APR1400
DESIGN CONTROL DOCUMENT TIER 2

CHAPTER 8
ELECTRIC POWER

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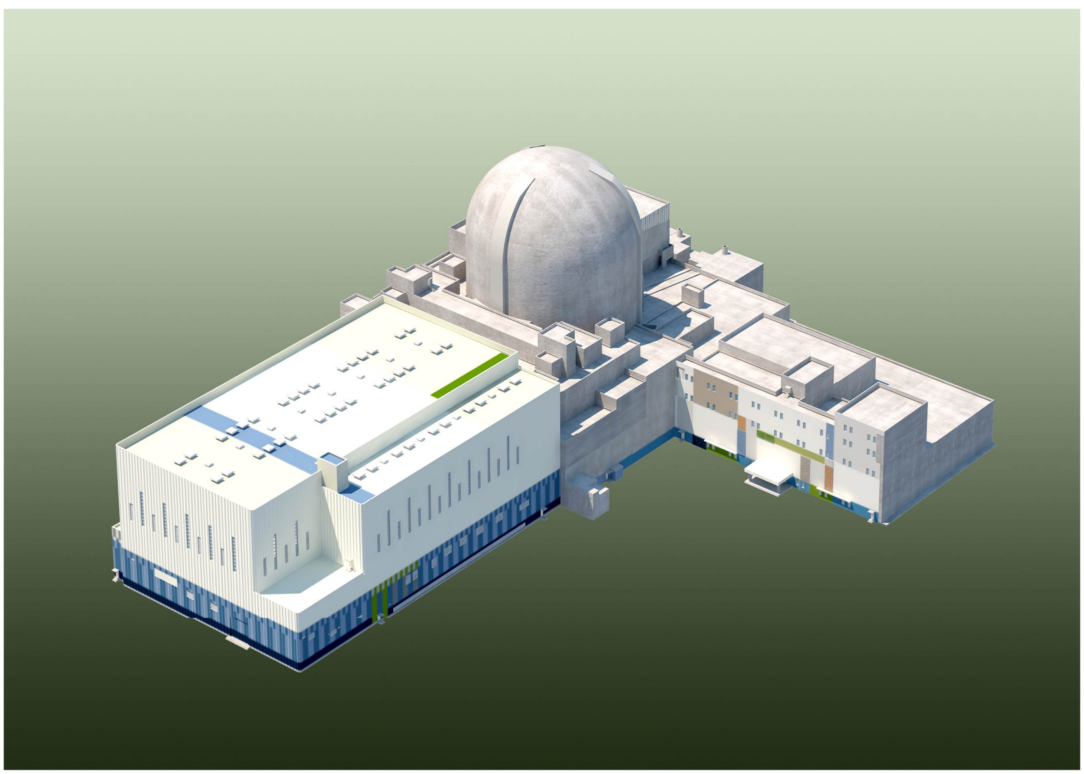

KOREA ELECTRIC POWER CORPORATION

KOREA HYDRO & NUCLEAR POWER CO., LTD

CHAPTER 8 – ELECTRIC POWER

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ACRONYM AND ABBREVIATION LIST

AAC	alternate alternating current
AC	alternating current
AFAS	auxiliary feedwater actuation signal
AOO	anticipated operational occurrence
ASME	American Society of Mechanical Engineers
bhp	brake horsepower
BTP	Branch Technical Position
CFR	Code of Federal Regulations
C&L	closing and latching
COL	combined license
CSAS	containment spray actuation signal
DBA	design basis accident
DBE	design basis event
DC	1) direct current 2) Design Certification
EAC	emergency alternating current
ECCS	emergency core cooling system
EDG	emergency diesel generator
EOP	emergency operating procedure
EPA	electrical penetration assembly
EPRI	Electric Power Research Institute
ESF	engineered safety features
ESFAS	engineered safety features actuation system
ESF-CCS	engineered safety features-component control system
ETAP	electrical transient analyzer program
FLC	full-load current
FMEA	failure modes and effects analysis
GCB	generator circuit breaker
GDC	general design criteria (of 10 CFR Part 50, Appendix A)

GL	Generic Letter
GTG	gas turbine generator
HVAC	heating, ventilation, and air conditioning
I&C	instrumentation and control
IEEE	Institute of Electrical and Electronics Engineers
IPB	isolated phase bus
IPS	information processing system
LC	load center
LOCA	loss-of-coolant accident
LOOP	loss-of-offsite power
LRC	locked rotor current
LWR	light water reactor
MCC	motor control center
MCR	main control room
MG	main generator
MOV	motor-operated valve
MT	main transformer
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NRC	Nuclear Regulatory Commission
OPC	Open Phase Condition
OPDP	Open Phase Detection and Protection
OFAF	oil forced air forced
P-CCS	process-component control system
PNS	permanent non-safety
PPS	1) plant protection system 2) preferred power supply
QA	quality assurance
QIAS	qualified indication and alarm system
QIAS-N	qualified indication and alarm system – non-safety

QIAS-P	qualified indication and alarm system – post-accident monitoring instrument
RCS	reactor coolant system
RG	Regulatory Guide
RPS	reactor protection system
RSR	remote shutdown room
SAT	standby auxiliary transformer
SBO	station blackout
SIAS	safety injection actuation signal
SRP	standard review plan
SSC	structure, system, or component
T/G	turbine-generator
THD	total harmonic distortion
TMI	Three Mile Island
TSO	transmission system operator
TSP	transmission system provider
UAT	unit auxiliary transformer
UPS	uninterruptible power supply

CHAPTER 8 – ELECTRIC POWER

8.1 Introduction

The electric power system is the source of power for station auxiliaries during normal operation and for the reactor protection system (RPS) and engineered safety features (ESF) during abnormal and accident conditions.

The electric power system single-line diagrams in Figure 8.1-1 depict the onsite and offsite electric power system for the APR1400.

8.1.1 Offsite Power System

The APR1400 is connected to the switchyard through two independent circuits.

The switchyard is connected to the main transformer (MT) by a normal preferred power circuit. The main generator (MG) is connected to the low-voltage winding of the MT and the high-voltage winding of the unit auxiliary transformers (UATs) through the generator circuit breaker (GCB). Under the normal power operating condition, the MG supplies power through an isolated phase bus (IPB) and GCB to the MT and two UATs. The UATs are connected to the IPB between the GCB and the MT.

The alternate preferred power circuit is connected to the switchyard through two standby auxiliary transformers (SATs) to provide an immediately available independent source of offsite power to the onsite power distribution system for safety and non-safety loads when power is not available through the UATs.

8.1.2 Onsite Power System

The onsite power system for the APR1400, as shown in Figure 8.1-1, consists of the following systems and components:

a. Alternating current (ac) power system: non-Class 1E 13.8 kV power system, non-Class 1E and Class 1E 4.16 kV systems, non-Class 1E and Class 1E low-voltage systems, emergency diesel generators (EDGs), and an alternate alternating current (AAC) source

b. Direct current (dc) power system: batteries, battery chargers, dc control centers, and distribution panels for both non-Class 1E and Class 1E

c. Instrumentation and control (I&C) power system: inverter, automatic transfer switch, manual transfer switch, regulating transformer, and ac distribution panel for both non-Class 1E and Class 1E

During normal power operation, the GCB is closed and onsite power is supplied from the MG through the UATs. During startup and shutdown, onsite power is supplied from the switchyard through the MT and UATs.

The Class 1E loads are divided into two redundant load groups: division I and division II. Each division has two independent subsystem trains: trains A and C (division I) and trains B and D (division II). Safety-related loads that require Class 1E electric power to perform their safety functions are listed in Table 8.1-1. Each train can be supplied with electric power from the following sources, listed in decreasing order of preference:

a. MG and UAT

b. MT and UAT

c. SAT

d. EDG

e. AAC gas turbine generator (GTG)

If both offsite power sources and the EDGs are unavailable, Class 1E train A or train B can be powered independently by the AAC GTG according to 10 CFR 50.63 (Reference 1) and U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.155 (Reference 2).

The Class 1E 125 Vdc power system is available to provide power to the Class 1E dc loads. Additionally, this system provides power to Class 1E 120 Vac I&C loads through inverters.

The APR1400 has the non-Class 1E 125 Vdc and 250 Vdc power systems to supply non-Class 1E dc loads. These systems provide power to non-Class 1E 120 Vac I&C loads through inverters.

The onsite power systems are described in Section 8.3.

8.1.3 Design Bases

8.1.3.1 Offsite Power System

The design bases for the offsite power system are as follows:

a. The two or more transmission lines from the transmission network are connected to the switchyard. The offsite power circuits to the switchyard are designed to be independent and physically separate to provide reasonable assurance of availability under normal and postulated accident conditions.

b. Each of the two preferred power circuits between the switchyard and onsite power system has sufficient capacity and is available to supply power to the plant safety-related systems within a few seconds following a loss-of-coolant accident (LOCA) to provide reasonable assurance that core cooling, containment integrity, and other vital safety functions are maintained.

c. The MT rating is selected to transfer the power generated by the APR1400 to an offsite power system and permit the offsite power source to supply power to the onsite loads.

d. The two UATs and two SATs are sized to provide the full load requirements of the main buses in their respective load groups.

e. The protection is provided to detect, alarm, protect against an open phase condition (OPC) at the primary sides of the MT or SAT, and automatically transfer the Class 1E switchgear buses to the alternate reliable offsite power source or onsite standby power system.

8.1.3.2 Onsite Power System

The design bases for the onsite power system are as follows:

a. The Class 1E onsite power systems are located in seismic Category I structures to provide protection from natural phenomena.

b. The redundant equipment of the Class 1E onsite power system is located in separate rooms and different fire areas with adequate independence to provide reasonable assurance that the plant protection system (PPS) and safety functions are performed assuming a single failure.

c. The voltage levels at each bus are optimized for full and minimum load conditions that are expected throughout the anticipated range of voltage variations of the power source by adjusting the voltage tap settings on the transformers.

d. Each redundant division of the Class 1E onsite power systems has sufficient capacity to safely shut down the APR1400 and mitigates the effects of an accident assuming a loss of offsite power (LOOP).

e. The Class 1E onsite power systems are designed to permit appropriate surveillance, periodic inspections, testing of important areas, assessing the continuity of the systems, and the condition of their components.

f. The EDGs are designed to be automatically initiated in the event of an accident or a LOOP. They are rated to have a continuous load rating plus margin. They are also sized to accelerate all of the loads in the loading sequence without exceeding the allowable voltage and frequency limits stated in NRC RG 1.9 (Reference 3).

g. The Class 1E 125 Vdc batteries have adequate capacity, without chargers, to provide the necessary dc power to perform the required safety functions in the event of a postulated accident assuming a single failure.

h. Each battery charger has adequate capacity to supply its assigned steady-state loads while simultaneously recharging its associated battery.

i. The non-Class 1E AAC source is provided to help mitigate the effects of station blackout (SBO) conditions in accordance with NRC RG 1.155. In addition, the AAC source is designed to supply ac power to the non-Class 1E permanent non-safety (PNS) 4.16 kV buses during a LOOP.

j. Non-Class 1E electrical equipment is designed to preclude adverse effects on Class 1E electrical equipment due to its failure during normal, accident, or post-accident modes of plant operation.

8.1.3.3 General Design Criteria, NRC Regulatory Guides, Branch Technical Positions, Generic Letters, and Industry Standards

The electric power system is designed to meet the following requirements of General Design Criteria (GDC), Regulatory Guides (RGs), Branch Technical Positions (BTPs), Generic Letters (GLs), and industry standards. Conformance with NRC RGs and BTPs for electric power systems is addressed in Table 8.1-2 and Section 1.9.

General Design Criteria

- GDC 1, "Quality Standards and Records"
- GDC 2, "Design Bases for Protection Against Natural Phenomena"
- GDC 4, "Environmental and Dynamic Effects Design Bases"
- GDC 17, "Electric Power Systems"
- GDC 18, "Inspection and Testing of Electric Power Systems"
- GDC 33, "Reactor Coolant Makeup"
- GDC 34, "Residual Heat Removal"
- GDC 35, "Emergency Core Cooling"
- GDC 38, "Containment Heat Removal"
- GDC 41, "Containment Atmosphere Cleanup"
- GDC 44, "Cooling Water"
- GDC 50, "Containment Design Basis"

NRC Regulatory Guides

- NRC RG 1.6, "Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems," (Safety Guide 6), March 1971.
- NRC RG 1.9, "Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants," Rev. 4, March 2007.

- NRC RG 1.22, “Periodic Testing of Protection System Actuation Functions” (Safety Guide 22), February 1972.
- NRC RG 1.29, “Seismic Design Classification,” Rev. 4, March 2007.
- NRC RG 1.30, “Quality Assurance Requirements for the Installation, Inspection and Testing of Instrumentation and Electric Equipment (Safety Guide 30),” August 1972.
- NRC RG 1.32, “Criteria for Power Systems for Nuclear Power Plants,” Rev. 3, March 2004.
- NRC RG 1.40, “Qualification of Continuous Duty Safety-Related Motors for Nuclear Power Plants,” Rev. 1, February 2010.
- NRC RG 1.41, “Preoperational Testing of Redundant On-site Electric Power Systems to Verify Proper Load Group Assignments,” March 1973.
- NRC RG 1.47, “Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems,” Rev. 1, February 2010.
- NRC RG 1.53, “Application of the Single-Failure Criterion to Safety Systems,” Rev. 2, November 2003.
- NRC RG 1.62, “Manual Initiation of Protective Actions,” Rev. 1, June 2010.
- NRC RG 1.63, “Electric Penetration Assemblies in Containment Structures for Nuclear Power Plants,” Rev. 3, February 1987.
- NRC RG 1.73, “Qualification Tests for Safety-Related Actuators in Nuclear Power Plants,” Rev. 1, October 2013.
- NRC RG 1.75, “Criteria for Independence of Electrical Safety Systems,” Rev. 3, February 2005.
- NRC RG 1.89, “Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants,” Rev. 1, June 1984.
- NRC RG 1.93, “Availability of Electric Power Sources,” Rev. 1, March 2012.

- NRC RG 1.100, "Seismic Qualification of Electric and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants," Rev. 3, September 2009.
- NRC RG 1.106, "Thermal Overload Protection for Electric Motors on Motor-Operated Valves," Rev. 2, February 2012.
- NRC RG 1.118, "Periodic Testing of Electric Power and Protection Systems," Rev. 3, April 1995.
- NRC RG 1.128, "Installation Design and Installation of Vented Lead-Acid Storage Batteries for Nuclear Power Plants," Rev. 2, February 2007.
- NRC RG 1.129, "Maintenance, Testing, and Replacement of Vented Lead-Acid Storage Batteries for Nuclear Power Plants," Rev. 3, September 2013.
- NRC RG 1.137, "Fuel Oil Systems for Emergency Power Supplies," Rev. 2, June 2013.
- NRC RG 1.153, "Criteria for Safety Systems," Rev. 1, June 1996.
- NRC RG 1.155, "Station Blackout," August 1988.
- NRC RG 1.156, "Qualification of Connection Assemblies for Nuclear Power Plants," Rev. 1, July 2011.
- NRC RG 1.158, "Qualification of Safety-Related Lead Storage Batteries for Nuclear Power Plants," February 1989.
- NRC RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," Rev. 3, May 2012.
- NRC RG 1.180, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems," Rev. 1, October 2003.
- NRC RG 1.189, "Fire Protection for Nuclear Power Plants," Rev. 2, October 2009.
- NRC RG 1.204, "Guidelines for Lightning Protection of Nuclear Power Plants," November 2005.

- NRC RG 1.206, “Combined License Applications for Nuclear Power Plants” (LWR Edition), June 2007.
- NRC RG 1.210, “Qualification of Safety-Related Battery Chargers and Inverters for Nuclear Power Plants,” June 2008.
- NRC RG 1.211, “Qualification of Safety-Related Cables and Field Splices for Nuclear Power Plants,” April 2009.
- NRC RG 1.212, “Sizing of Large Lead-Acid Storage Batteries,” November 2008.
- NRC RG 1.213, “Qualification of Safety-Related Motor Control Centers for Nuclear Power Plants,” May 2009.
- NRC RG 1.218, “Condition-Monitoring Techniques for Electric Cables Used in Nuclear Power Plants,” April 2012.

Branch Technical Positions

- BTP 8-1, “Requirements for Motor-Operated Valves in the ECCS Accumulator Lines,” Rev. 3, March 2007.
- BTP 8-2, “Use of Diesel Generator Sets for Peaking,” Rev. 3, March 2007.
- BTP 8-3, “Stability of Offsite Power Systems,” Rev. 3, March 2007.
- BTP 8-4, “Application of Single Failure Criterion to Manually Controlled Electrically Operated Valves,” Rev. 3, March 2007.
- BTP 8-5, “Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems,” Rev. 3, March 2007.
- BTP 8-6, “Adequacy of Station Electric Distribution System Voltages,” Rev. 3, March 2007.
- BTP 8-7, “Criteria for Alarms and Indications Associated with Diesel Generator Unit Bypassed and Inoperable Status,” Rev. 3, March 2007.
- BTP 8-9, “Open Phase Conditions in Electric Power System,” July 2015.

Generic Letters

- GL 77-07, “Reliability of Standby Diesel Generator (DG) Units,” December 15, 1977.
- GL 79-17, “Reliability of Onsite Diesel Generators at Light Water Reactors,” April 18, 1979.
- GL 84-15, “Proposed Staff Actions to Improve and Maintain Diesel Generator Reliability,” July 2, 1984.
- GL 88-15, “Electric Power Systems – Inadequate Control Over Design Processes,” September 12, 1988.
- GL 91-11, “Resolution of Generic Issues 48, ‘LCOs for Class 1E Vital Instrument Buses,’ and 49, ‘Interlocks and LCOs for Class 1E Tie Breakers,’ Pursuant to 10 CFR 50.54(f),” July 18, 1991.
- GL 94-01, “Removal of Accelerated Testing and Special Reporting Requirements for Emergency Diesel Generators,” May 31, 1994.
- GL 96-01, “Testing of Safety-Related Logic Circuits,” January 10, 1996.
- GL 2006-02, “Grid Reliability and the Impact on Plant Risk and the Operability of Offsite Power,” February 1, 2006.
- GL 2007-01, “Inaccessible or Underground Power Cable Failures That Disable Accident Mitigation System or Cause Plant Transients,” February 7, 2007.

Industrial Standards

- ASME NQA-1-2008, “Quality Assurance Requirements for Nuclear Facility Applications,” 2008.
- ASME NQA-1a-2009, “Quality Assurance Requirements for Nuclear Facility Applications,” 2009.
- IEEE Std. 80, “IEEE Guide for Safety in AC Substation Grounding,” 2000.
- IEEE Std. 141, “IEEE Recommended Practice for Electric Power Distribution for Industrial Plants,” 1993.

- IEEE Std. 142, "IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems," 2007.
- IEEE Std. 242, "IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems," 2001.
- IEEE Std. 308, "IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations," 2001.
- IEEE Std. 317, "IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations," 1983.
- IEEE Std. 323, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," 2003.
- IEEE Std. 334, "IEEE Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations," 2006.
- IEEE Std. 336, "IEEE Standard Installation, Inspection, and Testing Requirements for Instrumentation and Electric Equipment During the Construction of Nuclear Power Generating Stations," 1971.
- IEEE Std. 338, "IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems," 1987.
- IEEE Std. 344, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations," 2005.
- IEEE Std. 379, "IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems," 2000.
- IEEE Std. 382, "IEEE Standard for Qualification of Safety-Related Actuators for Nuclear Power Generating Stations," 2006.
- IEEE Std. 383, "IEEE Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations," 2003.
- IEEE Std. 384, "IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits," 1992.

- IEEE Std. 387, "IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations," 1995.
- IEEE Std. 420, "IEEE Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations," 2001
- IEEE Std. 450, "IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications," 2010.
- IEEE Std. 484, "IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications," 2002.
- IEEE Std. 485, "IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications," 2010.
- IEEE Std. 497, "IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations," 2002.
- IEEE Std. 519, "IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems," 1992.
- IEEE Std. 535, "IEEE Standard for Qualification of Class 1E Vented Lead Acid Storage Batteries for Nuclear Power Generating Stations," 2013.
- IEEE Std. 572, "IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations," 2006.
- IEEE Std. 603, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," 1991.
- IEEE Std. 622, "IEEE Recommended Practice for the Design and Installation of Electric Heat Tracing Systems for Nuclear Power Generating Systems," 1987.
- IEEE Std. 649, "IEEE Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations," 2006.
- IEEE Std. 650, "IEEE Standard Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations," 2006.
- IEEE Std. 665, "IEEE Guide for Generating Station Grounding," 1995.

- IEEE Std. 666, "IEEE Design Guide for Electric Power Service Systems for Generating Stations," 1991.
- IEEE Std. 690, "IEEE Standard for the Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Stations," 2004.
- IEEE Std. 741, "IEEE Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations," 2007.
- IEEE Std. 765, "IEEE Standard for Preferred Power Supply (PPS) for Nuclear Power Generating Stations (NPGS)," 2006.
- IEEE Std. 835, "IEEE Standard Power Cable Ampacity Tables," 1994.
- IEEE Std. 944, "IEEE Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations," 1986.
- IEEE Std. 946, "IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations," 2004.
- IEEE Std. 1023, "IEEE Recommended Practice for the Application of Human Factors Engineering to Systems, Equipment and Facilities of Nuclear Power Generating Stations and Other Nuclear Facilities," 2004.
- IEEE Std. 1050, "IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations," 1996.
- IEEE Std. 1313.2, "IEEE Guide for the Application of Insulation Coordination," 1999.
- IEEE Std. C37.010, "IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis," 1999.
- IEEE Std. C37.013, "IEEE Standard for AC High-Voltage Generator Circuit Breakers Rated on a Symmetrical Current Basis," 1997.
- IEEE Std. C37.04, "IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers," 1999.
- IEEE Std. C37.13, "IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures," 2008.

- IEEE Std. C37.14, "IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures," 2002.
- IEEE Std. C37.16, "IEEE Standard for Preferred Ratings, Related Requirements, and Application Recommendations for Low-Voltage AC (635 V and below) and DC (3200 V and below) Power Circuit Breakers," 2009.
- IEEE Std. C37.20.1, "IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear," 2002.
- IEEE Std. C37.20.2, "IEEE Standard for Metal-Clad Switchgear," 1999.
- IEEE Std. C37.21, "IEEE Standard for Control Switchboards," 2005.
- IEEE Std. C37.23, "IEEE Standard for Metal-Enclosed Bus," 2003.
- IEEE Std. C37.27, "IEEE Application Guide for Low-Voltage AC Power Circuit Breakers Applied with Separately-Mounted Current-Limiting Fuses," 2008.
- IEEE Std. C37.81, "IEEE Guide for Seismic Qualification of Class 1E Metal-Enclosed Power Switchgear Assemblies," 1989.
- IEEE Std. C37.82, "IEEE Standard for the Qualification of Switchgear Assemblies for Class 1E Applications in Nuclear Power Generating Stations," 1987.
- IEEE Std. C37.90, "IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus," 2005.
- IEEE Std. C37.90.1, "IEEE Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electrical Power Apparatus," 2004.
- IEEE Std. C37.90.2, "IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers," 2004.
- IEEE Std. C37.91, "IEEE Guide for Protecting Power Transformers," 2008.
- IEEE Std. C37.105, "IEEE Standard for Qualifying Class 1E Protective Relays and Auxiliaries for Nuclear Power Generating Stations," 2010.

- IEEE Std. C57.12.00, "IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers," 2010.
- IEEE Std. C57.13, "IEEE Standard Requirements for Instrument Transformers," 2008.
- IEEE Std. C62.23, "IEEE Application Guide for Surge Protection of Electric Generating Plants," 1995.
- IEEE Std. C62.41, "IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits," 1991.
- IEEE Std. C62.45, "IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits," 1992.
- IEEE Std. C62.82.1, "IEEE Standard for Insulation Coordination – Definitions, Principles, and Rules," 2010.
- NEMA C50.41, "American National Standard Polyphase Induction Motors for Power Generating Stations," 2000.
- NEMA MG 1, "Motors and Generators," 2009.
- NEMA VE 1, "Metal Cable Tray Systems," 2009.
- NEMA WC 51, "Ampacities of Cables Installed in Cable Trays," 2009.
- NEMA WC 57, "Standard for Control, Thermocouple Extension, and Instrumentation Cables," 2004.
- NEMA WC 70, "Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy," 2009.
- NEMA WC 74, "5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy," 2006.
- NFPA 70, "National Electrical Code," 2008.
- NFPA 780, "Standard for the Installation of Lightning Protection Systems," 2004.

