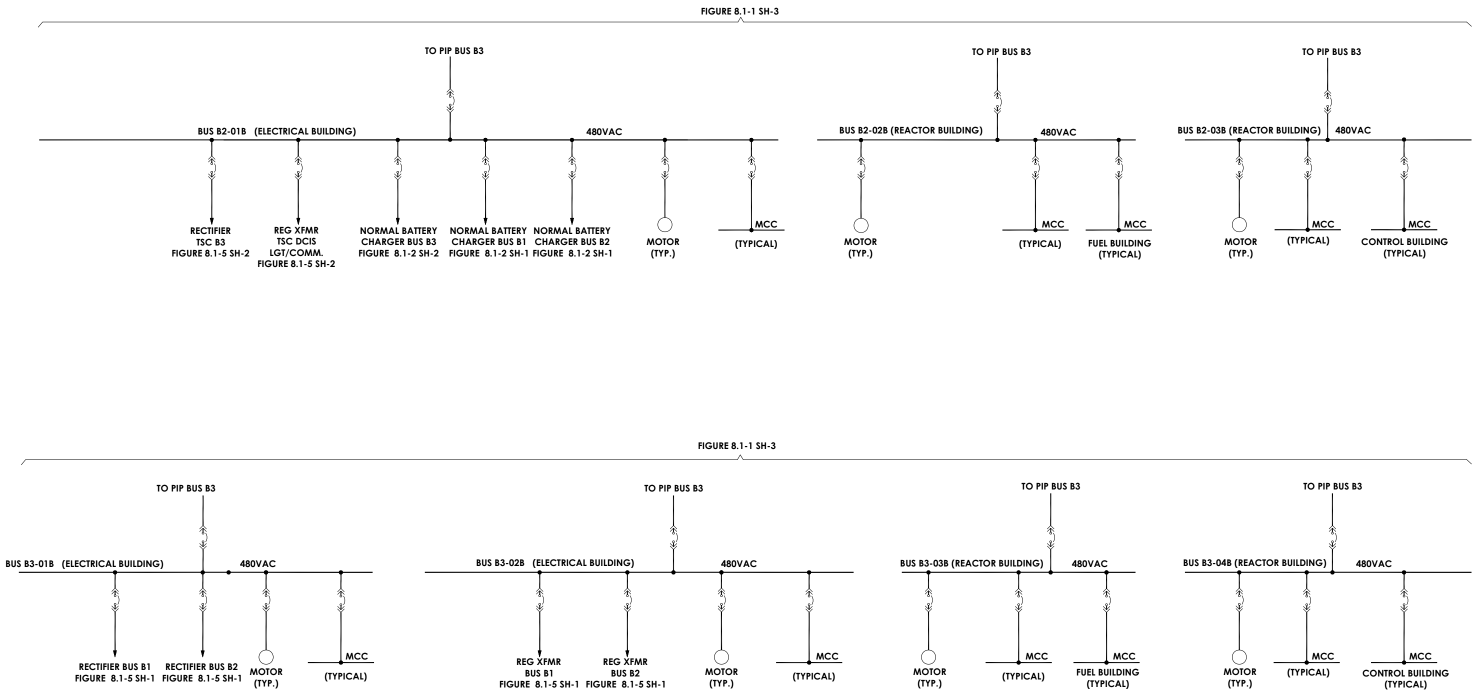
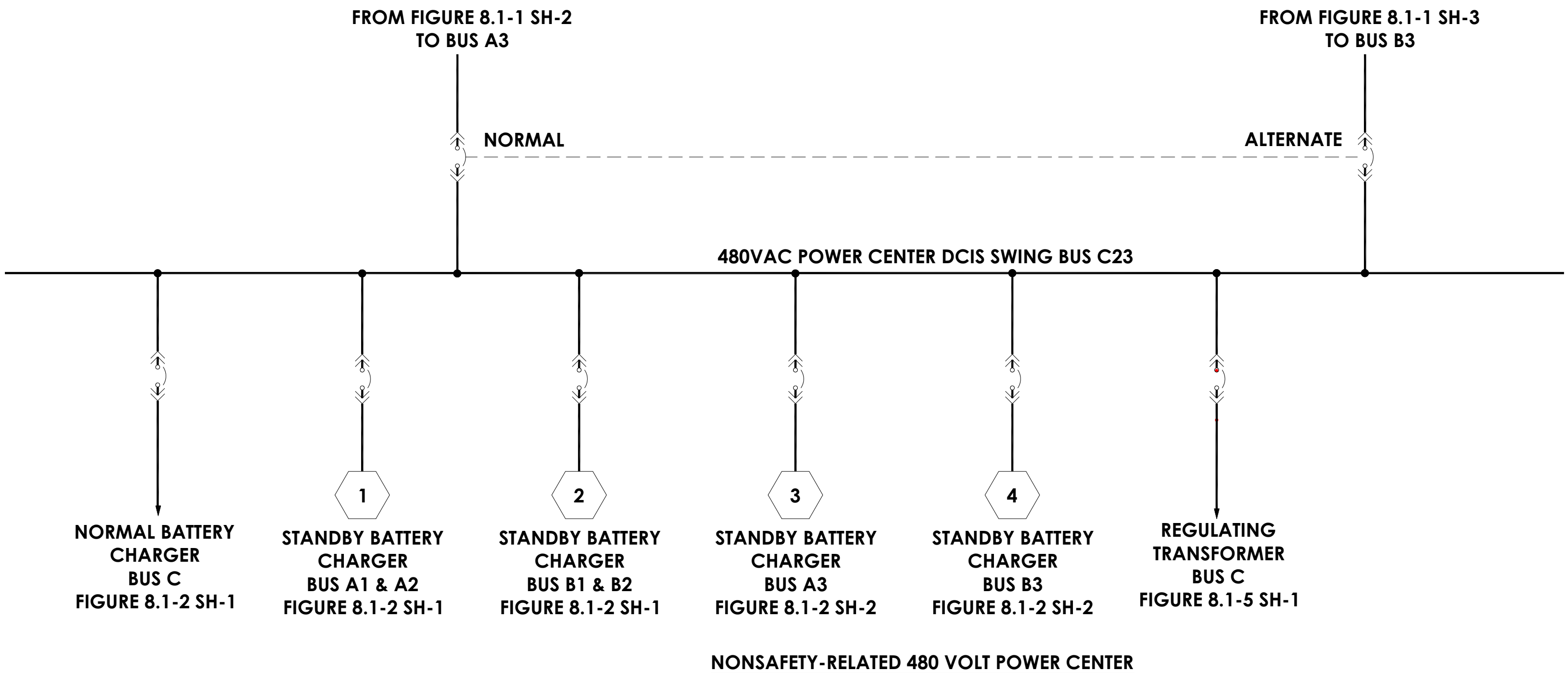

FROM 8.3-3 TO AD BUS A
FROM 8.1-1 SH.-2 TO PIP BUS A3
NORMAL
FROM 8.1-1 SH.-3 TO PIP BUS B3
FROM 8.3-3 TO AD BUS B
ALTERNATE
ISOLATION POWER CENTER BUS A31 (RB) 480VAC
TO NORMAL BATTERY CHARGER BUS 12 FIGURE 8.1-3
TO STANDBY BATTERY CHARGER BUS 11 & 12 FIGURE 8.1-3
TO NORMAL BATTERY CHARGER BUS 11 FIGURE 8.1-3
TO RECTIFIER BUS 12 FIGURE 8.1-4
TO RECTIFIER BUS 11 FIGURE 8.1-4
FROM 8.3-3 TO AD BUS A
FROM 8.1-1 SH.-2 TO PIP BUS A3
NORMAL
FROM 8.1-1 SH.-3 TO PIP BUS B3
FROM 8.3-3 TO AD BUS B
ALTERNATE
ISOLATION POWER CENTER BUS C31 (RB) 480VAC
TO NORMAL BATTERY CHARGER BUS 32 FIGURE 8.1-3
TO STANDBY BATTERY CHARGER BUS 31 & 32 FIGURE 8.1-3
TO NORMAL BATTERY CHARGER BUS 31 FIGURE 8.1-3
TO RECTIFIER BUS 32 FIGURE 8.1-4
TO RECTIFIER BUS 31 FIGURE 8.1-4
FROM 8.3-3 TO AD BUS A
FROM 8.1-1 SH.-2 TO PIP BUS A3
ALTERNATE
FROM 8.1-1 SH.-3 TO PIP BUS B3
FROM 8.3-3 TO AD BUS B
NORMAL
ISOLATION POWER CENTER BUS B31 (RB) 480VAC
TO NORMAL BATTERY CHARGER BUS 22 FIGURE 8.1-3
TO STANDBY BATTERY CHARGER BUS 21 & 22 FIGURE 8.1-3
TO NORMAL BATTERY CHARGER BUS 21 FIGURE 8.1-3
TO RECTIFIER BUS 22 FIGURE 8.1-4
TO RECTIFIER BUS 21 FIGURE 8.1-4
FROM 8.3-3 TO AD BUS A
FROM 8.1-1 SH.-2 TO PIP BUS A3
ALTERNATE
FROM 8.1-1 SH.-3 TO PIP BUS B3
FROM 8.3-3 TO AD BUS B
NORMAL
ISOLATION POWER CENTER BUS D31 (RB) 480VAC
TO NORMAL BATTERY CHARGER BUS 42 FIGURE 8.1-3
TO STANDBY BATTERY CHARGER BUS 41 & 42 FIGURE 8.1-3
TO NORMAL BATTERY CHARGER BUS 41 FIGURE 8.1-3
TO RECTIFIER BUS 42 FIGURE 8.1-4
TO RECTIFIER BUS 41 FIGURE 8.1-4
SAFETY-RELATED 480 VOLT ISOLATION POWER CENTERS