- NSAC-108, "Reliability of Emergency Diesel Generators at U.S Nuclear Power Plants," September 1986.
- NUMARC 87-00, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," Rev. 1, August 1991.
- NUMARC 93-01, "Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," Rev. 4A, 2011.

8.1.4 Combined License Information

No COL information is required with regard to Section 8.1.

8.1.5 References

1. 10 CFR 50.63, "Loss of All Alternating Current Power," U.S. Nuclear Regulatory Commission.
2. Regulatory Guide 1.155, "Station Blackout," U.S. Nuclear Regulatory Commission, August 1988.
3. Regulatory Guide 1.9, "Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants," Rev. 4, U.S. Nuclear Regulatory Commission, March 2007.

Table 8.1-1 (1 of 2)

Safety-Related Loads

Load	Function	Power
Safety injection system	Performs emergency core cooling	AC
Shutdown cooling system	Performs shutdown cooling and emergency core cooling	AC
Containment spray system	Performs emergency containment cooling and fission product removal	AC
Component cooling water system	Provides cooling water for engineered safety features equipment, emergency diesel generator, and safety-related ac equipment	AC
Essential service water system	Provides cooling for component cooling water heat exchanger	AC
Essential chilled water system	Provides cooling for safety-related heating, ventilation and air conditioning (HVAC) loads	AC
Auxiliary feedwater system	Provides water to steam generator when main feedwater is not available	AC
Chemical and volume control system	Controls chemistry and volume of the water in the reactor coolant system	AC
Spent fuel pool cooling and cleanup system	Provides cooling for the spent fuel pool	AC
Safety-related HVAC system	Provides cooling for Class 1E electrical areas, control areas, and ESF areas	AC
Motor-operated valves (Class 1E only)	Provide the system alignment to allow the associated system to perform its functions	AC
Diesel generator support loads (Class 1E only)	Provide support for maintaining availability and for operation	AC
Containment hydrogen control system	Controls combustible gas, mainly hydrogen gas inside containment	AC
Radiation monitoring system (Class 1E only)	Monitors radiation level of reactor containment building, auxiliary building, fuel handling area, and main control room (MCR) air intake	AC

Table 8.1-1 (2 of 2)

Load	Function	Power
Reactor protection system	Protects reactor core	DC
Engineered safety features actuation system	Protects reactor core and containment	DC
Essential instrumentation	Provides monitoring and essential control for safety-related systems	DC
Post-accident monitoring system (Class 1E only)	Provides post-accident indication and recording	DC

Table 8.1-2 (1 of 7)

Criteria and Guidelines for Electric Power Systems

Criteria		DCD Section				Remarks
		8.2	8.3.1	8.3.2	8.4	
1. Appendix A to 10 CFR Part 50 – GDC		Requirements				
GDC 2	Design Bases for Protection Against Natural Phenomena	A	A	A		
GDC 4	Environmental and Dynamic Effects Design Bases	A	A	A		
GDC 5	Sharing of Structures, Systems, and Components					Not applicable
GDC 17	Electric Power Systems	A	A	A	A	
GDC 18	Inspection and Testing of Electric Power Systems	A	A	A	A	
GDC 33	Reactor Coolant Makeup	A	A	A		
GDC 34	Residual Heat Removal	A	A	A		
GDC 35	Emergency Core Cooling	A	A	A		
GDC 38	Containment Heat Removal	A	A	A		
GDC 41	Containment Atmosphere Cleanup	A	A	A		
GDC 44	Cooling Water	A	A	A		
GDC 50	Containment Design Basis		A	A		

(A) Requirements and criteria provided in the subject document are applied to the noted section.

Table 8.1-2 (2 of 7)

Criteria			8.2	8.3.1	8.3.2	8.4	Remarks
2. Regulations (10 CFR Part 50 and 10 CFR Part 52)			Requirements				
10 CFR 50.34		Contents of Applications; Technical Information					
i	50.34(f)(2)(v)	Automatic indication of the bypassed and operable status of safety systems		A	A		TMI Item I.D.3
ii	50.34(f)(2)(xiii)	Power supplies to establish and maintain natural circulation		A			TMI Item II.E.3.1
iii	50.34(f)(2)(xx)	Power supplies for pressurizer relief valves, block valves, and level indicators		A			TMI Item II.G.1
10 CFR 50.55a		Codes and Standards		A	A		
10 CFR 50.63		Loss of All Alternating Current Power	A	A	A	A	
10 CFR 50.65(a)(4)		Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants	A	A	A	A	
10 CFR 52.47(b)(1)		Contents of Applications; Technical Information	A	A	A	A	Inspections, Tests, Analysis, and Acceptance Criteria
10 CFR 52.80(a)		Contents of Applications; Additional Technical Information	A	A	A	A	

(A) Requirements and criteria provided in the subject document are applied to the noted section.

Table 8.1-2 (3 of 7)

Criteria		DCD Section				Remarks
		8.2	8.3.1	8.3.2	8.4	
3. NRC RG		Guidance				
RG 1.6	Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems		G	G		
RG 1.9	Application, and Testing of Safety-Related Diesel Generators in Nuclear Power Plants		G		G	
RG 1.32	Criteria for Power Systems for Nuclear Power Plants	G	G	G		
RG 1.47	Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems		G	G		
RG 1.53	Application of the Single-Failure Criterion to Safety Systems		G	G		
RG 1.63	Electric Penetration Assemblies in Containment Structures for Nuclear Power Plants		G	G		
RG 1.75	Physical Independence of Electric Systems		G	G		
RG 1.81	Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants					Not applicable
RG 1.93	Availability of Electric Power Sources	G	G	G		

(G) Guidance provided in the subject document is applied to the noted section.

Table 8.1-2 (4 of 7)

Criteria		DCD Section				Remarks
		8.2	8.3.1	8.3.2	8.4	
3. NRC RG		Guidance				
RG 1.106	Thermal Overload Protection for Electric Motors on Motor-Operated Valves		G	G		
RG 1.118	Periodic Testing of Electric Power and Protection Systems		G	G		
RG 1.128	Installation Design and Installation of Vented Lead-Acid Storage Batteries for Nuclear Power Plants			G		
RG 1.129	Maintenance, Testing, and Replacement of Vented Lead-Acid Storage Batteries for Nuclear Power Plants			G		
RG 1.153	Criteria for Safety Systems		G	G		
RG 1.155	Station Blackout	G	G	G	G	
RG 1.160	Monitoring the Effectiveness of Maintenance at Nuclear Power Plants	G	G	G	G	
RG 1.204	Guidelines for Lightning Protection of Nuclear Power Plants	G	G			
RG 1.206	Combined License Application for Nuclear Power Plants (LWR Edition)	G	G	G	G	

(G) Guidance provided in the subject document is applied to the noted section.

Table 8.1-2 (5 of 7)

Criteria		DCD Section				Remarks
		8.2	8.3.1	8.3.2	8.4	
4. Branch Technical Position		Guidance				
BTP 8-1	Requirements on Motor-Operated Valves in the ECCS Accumulator Lines		G			
BTP 8-2	Use of Diesel-Generator Sets for Peaking		G			
BTP 8-3	Stability of Offsite Power Systems	G				
BTP 8-4	Application of the Single Failure Criterion to Manually Controlled Electrically Operated Valves		G			
BTP 8-5	Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems		G	G		
BTP 8-6	Adequacy of Station Electric Distribution System Voltages	G	G			
BTP 8-7	Criteria for Alarms and Indications Associated with Diesel-Generator Unit Bypassed and Inoperable Status		G			
BTP 8-8	Onsite (Emergency Diesel Generators) and Offsite Power Sources Allowed Outage Time Extensions					Not applicable
BTP 8-9	Open Phase Conditions in Electric Power System	G				

(G) Guidance provided in the subject document is applied to the noted section.

Table 8.1-2 (6 of 7)

Criteria		DCD Section				Remarks
		8.2	8.3.1	8.3.2	8.4	
5. NRC Technical Report Designation		Requirements/Guidance				
NUREG-0718	Licensing Requirements for Pending Applications for Construction Permits and Manufacturing License		G	G		
NUREG-0737	Clarification of TMI Action Plan Requirements		A			
NUREG/CR-0660	Enhancement of Onsite Diesel Generator Reliability		G			
NUREG-1793	Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design					Not applicable

(A) Requirements and criteria provided in the subject document are applied to the noted section.

(G) Guidance provided in the subject document is applied to the noted section.

Table 8.1-2 (7 of 7)

Criteria		DCD Section				Remarks
		8.2	8.3.1	8.3.2	8.4	
6. Commission Papers (SECY)		Requirements				
SECY-90-016	Evolutionary Light Water Reactor Certification Issues and Their Relationships to Current Regulatory Requirements, 1990	A	A		A	
SECY-94-084	Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs, 1994					Not applicable
SECY-95-132	Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems (RTNSS) in Passive Plant Designs, 1995					Not applicable
SECY-91-078	EPRI's Requirements Document and Additional Evolutionary LWR Certification Issues, 1991	A	A			
SECY-12-0025	Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami		A	A		
SECY-05-0227	Final Rule –AP1000 Design Certification, 2005					Not applicable

(A) Requirements and criteria provided in the subject document are applied to the noted section.

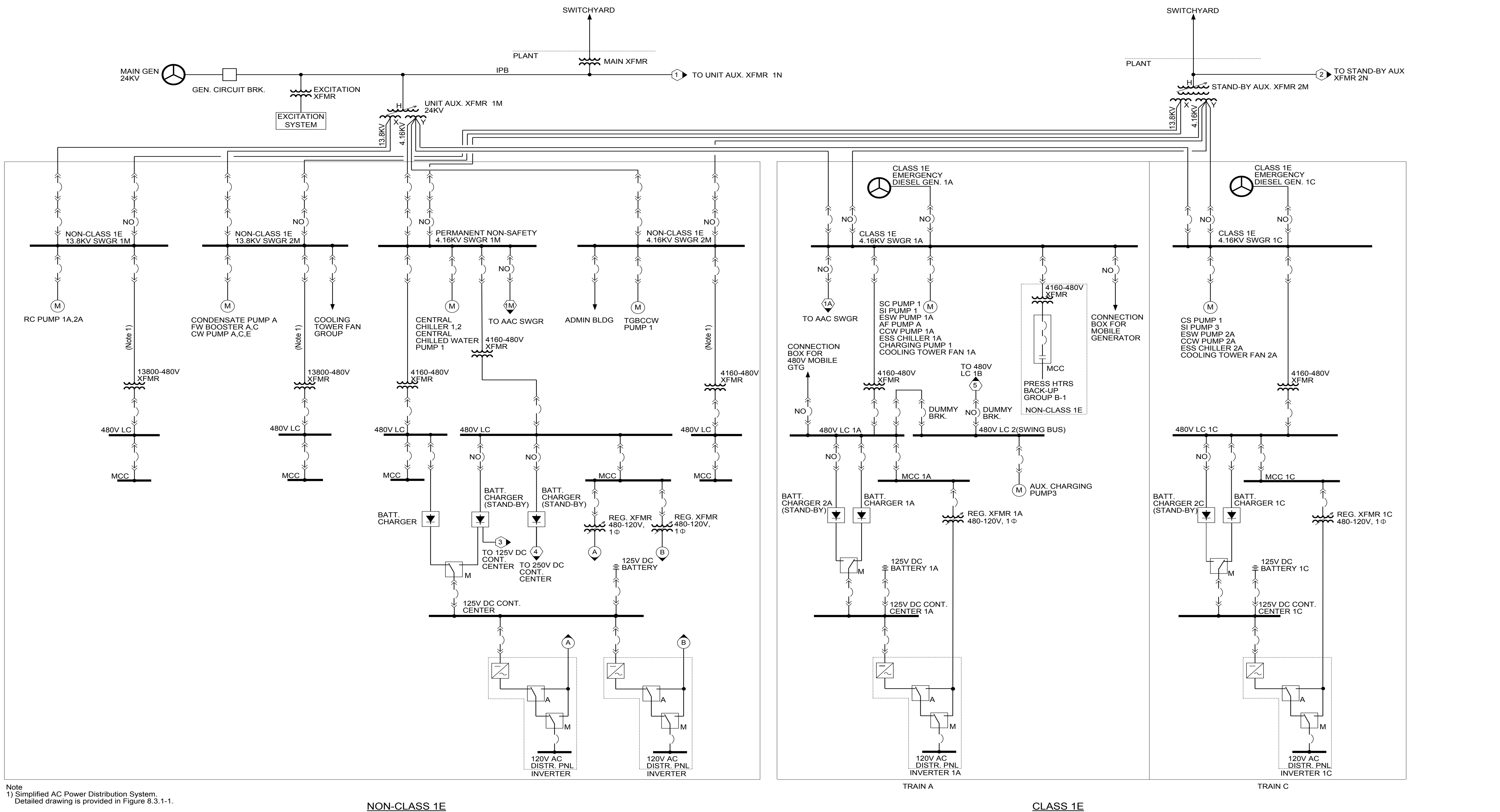

Figure 8.1-1 Electric Power System Single-Line Diagram (Division I) (1 of 2)

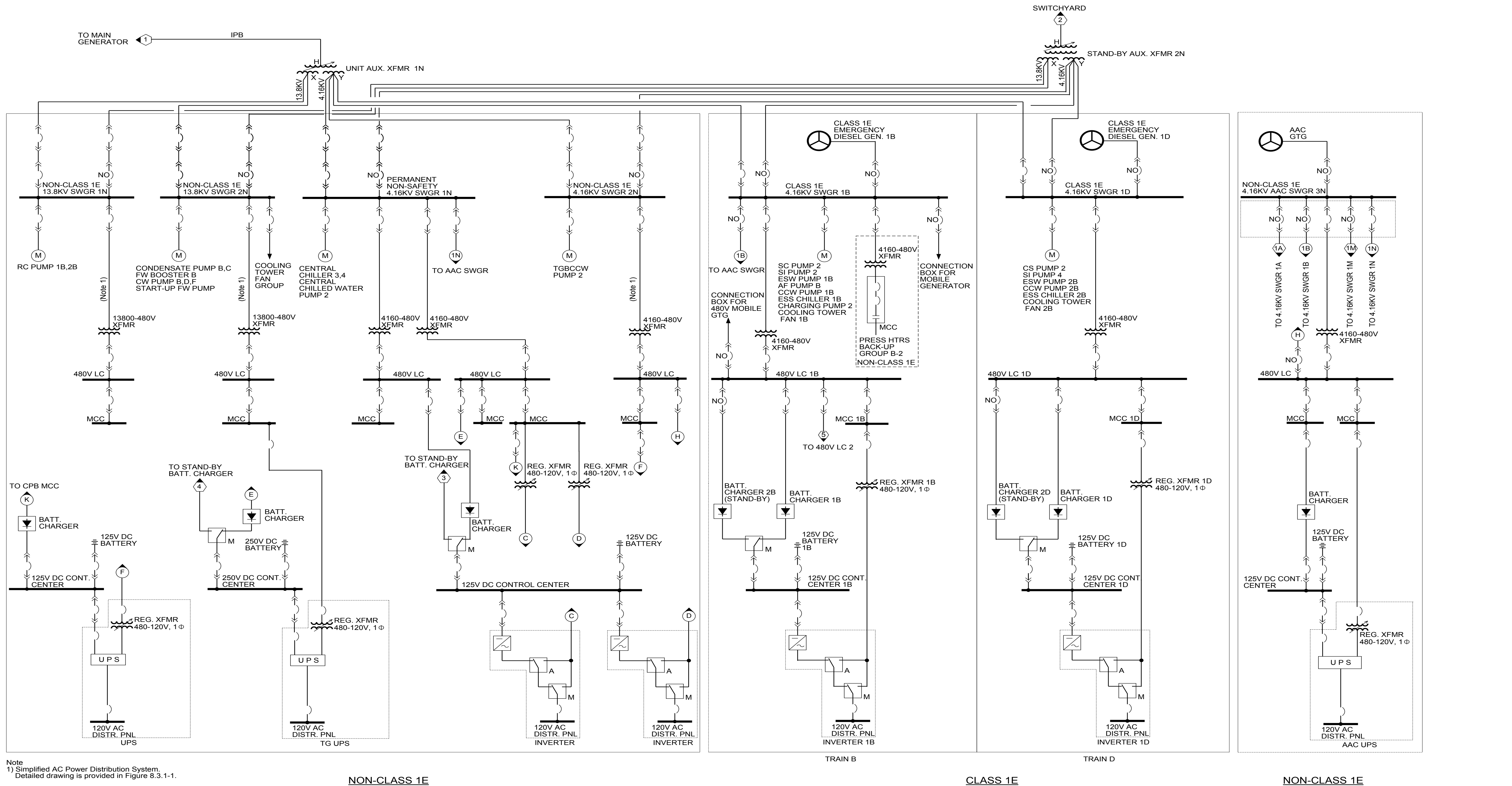

Figure 8.1-1 Electric Power System Single-Line Diagram (Division II) (2 of 2)

8.2 Offsite Power System

8.2.1 System Description

The offsite power system is the preferred source of power for the reactor protection system (RPS) and engineered safety features (ESF) during normal, abnormal, and accident conditions. It encompasses the transmission network, overhead or underground transmission lines, transmission line towers, switchyard components and control systems, switchyard battery systems, transmission tie lines, main generator (MG), generator circuit breaker (GCB), main transformer (MT), unit auxiliary transformers (UATs), standby auxiliary transformers (SATs), isolated phase bus (IPB), and the electrical components associated with them. The boundaries between the offsite power system and the onsite power system are the incoming circuit breakers of the switchgears, which are included in the onsite power system.

The switchyard is connected to the transmission lines to transmit the electricity produced by the APR1400 to the transmission network and to the transmission tie lines to provide offsite power to the auxiliary and service loads of the APR1400.

Electric power from the transmission network to the onsite electrical distribution system is supplied by two physically independent circuits. The COL applicant is to identify those independent circuits (COL 8.2(1)). The APR1400 is designed to meet the requirements in 10 CFR Part 50, Appendix A, and GDC 2, 4, 17, and 18 (References 1, 2, 4, and 5, respectively).

8.2.1.1 Transmission Network

The transmission network is not included in the scope of the APR1400 design. However, this subsection describes the transmission network in general terms. The transmission network is a source of reliable and stable power for the onsite power system. The transmission network design includes at least two preferred power supplies and each one has sufficient capacity and capability to supply power to the APR1400 safety-related and non-safety-related systems during all design modes.

The COL applicant is to provide information on the location of rights-of-way, transmission towers, voltage level, and length of each transmission line from the site to the first major substation that connects the line to the transmission network (COL 8.2(2)). The COL applicant is to describe the switchyard voltage related to the transmission system provider/operator (TSP/TSO) and the formal agreement between the nuclear power plant and the TSP/TSO. The COL applicant is to describe the capability and the analysis tool of the TSP. The COL applicant is also to describe the protocols for the plant to remain cognizant of grid vulnerabilities (COL 8.2(3)).

8.2.1.2 Switchyard

The plant switchyard design is site-specific and not within the scope of the APR1400 design. The COL applicant is to describe and provide layout drawings of the circuits connecting the onsite distribution system to the preferred power supply (COL 8.2(4)). The layout drawings are to include switchyard arrangement (breakers and bus arrangements), transmission lines, switchyard control systems, power supplies, and cable routing. The COL applicant is to describe the site-specific design for the switchyard equipment, including breaker arrangement, electrical schematics of breaker control system, protective devices and their settings, and auxiliary power supplies (ac and dc) for control and protection (COL 8.2(5)).

The COL applicant is to provide a high-impedance ground fault detection feature that actuates an alarm in the main control room (MCR) and remote shutdown room (RSR) upon detection of a high-impedance ground fault at the primary side of MT or SATs (COL 8.2(6)).

At least two physically independent transmission lines connect the offsite transmission network to the high-voltage switchyard of the plant. Two physically independent transmission tie lines supply offsite electric power from the switchyard to the APR1400 for plant maintenance, startup, shutdown, and postulated accident conditions. The interface requirement is that the TSP/TSO maintains operating frequency within 5 percent and operating voltage within 10 percent on nominal value bases at the interface boundary between the transmission network and the switchyard.

The COL applicant is to provide a failure modes and effects analysis (FMEA) of the switchyard in accordance with the following items:

a. The two preferred power circuits from the transmission network are linked to the onsite power system by passing through the switchyard. Because a switchyard can be common to both offsite circuits, the COL applicant is to provide an FMEA of the switchyard components to assess the possibility of simultaneous failure of both circuits as a result of single events (COL 8.2(7)).

b. When the normal preferred power supply is not available, the alternate preferred power supply maintains its availability.

c. The switchyard buses where the preferred power source circuits are connected are arranged as follows:

   1) Any incoming or outgoing transmission line for one preferred power source circuit can be switched without affecting the other preferred power source circuit.

   2) When a switchyard circuit breaker is isolated under maintenance condition, there is no disruption of service to either preferred power sources circuit.

8.2.1.3 Offsite Power System Components and Circuits

The offsite power system components consist of the MG, IPB, GCB, MT, two UATs, and two SATs. The MG is connected to the transmission network when the generator reaches rated speed and output voltage, and paralleling to the transmission network is accomplished automatically or manually by using the synchroscope and synchronizer. In the event that the MG is not in service, this system is used to supply power from the transmission network to the station auxiliaries.

The APR1400 design includes two offsite circuits to each independent safety train that is supplied directly from an offsite power source with no intervening non-safety buses, thereby permitting the offsite source to supply power to safety buses upon a failure or presence of transients on non-Class 1E electrical equipment. Discussion on the impact of faults or transients of non-Class 1E electrical equipment on the Class 1E loads is described in Subsection 8.3.1.1.2.3. This design feature complies with GDC 17 and the staff's position in SECY-91-078 (Reference 29). The preferred power supply system has provisions to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the MG or loss of power from the onsite electric power sources. Two physically independent circuits connect the switchyard to the APR1400.

Each preferred power source has the capacity and capability to permit functioning of structures, systems, and components important to safety and all other auxiliary systems under normal, abnormal, and accident conditions. The normal preferred power circuit is connected to the high-voltage side of the MT. During power operation mode, the GCB is closed and the MG is connected to the transmission system through the MT and also supplies power to the UATs. The alternate preferred power circuit is connected to the high-voltage side of the SATs. In case the power supply is unavailable from the UATs, the power supply is maintained because the onsite non-safety-related and safety-related bus connections are transferred automatically from the UATs to the SATs. This design feature satisfactorily addresses SECY-91-078. When the normal preferred power supply is restored, the transfer from the SATs to the UATs is accomplished manually. The UATs and SATs are three-winding transformers connected to the onsite non-safety-related and safety-related buses through their low-voltage side windings. Both non-safety-related and safety-related buses are normally supplied from the UATs.

The protection schemes including overcurrent, differential current, sudden pressure and ground fault protection for the MT, UATs, and SATs are provided in accordance with the recommendations in IEEE Std. 666 (Reference 23). The protective relay list of the MT, UATs, and SATs is shown in Table 8.2-2.

The IPB is used to connect the MG to the GCB. The IPB provides the electrical connection among the GCB, the MT, and the two UATs. The MT is composed of three single-phase transformers that are connected to the two UATs through the IPB.

The GCB is used as a means of providing immediate access of the onsite ac power systems to the offsite power system by isolating the MG from the MT and the UATs and allowing backfeeding of offsite power to the onsite ac power system. The GCB is capable of interrupting normal load current and maximum fault current during transient and various fault conditions. The APR1400 is designed to follow the guidance in Appendix A of Standard Review Plan (SRP) Section 8.2 (Reference 6). After the MT is connected to the transmission network by closing the switchyard breakers with the GCB open, the UATs supply plant startup power to auxiliary and service loads of the APR1400. As part of the normal turbine-generator shutdown process, the GCB is opened to separate the MG from the switchyard when the MG output has been reduced to almost no-load condition. After the MG is disconnected from the switchyard by opening the GCB, the MT remains connected to the network system and backfeeds plant shutdown power to the APR1400 through the UATs during plant shutdown.

The APR1400 electric power system is provided with the open phase detection and protection (OPDP) system to detect, alarm in the MCR and RSR, and mitigate against open phase conditions (OPCs) with and without a high-impedance ground fault during all plant operation.