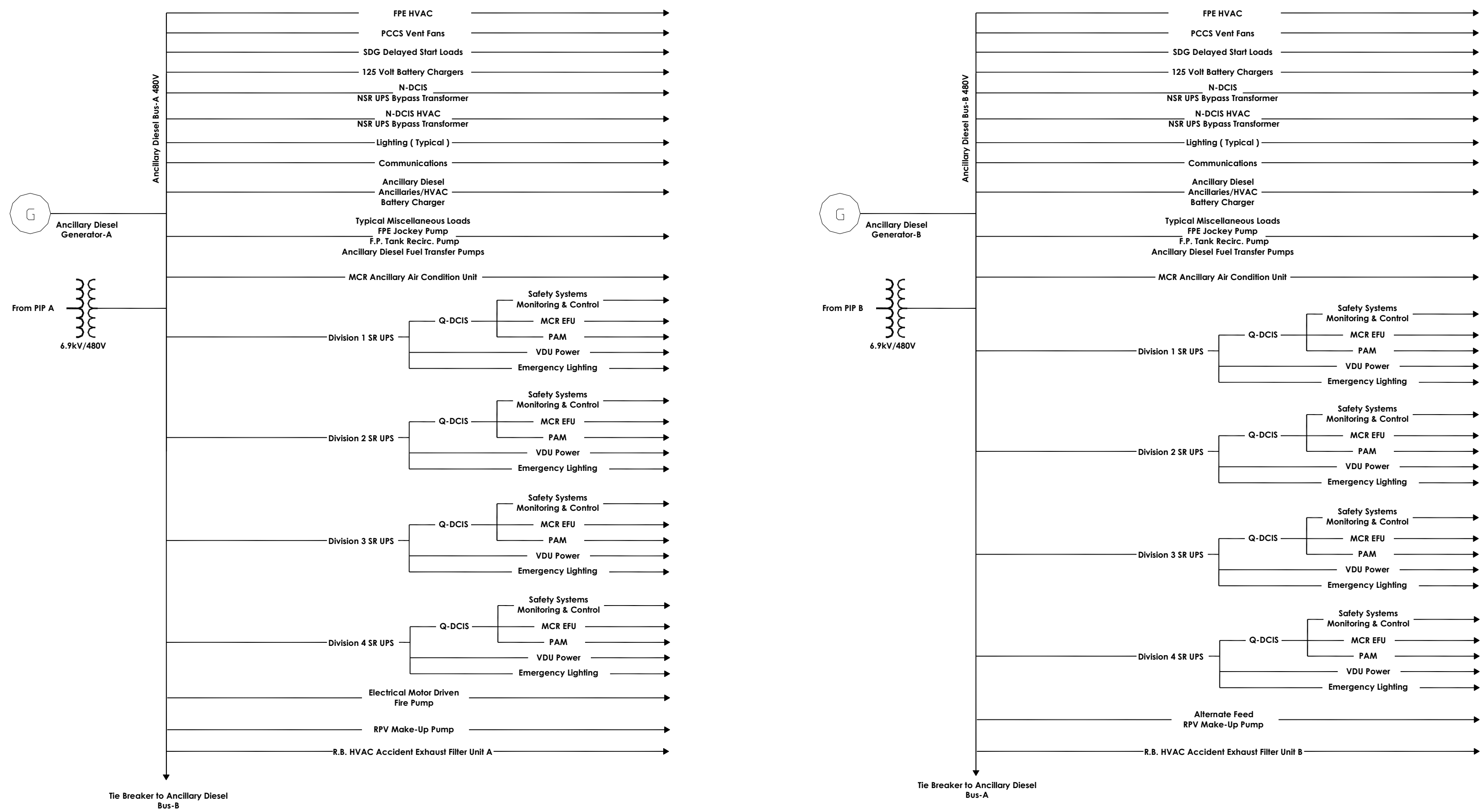
Figure 8.3-2 Nonsafety Related 480 Volt Power Centers (Sheet 1 of 3)





NONSAFETY-RELATED 480 VOLT POWER CENTERS


FROM FIGURE 8.1-1 SH-2
TO BUS A3
FROM FIGURE 8.1-1 SH-3
TO BUS B3
NORMAL
ALTERNATE
480VAC POWER CENTER DCIS SWING BUS C23
1
2
3
4
NORMAL BATTERY CHARGER BUS C FIGURE 8.1-2 SH-1
STANDBY BATTERY CHARGER BUS A1 & A2 FIGURE 8.1-2 SH-1
STANDBY BATTERY CHARGER BUS B1 & B2 FIGURE 8.1-2 SH-1
STANDBY BATTERY CHARGER BUS A3 FIGURE 8.1-2 SH-2
STANDBY BATTERY CHARGER BUS B3 FIGURE 8.1-2 SH-2
REGULATING TRANSFORMER BUS C FIGURE 8.1-5 SH-1
NONSAFETY-RELATED 480 VOLT POWER CENTER


Ancillary Diesel Bus-A 480V
FPE HVAC
PCCS Vent Fans
SDG Delayed Start Loads
125 Volt Battery Chargers
N-DCIS
NSR UPS Bypass Transformer
N-DCIS HVAC
NSR UPS Bypass Transformer
Lighting (Typical)
Communications
Ancillary Diesel
Ancillaries/HVAC
Battery Charger
G
Ancillary Diesel Generator-A
Typical Miscellaneous Loads
FPE Jockey Pump
F.P. Tank Recirc. Pump
Ancillary Diesel Fuel Transfer Pumps
MCR Ancillary Air Condition Unit
From PIP A
6.9kV/480V
Division 1 SR UPS
Division 2 SR UPS
Division 3 SR UPS
Division 4 SR UPS
Q-DCIS
Safety Systems
Monitoring & Control
MCR EFU
PAM
VDU Power
Emergency Lighting
Electrical Motor Driven
Fire Pump
RPV Make-Up Pump
R.B. HVAC Accident Exhaust Filter Unit A
Tie Breaker to Ancillary Diesel
Bus-B
Ancillary Diesel Bus-B 480V
Ancillary Diesel Generator-B
From PIP B
Alternate Feed
RPV Make-Up Pump
R.B. HVAC Accident Exhaust Filter Unit B
Tie Breaker to Ancillary Diesel
Bus-A

Appendix 8A Miscellaneous Electrical Systems

8A.1 Station Grounding and Surge Protection

8A.1.1 Description

The electrical grounding system is comprised of:

- An instrument and computer grounding network.
- An equipment-grounding network for grounding electrical equipment (e.g., transformer, switchgear, motors, distribution panels, cables) and selected mechanical components (for example, fuel tanks, chemical tanks).
- A plant-grounding grid.
- A lightning protection network for protection of all structures, transformers and equipment.