In case OPCs with or without a high-impedance ground fault occur on the primary side of MT or SATs and safe shutdown capability is not assured due to the OPCs while the transformer(s) is(are) under loading condition, the Class 1E and non-Class 1E medium voltage (MV) switchgear buses are automatically separated from the degraded offsite power source after a time delay, and transferred to the alternate offsite power source or the onsite standby source as designed.

During all plant operation, OPDP system provides continuous monitoring of OPCs, and self-diagnostics of its system if practicable, for the surveillance functions to ensure that the OPDP system maintains the capability of providing the detection and protection for the OPCs. In order to prevent an unintended separation from the normal or alternate offsite power source by misoperation, maloperation, or spurious actuation of the OPDP system, the OPDP system is comprised of redundant detection subsystems or devices such that a failure in any one of the constituent system (or device) will not cause a spurious trip and offsite power supply to all safety-related equipment remains unaffected. This redundant detection feature of the OPDP system is made up of a voting logic scheme (e.g., 2-out-of-2, 2-out-of-3, or 2-out-of-4) of the constituent system (or device).

The OPDP system shall have sufficient capacity and capability to properly address and meet the requirements of B.1. and B.2. of Branch Technical Position (BTP) 8-9 (Reference 7).

The COL applicant is to determine the specific type of the OPDP system which properly address and meet the requirements of B.1. and B.2. of BTP 8-9, taking into account the site-specific design configuration, installation condition, (field) performance testing and qualification status, and operation experiences of the OPDP system. The COL applicant is also to provide the detailed design of the OPDP system selected for the APR1400 site.

The COL applicant is to perform a field simulation on the site-specific design of the offsite power system to ensure that the settings of the OPDP system are adequate and appropriate for the site (COL 8.2(8)).

The COL applicant is to describe how testing is performed on the offsite power system components and identify the potential effects that must be considered during testing

(COL 8.2(9)). The ratings of the MG, GCB, MT, UATs, SATs, and IPB are shown in Table 8.2-1.

8.2.1.4 Separation Between Preferred Power Supply I and Preferred Power Supply II

The normal and alternate preferred power supplies are physically and electrically separated to minimize the chance of simultaneous failure. The two circuits of the offsite preferred power sources are designed in accordance with IEEE Std. 765 (Reference 8) so that a failure of one offsite preferred power source does not affect the capacity and capability of the other offsite preferred power source. The preferred power supply I (normal preferred power supply) and preferred power supply II (alternate preferred power supply) are routed from the switchyard to their respective transformers.

The separation distances between the MT, UATs, SATs, and cables are as follows:

a. The UATs are separated from each other and from the SATs and MT by a minimum distance of 15 m (50 ft) or by a 3-hour-rating fire barrier.

b. The IPB associated with the UATs is separated from the SATs by a minimum distance of 15 m (50 ft) or by a 3-hour-rating fire barrier.

c. The cables that are routed from the SATs to the switchgears are separated from the UATs and MT by a minimum distance of 15 m (50 ft) or by a 3-hour-rating fire barrier.

Once the cables enter the plant, separation is maintained so that a single failure does not affect both of the preferred power circuits. Separation of preferred power supply I and preferred power supply II within the turbine generator building and the auxiliary building is maintained by dedicated cable trays.

The I&C cables that are affiliated with the preferred power supplies I and II are routed in dedicated metal raceways. The preferred power supply I and preferred power supply II I&C cables do not share raceways with any other cables.

The separation between I&C cables of the preferred power supplies I and II is the same as the separation between power cables of the preferred power supplies I and II.

8.2.2 Analysis

The offsite power system is designed to meet the following criteria.

8.2.2.1 Conformance with 10 CFR Part 50

10 CFR 50.63 – Loss of All Alternating Current Power

A light-water-cooled nuclear power plant is required by 10 CFR 50.63 (Reference 9) to be able to withstand or cope with, and recover from, an SBO. Electrical systems that are necessary to support systems in an SBO have sufficient capability and capacity to provide reasonable assurance that core cooling and appropriate containment integrity are maintained.

The APR1400 design has minimal potential for common-cause failures between the AAC power source used for an SBO and the offsite power system. Electrical ties and physical arrangement between these systems are designed not to prevent the use of an AAC power source during loss of the offsite power system. Conformance with the requirements of 10 CFR 50.63 is described in Section 8.4.

Criterion 2 – Design Bases for Protection Against Natural Phenomena

GDC 2 requires that structures, systems, and components (SSCs) important to safety of the offsite power system be capable of withstanding the effects of natural phenomena (excluding earthquakes, tornadoes, hurricanes, and floods) without the loss of the capability to perform their intended functions.

The components of the offsite power system, determined to be risk-significant non-safety-related SSCs by the design reliability assurance program (RAP), are designed to withstand the effects of natural phenomena such as high and low atmospheric temperatures, high wind, rain, lightning discharges, ice and snow conditions, and weather events within the conditions given in Table 2.0-1. The lightning protection of the offsite power system is described in Subsection 8.3.1.1.8. The offsite power system has two physically independent circuits with provisions to minimize the probability of simultaneous failure.

Criterion 4 – Environmental and Dynamic Effects Design Bases

GDC 4 requires that SSCs associated with the offsite power system be appropriately protected against dynamic effects, including the effects of missiles that can result from equipment failures during normal operation, maintenance, testing, and postulated accidents.

The offsite power system is designed to provide power to systems important to safety during normal, abnormal, accident, and post-accident conditions. The offsite power system supplies electric power required for the operation of systems important to safety even if/when they are subject to adverse dynamic effects. The offsite power system is designed to meet the requirements of IEEE Std. 765.

Criterion 5 – Sharing of Structures, Systems, and Components

GDC 5 (Reference 3) is related to the sharing of SSCs. There are no shared SSCs because the APR1400 design is a single-unit plant. Therefore, this GDC is not applicable to the APR1400.

Criterion 17 – Electric Power Systems

GDC 17 requires that offsite electric power be provided to facilitate the functioning of SSCs important to safety. The offsite power system has sufficient capacity and capability to permit functioning of SSCs important to safety. It also requires that two physically independent circuits from the offsite power system to the onsite power system be designed and located to minimize the likelihood of their simultaneous failure under operating, postulated accident, and postulated environmental conditions. The offsite power sources are fully independent from the onsite power sources and AAC power source. Conformance with this requirement is described in Subsection 8.2.1.3.

The COL applicant is to provide the results of grid stability analyses to demonstrate that the offsite power system does not degrade the normal and alternate preferred power sources to a level where the preferred power sources do not have the capacity or capability to support the onsite Class 1E electrical distribution system in performing its intended safety function. The stability analyses include the following contingencies (COL 8.2(7)):

a. APR1400 turbine-generator trip

b. Loss of the largest unit supplying the grid

c. Loss of the largest transmission circuit or inter-tie

d. Loss of the largest load on the grid

The COL applicant is to provide the required number of immediate access circuits from the transmission network (COL 8.2(10)).

Criterion 18 – Inspection and Testing of Electric Power Systems

GDC 18 is related to the inspection and testing of the offsite electric power system. It requires that electric power systems important to safety be designed to permit the appropriate periodic inspection and testing of important areas and features to assess the continuity of the system and the condition of their components: (1) the operability and functional performance of the components of systems, such as onsite power sources, relays, switches, and buses and (2) the operability of the systems as a whole and the full operational sequence that brings the systems into operation, including operation of the protection system, the transfer of power among the nuclear power unit, the offsite power systems, and the onsite power systems.

The offsite power system of the APR1400 has the capability to perform integral testing on a periodic basis. It includes appropriate and unobtrusive access for required periodic inspection and testing, enabling verification of important system parameters, performance characteristics, and features, and detection of degradation and/or impending failure under controlled conditions.

Criteria 33, 34, 35, 38, 41, and 44

GDC 33, 34, 35, 38, 41, and 44 (References 10 through 15, respectively) require that offsite power supplies including electrical distribution systems be available for reactor coolant makeup during small breaks, residual heat removal, emergency core cooling, containment atmosphere cleanup, and cooling water for SSCs important to safety during normal and accident conditions.

The necessary electric power is provided for all the facility's operating modes, including transients and design basis accidents (DBAs), to meet these criteria. Conformance with these requirements is accomplished by meeting the requirements of GDC 17.

8.2.2.2 Conformance with NRC Regulatory Guides

NRC Regulatory Guide 1.32

NRC RG 1.32 (Reference 16) is related to the criteria for power systems for nuclear power plants.

The design, operation, and testing of offsite power system for the APR1400 meet the requirements of NRC RG 1.32.

NRC Regulatory Guide 1.93

NRC RG 1.93 is related to the LCO (Limiting Conditions for Operation) for availability of electric power sources. The LCO for availability of electric power sources is addressed in Technical Specification 3.8.1, 3.8.4, 3.8.7, and 3.8.9.

NRC Regulatory Guide 1.155

NRC RG 1.155 (Reference 17) is related to an SBO.

The APR1400 has an AAC power source of sufficient capacity, capability, and reliability for operation of all systems necessary for coping with an SBO. The offsite power sources are fully independent from the AAC power source. Conformance with NRC RG 1.155 is described in Section 8.4.

NRC Regulatory Guide 1.160

NRC RG 1.160 (Reference 18) is related to monitoring the effectiveness of maintenance at nuclear power plants.

NRC RG 1.160 endorses Revision 4A of NUMARC 93-01 (Reference 19), which provides methods for complying with the provisions of 10 CFR 50.65 (Reference 20) with some provisions and clarifications. Conformance with NRC RG 1.160 is addressed in Section 1.9.

NRC Regulatory Guide 1.204

NRC RG 1.204 (Reference 21) is related to the guidelines for lightning protection of nuclear power plants.

The lightning protection of the APR1400 is described in Subsection 8.3.1.1.8. The APR1400 is designed to meet the requirements related to the lightning protection of nuclear power plants in IEEE Std. 665 (Reference 22), IEEE Std. 666, IEEE Std. 1050 (Reference 24), and IEEE Std. C62.23 (Reference 25).

8.2.2.3 Conformance with NUREG-0800

Standard Review Plan, Section 8.2, Appendix A

The APR1400 has a GCB that is designed and tested in accordance with the SRP 8.2, Appendix A. The GCB is designed to perform its intended function during steady-state operation, power system transients, and major faults. The ratings and required characteristics of the GCB are the designated limits of operating characteristics based on definite conditions as defined in IEEE Std. C37.013 (Reference 28).

BTP 8-3 (Reference 27), "Stability of Offsite Power Systems"

The COL applicant is to analyze the stability of the offsite power systems, as described in GDC 17 (COL 8.2(7)).

BTP 8-6, "Adequacy of Station Electric Distribution System Voltages"

BTP 8-6 (Reference 26) is related to adverse effects on the Class 1E loads that are caused by sustained low grid voltage conditions when the Class 1E buses are connected to offsite power. The APR1400 provides a second level of undervoltage protection with time delays to protect the Class 1E equipment from sustained undervoltages. Conformance with BTP 8-6 is addressed in Subsection 8.3.1.1.3.11.

BTP 8-9, "Open Phase Conditions in Electric Power System"

BTP 8-9 is related to detect, alarm, and protect against an open phase condition which occurs in the offsite electric power system. Conformance with BTP 8-9 is addressed in Subsection 8.2.1.3.

8.2.2.4 Conformance with 10 CFR 52.47(b)(1) and 10 CFR 52.80(a)

10 CFR 52.47(b)(1) requires that a design certification (DC) application contain the proposed inspections, tests, analyses, and acceptance criteria (ITAAC) that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses

are performed and the acceptance criteria met, than a plant that incorporates the APR1400 design certification has been constructed and will be operated in accordance with the design certification.

10 CFR 52.80(a) requires that a DC or a combined license (COL) application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee will perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will be operated in conformity with the combined license.

The proposed ITAAC and those applicable to emergency planning are described in Subsection 14.3.2.6 and Section 13.3, respectively. Thus, the electrical design of the APR1400 conforms with 10 CFR 52.47(b)(1) and 10 CFR 52.80(a).

8.2.3 Combined License Information

COL 8.2(1) The COL applicant is to identify the circuits from the transmission network to the onsite electrical distribution system that are supplied by two physically independent circuits.

COL 8.2(2) The COL applicant is to provide information on the location of rights-of-way, transmission towers, voltage level, and length of each transmission line from the site to the first major substation that connects the line to the transmission network.

COL 8.2(3) The COL applicant is to describe the switchyard voltage related to the transmission system provider/operator (TSP/TSO) and the formal agreement between the nuclear power plant and the TSP/TSO. The COL applicant is to describe the capability and the analysis tool of the TSP. The COL applicant is also to describe the protocols for the plant to remain cognizant of grid vulnerabilities.

COL 8.2(4) The COL applicant is to describe and provide layout drawings of the circuits connecting the onsite distribution system to the preferred power supply.

COL 8.2(5) The COL applicant is to describe the site-specific design for the switchyard equipment, including breaker arrangement, electrical schematics of breaker control system, protective devices and their settings, and auxiliary power supplies (ac and dc) for control and protection.

COL 8.2(6) The COL applicant is to provide a high-impedance ground fault detection feature that actuates an alarm in the MCR and RSR upon detection of a high-impedance ground fault at the primary side of MT or SATs.

COL 8.2(7) The COL applicant is to provide an FMEA of the switchyard components to assess the possibility of simultaneous failure of both circuits as a result of single events. In addition, the COL applicant is to provide the results of grid stability analyses to demonstrate that the offsite power system does not degrade the normal and alternate preferred power sources to a level where the preferred power sources do not have the capacity or capability to support the onsite Class 1E electrical distribution system in performing its intended safety function.

COL 8.2(8) The COL applicant is to determine the specific type of the OPDP system which properly address and meet the requirements of B.1. and B.2. of BTP 8-9, taking into account the site-specific design configuration, installation condition, (field) performance testing and qualification status, and operation experiences of the OPDP system. The COL applicant is also to provide the detailed design of the OPDP system selected for the APR1400 site.

The COL applicant is to perform a field simulation on the site-specific design of the offsite power system to ensure that the settings of the OPDP system are adequate and appropriate for the site.

COL 8.2(9) The COL applicant is to describe how testing is performed on the offsite power system components and identify the potential effects that must be considered during testing.

COL 8.2(10) The COL applicant is to provide the required number of immediate access circuits from the transmission network.

8.2.4 References

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Table 8.2-1 (1 of 2)

Ratings of Main Components

Equipment	Rating
Main generator	• Maximum MVA: 1,690 MVA • Voltage: 24 kV, 3 phase, 60 Hz
Generator circuit breaker	• Rated maximum voltage: 25.2 kV, rms Minimum continuous current: 43 kA, rms (60 Hz and 40 °C [104 °F]) • Rated frequency: 60 Hz
Main transformer	• Three-single phase with two windings, Y/Δ (High/Low voltage side) • Transformer size: 1,670/1,870 MVA (OFAF 55 °C [131 °F]/65 °C [149 °F]) • Rated frequency: 60 Hz • Rated voltage of low-voltage side: 24 kV • Rated voltage of high-voltage side: site-specific
Unit auxiliary transformers (UAT 1 and UAT 2)	For each UAT • Continuous MVA ratings (H-Winding) 71.0/94.7 MVA (ONAN/ONAF, 55 °C [131 °F]) 79.6/106.0 MVA (ONAN/ONAF, 65 °C [149 °F]) • Rated frequency: 60 Hz • Nominal system voltage (line-to-line) High voltage (H-Winding): 24 kV Low voltage (X-Winding): 14.49 kV Low voltage (Y-Winding): 4.37 kV

Table 8.2-1 (2 of 2)

Equipment	Rating
Standby auxiliary transformers (SAT 1 and SAT 2)	For each SAT • Continuous MVA ratings (H-Winding) 67.0/89.4 MVA (ONAN/ONAF, 55 °C [131 °F]) 75.1/100.0 MVA (ONAN/ONAF, 65 °C [149 °F]) • Rated frequency: 60 Hz • Nominal system voltage (line-to-line) High voltage (H-Winding): site-specific Low voltage (X-Winding): 13.8 kV Low voltage (Y-Winding): 4.16 kV
Isolated phase bus	• Nominal voltage: 24 kV • Number of phase: 3 • Rated frequency: 60 Hz • Insulation level: 125 kV • Continuous current of main generator bus: 43,000 A

Table 8.2-2

Protective Relay List of the MT, UATs, and SATs

Application	Relay Device No. (1)	Description	Remark
MT	687MT	MT differential relay	Protection and alarm
MT	687GMT	MT ground differential relay	Protection and alarm
MT	650/651GN	MT neutral ground overcurrent relay	Alarm and supervision of out-of-step relay
MT	359GB	Isolated phase bus ground fault relay	Protection and alarm
MT	650B	Sudden pressure relay blocking relay	Alarm and supervision of 663MT
MT	663MT	MT sudden pressure relay	Protection and alarm
MT	687U	Unit overall differential relay	Protection and alarm
MT	--	Thermal overload protection (2)	Protection and alarm
UAT	151GN	UAT neutral ground overcurrent relay	Protection and alarm
UAT	251GN	UAT neutral ground overcurrent relay	Protection and alarm
UAT	387AT	UAT differential relay	Protection and alarm
UAT	350/351	UAT overcurrent relay	Protection and alarm
UAT	363AT	UAT sudden pressure relay	Protection and alarm
UAT	--	Thermal overload protection (2)	Protection and alarm
SAT	151GN	SAT neutral ground overcurrent relay	Protection and alarm
SAT	251GN	SAT neutral ground overcurrent relay	Protection and alarm
SAT	451GN	SAT neutral ground overcurrent relay with instantaneous element	Alarm only
SAT	450/451	SAT overcurrent relay with instantaneous element	Protection and alarm
SAT	487ST	SAT differential relay	Protection and alarm
SAT	487GT	SAT ground differential relay	Protection and alarm
SAT	463ST	SAT sudden pressure relay	Protection and alarm
SAT	--	Thermal overload protection (2)	Protection and alarm

(1) Relay device prefix codes represent the voltage levels as follows :
1 : 4.16 kV
2 : 13.8 kV
3 : 24 kV
4 : High voltage side of SAT
6 : High voltage side of MT

(2) The thermal overload protection function is included as part of supplier furnished provisions.

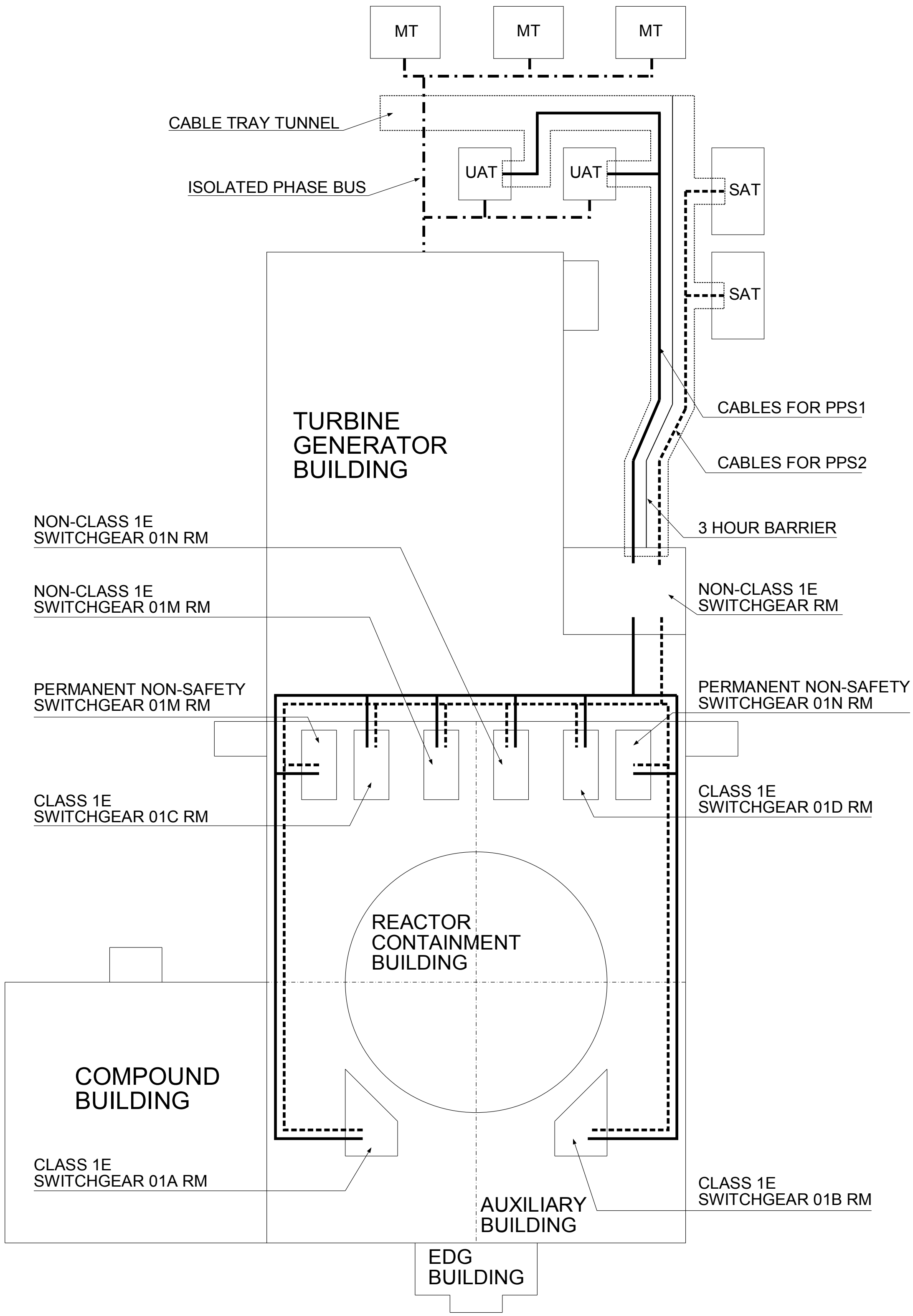

Figure 8.2-1 Layout Drawing Showing MT, UAT, SAT, MV Buses

8.3 Onsite Power Systems

8.3.1 AC Power Systems

8.3.1.1 Description

The onsite ac power system includes standby power sources, distribution systems, and auxiliary supporting systems that are provided to supply power to safety-related equipment or equipment important to safety for all normal operating and accident conditions. There are four Class 1E emergency diesel generators (EDGs) and one non-Class 1E gas turbine generator (GTG). The alternate alternating current (AAC) source is used as a standby power source for the onsite ac power system. The four Class 1E EDGs provide backup power to the Class 1E 4.16 kV buses in the event of a loss of offsite power (LOOP). One Class 1E EDG is dedicated to the respective Class 1E 4.16 kV bus. The non-Class 1E AAC GTG provides backup power to the permanent non-safety (PNS) buses during a LOOP and the dedicated Class 1E 4.16 kV bus during a station blackout (SBO).

The Class 1E ac power system is supplied power from one 4.16 kV mobile generator or one of two 480V mobile GTGs in case of a beyond-design-basis external event. The 4.16 kV mobile generator is connected to the 4.16 kV switchgear 1A (or 1B), and the 480V mobile GTG is connected to 480V load center 1A (or 1B). The watertight connection boxes are installed for the cable connection from the 4.16 kV mobile generator or 480V mobile GTGs to the respective Class 1E bus. The connection boxes are installed in the entry and exit of the auxiliary building where the connection boxes are readily accessible to the 4.16 kV mobile generator and the 480V mobile GTGs. The COL applicant is to provide and to design the 4.16 kV mobile generator and the 480V mobile GTGs and their support equipment (COL 8.3(1)). In addition, Class 1E switchgear rooms are also designed with watertight exterior barriers and doors to prevent the inflow of floodwater.

The mitigation strategies for beyond-design-basis external events, which involve operation of the mobile generators, are described in Section 19.3 of Chapter 19.

The onsite power system consists of the Class 1E power system and the non-Class 1E power system. The onsite power system is normally powered from two unit auxiliary transformers (UATs). If the normal preferred power source from UATs is unavailable, all Class 1E and non-Class 1E buses are automatically transferred to the alternate preferred power source from standby auxiliary transformers (SATs) by the fast and residual transfer scheme. For the automatic fast transfer, the synchro-check relay for each bus is used to supervise the voltage difference between the switchgear bus and upstream of the alternate feed incoming breaker and to provide a permissive for closing of the alternate feed incoming breaker to preclude unintended bus transfer. In case the fast transfer is not successful, residual transfer is performed automatically. The fast and residual transfer on each bus are permitted only when the alternate preferred power source from the SATs is available and the protection relay for the bus is not tripped.

The onsite ac power system consists of the 13.8 kV and 4.16 kV switchgears, 480V load centers, and 480V motor control centers (MCCs). The configuration of the onsite ac power system and offsite power system is shown in Figure 8.1-1.

8.3.1.1.1 Non-Class 1E Onsite AC Power System

There are two 3-winding UATs and two 3-winding SATs in the APR1400, and each transformer provides 13.8 kV and 4.16 kV power. During normal plant operation, two non-Class 1E 13.8 kV switchgears, one non-Class 1E 4.16 kV switchgear, and one PNS 4.16 kV switchgear are powered from a UAT in each division. One non-Class 1E AAC 4.16 kV switchgear can be aligned to either of PNS 4.16 kV switchgears.

The AAC GTG is automatically started by a starting signal from an undervoltage relay and supplies power to two PNS buses (division I and division II) manually during a LOOP. The loads that are not safety-related, but require operation during a LOOP, are connected to these buses manually. The AAC source is provided with diverse starting mechanisms compared to the Class 1E EDG. The AAC source is selected to minimize common-mode failures with the Class 1E EDG. The AAC source rating is adequate to meet the load requirements shown in Tables 8.3.1-4 and 8.3.1-5 during an SBO and a LOOP conditions.

Two independent circuit breakers (referred to as double incoming circuit breakers), connected in series, are used as a set of incoming breakers for all non-Class 1E 13.8 kV and 4.16 kV switchgear incomers, thereby significantly reducing the probability of failure of the non-Class 1E incoming breakers in case of bus fault. Of the two independent circuit breakers, only one breaker is used for switching operation and protection and the other only for protection as shown in Figure 8.3.1-1.

The double incoming circuit breakers to the non-Class 1E 13.8 kV and 4.16 kV buses are provided with undervoltage and timed overcurrent protections. The feeders on 13.8 kV and 4.16 kV buses are provided with instantaneous and timed overcurrent protection.

Load center transformers are connected to 13.8 kV or 4.16 kV switchgears and provide power to 480V load center buses. The non-Class 1E MCC buses are connected to the non-Class 1E load center buses.

8.3.1.1.1.1 13.8 kV Onsite AC Power System

The 13.8 kV onsite ac power system consists of four non-Class 1E switchgears and supplies power to large motors such as the reactor coolant pump motors, condensate pump motors, feedwater booster pump motors, circulating water pump motors, startup feedwater pump motor, and associated 480V load centers.

Preliminary fault studies under bounding conditions are performed using IEEE Std. 141 (Reference 1) to determine the fault levels.

The protective relaying for the 13.8 kV switchgear feeders and buses is classified as follows:

a. Protection of large motors and transformers

b. Protection of buses and feeders

The protective schemes are designed to isolate the faulted equipment from the rest of the system, minimize the effect of the fault, and maximize availability of the remaining equipment. The scheme limits the damage and the time out of service of the faulted equipment. The basic protective schemes consist of ground fault protection and instantaneous overcurrent and timed overcurrent protection. Other forms of protection, such as undervoltage and differential protections, are provided where applicable.

The non-Class 1E 13.8 kV switchgear buses and breaker ratings are listed in Table 8.3.1-6.

8.3.1.1.1.2 4.16 kV Onsite AC Power System

The 4.16 kV onsite ac power system consists of two non-Class 1E switchgears, two PNS switchgears, and one non-Class 1E switchgear with the non-Class 1E AAC source. The two non-Class 1E switchgears supply power to the closed cooling water pump in the turbine building and 480V load centers. The PNS switchgear supplies power to the central chiller, central chilled water pump, and 480V load centers, which are required to operate in a LOOP condition.

Preliminary fault studies under bounding conditions are performed using IEEE Std. 141 to determine the fault levels.

The protective relaying for the 4.16 kV switchgear feeders and buses is classified into three protection configurations as follows:

a. Protection of the motors and transformers

b. Protection of the gas turbine generator (AAC source)

c. Protection of the buses and feeders

The protective schemes are designed to isolate the faulted equipment from the rest of the system, minimize the effect of the fault, and maximize availability of the remaining equipment. The schemes also limit the damage and the time out of service of the faulted equipment. The basic protective schemes consist of ground fault protection, instantaneous overcurrent, and timed overcurrent protection. Other forms of protection, such as undervoltage, are provided where applicable.

The non-Class 1E 4.16 kV switchgear and breaker ratings are as shown in Table 8.3.1-6.

8.3.1.1.1.3 480V Onsite AC Power System

The 480V onsite ac power system is energized by the 13.8 kV and 4.16 kV switchgears through 13.8 kV/480V and 4.16 kV/480V transformers. The transformer secondary side is connected to a 480V load center bus through a 480V load center incoming breaker. The 480V load center breakers are three-pole, metal-enclosed, draw-out, and stored-energy operating mechanism type. These load centers are distributed throughout the plant and are located indoors. The load center and transformer ratings are shown in Table 8.3.1-6. Loads of the load centers are large low-voltage motors, large heaters, and 480V MCCs.

The 480V load center main and feeder breakers are selectively coordinated so that the breaker closest to a fault trips. The breaker interrupting rating is selected to meet the required fault duty. The main breakers are equipped with overcurrent trip devices having long-time and short-time delay functions and the feeder breakers are equipped with overcurrent trip devices having long-timed and instantaneous functions.

Non-Class 1E MCCs are located indoors in various areas of the plant. Each MCC is totally enclosed and the MCC ratings are shown in Table 8.3.1-6.

8.3.1.1.2 Class 1E Onsite AC Power System

The Class 1E onsite ac power system consists of two redundant load groups (division I and division II). Each load group has two EDGs. The Class 1E onsite ac power system consists of 4.16 kV switchgears, 480V load centers, 480V MCCs, and miscellaneous low-voltage ac supplies.

The Class 1E 4.16 kV switchgears are connected to offsite power sources through the UAT and SAT. Each Class 1E 4.16 kV switchgear is also powered by an EDG during a LOOP condition. The dedicated Class 1E 4.16 kV switchgear (train A or train B) has access to the non-Class 1E AAC source for an SBO event. Each 4.16 kV bus supplies power to the motor loads and 4.16 kV/480V load center transformers.

The Class 1E 4.16 kV switchgears are located in the auxiliary building. Each switchgear is arranged as an independent distribution system, located in separate fire zones in a seismic Category I room. The switchgear is a metal-clad, three-phase lineup with draw-out, stored-energy operating mechanism type circuit breakers. Each switchgear is provided with potential transformers, relays, and current transformers. The switchgear ratings are shown in Table 8.3.1-6.

Class 1E 4.16 kV switchgears A and B supply power to the non-Class 1E load of the pressurizer heaters back-up group in their division as required by the Three Mile Island (TMI) Action Item Plan in NUREG-0737, Item II.E.3.1 (Reference 2). These non-Class 1E loads are connected to the Class 1E buses by Class 1E circuit breakers, which serve as isolation devices.

The 480V Class 1E load centers and MCCs are located indoors in seismic Category I buildings. Each load center and MCC is provided with potential transformers, relays, and current transformers. The Class 1E load center transformer rating is shown in Table 8.3.1-6.

Load center transformers connected to the Class 1E 4.16 kV buses provide power to Class 1E 480V load center buses. The Class 1E 480V MCC buses are connected to the Class 1E load center buses.

The load center (LC02) located at the train B area of auxiliary building is used as a swing bus for the auxiliary charging pump. LC02 is connected to the train A load center (LC01A) during normal operation. In case of a loss of power from LC01A, LC02 is manually transferred to the train B load center (LC01B) through a dummy breaker. The auxiliary charging pump is manually controlled by the train A or train B hand switches in the main control room (MCR) and remote shutdown room (RSR).

8.3.1.1.2.1 System Redundancy

The onsite ac power system has the required redundancy of safety-related components and systems assuming a single failure. The Class 1E onsite ac power system consists of two redundant load groups (division I and division II), with four independent trains (A, B, C, and D), as shown in Figure 8.3.1-1. One of the two divisions (trains A and C or trains B and D), including associated Class 1E EDGs and electrical distribution systems, is required to supply the loads for safe shutdown during a LOCA concurrent with a LOOP.

Safety-related loads within a division are distributed between its two safety trains. Power for instrumentation and control (I&C) devices for Class 1E loads is supplied from the same safety train that supplies power to their loads, and 120 V power for Class 1E I&C devices is supplied through the inverter of the same safety train as described in Subsection 8.3.2.1.2.2. The configuration of the onsite ac power distribution system, including busing arrangements, loads supplied from each medium-voltage bus, safety-related equipment identification, and power connections to the I&C devices of the power systems is shown in a simplified electric power system single-line diagram in Figure 8.1-1. Switchgear locations are shown in Figure 8.2-1.

8.3.1.1.2.2 Single Failure Criteria

The Class 1E power system has sufficient capability to perform its safety function assuming a single failure. The independent trains of the Class 1E power system are provided with the required electrical and physical separation between trains to meet the single failure criterion. If one-out-of-two divisions is not available assuming a single failure, the other division (trains A and C or trains B and D) is capable of performing a safe shutdown of the plant. The capability to perform the safety function assuming postulated accidents (including a single failure) is verified as a failure modes and effects analysis (FMEA) for the onsite ac power system. The FMEA is presented in Table 8.3.1-7.

Each independent electrical train distribution system consisting of Class 1E 4.16 kV switchgear, 480V load center, and MCC are physically separated and located in separate rooms within the seismic Category I auxiliary building. The structures of the auxiliary building are designed to withstand the effects of natural phenomena such as hurricanes, floods, tornadoes, tsunami, and earthquakes without a failure to perform their safety functions.

There are no bus tie connections among the four Class 1E trains or between Class 1E and non-Class 1E system buses, except that an AAC switchgear bus for an SBO and swing bus for the auxiliary charging pump are manually connected to the Class 1E system buses. No automatic connection is provided among the Class 1E buses and between non-Class 1E loads and Class 1E buses. The Class 1E EDGs are not shared with any common bus. The criteria and bases governing the installation of electrical cables for redundant power systems are described in Subsection 8.3.1.1.10.

The onsite power system is designed to conform with the single failure criterion requirements in accordance with IEEE Std. 603 (Reference 3) and NRC RG 1.153 (Reference 4).

8.3.1.1.2.3 System Independence

There are two physically independent offsite preferred power supply circuits connected to each Class 1E 4.16 kV bus: the normal preferred power supply connection through the UAT and the alternate preferred power supply connection through the SAT. Separation between the normal and alternate preferred power supply within the plant boundary is described in Subsection 8.2.1.4. Although the preferred power supply circuits are non-safety-related, the Class 1E bus incoming circuit breakers serve as isolation devices in accordance with IEEE Std. 384 (Reference 5) as endorsed by NRC RGs 1.32 and 1.75 (References 6 and 7, respectively).

The onsite power system is designed with the physical and electrical independence from an offsite power system so that single failure does not prevent separation of the redundant portions of the onsite power system from the offsite power system. If power from the normal preferred power source is lost, the Class 1E 4.16 kV bus initiates an automatic fast transfer and residual transfer to the alternate preferred power source. If the fast transfer and residual transfer fail, the Class 1E 4.16 kV bus is automatically isolated from the preferred power sources and connected to its dedicated Class 1E EDG by the load sequencer.

The four independent Class 1E buses of the onsite power system and the connection between the onsite and offsite power systems are provided with physical separation and electrical isolation. The arrangement is shown in Figure 8.3.1-1.

Following a LOOP, the associated Class 1E EDGs are started and the safety buses are isolated from offsite sources and fed solely from the associated EDG. The four load sequencers (one for each Class 1E bus) used for bus load shedding and load sequencing are independent from one another. The Class 1E 4.16 kV bus degraded voltage relay scheme is designed to meet the requirements of Branch Technical Position (BTP) 8-6 (Reference 8). The protective relay scheme is described in detail in Subsection 8.3.1.1.3.11.

Non-Class 1E loads are connected to the Class 1E bus by Class 1E isolation devices. The isolation devices meet Regulatory Position (1) of NRC RG 1.75. Periodic testing of the isolation devices (e.g., visual inspection of fuses and fuse holders, circuit breaker operability tests, etc.) is performed during every refueling outage to demonstrate that the overall coordination scheme under multiple faults of non-safety-related loads remains within the limits specified in the design criteria. Pressurizer heater backup groups are provided power from the Class 1E 4.16 kV bus in accordance with 10 CFR 50.34 (Reference 9). Emergency ac lighting is powered from the Class 1E 480V MCC buses. Emergency lighting is described in Subsection 9.5.3.

The Class 1E and non-Class 1E onsite power system is designed such that the Class 1E loads will not fail upon a failure or presence of transients on non-Class 1E electrical equipment. In the event of a fault on non-Class 1E buses, the faulted bus is securely isolated by protective devices while the other Class 1E and non-Class 1E buses remain connected to the offsite power source by proper coordination of protective devices. In case of a fault at UAT or SAT winding or its connection to the Class 1E and non-Class 1E buses, the faulted non-Class 1E equipment or circuit is properly isolated by protective devices and the power supply to Class 1E buses is automatically transferred to the SATs or EDGs. The operational occurrences and incidental conditions of the non-Class 1E power system, such as voltage regulation, large motor starting, re-acceleration of motors during bus transfer, and short circuit conditions, are evaluated by the electrical power system studies as described in Subsection 8.3.1.3 to demonstrate that the Class 1E onsite ac power system retains its intended function during the operational and incidental conditions caused or affected by the non-Class 1E offsite and onsite power systems. This design feature properly satisfies GDC 17 and the staff position in SECY-91-078 (Reference 68).

The physical separation between the redundant equipment, including cables and raceways, is designed in accordance with IEEE Std. 384 as endorsed by NRC RG 1.75. The design criteria for the cable designs are described in Subsection 8.3.1.1.10. The identification of onsite power system components, including cables and raceways, is described in Subsection 8.3.1.1.10.

8.3.1.1.2.4 System Capacity and Capability

The Class 1E onsite power system has four independent trains. Each train is connected to one EDG. The selected two EDGs (trains A and C or trains B and D) are sufficient to meet the emergency load requirements for a safe shutdown during a LOOP concurrent with LOCA conditions.

The Class 1E EDG rating shown in Tables 8.3.1-2 and 8.3.1-3 is based on the characteristics of each load and the combined bus load demand connected to each diesel generator during the worst-case operating condition. Trains A and B EDGs are rated at 9,100 kW continuous rating and 10,010 kW short-time rating (2 hours), and trains C and D EDGs are rated at 7,500 kW continuous rating and 8,250 kW short-time rating.

Each EDG is designed to attain a rated voltage and frequency within 17 seconds after receipt of a start signal, supply power to its Class 1E 4.16 kV bus within 19 seconds, and begin to accept sequenced loads to meet the response times assumed in Chapter 15 analyses. The loading sequence and bases are shown in Tables 8.3.1-2 and 8.3.1-3.

The characteristics of the generator exciter and voltage regulator provide satisfactory starting and acceleration of sequenced loads and provide reasonable assurance of rapid voltage recovery when starting large motors. The ratings of the switchgear, load center, and MCC shown in Table 8.3.1-6 indicate sufficient capacity to supply power to the safety equipment during all operating modes.

8.3.1.1.3 Class 1E Emergency Diesel Generators

Each EDG train and its associated auxiliaries are installed in a separate room within physically separate seismic Category I structures that provide protection against tornadoes, hurricanes, external missiles, and seismic phenomena and are electrically isolated from the circuits of other EDGs trains and non-Class 1E circuits. Each EDG room is a separate fire area with 3-hour fire-rated walls, floors, and ceilings. Each EDG room is provided with its own independent ventilation system that automatically maintains the design room temperature for proper equipment operation and personnel access. The EDG room HVAC system and other EDG support auxiliaries are powered from the same electrical train as the EDG.

The EDG controls and monitoring instrumentation, with exception of the sensors and other equipment that are necessarily mounted on the EDG or its associated piping, are installed in free-standing, floor-mounted panels. These panels are designed for their normal vibration environment and are qualified to seismic Category I requirements.

The EDG units have the minimum target reliability factor of 0.95 in accordance with NRC RG 1.9 (Reference 10) and NRC RG 1.155 (Reference 11).

The COL applicant is to establish procedures to monitor and maintain EDG reliability during plant operations to verify the selected reliability level target is being achieved as intended in NRC RG 1.155 (COL 8.3(3)).

The EDG system provides the requirements with respect to the bypassed and inoperable status indication as described in Subsection 7.5.1.3.

8.3.1.1.3.1 Starting Initiating Circuits

The EDGs are started in the event of the following occurrences:

a. Automatic (through load sequencer logic shown in Figure 7.3-21)

   1) Initiation of an engineered safety features (ESF) actuation signal:

      a) Safety injection actuation signal (SIAS)

      b) Auxiliary feedwater actuation signal (AFAS)

      c) Containment spray actuation signal (CSAS)

   2) Initiation of a two-out-of-four loss of voltage or degraded voltage signal from the Class 1E 4.16 kV bus to which the EDG is connected

b. Normal manual

   Local switch actuation in EDG control room

c. Emergency manual

   Emergency manual actuation is accomplished by the emergency start and stop pushbuttons in the MCR and RSR.

8.3.1.1.3.2 EDG Support Systems

The EDG support systems consist of EDG fuel oil system, EDG engine cooling system, EDG starting air system, EDG lubrication system, air intake and exhaust system, and HVAC system. The following DCD Tier 2 sections provide a description of the associated EDG support system: The EDG fuel oil system is described in Subsection 9.5.4. The EDG engine cooling system is described in Subsection 9.5.5. The EDG starting air system is described in Subsection 9.5.6. The EDG lubrication system is described in Subsection 9.5.7. The air intake and exhaust system is described in Subsection 9.5.8. The HVAC system is described in Subsection 9.4.5.

8.3.1.1.3.3 Tripping Devices

The following mechanical trips are provided to protect the EDGs during testing:

a. High temperature – in the high temperature cooling water loop

b. Low temperature – in the high or low temperature cooling water loop

c. High pressure – in the crankcase

d. Low pressure – in the lubrication system

e. High temperature – in the lubrication system

f. Low level – in the lubrication system

g. Low level – in the fuel oil day-tank

h. High temperature – at the diesel engine or generator bearings

i. High temperature – at the diesel generator winding

j. Governor failure

These mechanical trips are bypassed in the event of an engineered safety features (ESF) actuation condition concurrent with a LOOP. The design of the bypass circuitry meets the requirements of IEEE Std. 603 and NRC RG 1.9.

The following electrical trips are provided to protect the EDGs during testing:

a. Generator overcurrent protection

b. Generator overvoltage or undervoltage protection

c. Generator negative sequence current protection

d. Generator underfrequency protection

e. Excitation fault protection

f. Generator loss-of-field protection

g. Generator reverse power protection

h. Generator ground fault protection

i. Generator voltage controlled overcurrent protection

All signals of the protective relay trip, except the trip signals listed below, are bypassed during the operation of the Class 1E EDG in a LOCA condition.

a. Engine overspeed

b. Generator differential current

c. Manual emergency trip

d. Diesel engine stop lever

The operating condition of each Class 1E EDG is monitored in the MCR and RSR. The following alarms from the following relays are provided in the MCR and RSR:

a. Differential/overspeed/emergency stop

b. Reverse power

c. Loss of field

d. Overcurrent with voltage restraint

e. Ground overvoltage

f. Phase (negative phase sequence) unbalance

g. Diesel generator fail to start

h. Running unloaded

i. Cranking

j. Subsystem trouble (ac generator, fuel oil system, lube oil system, cooling water system, starting system, excitation loss, and miscellaneous).

8.3.1.1.3.4 Interlocks

Each Class 1E 4.16 kV bus can be powered by either of the two offsite power sources or the Class 1E EDG of each train. In addition, each of train A and train B Class 1E 4.16 kV bus can also be powered by non-Class 1E AAC GTG or 4.16 kV mobile generator.

a. The interlock circuits of incoming breakers prevent parallel operation between normal and alternate preferred power supplies during manual transfer between UAT and SAT.

b. The EDG is permitted to operate in parallel with an offsite power source after synchronizing both sources during periodic testing.

c. The incoming circuit breakers are manually closed after synchronizing the offsite power sources with the Class 1E 4.16 kV bus when the preferred power supply is restored from a LOOP or an SBO event.

d. The electrical interlocks of the circuit breaker are provided to prevent the automatic closing of an EDG breaker onto an energized or faulted bus.

8.3.1.1.3.5 Permissive

The EDG operational mode selection is provided at the EDG local control panel through a "LOCAL/REMOTE" selector switch and a "NORMAL/MAINTENANCE" selector switch. Emergency start and emergency trip functions are not blocked by "LOCAL" mode selection.

Selection of the "NORMAL" mode also enables the selection of "REMOTE/LOCAL" mode switch. Selection of the "MAINTENANCE" mode blocks all automatic or manual start functions. All automatic or manual start functions are restored after switching to "NORMAL" mode.

8.3.1.1.3.6 Load Shedding and Sequencing Circuits

Shedding of all loads at the Class 1E 4.16 kV bus, except for the 4.16 kV/480V load center transformers, occurs whenever a sustained bus degraded voltage or loss of voltage condition is detected by the undervoltage relays. Separate sets of undervoltage relays are provided for each function.

A loss of voltage is detected by four time-delay undervoltage relays. Degraded voltage is detected by four time-delay undervoltage relays whose setting is higher than the setpoint value of the undervoltage relay for loss of voltage and lower than the required minimum operating voltage of the equipment. These relays consist of a two-out-of-four coincidence logic and a detection signal is provided to the engineered safety features-component control system (ESF-CCS) when two or more relays are operated. After the EDG attains the rated speed and voltage, circuit breakers for ESF loads are closed sequentially.

The EDGs are started on an ESF actuation signal (SIAS, AFAS, CSAS) and ready for operation within 17 seconds. However, the EDG is not connected to the Class 1E 4.16 kV bus when preferred power is available. The Class 1E loads are powered sequentially from the preferred power source in a predetermined order. The EDG is manually stopped after 1 hour when preferred power is continuously available.

Following an ESF actuation signal and an undervoltage relay operation signal, the Class 1E bus is separated from the offsite source and the Class 1E EDG is connected after it achieves a rated voltage and frequency. The Class 1E EDG load sequencer automatically sequences the required loads on the Class 1E 4.16 kV switchgear listed in Tables 8.3.1-2 and 8.3.1-3, as described in Subsection 7.3.1.8. The required safety-related loads are connected to the bus in the preselected interval time. A time interval is provided between motor starts to allow motor terminal voltage to sustain a minimum 75 percent of the motor rated voltage in accordance with requirements of NRC RG 1.9 and the quick-response excitation system and voltage regulation system are applied to restore voltage before loading the next step loads. The generator voltage and frequency variations between sequencing steps are in compliance with the intent of NRC RG 1.9.

8.3.1.1.3.7 Testability

The following preoperational onsite acceptance tests and periodic tests are conducted on each EDG and its associated auxiliary systems:

a. Preoperational testing

These preoperational tests conform with the provisions of NRC RG 1.9 and IEEE Std. 387 (Reference 12) regarding tests to be performed on EDGs. In addition, this test includes a minimum of 25 valid start and load tests without failure on each EDG to demonstrate required reliability.

b. Periodic testing

Periodic testing of the EDG meets the requirements of NRC RG 1.9, IEEE Std. 387, and GL 84-15 (Reference 13). Periodic testing of each EDG demonstrates capability of load sequencing during an interval of not less than 1 hour. Testing is performed by manually synchronizing the EDG with the offsite power system. This synchronization is supervised by a synchronism check relay.

In case the preferred power sources are lost while paralleled to the EDG during testing, the diesel generator circuit breaker is tripped automatically by electrical protective devices such as an overcurrent relay. Upon detection of undervoltage on the Class 1E 4.16 kV buses, load shedding and sequencing are initiated.

8.3.1.1.3.8 Electric Generator and Subsystems

The electric generator is a horizontal open drip-proof type air-cooled AC synchronous generator. The generator subsystems include the exciter and voltage regulator.

The excitation system is an external DG shaft-driven static exciter that controls the field current of generator, thereby controlling the output of the generator. The exciter is designed to operate in conjunction with the voltage regulator and include provisions to permit local manual adjustment of generator output voltage if the regulator is out of service.

The voltage regulator system is provided to adjust the DG output voltage and manual adjustment of the setpoint. The regulator type is typically static solid-state type. The electric generator, excitation and voltage regulator systems are Class 1E and seismic Category I.