A separate instrumentation grounding system is provided to include both the plant analog (relays, solenoids, etc.) and digital instrumentation systems. The plant instrumentation is grounded through a separate insulated radial grounding system comprised of buses and insulated cables. The instrumentation grounding system is connected to a discrete point of the station-grounding grid at a dedicated instrumentation grounding rod by exothermic welding. The instrumentation grounding system is insulated from all other grounding and surge protection circuits up to the point of connection at the ground grid. It is recognized that there are numerous accepted grounding techniques and that the actual installation of a ground system is made with reference to the recommendations of the Instrumentation and Control (I&C) equipment manufacturers since the techniques used to solve one problem may result in the creation of a different problem (IEEE-1050 "IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations" [Reference 8A-8]).

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

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

Each building is equipped with grounding systems connected to the plant-grounding grid. As a minimum, every other steel column of the building perimeter is connected directly to the grounding grid.

The plant's main generator is grounded with a neutral grounding device to limit the magnitude of fault current due to a solid phase-to-ground fault. The impedance of the neutral grounding device limits the maximum phase-to-ground current under short-circuit conditions, however, it does not limit the current for a three-phase fault or phase-to-phase fault at its terminals.

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

The neutral point of the low-voltage AC distribution systems is either solidly or impedance grounded to ensure proper coordination of ground fault protection. The DC systems are ungrounded.

The target value of ground resistance is one ohm or less for the Reactor, Turbine, Control, Service, Radwaste, and other miscellaneous outdoor buildings. This is consistent with Section 14.1 of IEEE 80 (Reference 8A-1). If the target grounding resistance is not achieved by the ground grid, auxiliary ground grids, shallow buried ground rods or deep buried ground rods will be used in combination as necessary to meet the target ground resistance value.

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

8A.1.2 **Analysis**

No SRP or regulatory guidance is provided for the grounding protection system. Lightning protection is provided in accordance with Regulatory Guide (RG) 1.204, “Guidelines for Lightning Protection of Nuclear Power Plants.” (See Subsection 8.1.5.2.4 and Table 8.1-1.) Both systems are designed and required to be installed to the applicable sections of the following codes and standards.

1. IEEE-80, Guide for Safety in AC Substation Grounding (Reference 8A-1).
2. IEEE-81, Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System (Reference 8A-2).
3. IEEE-665, Guide for Generation Station Grounding (Reference 8A-3).

4. IEEE-1050, IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations (Reference 8A-8).
5. NFPA-780, Standard for the Installation of Lightning Protection Systems[1] (Reference 8A-4).
6. IEEE-C62.23, IEEE Application Guide for Surge Protection of Electric Generating Plants (Reference 8A-9).
7. IEEE-666, Design Guide for Electric Power Service Systems for Generating Stations (Reference 8A-7).

8A.2 Cathodic Protection

8A.2.1 Description

A cathodic protection system is provided to the extent required. The system is designed in accordance with the requirements of the National Association of Corrosion Engineers (NACE) Standards (Reference 8A-5).

8A.2.2 Analysis

There are no SRP or regulatory requirements for cathodic protection systems. The system is designed to the requirements listed in Subsection 8A.2.1.

8A.2.3 COL Information 8A.2.3-1-A Cathodic Protection System

This COL item is addressed in Subsection 8A.2.1.

8A.3 Electric Heat Tracing

8A.3.1 Description

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

8A.3.2 Analysis

There are no SRP or regulatory guidance provided for electric heat tracing systems.

1 This code is utilized as recommended practices only. As stated in NFPA 780, the standard does not apply directly to electric generating facilities. However, concurrent with RG 1.204, NFPA 780 may be used for guidance in nuclear power plants and the identification of applicable standards.

- IEEE-622, Recommended Practice for the Design and Installation of Electric Heat Tracing Systems for Nuclear Power Generating Stations Reference 8A-6.

8A.4 References

8A-1 IEEE-80, "Guide for Safety in AC Substation Grounding."

8A-2 IEEE-81, "Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System."

8A-3 IEEE-665, "Guide for Generating Station Grounding."

8A-4 NFPA-780, "Standard for the Installation of Lightning Protection Systems."

8A-5 National Association of Corrosion Engineers (NACE) Standards.

8A-6 IEEE-622, "Recommended Practice for the Design and Installation of Electric Heat Tracing Systems for Nuclear Power Generating Stations."

8A-7 IEEE 666, "Design Guide for Electric Power Service Systems for Generating Stations."

8A-8 IEEE-1050, "IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations."

8A-9 IEEE-C62.23, "IEEE Application Guide for Surge Protection of Electric Generating Plants."