8.3.1.1.3.9 Instrumentation and Control Systems

Controls are provided in the MCR and RSR for each EDG for the following operations:

a. Manual synchronization

b. Manual speed, load, and voltage adjustment

c. Emergency start and stop pushbuttons

A local control panel is provided at the EDG room for the following operations:

a. Normal or maintenance selection

b. Remote or local selection

c. Automatic or manual selection

d. Manual or automatic voltage regulation

e. Manual start and stop

f. Manual emergency stop

g. Reset (normal/emergency stop)

h. Manual voltage adjustment

i. Manual speed adjustment

j. Auxiliary equipment control switches

The dc power source for the EDG I&C system is a part of the same load group as the respective EDG and is described in Subsection 8.3.2.

The status of each Class 1E 4.16 kV breaker position is indicated in the MCR and RSR and at the circuit breaker cubicle. The analog instrumentation for the EDG provides the following indicators in the MCR and RSR:

a. Output voltage

b. Output frequency

c. Output ampere

d. Output watts

e. Output vars

f. Power factor

Each emergency diesel generator set is equipped with one diagnostic monitoring and display system (DMDS).

The DMDS is designed to ensure the maximum availability and reliability of the diesel generator set. The main functions of the DMDS are as follows:

a. Monitoring and recording the DG system alarms

b. Validation of start configuration

c. Starting sequence: monitoring and failure identification

d. Diesel generator operating assistance, including CRT based emergency and normal procedures

e. Identification of the causes for diesel generator malfunction causes identification

f. Support diesel generator engine predictive maintenance

The DMDS equipment for each diesel generator set is located in the local EDG control room.

8.3.1.1.3.10 Prototype Qualification Program

The qualification program of Class 1E equipment is in accordance with IEEE Std. 323 (Reference 14), IEEE Std. 344 (Reference 15), and the applicable equipment standards.

The environmental qualifications of mechanical and electrical equipment are described in Section 3.11.

8.3.1.1.3.11 Protective Relaying System

The basic criterion for the protective relaying system in accordance with IEEE Std. 242 (Reference 16) is that it promptly initiates, with precision and reliability, the operation of isolation devices that serve to remove from service any element of the onsite power system when that element is subjected to an abnormal condition that may prove detrimental to the effective operation or integrity of the unit.

Protective devices for the Class 1E ac power system are designed with the same as non-Class 1E ac power system described in Subsections 8.3.1.1.1.1, 8.3.1.1.1.2, and 8.3.1.1.1.3.

Protective device coordination studies are performed in accordance with IEEE Std. 141 and IEEE Std. 242 to verify that breakers closest to a fault open before upstream breakers. The protective relaying system for the Class 1E ac distribution system, dc distribution system, I&C system, electrical penetrations in the reactor containment building, and motor-operated valves (MOVs) is designed in accordance with IEEE Std. 741 (Reference 17) as endorsed by NRC RG 1.106 (Reference 18).

Class 1E buses are provided with separate bus voltage monitoring and protection schemes for degraded voltage and loss of voltage conditions, respectively. These schemes are designed in accordance with the recommendations of BTP 8-6. Two separate time delays are selected for degraded voltage protection as recommended in IEEE Std. 741 Appendix A.

There are of four first-level undervoltage relays to detect loss of voltage and four second-level undervoltage relays to detect degraded voltage on each of the four Class 1E buses. These relays consist of a two-out-of-four coincidence logic in the component control system (CCS) that starts the EDG, trips the incoming breakers of the Class 1E 4.16 kV bus, sheds load, closes the EDG breaker on the switchgear, and begins sequencing.

The dropout for the first-level undervoltage relays for the Class 1E distribution system is set at a level below minimum voltage during motor starting. Its associated time delay is set to ride out power system transients and initiate action in a time that is consistent with the accident analysis.

The dropout for the second-level undervoltage relays for the Class 1E distribution system is set at a level above the minimum voltage that allows proper operation of safety loads with the worst-case line-up and minimum switchyard voltage. Its associated first time delay is set to establish existence of a sustained undervoltage longer than motor starting.

Following the first time delay, an alarm is provided in the MCR and RSR. The subsequent occurrence of a safety injection actuation signal (SIAS) immediately separates the Class 1E bus from the offsite power system. The second time delay is limited so that the connected Class 1E equipment is not damaged.

Voltage studies are to be performed in conformance with BTP 8-6, Subsection B.3. The results are to be verified by testing as described in BTP 8-6, Subsection B.4.

Voltage studies are used to determine the relay pickup and time delays of all levels of the undervoltage protection described above. The capability to test and calibrate during power operation is provided and annunciation in the MCR and RSR is provided for any bypasses incorporated into the design.

8.3.1.1.4 Electrical Equipment Layout

The locations of Class 1E and non-Class 1E electrical equipment rooms shown in Figure 8.2-1 are selected to minimize vulnerability to physical damage. The electrical equipment is located away from mechanical piping in order to minimize the damaging effects of pipe ruptures. Separation is achieved by locating equipment and circuits in separate rooms, maintaining distance, or use of barriers. The potential hazard of non-safety-related equipment failure on safety-related redundant equipment is considered in the choice of equipment location or protection.

The followings are the general features of the electrical equipment layout:

a. The Class 1E switchgears, load centers, and MCCs of the independent train are located in four separate rooms of the auxiliary building. Separate ventilation systems are used for each room powered from the corresponding train.

b. Class 1E batteries are located in the auxiliary building. Each battery is located in a separate room and each room is equipped with a separate ventilation system powered from the corresponding train.

c. Four separate and independent cable routes are provided for the four Class 1E trains A, B, C, and D in accordance with IEEE Std. 384.

d. Class 1E EDGs and associated equipment are located in separate rooms of the auxiliary building and EDG building.

e. The Class 1E battery chargers, inverters, and dc buses associated with each of the independent trains are located in four separate rooms of the auxiliary building.

f. In addition to the preceding, two Class 1E MCCs (Train A and Train B) are each located in geographically separated ESW buildings.

g. Piping containing fluids is excluded from the Class 1E electrical distribution equipment rooms. Class 1E electrical distribution equipment rooms of different trains are separated from each other by concrete walls and floors. Any electrical or physical failure in one room has no effect on the redundant equipment in the other rooms.

8.3.1.1.5 Design Criteria for Class 1E Equipment

Motor Size

The motor horsepower rating is selected to be equal or greater than maximum horsepower requirement of the driven load when operating at design condition.

Minimum Motor Accelerating Voltage

Class 1E motors are designed to accelerate with 75 percent rated voltage at the motor terminals throughout the starting period and are capable of accelerating their connected loads without overheating. All other motors are designed to accelerate to the rated speed with 80 percent rated voltage at the motor terminal throughout the starting period and are capable of accelerating their connected loads without exceeding the thermal limits.

Motor Starting Torque

The torque of 225 hp and smaller motors is designed in accordance with standard NEMA MG 1 (Reference 19). The torque of 250 hp and larger motors is designed in accordance with NEMA C50.41 (Reference 20), except that locked rotor torques and pull-up torques for normal torque type motors are not less than 80 percent of full-load torque. The motor starting torque at minimum specified voltage is adequate for starting and accelerating the connected load to normal speed within motor starting time to perform its safety function during the motor acceleration time.

Minimum Motor Torque Margin Over Pump Torque

The minimum motor torque is larger than the pump torque so that the motor reaches normal speed within the starting time that is required to perform its safety function at minimum motor terminal voltage.

Motor Insulation

Motor insulation is selected on the basis of the particular ambient conditions to which the insulation is exposed. The insulation system for the safety-related motors within the reactor containment building is selected to withstand the postulated accident environment.

Temperature Monitoring Devices

The 4.16 kV motors have at least six (two per phase) dual-type, stator winding, resistance temperature detectors with 100 Ω platinum resistance at 0 °C (32 °F).

Interrupting Capacities

Circuit breakers are designed with sufficient interruption rating under the maximum short-circuit current. The short-circuit current is calculated by the Electrical Transient Analyzer Program (ETAP, version 12.0.0N) based on IEEE Std. 141. The interrupting capacity of switchgears, load centers, and MCCs is shown in Table 8.3.1-6.

Electric Circuit Protection

The electric circuit protection is described in Subsection 8.3.1.1.3.11.

Grounding Requirements

Grounding requirements are described in Subsection 8.3.1.1.8.

8.3.1.1.6 Testing of Onsite AC Power System

Testing of onsite ac power system equipment is performed in accordance with GDC 18 (Reference 21), NRC RG 1.9, and NRC RG 1.118 (Reference 22). All Class 1E circuit breakers and motor starters, except for the equipment associated with certain safety loads described in Subsection 7.1.2.37, are testable during normal operation.

During periodic testing of Class 1E systems, engineered safety features actuation system (ESFAS) subsystems are actuated or simulated to verify the appropriate circuit breaker or contactor operational response. The Class 1E 4.16 kV switchgear and 480V load center circuit breakers can also be tested independently while the equipment is shut down. These circuit breakers can be placed in a test position and exercised without operation of the associated equipment.

LOOP testing or combined LOOP and LOCA testing is performed during a plant shutdown condition. The EDG testing capability is described in Subsection 8.3.1.1.3.7.

Surveillance testing of the Class 1E distribution system is described in Section 3.8 of Chapter 16.

8.3.1.1.7 Heat Tracing

The heat tracing system is provided with non-Class 1E power to prevent freezing of fluid in pipes and equipment and to maintain the required temperature in critical process control systems.

The heater is energized by a signal from the temperature sensor attached to each system. The heat tracing system is operated by an automatic control device in the heat tracing panel when the temperature is below the required setpoint.

8.3.1.1.8 Grounding and Lightning Protection Criteria

Station grounding is provided for personnel and equipment protection from the effects of transient overvoltage that can occur in electrical systems due to electrical faults or lightning strikes. Station grounding is designed in accordance with IEEE Std. 665 (Reference 23), IEEE Std. 666 (Reference 24), and IEEE Std. 1050 (Reference 25), as endorsed by NRC RG 1.204 (Reference 26). The primary function of the grounding system is to limit the step and touch potentials for plant personnel to safe levels at any location on the plant site.

The COL applicant is to describe and provide detailed ground grid and lightning protection (COL 8.3(4)).

The guidelines for the design of the plant grounding and lightning protection systems are as follows:

a. The plant ground grid, consisting of bare copper cables, limits the step and touch potentials to safe values under all fault conditions. The design and analysis are based on the procedures and recommendations of IEEE Std. 80 (Reference 27).

b. The grounding system has bare copper cables for connections to all electrical underground ducts, equipment, and the grounding systems within buildings.

c. The design of the grounding system follows the procedures and recommendations of IEEE Std. 665.

d. Each building has 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.

e. The main generator (MG) is grounded with a neutral grounding device having high impedance that limits the maximum phase current under short-circuit conditions. Protective relays are provided for ground fault protection.

f. The isolated phase bus (IPB) is electrically continuous with three phase enclosures bonded together at the generator end and transformer end. The bus enclosures are electrically insulated from the support structures and adjoining equipment. The IPB supports located inside the turbine building are connected to the building ground grid. Outdoor supports are grounded by connecting the base of each support to the ground grid with two grounding conductors bonded to the ground grid in two locations. The IPB is grounded in accordance with manufacturer's recommendation.

g. The onsite medium-voltage ac distribution system is resistance grounded at the neutral point of the low-voltage windings of the UATs and SATs. The UAT and SAT secondary neutral relays are provided protection against internal ground faults in transformer low-voltage windings, as well as the backup ground fault protection for the medium-voltage bus.

h. The neutral point of the EDG and AAC GTG windings is grounded through distribution transformers and loading resistors sized for continuous operation with a ground fault. A ground overvoltage relay connected to the secondary winding of each distribution transformer provides protection against generator stator ground fault.

i. Ground fault protection of the low-voltage ac distribution system is provided by an overcurrent relay located in the neutral of the transformer secondary winding. It is set to coordinate with downstream ground fault protective devices.

j. The ground buses of all switchgears, load centers, and MCCs are connected to the plant ground grid through at least two parallel paths. The ground buses of other electrical cabinets are connected to the plant ground grid through at least one path.

k. Each major piece of equipment, metal structure, or metallic tank has two diagonally opposed ground connections.

l. The underground electrical duct bank and door frame are grounded with bare copper cable.

m. The dc systems are ungrounded.

n. Plant instrumentation is grounded through separate radial grounding systems that consist of isolated instrumentation ground buses and insulated cables. The instrumentation grounding systems are connected to the station grounding grid at one point only and insulated from all other grounding circuits. The I&C equipment grounding is designed based on the recommendations of the latest revision of IEEE Std. 142 (Reference 28) and IEEE Std. 1050.

o. Plant instrumentation and monitoring equipment located outdoors or connected to outdoor cables are provided with built-in surge suppression devices to protect the equipment from lightning-induced surges.

p. Lightning protection is provided for all major plant structures, including the reactor containment building. The lightning protection is in accordance with the National Fire Protection Association's Lightning Protection Code, NFPA 780 (Reference 29).

q. Each phase of all tie lines connecting the plant electrical systems to the switchyard and offsite transmission system is protected by lightning arresters. The arresters are connected to the high-voltage terminals of the MT and SATs. The UAT is fed from the MG terminals using IPB and therefore does not require lightning protection.

8.3.1.1.9 Containment Electrical Penetrations

The electrical penetration assemblies (EPAs) are designed, fabricated, qualified, and tested in accordance with IEEE Std. 317 (Reference 30), IEEE Std. 323, and IEEE Std. 383 (Reference 31).

Class 1E containment EPAs are physically separated and electrically isolated to maintain the independence of Class 1E circuits and equipment. These EPAs are located in four quadrants of the reactor containment building. The minimum separation between the Class 1E and non-Class 1E cables is maintained in accordance with IEEE Std. 384, as endorsed by NRC RG 1.75. Class 1E EPAs are classified as seismic Category I and are qualified for a harsh environment.

Containment EPAs are designed and tested in accordance with IEEE Std. 317, as endorsed by NRC RG 1.63 (Reference 32). Selection and setting of protective devices for containment EPAs are in accordance with IEEE Std. 741 to provide proper coordination with thermal capability of the containment EPA defined in IEEE Std. 317. In order to protect the EPAs from damage due to short-circuit current or overload, primary and backup protections are provided. For MCCs, backup protection is provided with two thermal-magnetic breakers in series. For 480V load centers and 13.8 kV medium-voltage switchgears for the reactor coolant pump, backup protection is provided by the main breaker and overcurrent relays coordinated with the feeder breaker to protect the electrical penetration assemblies.

The COL applicant is to conduct periodic inspection and testing of the protection devices for the EPA conductors. All circuit breakers for the EPA conductors shall be inspected and tested in 60 months, low voltage circuit breaker overcurrent protection devices for the EPA conductors shall be inspected and tested once per 18 months for 10 % of each type of circuit breakers, and overcurrent relay for medium voltage circuit breakers for the EPA conductors shall be inspected and tested once per 18 months (COL 8.3(5)).

8.3.1.1.10 Cable and Raceway Design Criteria

The power cables are designed, fabricated, and tested in accordance with NEMA WC 74 (Reference 33) and NEMA WC 70 (Reference 34). The control cables are designed, fabricated, and tested in accordance with NEMA WC 57 (Reference 35). The instrumentation cables are designed, fabricated, and tested in accordance with

NEMA WC 57. Safety-related cables are qualified for the design life of the plant in accordance with IEEE Std. 323.

Cable conductor size selection for medium and low-voltage power and control cables is based on cable ampacity and voltage drop considerations. In addition, the conductors of all medium- and low-voltage power cables are sized to withstand the maximum available fault current. The cable ampacity is based on the maximum cable ambient temperature, the rated cable insulation temperature of 90 ºC (194 ºF), the cable raceway design, and cable routing paths. IEEE Std. 835 (Reference 36) and NEMA WC 51/ICEA P-54-440 (Reference 37) are used for cable conductor size selections.

In order to properly address the concerns of cable degradation as per NRC GL 2007-01 (Reference 62), electrical duct banks (EDB) and underground tunnels in which electric cables are installed are designed not to degrade cables due to the submergence by means of slope of EDB and sump pumps for drainage. Furthermore, cables are monitored in accordance with NRC RG 1.218 (Reference 38).

NRC RG 1.218 requires that the plant have monitoring techniques for electric cables. Cable monitoring programs include cable tests to measure and trend the condition of the cable. Tests that can be used for detecting insulation degradation in underground cable include partial discharge testing, time-domain reflectometry, dissipation factor testing, and very-low-frequency ac testing.

The COL applicant is to provide testing, inspection, and monitoring programs for detecting insulation degradation of underground and inaccessible power cables within the scope of 10 CFR 50.65 (Reference 39) (COL 8.3(6)).

All cables and raceways are identified by permanent color coding for divisions and trains according to IEEE Std. 384. The color coding uses five basic colors. These colors correspond to the following Class 1E and non-Class 1E divisions and trains:

Class 1E Cables and Raceways

Train A: Red

Train B: Green

Train C: Yellow

Train D: Blue

Non-Class 1E Cables and Raceways

Division I: Black

Division II: Black

Raceway identifications are permanently marked at an interval not exceeding 4.6 m (15 ft) within an area where the tray enters and exits. Conduits are marked in the same manner.

All Class 1E and non-Class 1E equipment is identified with a corresponding color-coded engraving name plate per train and division. The color coding of the name plate is the same as that of the raceway.

Cables of different voltage levels are installed in separate raceways. The voltage levels are classified as follows:

a. Medium-voltage power (13.8 kV)

b. Medium-voltage power (4.16 kV)

c. Low-voltage power (480V and dc power)

d. Control

e. Instrumentation

If the trays are stacked, the order from top to bottom is as shown above.

Cables of each train run in separate raceways are physically separated from cables of the other trains. Separation of trains is in accordance with IEEE Std. 384, as endorsed by NRC RG 1.75. Raceways for non-Class 1E are separated from each Class 1E train A, B, C, and D in accordance with IEEE Std. 384. The raceway in the cable spreading area, main control room, and other congested areas is designed in accordance with IEEE Std. 384. The power and control wiring in control boards or panels is separated in accordance with IEEE Std. 420 (Reference 40).

Medium-voltage power cables are routed in an open-top ladder-type cable tray in a single layer with maintained spacing. The distance between adjacent cables within a tray is onequarter the diameter of the larger cable. The cable tray fill criterion for low-voltage power cables does not exceed 30 percent of the cross-sectional area of the open-top ladder-type tray. The cable tray fill criterion for control cable does not exceed 50 percent of the cross-sectional area of the open-top ladder-type tray. Solid-bottom and solid-cover type cable trays are used for routing instrumentation cables, with an allowable fill of 50 percent of tray cross-sectional area. Cable splicing in a raceway is prohibited.

The COL applicant is to establish Administrative Program(s), including application of dedicated cable and raceway management database tool as necessary, which is (are) developed on the basis of the cable and raceway numbering system to efficiently manage cable routing and cable termination and verify that the cable design fulfills the acceptance criteria (i.e., separation, filling criteria, and ampacity) (COL 8.3(7)).

8.3.1.1.11 Cathodic Protection

The cathodic protection system disturbs the electrochemical reaction that causes corrosion of metal structures and piping of which protection is decided as per the site conditions. Basically, two methods of cathodic protection are applied. One is the sacrificial system, which is a passive method, and the other is impressed current system, which is an active method.

The COL applicant is to provide the detailed design of the cathodic protection system as applicable to the site conditions (COL 8.3(8)).

8.3.1.2 Analysis

The APR1400 Class 1E ac power system is designed to meet the requirements of GDCs 2, 4, 17 (Reference 41), 18, 33, 34, 35, 38, 41, and 44, 50; and the intent of NRC RGs 1.6, 1.9, 1.32, 1.47, 1.53, 1.63, 1.75, 1.93, 1.106, 1.118, 1.153, 1.155, 1.160, 1.204, 1.218, 10 CFR 50.34, 10 CFR 50.55a(h), 10 CFR 52.47(b)(1), 10 CFR 52.80(a), BTPs 8-1 (Reference 63), 8-2 (Reference 64), 8-4 (Reference 65), 8-5 (Reference 66), and 8-7 (Reference 67). The criteria and guidelines are shown in Table 8.1-2 and include their applicability in the electrical system design.

8.3.1.2.1 Conformance with General Design Criteria

Criterion 2 – Design Bases for Protection Against Natural Phenomena

GDC 2 requires that systems and components important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without the loss of their safety function capabilities.

The Class 1E onsite ac power system and its components are located in seismic Category I structures that provide protection from the effects of natural phenomena. Class 1E equipment is seismically qualified, and its mounting and installation are seismically designed to worst-case design basis earthquake for the site. Conformance with GDC 2 against earthquakes, tornadoes, hurricanes, and floods is provided in Sections 3.3, 3.4, 3.5, and 3.7, respectively.

Criterion 4 – Environmental and Dynamic Effects Design Bases

GDC 4 requires that systems and components important to safety be designed to accommodate the effects of, and be compatible with, the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents and be appropriately protected against dynamic effects, including the effects of missiles, that may result from equipment failures.

The Class 1E ac power system is designed to provide power to systems important to safety during normal, abnormal, accident, and post-accident conditions. The equipment and components of the Class 1E onsite ac power system are designed to meet IEEE Std. 323 for qualifying Class 1E application equipment in nuclear power plants. Class 1E electrical distribution equipment is located away from high- or moderate-energy lines and potential internal missile areas. Conformance with GDC 4 is addressed in Section 3.1.

Criterion 5 – Sharing of Structures, Systems, and Components

GDC 5 is related to the sharing of SSCs. There are no shared SSCs because the APR1400 design is a single-unit plant. Therefore, this GDC is not applicable to the APR1400.

Criterion 17 – Electric Power Systems

GDC 17 requires that an onsite electric power system be provided to facilitate the functioning of SSCs important to safety. The onsite electric power system has sufficient capacity and capability to perform its intended safety functions for all plant operating modes, including anticipated operational occurrences (AOOs) and design basis accidents (DBAs). The specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of an AOO, the core is cooled, and containment integrity and other vital functions are maintained in the event of a postulated accident.

The onsite ac power sources and onsite electrical distribution system have sufficient independence, redundancy, and testability to perform their safety functions assuming a single failure. Therefore, no single failure prevents the onsite ac power system from supplying electric power, thereby permitting safety functions and other vital functions needing electric power to be performed in the event of any single failure in the power system. Conformance with the requirements of GDC 17 is addressed in Subsection 8.3.1.1.2.

Criterion 18 – Inspection and Testing of Electric Power Systems

GDC 18 requires that electric power systems important to safety be designed to permit appropriate periodic inspection and testing of important areas and features to assess the continuity of the system and the condition of their components.

The onsite ac power system of the APR1400 is designed to have the capability to perform integral testing of a Class 1E system periodically. The periodic test for EDGs is described in Subsection 8.3.1.1.3.7. The testing of the onsite ac power system is described in Subsection 8.3.1.1.6. Conformance with the requirements of GDC 18 is addressed in Subsection 8.3.1.1.6.

Criteria 33, 34, 35, 38, 41, and 44

GDC 33, 34, 35, 38, 41, and 44 require that the onsite power supplies including electrical distribution systems be available for reactor coolant makeup during small breaks, residual heat removal, emergency core cooling, containment heat removal, containment atmosphere cleanup, and cooling water for SSCs important to safety during normal and accident conditions. These GDC also require the safety system to have redundancy. Redundant safety loads are distributed between redundant divisions of the Class 1E electrical distribution systems, and associated redundant division of the Class 1E electrical distribution systems supply the I&C devices for safety-related loads.

The necessary electric power is provided for all facility operating modes including transients and DBA to meet these criteria. Conformance with these requirements is accomplished by meeting the requirements of GDC 17.

Criterion 50 – Containment Design Basis

GDC 50 requires that the reactor containment structure, including access opening, penetrations, and containment heat removal systems be designed to accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from a LOCA.

Electrical penetration assemblies are designed to accommodate the calculated pressure and temperature conditions resulting from a LOCA without exceeding their design leakage rate in accordance with and IEEE Std. 323 and IEEE Std. 317.

The design and protection of the electrical penetration assemblies conform with IEEE Std. 741 and NRC RG 1.63 requirements. The selection and settings of electrical protective devices provides reasonable assurance that the containment electrical penetration conductors do not exceed their design withstand ratings for overload and maximum short-circuit current. Electrical penetrations are provided with primary and backup protection. Each protection scheme has a separate interrupting device. Reactor containment electrical penetration assembly protection is described in Subsection 8.3.1.1.9.

8.3.1.2.2 Conformance with NRC Regulatory Guides

NRC Regulatory Guide 1.6

NRC RG 1.6 is related to the independence between redundant standby (onsite) power sources and between their distribution systems.

Class 1E onsite ac loads are separated into two redundant and independent load groups (divisions). Each load group is further separated into two independent small load groups (trains). Each Class 1E electrical distribution train has two connections to the preferred offsite power sources and a connection to an onsite standby power source. The Class 1E switchgear buses have no automatic connection to any loads or buses in different trains. Each EDG is connected exclusively to its associated Class 1E 4.16 kV switchgears, which provides reasonable assurance of the independence of the onsite Class 1E standby power sources.

No single failure prevents operation of the minimum number of required safety loads, and the loss of any one division does not prevent the operation of the required safety functions. The redundancy and independence of the APR1400 are described in Subsections 8.3.1.1.2.1 and 8.3.1.1.2.3.

NRC Regulatory Guide 1.9

NRC RG 1.9 is related to the application and testing of safety-related emergency diesel generators in nuclear power plants.

The design of the EDGs used as standby power sources conforms with the intent of NRC RG 1.9. Each EDG set is capable of starting and accelerating to rated speed and energizing all the required ESF and emergency shutdown loads. The EDGs conform with the requirements specified by NRC RG 1.9.

NRC Regulatory Guide 1.32

NRC RG 1.32 is related to the criteria for power systems for nuclear power plants.

The design, operation and testing of the onsite ac power system for the APR1400 meet the guidelines of IEEE Std. 308 (Reference 42), endorsed by NRC RG 1.32, with an exception that pertains to sharing of Class 1E dc power systems at multi-unit nuclear power plants. This exception is not applicable to the APR1400 because it is a single unit. The onsite power system is designed to conform with the requirements of NRC RG 1.32.

NRC Regulatory Guide 1.47

NRC RG 1.47 is related to the criteria for bypassed and inoperable status indication for nuclear power plants.

NRC RG 1.47 provides the requirements with respect to the bypassed and inoperable status indication of a Class 1E ac power system for a nuclear power plant. The APR1400 conforms with the requirements of NRC RG 1.47.

NRC Regulatory Guide 1.53

NRC RG 1.53 is related to application of the single-failure criterion to safety systems.

The Class 1E onsite ac electric power system has two redundant divisions divided into four independent trains: division I with trains A and C and division II with trains B and D. Each Class 1E electrical train consists of Class 1E EDG and power distribution equipment. Each component and the equipment of the four independent trains is electrically isolated and housed in a physically separate seismic Category I building. HVAC systems that support the operation of the Class 1E ac power systems are powered from the same electrical train they serve. A single failure of any component in one train does not affect the other trains. NRC RG 1.53 endorses IEEE Std. 379 (Reference 43), which provides guidance on the application of the single-failure criterion and describes an acceptable method of single-failure analysis. The onsite power system is designed to conform with requirements specified by NRC RG 1.53. Conformance with NRC RG 1.53 is addressed in Subsection 8.3.1.1.2.2.

<u>NRC Regulatory Guide 1.63</u>

NRC RG 1.63 is related to the EPAs in the containment structures of nuclear power plants.

The EPAs in containment structures are designed to meet NRC RG 1.63 and IEEE Std. 317, which is endorsed by the NRC. Conformance with NRC RG 1.63 is addressed in Subsection 8.3.1.1.9.

<u>NRC Regulatory Guide 1.75</u>

NRC RG 1.75 is related to the criteria for independence of electrical safety systems.

The independence of the onsite power system is described in Subsection 8.3.1.1.2.3. The cable and raceway design related to NRC RG 1.75 is addressed in Subsection 8.3.1.1.10. The Class 1E onsite power system is designed to meet the requirements of NRC RG 1.75.

<u>NRC Regulatory Guide 1.81</u>

NRC RG 1.81 is related to the criteria for shared emergency and shutdown electric systems for multi-unit nuclear power plants.

The APR1400 is a single-unit plant. Therefore, NRC RG 1.81 is not applicable to the APR1400.

NRC Regulatory Guide 1.93

NRC RG 1.93 is related to the LCO (Limiting Conditions for Operation) for availability of electric power sources. The LCO for availability of electric power sources is addressed in Technical Specification 3.8.1, 3.8.4, 3.8.7, and 3.8.9.

NRC Regulatory Guide 1.106

NRC RG 1.106 is related to the thermal overload protection for electric motors on motor-operated valves (MOVs).

NRC RG 1.106 provides criteria to provide reasonable assurance that safety-related MOVs, whose motors are equipped with thermal overload protection devices integral with the motor starter, perform their safety function. The thermal overload protection devices for safety-related MOVs conform with the requirements of NRC RG 1.106.

NRC Regulatory Guide 1.118

NRC RG 1.118 is related to the periodic testing of electric power and protection systems.

Class 1E onsite electric power and protection systems are designed to be testable during operation of the nuclear power generating station as well as when the station is shut down. IEEE Std. 338 (Reference 44), which is endorsed by NRC RG 1.118, provides design and operational criteria for the performance of periodic testing as part of the surveillance program of nuclear power plant safety systems. Class 1E onsite electric power and protection systems are designed to conform with GDC 18, NRC RG 1.9, and NRC RG 1.118.

NRC Regulatory Guide 1.153

NRC RG 1.153 is related to the criteria for safety systems.

IEEE Std. 603, endorsed by NRC RG 1.153, provides minimum functional and design requirements for the power, instrumentation, and control portions of safety systems for nuclear power plants. The Class 1E onsite ac power system is designed to conform with the requirements of NRC RG 1.153 and IEEE Std. 603.

NRC Regulatory Guide 1.155

NRC RG 1.155 is related to an SBO.

The APR1400 has an AAC power source of sufficient capacity, capability, and reliability for operation of all systems necessary for coping with an SBO. The AAC power source is designed to be available to power the shutdown buses within 10 minutes of the onset of an SBO. The AAC power source is fully independent from the offsite power sources and Class 1E onsite ac power sources. Conformance with NRC RG 1.155 is described in Section 8.4.

NRC Regulatory Guide 1.160

NRC RG 1.160 is related to monitoring the effectiveness of maintenance at nuclear power plants.

NRC RG 1.160 endorses Revision 4A of NUMARC 93-01 (Reference 45), which provides methods for complying with the provisions of 10 CFR 50.65 with some provisions and clarifications. Conformance with NRC RG 1.160 is addressed in Section 1.9.

NRC Regulatory Guide 1.204

NRC RG 1.204 is related to the guidelines for lightning protection of nuclear power plants.

The APR1400 onsite ac power system is designed to meet the requirements of IEEE Std. 665, IEEE Std. 666, IEEE Std. 1050, and IEEE Std. C62.23 (Reference 46), which are related to the lightning protection of nuclear power plants.

NRC Regulatory Guide 1.218

NRC RG 1.218 provides the cable design and maintenance criteria for the performance of periodic testing as part of the condition-monitoring techniques for the electric cables that are used in nuclear power plants. The inaccessible cable condition-monitoring techniques related to NRC RG 1.218 are addressed in Subsection 8.3.1.1.10.

8.3.1.2.3 Conformance with 10 CFR 50.34 Related to TMI Action Plan Requirements

10 CFR 50.34(f)(2)(v) (TMI Item I.D.3) requires the applicant to provide for automatic indication of the bypassed and operable status of safety systems. Information regarding bypassed and inoperable status indication of the Class 1E onsite ac and dc power system and the Class 1E EDG system is described in Subsection 7.5.1.3. Conformance with the requirement of 10 CFR 50.34(f)(2)(v) is addressed in Subsection 7.5.2.3.

10 CFR 50.34(f)(2)(xiii) (TMI Item II.E.3.1) is related to providing pressurizer heater power supply and conformance with the requirement of 10 CFR 50.34(f)(2)(xiii) is addressed in Subsection 8.3.1.1.2.

10 CFR 50.34(f)(2)(xx) (TMI Item II.G.1) is related to providing power supplies for pressurizer relief valves, block valves, and level indicators. For the APR1400, there is no power-operated relief valve (PORV) or block valve which requires any electrical power. The Class 1E 120 Vac I&C power system, backed up by EDGs and batteries, supplies power for pressurizer level indication instruments as described in Subsection 7.1.2.11. Thus, it conforms with 10 CFR 50.34(f)(2)(xx).

8.3.1.2.4 Conformance with Branch Technical Positions

BTP 8-1, "Requirements on Motor-Operated Valves in the ECCS Accumulator Lines"

The design of motor operated valves in the ECCS accumulator lines conforms with BTP 8-1. Conformance with BTP 8-1 is addressed in DCD Tier 2, Subsections 6.3.2.5.1, 6.3.2.1.1, 6.3.5.3.2, 7.3.1.3 and Figure 7.6-2.

BTP 8-2, "Use of Diesel-Generator Sets for Peaking"

The Class 1E EDGs are not used for peaking service. They provide standby power in the event of a loss of the offsite preferred power source(s). They are connected to the offsite power source, one at a time, for periodic testing as described in DCD Tier 2, Subsection 8.3.1.1.3.7.

<u>BTP 8-4, "Application of the Single Failure Criterion to Manually Controlled Electrically Operated Valves"</u>

The APR1400 design of manually controlled electrically operated valves conforms with BTP 8-4.

The following provides descriptions of the electrically operated valves, for which electric power is required be removed and restored to meet the single failure criterion addressed in BTP 8-4.

a. Safety injection tank (SIT) isolation valves are motor-operated gate valves provided in each SIT discharge line and are administratively controlled to open from the MCR during normal operation. Power to the motor operator of each valve is removed to prevent inadvertent closure as described in Subsection 6.3.2.1.1, 6.3.5.3.2.a and verified by surveillance requirement 3.5.1.5.

b. SIT atmospheric vent isolation valves are solenoid globe valves provided for tank venting. The valves are locked closed and power to each valve is removed during normal operating to prevent inadvertent SIT venting as described in Subsection 6.3.2.1.1 and 6.3.2.5.1.

c. Valves in the cavity flooding system of the in-containment water storage system consist of the holdup volume tank (HVT) flooding valves and the reactor cavity flooding valves. The HVT flooding valves are motor-operated gate valves in the flow paths that connect the IRWST to the HVT, and the reactor cavity flooding valves are motor-operated gate valves in the flow paths that connect HVT to the reactor cavity. The valves are only used to flood the reactor cavity through the HVT for severe accident mitigation in the event of a severe accident. The valves remain locked closed with the power connections for the valves separated from the power source during all plant conditions. Connections are established to the power source during severe accidents as described in Subsection 6.8.2.1.2 and 6.8.2.2.4.

All safety-related electrically operated valves are operated from the MCR and the position of these valves is indicated on the Information Flat Panel Display (IFPD) and the Large Display Panel (LDP), which are driven by the Information Processing System (IPS). The valve position indications are also provided on the Qualified Indication and Alarm System-N (QIAS-N) FPD. The IPS is electrically isolated, physically separated, and diverse from the QIAS-N. Therefore, any failure of the IPS does not adversely affect the operation of the QIAS-N. Also, the position of safety-related electrically operated valves is indicated on the safety-related soft control display (ESCM).

BTP 8-5, "Supplement Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems"

The Bypassed and Inoperable Status Indication for onsite power system complies with BTP 8-5. Descriptions of the bypassed and inoperable status indication for engineered safety features systems are provided in Subsection 7.5.1.3.

BTP 8-7, "Criteria for Alarms and Indications Associated with Diesel-Generator Unit Bypassed and Inoperable Status"

The bypassed and inoperable status indication (BISI) design for the EDGs conforms to the recommendations of BTP 8-7, except the position number 3. The EDG units of APR1400 are not shared with other units. Descriptions of the system-level BISI for the plant auxiliary systems including EDGs are provided in Subsection 7.5.1.3.

8.3.1.2.5 Conformance with 10 CFR 50.55a(h)

10 CFR 50.55a(h) is related to the codes and standards for protection and safety systems.

IEEE Std. 603, incorporated and specified in 10 CFR 50.55a(h), provides minimum functional and design requirements for the power, instrumentation, and control portions of safety systems for nuclear power plants. The Class 1E ac and dc power system is designed to conform with the requirements of 10 CFR 50.55a(h) and IEEE Std. 603.

8.3.1.2.6 Conformance with 10 CFR 52.47(b)(1) and 10 CFR 52.80(a)

See Subsection 8.2.2.4.

8.3.1.3 Electrical Power System Calculations and Distribution System Studies for AC System

The analysis of load flow, voltage regulation, and short-circuit studies is performed by using ETAP, version 12.0.0N, which is qualified for nuclear power plants in accordance with 10 CFR Part 21, 10 CFR Part 50, Appendix B (Reference 47), and ASME NQA-1 (Reference 48).

8.3.1.3.1 Load Flow/Voltage Regulation Studies and Under/Overvoltage Protection

Load flow studies of onsite power systems are performed to demonstrate that acceptance voltage regulation is maintained within 90 to 110 percent of the rated voltage at the equipment terminals under the worst-case condition among normal, startup, hot standby, and LOCA operation mode. Lager motor starting studies calculate the voltage drop so that motor terminal voltages are maintained at not less than acceptance voltage of 75 percent of motor rating for Class 1E motors and 80 percent of motor rating for non-Class 1E motors. Acceptance criteria for EDG loading are described in Subsection 8.3.1.1.3.6. Safety and non-safety motors, switchgears, load centers, MCCs, and distribution transformers are included in load flow and voltage regulation studies.

8.3.1.3.2 Short-Circuit Studies

Analysis is performed to demonstrate maximum short-circuit current by considering the bus fault in the onsite ac power system. ETAP, based on IEEE Std. C37 series, is used for short-circuit studies. Short-circuit current for each study case is less than the acceptance criteria, which are the applicable circuit breaker interrupting and close and latch ratings described in Table 8.3.1-6. Buses of switchgears and load centers are considered for maximum fault current analysis. Containment electrical penetration assemblies are protected by overload and short-circuit current in accordance with IEEE Std. 741.

8.3.1.3.3 Equipment Sizing Studies

Electrical equipment sizing of the distribution system is performed using the spreadsheet load list and verified using ETAP analysis. The ratings of major electrical system components are not exceeded when load flow, short-circuit, and motor starting analysis are performed under normal and abnormal operation modes, including DBAs. The medium-voltage switchgear loads are listed in Table 8.3.1-1. The Class 1E EDG loads are shown in Tables 8.3.1-2 and 8.3.1-3. The AAC GTG loads are shown in Tables 8.3.1-4 and 8.3.1-5.

8.3.1.3.4 Equipment Protection and Coordination Studies

The protective relaying coordination of onsite distribution system is performed so that the circuit breaker separates the faulted electrical equipment from service in sufficient time to minimize the extent of damage to the faulted equipment and to prevent damage to other electrical equipment. The degraded voltage and loss of voltage protection and time delay function are in accordance with BTP 8-6. The COL applicant is to provide protective device coordination (COL 8.3(9)).

8.3.1.3.5 Insulation Coordination (Surge and Lightning Protection)

Surge and lightning protection is provided for the security of equipment and personnel from transient overvoltage due to lightning and electrical faults. Electrical equipment protected from lightning includes the main transformer, unit auxiliary transformer, standby auxiliary transformer, and switchyard facilities. The guidelines for the design of the surge and lightning protection are described in Subsection 8.3.1.1.8. Insulation coordination is performed in accordance with IEEE Std. C62.82.1 (Reference 49) and IEEE Std. 1313.2 (Reference 50). The COL applicant is to provide the analysis and underlying assumptions used to demonstrate adequacy for the insulation coordination of surge and lightning (COL 8.3(10)).

8.3.1.3.6 Power Quality Limits

Nonlinear loads such as battery chargers and inverters contribute total harmonic distortion (THD) to the distribution power system. THD degrades electric power quality, causing increased heating due to copper and iron losses at harmonic frequencies on electrical equipment such as motors, transformers, and switchgears. Therefore, the electrical distribution system is designed so that THD does not affect Class 1E equipment. THD is maintained within the acceptance criteria in accordance with IEEE Std. 519 (Reference 51). The power quality analyses are performed in accordance with NRC RG 1.206 and allowable THD is limited to less than or equal to 5 percent. Reasonable assurance of the protective device application within the power quality that is needed for the device to operate, is provided. The COL applicant is to provide the analysis and underlying assumptions used to demonstrate adequacy for power quality limits (harmonic distortion) (COL 8.3(11)).

8.3.1.3.7 Monitoring and Testing

Monitoring of the distribution power system is provided with information such as the quantitative value of equipment, circuit breaker status, and the protective device alarm by ESF-CCS and QIAS-P for Class 1E and the P-CCS and IPS for non-Class 1E equipment in the main control room and remote shutdown console. The operator can use the information that is necessary for efficient operation of the unit. All control room I&C is designed in accordance with the human factors engineering design criteria and implementation methods as described in Chapter 18.

Testing of the onsite ac power system is described in Subsection 8.3.1.1.6.

Load sequence testing for LOOP or combined LOOP and LOCA is performed during the plant shutdown condition. EDG testing capability is described in Subsection 8.3.1.1.3.7.

8.3.1.3.8 Grounding

The grounding system complies with the guidelines in IEEE Std. 665 and IEEE Std. 1050, as endorsed by NRC RG 1.204. The grounding system consists of station grounding, system grounding, equipment grounding, safety grounding, and instrumentation grounding.

The station grounding consisting of interconnected bare copper conductors is provided to protect personnel and equipment from the hazard voltages. System grounding is intended to provide grounds of neutral points of MG, UATs, SATs, load center transformers, EDG, and AAC GTG. Equipment grounding is provided for the ground fault return path via the raceway system. Safety grounding is for protecting personnel from injury and property from damage. Instrumentation grounding is intended to establish the signal reference and minimize degradation of instrumentation signals by grounding signal cable shields, instrumentation applications, and signal return conductors. Guidelines for the design of the grounding system are described in Subsection 8.3.1.1.8. The COL applicant is to provide the analysis for the station and switchyard grounding system with underlying assumptions, based on the site-specific parameters including soil resistivity and site layout (COL 8.3(12)).

8.3.1.3.9 Bus Transfer Study

Analysis is performed to check if a fast bus transfer is expected on each bus upon a fault on the normal offsite power source and to demonstrate the bus transfer (fast transfer or residual voltage transfer) will be performed successfully at each bus without failure of motor re-acceleration in the Class 1E and non-Class 1E power system. The COL applicant is to provide a bus transfer study of the onsite power system. Based on the bus transfer study, the COL applicant is also to provide final relay selection and settings for the bus transfer (COL 8.3(2)).

8.3.2 DC Power System

8.3.2.1 System Description

The onsite dc power system includes the dc power sources and their distribution systems and auxiliary supporting systems that are provided to supply motive or control power to the safety-related and non-safety-related equipment. Batteries and battery chargers serve as the power sources for the dc power system, and inverters convert dc power to ac power for I&C power, as required. These three components, when combined, provide an uninterruptible power supply (UPS) that furnishes a continuous and reliable source of 120 Vac power. Under normal conditions, the dc distribution systems are designed to provide power for switchgear group controls, uninterruptible power supplies, inverters, diesel generator control, relays, solenoid valves, dc motors, emergency dc lighting, and other electric devices and components. Under abnormal and accident conditions when there is no ac power, batteries provide power to the assigned loads.

The onsite dc power system is divided into independent Class 1E and non-Class 1E dc power systems. The Class 1E dc power system consists of four separate subsystem trains. The onsite Class 1E dc power system has the capacity and capability to permit the functioning of structures, systems, and components (SSCs) important to safety and the independence and redundancy necessary to perform their safety functions, assuming a single failure.

The SSCs of the Class 1E dc power systems are capable of withstanding the effects of missiles and environmental conditions associated with normal operation and postulated accidents.

Class 1E batteries are designed to provide control power for emergency operation of safety-related equipment or equipment important to safety, including power for automatic operation of the RPS and ESF protection systems during abnormal and accident conditions through associated inverters.

The dc power system is designed to be testable during power operation of the plant as well as when the plant is shut down.

The system configuration is shown in Figures 8.3.2-1 and 8.3.2-2. The dc power system loads are listed in Tables 8.3.2-1 and 8.3.2-2.

8.3.2.1.1 Non-Class 1E DC Power Systems

8.3.2.1.1.1 Non-Class 1E 125 Vdc Power System

The non-Class 1E 125 Vdc power system is composed of four independent subsystems. Two subsystems are installed in the auxiliary building, one subsystem is installed in the compound building, and one subsystem is installed in the AAC GTG building. The system in the AAC GTG building is designed to supply the dc power necessary to start and operate the AAC GTG. The 125 Vdc power system is shown in Figure 8.3.2-2. Each of these dc systems consists of a battery, battery chargers, a dc control center, and distribution panels. Each dc control center is powered from its respective battery or battery charger depending on the plant condition.

The two non-Class 1E 125 Vdc power systems located in the auxiliary building share a standby battery charger that is designed to replace one of the two normal battery chargers for maintenance outage or a normal battery charger failure. The normal battery chargers and standby battery charger are interlocked to prevent paralleling.

The dc loads for the non-Class 1E dc power system are listed in Table 8.3.2-2. The electrical equipment rating of the non-Class 1E dc power system is shown in Table 8.3.2-4.

8.3.2.1.1.2 Non-Class 1E 250 Vdc Power System

The 250 Vdc power system in the turbine generator building consists of a battery, two battery chargers (normal and standby), and a dc control center. This system is shown in Figure 8.3.2-2.

The 250 Vdc power system supplies power to high-inrush dc loads that generally serve as backups to turbine generator ac loads. The electrical equipment rating of the non-Class 1E dc power system is shown in Table 8.3.2-4.

8.3.2.1.1.3 Non-Class 1E 120 Vac Instrumentation and Control Power System

The non-Class 1E 120 Vac I&C power system supplies continuous, reliable, and regulated ac power to the plant non-safety-related I&C equipment, information processing system (IPS), and process-component control system (P-CCS), which require uninterruptable ac power for operation.

The non-Class 1E 120 Vac I&C power system consists of inverters, regulating transformers, manual and automatic transfer switches, and distribution panels, as shown in Figure 8.3.2-4. The I&C power system is designed to provide an output frequency of 60 Hz ± 0.5 percent and voltage regulation within ± 2 percent at full rated load for a load power factor greater than 0.8.

The 120 Vac distribution panel receives power from its associated inverter or regulating transformer through transfer switches. The automatic transfer switch is to automatically transfer total load from the normal ac power source to the alternate ac power source without interruption. The automatic transfer switch is a make-before-break type with automatic synchronization between the inverter and regulating transformer upon inverter faults and overload condition. A manual transfer switch transfers full load to the alternate power source, bypassing inverter and automatic transfer switch, for maintenance purposes. The two power sources are interlocked to prevent paralleling.

8.3.2.1.2 Class 1E DC Power System

8.3.2.1.2.1 Class 1E 125 Vdc Power System

The onsite Class 1E 125 Vdc power system is composed of four independent subsystems (trains A, B, C, and D) and supplies reliable power to the plant safety system dc loads and essential I&C system loads. Each dc power subsystem consists of a battery, two battery chargers (normal and standby), a dc control center, and distribution panels. The standby battery charger is designed to replace the normal battery charger in case of a maintenance outage or a normal battery charger failure. The normal and standby battery chargers are interlocked to prevent paralleling.

Each dc control center is powered from its respective battery or battery charger depending on the plant condition. The 125 Vdc power system is shown in Figure 8.3.2-1.

The Class 1E 125 Vdc power systems, located in a seismic Category I structure, are designed to remain functional in the event of a safe shutdown earthquake, operating basis earthquake, tornadoes, hurricanes, floods, and other design basis events including missile impact and internal accidents.

The Class 1E dc loads are listed in Table 8.3.2-1. The electrical equipment rating of the Class 1E dc power system is shown in Table 8.3.2-4.

8.3.2.1.2.2 Class 1E 120 Vac Instrumentation and Control Power System

The Class 1E 120 Vac I&C power system is required for all plant operating conditions. The Class 1E 120 Vac I&C power system supplies a continuous, reliable, and regulated ac power to the safety-related plant instruments, control equipment, and engineered safety features-component control system (ESF-CCS), which are required to be operational during the momentary or complete loss of onsite ac power. Class 1E 120 Vac I&C loads are listed in Table 8.3.2-3.

The Class 1E 120 Vac I&C power system consists of four separate and independent 120 Vac power systems. Each Class 1E 120 Vac I&C power system has an inverter, regulating transformer, distribution panel, manual and automatic transfer switch, and distribution panel, as shown in Figure 8.3.2-3. The Class 1E 120 Vac I&C power system is designed to provide an output frequency of 60 Hz ± 0.5 percent and voltage regulation within ± 2 percent at full rated load for a load power factor greater than 0.8.

The four trains are separated in accordance with NRC RG 1.75 so that a single failure cannot cause multiple train malfunctions or interactions between trains. Independence is provided between safety trains and non-safety equipment. The distribution panel receives power from its associated inverter or regulating transformer through the transfer switches. The inverter is the normal and preferred power source and the regulating transformer serves as an alternate source when the inverter fails. The automatic transfer switch is a make-before-break type with automatic synchronization between the inverter and regulating transformer upon inverter faults and overload condition. A manual transfer switch transfers full load to the alternate power source, bypassing the inverter and auto transfer switch, for maintenance purposes. Two power sources are interlocked to prevent paralleling.

The Class 1E 120 Vac I&C power system, located in a seismic Category I structure, is designed to remain functional in the event of a safe shutdown earthquake, operating basis earthquake, tornadoes, hurricanes, floods, and other design basis events including missile impact or internal accidents.

8.3.2.1.2.3 System Redundancy

The Class 1E dc power system has the required redundancy of the safety-related components and systems assuming a single failure. Class 1E dc power systems and components are designed to perform their safety function in the event of a single failure.

The Class 1E dc power system is divided into four subsystems (trains A, B, C, and D), two per division: trains A and C for division I and trains B and D for division II. The Class 1E dc power system consists of two redundant divisions as shown in Figure 8.3.2-1. The configuration of the dc power distribution system including the batteries, battery chargers, and associated distribution systems is shown in a simplified single-line diagram in Figure 8.3.2-1.

8.3.2.1.2.4 Single Failure Criteria

The Class 1E dc power system has sufficient capability to perform its safety function assuming a single failure. The redundant divisions of Class 1E dc power system provide electrical and physical separation, respectively, to meet the single failure criterion. If one safety-related power division is inoperable due to a single failure, the other division accomplishes the intended safety function.

The batteries, battery chargers, and associated distribution systems, including their connected loads, are designed to meet the requirements of IEEE Std. 384 and NRC RG 1.75.

The battery charger of each train is powered from the same train of the Class 1E onsite ac power system. Each battery charger normally supplies the loads of its associated train while maintaining a float charge on its associated battery.

The Class 1E dc power system is designed to conform with the single failure criterion requirements in accordance with IEEE Std. 603 and NRC RG 1.153.

8.3.2.1.2.5 System Independence

Two redundant divisions of the Class 1E dc power system, located in a seismic Category I structure, are separated so that a single failure does not cause multiple malfunctions or interactions between divisions. There is no interconnection or inadvertent closure of interconnecting devices between redundant divisions.

The physical separation between the redundant equipment, including cables and raceways, is designed in accordance with IEEE Std. 384, as endorsed by NRC RG 1.75. The cable and raceway design criteria are described in Subsection 8.3.1.1.10. Subsection 8.3.1.1.10 also describes the means for identifying the onsite power system components.

8.3.2.1.2.6 System Capacity and Capability

The battery is sized based on the duty cycle of the respective subsystems. Each battery is capable of supplying power to the worst-case operating loads for a period of the battery duty cycle. The sizing of the battery is performed in accordance with the IEEE Std. 485 (Reference 52). Class 1E battery loads and duty cycles are shown in the Table 8.3.2-1 and the battery rating is shown in Table 8.3.2-4. The Class 1E batteries are qualified in accordance with IEEE Std. 535 (Reference 53).

The each Class 1E dc power system has one normal battery charger and one standby battery charger. A standby battery charger provides complementary redundancy to a normal battery charger. The power supply for the connected dc power system is transferred using a manual transfer switch from the normal battery charger to the standby battery charger when the normal battery charger needs maintenance or repair. Interlocks are provided to prevent normal and standby chargers from operating in parallel. Each battery charger is capable of supplying the largest combined demand of the various steady-state loads and charging simultaneously the battery from the design minimum charged state to the fully charged state, irrespective of plant status when these demands occur. Sizing of the battery chargers is in accordance with the recommendations in IEEE Std. 946 (Reference 54). The battery charger rating is shown in Table 8.3.2-4.

The inverters that provide reliable I&C power have sufficient capacity and capability to perform their intended function. The Class 1E 120 Vac I&C power system loads are listed in Table 8.3.2-3 and the inverter rating is shown in Table 8.3.2-4.

A 125 Vdc control center is provided for each of the 125 Vdc power system load groups. Each control center supplies power to its assigned bus and equipment and is powered directly from its associated 125 Vdc battery and battery chargers irrespective of the condition of other control centers. The Class 1E dc control center supplies power to one dc distribution panel and one static inverter.

8.3.2.1.2.7 Class 1E 125 Vdc Power System and 120 Vac Instrumentation and Control Power System Status Information

The parameters or status that are monitored in the MCR for the 125 Vdc power system and 120 Vac I&C power system are listed in Table 8.3.2-5.

Ammeters provided to monitor battery current have the capability to monitor both charge and discharge currents. Voltmeters are supplied to monitor dc and ac voltage of the buses and inverter distribution panels. The indications and alarms in the dc control center, battery charger control panel, and inverter distribution panel are listed in Table 8.3.2-5.

Ground fault detectors and their corresponding ground monitoring alarms are provided with sufficient sensitivity.

8.3.2.2 Analysis

The APR1400 Class 1E 125 Vdc power system is designed to meet the requirements of GDCs 2, 4, 17, 18, 33, 34, 35, 38, 41, 44, and 50 and the intent of NRC RGs 1.6, 1.32, 1.47, 1.53, 1.63, 1.75, 1.93, 1.106, 1.118, 1.128, 1.129, 1.153, 1.155, 1.160, 1.212, and 10 CFR 50.34, 10 CFR 50.55a(h), 10 CFR 52.47(b)(1), and 10 CFR 52.80(a). Table 8.1-2 includes their applicability of the GDC and NRC RGs to the electrical system design.

8.3.2.2.1 Conformance with General Design Criteria

Criterion 2 – Design Bases for Protection Against Natural Phenomena

GDC 2 requires that systems and components important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

The Class 1E 125 Vdc power system and 120 Vac I&C power system and their components are located in seismic Category I structures that provide protection from the effects of natural phenomena. Class 1E equipment is seismically qualified and the mounting and installations are seismically designed to the worst-case design basis earthquake for the site. Conformance with GDC 2 against earthquakes, tornadoes, hurricanes, and floods is provided in Sections 3.3, 3.4, 3.5, and 3.7, respectively.

Criterion 4 – Environmental and Dynamic Effect Design Bases

GDC 4 requires that systems and components important to safety be designed to accommodate the effects of, and be compatible with, the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents and be appropriately protected against dynamic effects, including the effects of missiles, that may result from equipment failures. The Class 1E 125 Vdc power system is designed to provide power to systems important to safety during normal, abnormal, accident, and post-accident conditions. The equipment and components of the Class 1E 125 Vdc power systems are designed to meet the IEEE Std. 323 for qualifying Class 1E application equipment in nuclear power plants. The Class 1E 125 Vdc electrical distribution equipment is located away from high- or moderate-energy lines and potential missile areas. Conformance with GDC 4 is described in Subsection 8.3.2.1.2.

Criterion 5 – Sharing of Structures, Systems and Components

GDC 5 is related to the sharing of SSCs. There are no shared SSCs because the APR1400 design is a single-unit plant. Therefore, this GDC is not applicable to the APR1400.

Criterion 17 – Electric Power Systems

GDC 17 requires that the onsite electric power system be provided in order to facilitate the function of SSCs important to safety. The onsite electric power system has sufficient capacity and capability to perform intended safety functions during all normal and emergency modes of plant operation including DBEs.

The Class 1E 125 Vdc power system has two independent and redundant divisions and four independent trains. Class 1E 125 Vdc division loads are distributed between divisions, and Class 1E 125 Vdc train loads are distributed between trains, trains A and C on division I, and trains B and D on division II. Each independent train consists of a battery, normal and standby battery chargers, and associated power distribution equipment. The Class 1E 125 Vdc power system, including the batteries and onsite electrical distribution system, has sufficient independence, redundancy, and testability to perform its safety functions assuming a single failure. Therefore, no single failure prevents the onsite dc power system from supplying electric power, thereby permitting safety functions and other vital functions that require dc electric power to be performed after any single failure in the power system. Conformance with GDC 17 is described in Subsection 8.3.2.1.2.

Criterion 18 – Inspection and Testing of Electric Power Systems

GDC 18 requires that electric power systems important to safety be designed to permit appropriate periodic inspection and testing of important areas and features to assess the continuity of the system and the condition of their components.

The Class 1E dc power system provides the capability to perform integral, periodic testing of Class 1E dc systems. Conformance with GDC 18 is described in Subsection 8.3.2.3.6.

Criteria 33, 34, 35, 38, 41, and 44

GDC 33, 34, 35, 38, 41, and 44 require that onsite power supplies, including electrical distribution systems, be available for reactor coolant makeup during small breaks, residual heat removal, emergency core cooling, containment heat removal, containment atmosphere cleanup, and cooling water for SSCs important to safety during normal and accident conditions. These GDC also require the safety system to have redundancy. Redundant safety loads are distributed between redundant divisions of the Class 1E 125 Vdc electrical distribution systems, and associated redundant divisions of the Class 1E 125 Vdc distribution systems supply the I&C devices for the Class 1E loads and power system.

The necessary electric power is provided for all facility operating modes including transients and DBAs to meet these criteria. Conformance with these requirements is accomplished by meeting the requirements of GDC 17.

Criterion 50 – Containment Design Basis

GDC 50 requires that the reactor containment structure, including access opening, penetrations, and containment heat removal systems be designed to accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from a LOCA.

Electrical penetration assemblies are designed to accommodate the calculated pressure and temperature conditions resulting from a LOCA without exceeding their design leakage rate in accordance with IEEE Std. 323 and IEEE Std. 317.

The design and protection of the electric penetration assemblies conform with IEEE Std. 741 and NRC RG 1.63 requirements. The selection and settings of electrical protection devices provide reasonable assurance that the containment electrical penetration conductors do not exceed their design ratings for overload and for the maximum short-circuit current. Electrical penetrations are provided with primary and backup protection. Conformance with GDC 50 is described in Subsection 8.3.1.1.9.

8.3.2.2.2 Conformance with NRC Regulatory Guides

NRC Regulatory Guide 1.6

NRC RG 1.6 is related to the independence between redundant standby (onsite) power sources and their distribution systems.

Regulatory Position D.1

The load groups of the Class 1E dc power system are divided into two redundant divisions, division I and division II, and each division has two independent subsystem trains (A and C for division I and B and D for division II). Each load group of the Class 1E 125 Vdc power system is separated into redundant load groups so that loss of any one group does not prevent the minimum safety functions from being performed.

Regulatory Position D.3

Each redundant division load group consists of two independent subsystem trains (A and C for the division I load group and B and D for the division II load group). The dc load of each train is powered by its own battery and battery charger. The redundant load groups are electrically independent and physically separate and have no automatic connection to any other load group.

Regulatory Position D.4

Each redundant divisional load group consists of two independent subsystem trains (A and C for division I load group and B and D for division II load group). Each train has its own dc power source and distribution system for the train dc loads, which are independent from the other trains. The dc power source of one load group is not automatically paralleled with the power source of another load group under accident conditions. No provisions exist for automatically connecting one load group to another load group. No provisions exist for automatically transferring loads between redundant power sources.

NRC Regulatory Guide 1.32

NRC RG 1.32 is related to the criteria for power systems of nuclear power plants.

The design, operation, and testing of the Class 1E dc power systems for the APR1400 meet the guidelines of IEEE Std. 308, which is endorsed by NRC RG 1.32, with an exception that pertains to sharing of Class 1E dc power systems at multi-unit nuclear power plants. This exception is not applicable to the APR1400 because it is a single unit. The onsite power system is designed to conform with the requirements of NRC RG 1.32.

NRC Regulatory Guide 1.47

NRC RG 1.47 is related to the criteria for bypassed and inoperable status indication for nuclear power plants.

NRC RG 1.47 provides the requirements with respect to the bypassed and inoperable status indication of a Class 1E dc power system for a nuclear power plant. The APR1400 conforms with the requirements provided in NRC RG 1.47.

NRC Regulatory Guide 1.53

NRC RG 1.53 is related to the application of single-failure criterion to safety systems.

The Class 1E dc power system has the required redundancy of safety-related components and systems assuming a single failure. The Class 1E dc power system is divided into two redundant divisions and four subsystems, two per division: trains A and C for division I, and trains B and D for division II. The redundant divisions of the Class 1E dc power system provide electrical and physical separation and independence to meet the single failure criterion. If one safety-related power division is inoperable because of a single failure, the other division can accomplish the intended safety function.

The components and equipment of the redundant divisions are installed in a physically separate seismic Category I building. Therefore, DBEs do not prevent the safety function of the Class 1E dc power system. NRC RG 1.53 endorses IEEE Std. 379, which provides guidance on the application of the single-failure criterion and describes an acceptable method of single-failure analysis. The onsite power system is designed to conform with requirements specified in NRC RG 1.53. Conformance with NRC RG 1.53 is described in Subsection 8.3.2.1.2.4.

NRC Regulatory Guide 1.63

NRC RG 1.63 is related to the electric penetration assemblies (EPAs) in containment structures for nuclear power plants and endorses IEEE Std. 317. EPAs in containment structures are designed to meet NRC RG 1.63 and IEEE Std. 317. Conformance with NRC RG 1.63 is described in Subsection 8.3.1.1.9.

NRC Regulatory Guide 1.75

NRC RG 1.75 is related to the criteria for the independence of electrical safety systems.

The independence of the onsite power system is described in Subsection 8.3.2.1.2.5. The cable and raceway design related to NRC RG 1.75 is addressed in Subsection 8.3.1.1.10. The Class 1E 125 Vdc onsite power system is designed to meet the requirements of NRC RG 1.75. Redundant Class 1E batteries are placed in separate safety class structures as required in IEEE Std. 384, which is endorsed by NRC RG 1.75.

NRC Regulatory Guide 1.81

NRC RG 1.81 is related to the criteria for shared emergency and shutdown electric systems for multi-unit nuclear power plants.

The APR1400 is a single-unit plant. Therefore, NRC RG 1.81 is not applicable to the APR1400.

NRC Regulatory Guide 1.93

NRC RG 1.93 is related to the LCO (Limiting Conditions for Operation) for availability of electric power sources. The LCO for availability of electric power sources is addressed in Technical Specification 3.8.1, 3.8.4, 3.8.7, and 3.8.9.

NRC Regulatory Guide 1.106

NRC RG 1.106 is related to the thermal overload protection for electric motors on motor-operated valves (MOVs).

NRC RG 1.106 provides the criteria to ensure that safety-related MOVs whose motors are equipped with thermal overload protection devices integral to the motor starter perform their safety function. The thermal overload protection devices for safety-related MOVs are in conformance with the requirements of NRC RG 1.106.

NRC Regulatory Guide 1.118

NRC RG 1.118 is related to the periodic testing of electric power and protection systems.

Class 1E dc power systems are designed to be testable during operation of the nuclear power generating station as well as when the station is shut down. IEEE Std. 338, which is endorsed by NRC RG 1.118, provides design and operational criteria for the performance of periodic testing as part of the surveillance program of nuclear power plant safety systems. Class 1E dc power systems are designed to conform with the GDC 18 and NRC RG 1.118.

NRC Regulatory Guide 1.128

NRC RG 1.128 is related to the installation design and installation of vented lead-acid storage batteries in nuclear power plants. IEEE Std. 484 (Reference 55), endorsed by NRC RG 1.128, provides the recommended design practice and procedures for storage, location, mounting, ventilation, instrumentation, pre-assembly, assembly, and charging of vented lead-acid batteries.

The Class 1E batteries of the APR1400 are installed in a separate seismic Category I room for each train. The battery cells are arranged on the racks to provide for the inspection of cell plates. Class 1E batteries, racks, and anchors are installed to withstand a safe shutdown earthquake to allow continuous battery service during and following the event in accordance with IEEE Std. 344, as endorsed by NRC RG 1.100 (Reference 56). The battery installation area is clean, dry, and well ventilated and provides adequate space and illumination for inspection, maintenance, testing, and battery cell replacement.

Each ventilation system of the Class 1E battery rooms limits hydrogen accumulation to less than 1 percent of the total volume of the battery area. An automatic fire detection system is installed in each battery room with provision for local alarm and annunciation in the MCR.

The APR1400 is designed to meet the requirements of NRC RG 1.128.

NRC Regulatory Guide 1.129

NRC RG 1.129 is related to the maintenance, testing, and replacement of vented lead-acid storage batteries for nuclear power plants. IEEE Std. 450 (Reference 57), endorsed by the NRC RG 1.129, provides recommended practices for maintenance, testing, and replacement of vented lead-acid batteries for stationary applications.

The Class 1E onsite dc power system of the APR1400 is designed to meet the requirements of GDCs 1 (Reference 58), 17, 18, and Criterion III of Appendix B to 10 CFR Part 50

(Reference 59). Therefore, the APR1400 conforms with the requirements of NRC RG 1.129. The COL applicant is to develop the maintenance program to optimize the life and performance of the batteries (COL 8.3(13)).

NRC Regulatory Guide 1.153

NRC RG 1.153 is related to the criteria for safety systems.

IEEE Std. 603, endorsed by NRC RG 1.153, provides minimum functional and design requirements for the power, instrumentation, and control portions of safety systems for nuclear power plants. The Class 1E dc power system is designed to conform with the requirements of NRC RG 1.153 and IEEE Std. 603.

NRC Regulatory Guide 1.155

NRC RG 1.155 is related to an SBO.

Class 1E onsite dc power systems are designed to meet the requirements of 10 CFR 50.63 and to have sufficient capacity and capability to enable the APR1400 to withstand and recover from an SBO event. The AAC GTG is available to supply the electrical loads that are required to be operational within 10 minutes of the initiation of an SBO event. Restoration of ac power also restores power to the battery charger that supplies the auxiliary dc power for those loads and their I&Cs. The Class 1E battery has sufficient capacity to provide uninterrupted dc power from the initiation of the SBO event to the restoration of the ac power for the battery charger. Conformance with NRC RG 1.155 is described on Section 8.4.

NRC Regulatory Guide 1.160

NRC RG 1.160 is related to monitoring the effectiveness of maintenance at nuclear power plants.

NRC RG 1.160 endorses Revision 4A of NUMARC 93-01, which provides methods for complying with 10 CFR 50.65 with some provisions and clarifications. Conformance with NRC RG 1.160 is described in Section 1.9.

NRC Regulatory Guide 1.212

NRC RG 1.212 is related to sizing of lead-acid storage batteries. IEEE Std. 485, endorsed by NRC RG 1.212, provides recommended practice for sizing lead-acid batteries for stationary applications.

The Class 1E dc batteries are designed to conform with the requirements of NRC RG 1.212 and IEEE Std. 485.

8.3.2.2.3 Conformance with 10 CFR 50.34 Related to TMI Action Plan Requirements

See Subsection 8.3.1.2.3.

8.3.2.2.4 Conformance with 10 CFR 50.55a(h)

See Subsection 8.3.1.2.5.

8.3.2.2.5 Conformance with 10 CFR 52.47(b)(1) and 10 CFR 52.80(a)

See Subsection 8.2.2.4.

8.3.2.3 Electrical Power System Calculations and Distribution System Studies for DC System

Analysis of load flow, voltage regulation, short-circuit studies, and equipment sizing studies is performed in accordance with the guidance provided in IEEE Std. 946 and other referenced IEEE standards.

8.3.2.3.1 Load Flow and Under/Overvoltage Protection

Load flow studies are implemented to check whether the equipment terminal voltage is maintained within the acceptable voltage range under the most severe loading condition. Voltage drops at equipment terminals are also derived from the largest discharge current conditions. Consequently, terminal voltages of equipment meet the voltage range that is recommended in IEEE Std. 946.

8.3.2.3.2 Short-Circuit Studies

Short-circuit studies are implemented to calculate the magnitudes of the expected currents in the power system during the most severe fault condition. In case of Class 1E dc bus short-circuit calculations, the contributing short-circuit current sources are the batteries and battery chargers because there are no dc motors directly connected to the Class 1E dc buses. The maximum short-circuit current in the calculation is used to select the circuit breaker rating based on IEEE Std. C37.16 (Reference 61). The COL applicant is to provide the short-circuit analysis of onsite dc power system with actual data (COL 8.3(14)).

8.3.2.3.3 Equipment Sizing Studies

Battery sizing is performed in accordance with IEEE Std. 485. Battery loads and durations are shown in Table 8.3.2-1. The calculation of battery charger rating is based on IEEE Std. 946. The rating of the dc control center and the circuit breaker is determined by the result of the load flow and short-circuit studies.

8.3.2.3.4 Equipment Protection and Coordination Studies

Analyses of the dc equipment protection and coordination are performed using a methodology similar to that used in analyses of the onsite ac power system, which is described in Subsection 8.3.1.3.4. The COL applicant is to perform the equipment protection and coordination study with actual data (COL 8.3(9)).

8.3.2.3.5 Power Quality Limits

Battery chargers and inverters are the main harmonic contributors of the dc power system. The power quality limits are analyzed by methods that are similar to the onsite ac power system as described in Subsection 8.3.1.3.6.

8.3.2.3.6 Monitoring and Testing

The Class 1E dc power system is designed to be testable during normal operation as well as when the station is shut down. Batteries are tested and inspected in accordance with the manufacturer's recommendations, IEEE Std. 450, and IEEE Std. 484. The COL applicant is to describe any special features of the design that would permit online replacement of an individual cell, group of cells, or entire battery (COL 8.3(15)).

The dc power system monitoring capability is described in Subsection 8.3.2.1.2.7.

8.3.2.3.7 Grounding

The dc power system is designed to be an ungrounded system, which enhances the system reliability and service continuity because a single ground has no adverse effect on the system operation. Each train has a ground detector to isolate and monitor the fault area. The ground detector has an alarm in the MCR and RSR to monitor constant grounding and recording. The ground detector has high sensitivity.

8.3.3 Combined License Information

COL 8.3(1) The COL applicant is to provide and to design the 4.16 kV mobile generator and the 480V mobile GTGs and their support equipment.

COL 8.3(2) The COL applicant is to provide a bus transfer study of the onsite power system. Based on the bus transfer study, the COL applicant is also to provide final relay selection and settings for the bus transfer.

COL 8.3(3) The COL applicant is to establish procedures to monitor and maintain EDG reliability during plant operations to verify the selected reliability level target is being achieved as intended in NRC RG 1.155.

COL 8.3(4) The COL applicant is to describe and provide detailed ground grid and lightning protection.

COL 8.3(5) The COL applicant is to conduct periodic inspection and testing of the protection devices for the EPA conductors. All circuit breakers for the EPA conductors shall be inspected and tested in 60 months, low voltage circuit breaker overcurrent protection devices for the EPA conductors shall be inspected and tested once per 18 months for 10 % of each type of circuit breakers, and overcurrent relay for medium voltage circuit breakers for the EPA conductors shall be inspected and tested once per 18 months.

COL 8.3(6) The COL applicant is to provide testing, inspection, and monitoring programs for detecting insulation degradation of underground and inaccessible power cables within the scope of 10 CFR 50.65.

COL 8.3(7) The COL applicant is to establish Administrative Program(s), including application of dedicated cable and raceway management database tool as necessary, which is(are) developed on the basis of the cable and raceway numbering system to efficiently manage cable routing and cable termination and verify that the cable design fulfills the acceptance criteria (i.e., separation, filling criteria, and ampacity).

COL 8.3(8) The COL applicant is to provide the detailed design of the cathodic protection system as applicable to the site conditions.

COL 8.3(9) The COL applicant is to provide protective device coordination.

COL 8.3(10) The COL applicant is to provide the analysis and underlying assumptions used to demonstrate adequacy for insulation coordination of surge and lightning protection.

COL 8.3(11) The COL applicant is to provide the analysis and underlying assumptions used to demonstrate adequacy for power quality limits (harmonic distortion).

COL 8.3(12) The COL applicant is to provide the analysis for the station and switchyard grounding system with underlying assumptions, based on the site-specific parameters including soil resistivity and site layout.

COL 8.3(13) The COL applicant is to develop the maintenance program to optimize the life and performance of the batteries.

COL 8.3(14) The COL applicant is to provide a short-circuit analysis of the onsite dc power system with actual data.

COL 8.3(15) The COL applicant is to describe any special features of the design that would permit online replacement of an individual cell, group of cells, or entire battery.

8.3.4 References

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Table 8.3.1-1 (1 of 4)

Electrical Bus Loads

Bus		Component	Load (Estimated)
Class 1E 4.16 kV Bus	Train A	Motor-driven Auxiliary Feedwater Pump A	1,260 hp
		Safety Injection Pump 1	1,000 hp
		Essential Service Water Pump 1A	1,248 hp
		Cooling Tower Fan Group	900 hp
		Component Cooling Water Pump 1A	2,355 hp
		Shutdown Cooling Pump 1	1,000 hp
		Essential Chiller 1A	1,100 hp
		Charging Pump 1	780 hp
		Load Center (Auxiliary Building)	2,000 kVA (1)
		Motor Control Center (Press HTRs Back-up Group B-1)	350 kVA
	Train B	Motor-driven Auxiliary Feedwater Pump B	1,260 hp
		Safety Injection Pump 2	1,000 hp
		Essential Service Water Pump 1B	1,248 hp
		Cooling Tower Fan Group	900 hp
		Component Cooling Water Pump 1B	2,355 hp
		Shutdown Cooling Pump 2	1,000 hp
		Essential Chiller 1B	1,100 hp
		Charging Pump 2	780 hp
		Load Center (Auxiliary Building)	2,000 kVA (1)
		Motor Control Center (Press HTRs Back-up Group B-2)	350 kVA
	Train C	Safety Injection Pump 3	1,000 hp
		Essential Service Water Pump 2A	1,248 hp
		Cooling Tower Fan Group	900 hp
		Component Cooling Water Pump 2A	2,355 hp
		Containment Spray Pump 1	1,000 hp
		Essential Chiller 2A	1,100 hp
		Load Center (Auxiliary Building)	2,000 kVA (1)

(1) FA rating of the load center transformer

Table 8.3.1-1 (2 of 4)

Bus		Component	Load (Estimated)
Class 1E 4.16 kV Bus (cont.)	Train D	Safety Injection Pump 4	1,000 hp
		Essential Service Water Pump 2B	1,248 hp
		Cooling Tower Fan Group	900 hp
		Component Cooling Water Pump 2B	2,355 hp
		Containment Spray Pump 2	1,000 hp
		Essential Chiller 2B	1,100 hp
		Load Center (Auxiliary Building)	2,000 kVA (1)
Permanent Non-safety 4.16 kV Bus	Division I	Central Chiller 1	1,100 hp
		Central Chiller 2	1,100 hp
		Load Center (Auxiliary Building)	1,333 kVA (1)
		Load Center (Turbine Building)	1,333 kVA (1)
		Central Chilled Water Pump 1	500 hp
	Division II	Central Chiller 3	1,100 hp
		Central Chiller 4	1,100 hp
		Load Center (Auxiliary Building)	2,000 kVA (1)
		Load Center (Turbine Building)	1,333 kVA (1)
		Central Chilled Water Pump 2	500 hp
Non-Class 1E 4.16 kV Bus	Division I	Load Center (Turbine Building)	2,000 kVA (1)
		Load Center (Auxiliary Building)	2,000 kVA (1)
		Load Center (Auxiliary Building)	2,000 kVA (1)
		Load Center (Auxiliary Building)	2,000 kVA (1)
		Load Center (Auxiliary Building)	1,000 kVA (1)
		TGB CCW Pump 1	672 hp
		Administration BLDG	1,000 kVA

(1) FA rating of the load center transformer

Table 8.3.1-1 (3 of 4)

Bus		Component	Load (Estimated)
Non-Class 1E 4.16 kV Bus (cont.)	Division II	Load Center (Turbine Building)	1,333 kVA (1)
		Load Center (Auxiliary Building)	2,000 kVA (1)
		Load Center (Auxiliary Building)	2,000 kVA (1)
		Load Center (Auxiliary Building)	2,000 kVA (1)
		Load Center (Auxiliary Building)	1,000 kVA (1)
		Load Center (Compound Building)	2,000 kVA (1)
		Load Center (Compound Building)	2,000 kVA (1)
		Load Center (Compound Building)	2,000 kVA (1)
		TGB CCW Pump 2	672 hp
Non-Class 1E 4.16 kV AAC Bus	Division II	Load Center (AAC Building)	1,333 kVA (1)
Non-Class 1E 13.8 kV Bus	Division I	Reactor Coolant Pump 1A	13,500 hp
		Reactor Coolant Pump 2A	13,500 hp
		Load Center (Auxiliary Building)	1,333 kVA (1)
		Load Center (Auxiliary Building)	1,333 kVA (1)
		Load Center (Auxiliary Building)	2,000 kVA (1)
	Division II	Reactor Coolant Pump 1B	13,500 hp
		Reactor Coolant Pump 2B	13,500 hp
		Load Center (Auxiliary Building)	1,333 kVA (1)
		Load Center (Auxiliary Building)	1,333 kVA (1)
		Load Center (Auxiliary Building)	2,000 kVA (1)
	Division I	Circulating Water Pump A	4,357 hp
		Circulating Water Pump C	4,357 hp
		Circulating Water Pump E	4,357 hp
		Condensate Pump A	4,600 hp
		Feedwater Booster Pump A	5,000 hp
		Feedwater Booster Pump C	5,000 hp
		Cooling Tower Fan A Load Group	5,220 kW

(1) FA rating of load center transformer

Table 8.3.1-1 (4 of 4)

Bus		Component	Load (Estimated)
Non-Class 1E 13.8 kV Bus (cont.)	Division I (Cont.)	Load Center (CW Pump House)	667 kVA (1)
		Load Center (Turbine Building)	2,000 kVA (1)
		Load Center (Auxiliary Boiler Building)	1,333 kVA (1)
	Division II	Circulating Water pump B	4,357 hp
		Circulating Water pump D	4,357 hp
		Circulating Water pump F	4,357 hp
		Condensate Pump B	4,600 hp
		Condensate Pump C	4,600 hp
		Feedwater Booster Pump B	5,000 hp
		Cooling Tower Fan B	5,220 kW
		Startup Feedwater Pump	2,681 hp
		Load Center (CW Pump House)	667 kVA (1)
		Load Center (Turbine Building)	2,000 kVA (1)

(1) FA rating of load center transformer

Table 8.3.1-2 (1 of 5)

Class 1E Loads (Division I)

Train A

Equipment	Volts	Component Estimated (bhp/kW/ kVA) (1)	Power Factor	Motor Efficiency	Equivalent Load (kW)	LOOP Load (kW)	DBA Concurrent with a LOOP Load (kW)	Load Sequence Time (Seconds) (2)
Medium Voltage								
Safety Injection Pump 1	4,160	898.5 (bhp)		0.9	744.8		744.8	5
Cooling Tower Fan 1A	4,160	750 (bhp)		0.9	621.7	621.7	621.7	10
Motor-driven Auxiliary Feedwater Pump A	4,160	1,15 (bhp)		0.9	954.1	954.1	954.1	15
Shutdown Cooling Pump 1	4,160	940 (bhp)		0.9	779.2		779.2	23
Component Cooling Water Pump 1A	4,160	2,000 (bhp)		0.9	1657.8	1657.8	1657.8	28
Essential Service Water Pump 1A	4,160	1,021 (bhp)		0.9	846.3	846.3	846.3	33
Essential Chiller 1A	4,160	930 (bhp)		0.9	760.9	760.9	760.9	38
Subtotal, Loading for Load Sequence of Medium Voltage						4,840.8	6,364.8	
Load Sequence Group A (3), (4) – Low Voltage								
480V LC – CH A Battery Charger	480	125 kVA	0.9		112.5	112.5	112.5	
480V LC – EDG Room Elec. Heating Coil 11A	480	211 kW	1.0		211	211	211	
480V LC – Control Room Elec. Heating Coil 01A	480	225 kW	1.0		225	225	225	
480V LC – Control Room Supply AHU HV01A Fan	480	104 (bhp)		0.9	86.2	86.2	86.2	

Table 8.3.1-2 (2 of 5)

Train A

Equipment	Volts	Component Estimated (bhp/kW /kVA) (1)	Power Factor	Motor Efficiency	Equivalent Load (kW)	LOOP Load (kW)	DBA Concurrent with a LOOP Load (kW)	Load Sequence Time (Seconds) (2)
Load Sequence Group A (3), (4) – Low Voltage								
480V LC – Battery Room Elec. Duct Heater	480	77 kW	1.0		77	77	77	
480V LC – Aux. Charging Pump	460	100 (bhp)		0.9	82.9	82.9	82.9	
480V LC – Essential Chilled Water Pump 01A	460	81.3 (bhp)		0.9	67.4	67.4	67.4	
480V LC – CCW HX EDH A	460	180 kW	1.0		180	180	180	
480V LC – Cooling Tower Makeup Pump 3A	460	139.8		0.9	115.9	115.9	115.9	
480V MCC Loads (4)	480	522.2 kW	1.0	1.0	522.2	522.2	522.2	
Subtotal, Loading for Load Sequence Group B						1,680.1	1,680.1	0
Manual Load Group (5)								
480V LC – Pressurizer Heaters Back-up Group B1	480	300 kW	1.0		300	300	300	
480V LC – Spent Fuel Pool Cooling Pump	480	93.4 (bhp)		0.9	77.4	77.4	77.4	
Subtotal, Loading for Manual Load						377.4	377.4	
EDG Loads of Train A								
Total Diesel Load on LOOP excluding Manual Load						6,520.9		
Total Diesel Load on LOOP including Manual Load						6,898.3		
Total Diesel Load on DBA/LOOP excluding Manual Load							8,044.9	
Total Diesel Load on DBA/LOOP including Manual Load							8,422.3	

Table 8.3.1-2 (3 of 5)

Train C

Equipment	Volts	Component Estimated (bhp/kW /kVA) (1)	Power Factor	Motor Efficiency	Equivalent Load (kW)	LOOP Load (kW)	DBA Concurrent with a LOOP Load (kW)	Load Sequence Time (Seconds) (2)
Safety Injection Pump 3	4,160	898.5 (bhp)		0.9	744.8		744.8	10
Cooling Tower Fan 2A	4,160	750 (bhp)		0.9	621.7	621.7	621.7	15
Containment Spray Pump 1	4,160	920 (bhp)		0.9	762.6		762.6	23
Component Cooling Water Pump 2A	4,160	2,000 (bhp)		0.9	1,657.8	1,657.8	1,657.8	28
Essential Service Water Pump 2A	4,160	1,021 (bhp)		0.9	846.3	846.3	846.3	33
Essential Chiller 2A	4,160	930 (bhp)		0.9	760.9	760.9	760.9	38
Subtotal, Loading for Load Sequence of Medium Voltage						3,886.7	5,394.1	
Load Sequence Group C (3), (4) – Low Voltage								
480V LC – CH C Battery Charger	480	210	0.9		189	189	189	
480V LC – EDG Room Elec. Heating Coil 11C	480	240 kW	1.0		240	240	240	
480V LC – Control Room Supply AHU HV01C Fan	460	104 (bhp)		0.9	86.2	86.2	86.2	
480V LC – Control Room Elec. Heating Coil 01A	480	225 kW	1.0		225	225	225	
480V LC – Essential Chilled Water Pump 02A	460	81.3 (bhp)		0.9	67.4	67.4	67.4	
480V LC - Battery Room Elec. Duct Heater	480	74 kW	1.0		74	74	74	

Table 8.3.1-2 (4 of 5)

Train C

Equipment	Volts	Component Estimated (bhp/kW /kVA) (1)	Power Factor	Motor Efficiency	Equivalent Load (kW)	LOOP Load (kW)	DBA Concurrent with a LOOP Load (kW)	Load Sequence Time (Seconds) (2)
Load Sequence Group C (3), (4) – Low Voltage								
480V LC – Cooling Tower Makeup Pump 4A	460	139.8		0.9	115.9	115. 9	115.9	
480V MCC (4EA) Loads (4)	480	375.7 kW	1.0	1.0	375.7	375.7	375.7	
Subtotal, Loading for Load Sequence Group C						1,373.2	1,373.2	0
Manual Load Group (5)								
Subtotal, Loading for Manual Load	0	0						
EDG Loads of Train C								
Total Diesel Load on LOOP excluding Manual Load						5,259.9		
Total Diesel Load on LOOP including Manual Load						5,259.9		
Total Diesel Load on DBA/LOOP excluding Manual Load							6,767.3	
Total Diesel Load on DBA/LOOP including Manual Load							6,767.3	

Table 8.3.1-2 (5 of 5)

(1) Conversion into equivalent kilowatts for rated horsepower involves multiplying rated horsepower by the conversion factor 0.746 kW/hp. When unit of brake horsepower (bhp) is assumed, a motor efficiency of 0.9 is used in addition to this conversion factor to calculate equivalent load. Unless designated as bhp, all horsepower is rated.

(2) The following components and times apply to accident scenarios coincident with a LOOP.

Train A Sequencer	
480V load center load group A	0.0 second
Safety injection pump 1	5.0 seconds
Cooling Tower Fan 1A	10.0 seconds
Motor-driven AFW pump A (if required)	15.0 seconds
Shutdown cooling pump 1	23.0 seconds
Component cooling water pump 1A	28.0 seconds
Essential service water pump 1A	33.0 seconds
Essential chiller 1A	38.0 seconds
Train C Sequencer	
480V load center load group C	0.0 second
Safety injection pump 3	10.0 seconds
Cooling Tower Fan 1C	15.0 seconds
Containment spray pump 1	23.0 seconds
Component cooling water pump 2A	28.0 seconds
Essential service water pump 2A	33.0 seconds
Essential chiller 2A	38.0 seconds

(3) The 480V loads are energized immediately upon closure of the EDG incoming breaker.

(4) Although motor-operated valves (MOVs) are connected to the Class 1E MCC buses, they are considered to be zero for purpose of EDG sizing due to their intermittent and short operating time.

480V HVAC loads were classified into summer season loads and winter season loads, and the worst-case loads of winter season were allocated in the 480V MCC loads for EDG sizing.

(5) Manual loads are added to the Class 1E buses by operator in case plant conditions require their usage.

Table 8.3.1-3 (1 of 5)

Class 1E Loads (Division II)

Train B

Equipment	Volts	Component Estimated (bhp/kW /kVA) (1)	Power Factor	Motor Efficiency	Equivalent Load (kW)	LOOP Load (kW)	DBA Concurrent with a LOOP Load (kW)	Load Sequence Time (Seconds) (2)
Medium Voltage								
Safety Injection Pump 2	4,160	898.5 (bhp)		0.9	744.8		744.8	5
Cooling Tower Fan 1B	4,160	750 (bhp)		0.9	621.7	621.7	621.7	10
Motor-driven Auxiliary Feedwater Pump B	4,160	1,151 (bhp)		0.9	954.1	954.1	954.1	15
Shutdown Cooling Pump 2	4,160	940 (bhp)		0.9	779. 2		779.2	23
Component Cooling Water Pump 1B	4,160	2,000 (bhp)		0.9	1,657.8	1,657.8	1,657.8	28
Essential Service Water Pump 1B	4,160	1,021 (bhp)		0.9	846.3	846.3	846.3	33
Essential Chiller 1B	4,160	930 (bhp)		0.9	760.9	760.9	760.9	38
Subtotal, Loading for Load Sequence of Medium Voltage						4,840.8	6,364.8	
Load Sequence Group B (3), (4) – Low Voltage								
480V LC CH B Battery Charger	480	125 kVA	0.9		112.5	112. 5	112.5	
480V LC – EDG Room Elec. Heating Coil 11B	480	211 kW	1.0		211	211	211	
480V LC – Control Room Elec. Heating Coil 01B	480	225 kW	1.0		225	225	225	
480V LC – Control Room Supply AHU HV01B Fan	480	104 (bhp)		0.9	86.2	86.2	86.2	
480V LC – Battery Room Elec. Duct Heater	480	109 kW	1.0		109	109	109	

Table 8.3.1-3 (2 of 5)

Train B

Equipment	Volts	Component Estimated (bhp/kW /kVA) (1)	Power Factor	Motor Efficiency	Equivalent Load (kW)	LOOP Load (kW)	DBA Concurrent with a LOOP Load (kW)	Load Sequence Time (Seconds) (2)
Load Sequence Group B (3), (4) – Low Voltage								
480V LC – Aux. Charging Pump	460	100 (bhp)		0.9	82.9	82.9	82.9	
480V LC – Essential Chilled Water Pump 01B	460	81.3 (bhp)		0.9	67.4	67.4	67.4	
480V LC – CCW HX EDH B	480	180 kW	1.0		180	180	180	
480V LC – Cooling Tower Makeup Pump 3B	460	139.8		0.9	115.9	115.9	115.9	
480V MCC Loads (4)	480	511.9 kW	1.0	1.0	511.9	511.9	511.9	
Subtotal, Loading for Load Sequence Group B						1,701.8	1,701.8	0
Manual Load Group (5)								
480V LC – Pressurizer Heaters Backup Group B2	480	300 kW	1.0		300	300	300	
480V LC – Spent Fuel Pool Cooling Pump B	480	93.4		0.9	77.4	77.4	77.4	
Subtotal, Loading for Manual Load						377.4	377.4	
EDG Loads of Train B								
Total Diesel Load on LOOP excluding Manual Load						6,542.6		
Total Diesel Load on LOOP including Manual Load						6,920.0		
Total Diesel Load on DBA/LOOP excluding Manual Load							8,066.6	
Total Diesel Load on DBA/LOOP including Manual Load							8,444.0	

Table 8.3.1-3 (3 of 5)

Train D

Equipment	Volts	Component Estimated (bhp/kW /kVA) (1)	Power Factor	Motor Efficiency	Equivalent Load (kW)	LOOP Load (kW)	DBA Concurrent with a LOOP Load (kW)	Load Sequence Time (Seconds) (2)
Medium Voltage								
Safety Injection Pump 4	4,160	898.5 (bhp)		0.9	744.8		744.8	10
Cooling Tower Fan 2B	4,160	750 (bhp)		0.9	621.7	621.7	621.7	15
Containment Spray Pump 2	4,160	920 (bhp)		0.9	762.6		762.6	23
Component Cooling Water Pump 2B	4,160	2,000 (bhp)		0.9	1,657.8	1,657.8	1,657.8	28
Essential Service Water Pump 2B	4,160	1,201 (bhp)		0.9	846.3	846.3	846.3	33
Essential Chiller 2B	4,160	930 (bhp)		0.9	760.9	760.9	760.9	38
Subtotal, Loading for Load Sequence of Medium Voltage						3,886.7	5,394.1	
Load Sequence Group D (3), (4) – Low Voltage								
480V LC – CH D Battery Charger	480	210 kVA	0.9		189	189	189	
480V LC – EDG Room Elec. Heating Coil 11D	480	240 kW	1.0		240	240	240	
480V LC – Control Room Supply AHU HV01D Fan	460	104 (bhp)		0.9	86.2	86.2	86.2	
480V LC – Control Room Elec. Heating Coil 01D	480	225 kW	1.0		225	225	225	
480V LC – Essential Chilled Water Pump 02 B	460	81.3 (bhp)		0.9	67.4	67.4	67.4	
480V LC - Battery Room Elec. Duct Heater	480	74 kW	1.0		74	74	74	

Table 8.3.1-3 (4 of 5)

Train D

Equipment	Volts	Component Estimated (bhp/kW /kVA) (1)	Power Factor	Motor Efficiency	Equivalent Load (kW)	LOOP Load (kW)	DBA Concurrent with a LOOP Load (kW)	Load Sequence Time (Seconds) (2)
Load Sequence Group D (3), (4) – Low Voltage								
480V LC – Cooling Tower Makeup Pump 4B	460	139.8		0.9	115.9	115.9	115.9	
480V MCC (4EA) Loads (4)	480	375.6 kW	1.0	1.0	375.6	375.6	375.6	
Subtotal, Loading for Load Sequence Group D						1,373.1	1,373.1	0
Manual Load Group (5)								
Subtotal, Loading for Manual Load						0	0	
EDG Loads of Train D								
EDG Loads of Train D								
Total Diesel Load on LOOP excluding Manual Load						5,259.8		
Total Diesel Load on LOOP including Manual Load						5,259.8		
Total Diesel Load on DBA/LOOP excluding Manual Load							6,767.2	
Total Diesel Load on DBA/LOOP including Manual Load							6,767.2	

Table 8.3.1-3 (5 of 5)

(1) Conversion into equivalent kilowatts for rated horsepower involves multiplying rated horsepower by the conversion factor 0.746 kW/hp. When unit of brake horsepower (bhp) is assumed, a motor efficiency of 0.9 is used in addition to this conversion factor to calculate equivalent load. Unless designated as bhp, all horsepower is rated.

(2) The following components and times apply to accident scenarios coincident with LOOP.

Train B Sequencer	
480V load center load group B	0.0 second
Safety injection pump 2	5.0 seconds
Cooling Tower Fan 1B	10.0 seconds
Motor-driven AFW pump B (if required)	15.0 seconds
Shutdown cooling pump 2	23.0 seconds
Component cooling water pump 1B	28.0 seconds
Essential service water pump 1B	33.0 seconds
Essential chiller 1B	38.0 seconds

Train D Sequencer	
480V load center load group D	0.0 second
Safety injection pump 4	10.0 seconds
Cooling Tower Fan 1D	15.0 seconds
Containment spray pump 2	23.0 seconds
Component cooling water pump 2B	28.0 seconds
Essential service water pump 2B	33.0 seconds
Essential chiller 2B	38.0 seconds

(3) The 480V loads are energized immediately upon closure of the EDG incoming breaker.

(4) Although motor-operated valves (MOVs) are connected to the Class 1E MCC buses, they are considered to be zero for purpose of EDG sizing due to their intermittent and short operating time.

480V HVAC loads were classified into summer season loads and winter season loads, and the worst-case loads of winter season were allocated in the 480V MCC loads for EDG sizing.

(5) Manual loads are added to the Class 1E buses by operator in case plant conditions are required their usage.

Table 8.3.1-4

AAC GTG Loads (SBO)

Load Name	Quantity Installed	Voltage [V]	Load Rating [hp or kW]		Brake Horse Power [bhp]	Eff. [%]	Capacity [kW]	SBO	
								Quantity	Capacity [kW] (Winter season)
Safety Injection Pump	1	4,000	1,000	hp	898.5	90.0	744.76	1	744.76
Shutdown Cooling Pump	1	4,000	1,000	hp	940	90.0	779.16	1	779.16
Component Cooling Water Pump	1	4,000	2,355	hp	2,000	90.0	1,657.78	1	1,657.78
Essential Service Water Pump	1	4,000	1,248	hp	1,021	90.0	846.3	1	846.3
Cooling Tower Fan	1	4,000	900	hp	750	90.0	621.67	1	621.67
Motor-driven Auxiliary Feedwater Pump	1	4,000	1,260	hp	1,151	90.0	954.05	1	954.05
Essential Chiller	1	4,000	1,100	hp	930	90.0	770.87	1	760.92
Subtotal (4.16 kV Loads)									6,364.64
Auxiliary Charging Pump	1	460	100	hp	100	90.0	82.89	1	82.89
Cooling Tower Makeup Pump	1	460	157	hp	139.8	90.0	115.88	1	115.88
Spent Fuel Pool Cooling Pump	1	460	100	hp	93.4	90.0	77.42	1	77.42
Control Room Supply AHU Fan	1	460	125	hp	104	90.0	86.2	1	86.2
Control Room Supply AHU Elec. Heating Coil	1	480	225	kW		100.0	225.00	1	225
EDG Room Normal Supply AHU Elec. Heating Coil	1	480	211	kW		100.0	211.00	1	211
Class 1E Battery Room Elec. Duct Heater	1	480	109	kW		100.0	109	1	109
Class 1E 125 Vdc Battery Charger	1	480	125	kVA			112.5	1	112.5
Class 1E 480V MCC Loads							698.93		698.93
Subtotal (480V Loads)									1,718.82
AAC Facility Loads									610.54
Total loads of AAC GTG									8,694

Table 8.3.1-5

AAC GTG Loads (LOOP)

Load Name	Quantity Installed	Voltage [V]	Load Rating [hp or kW]		Brake Horse Power [bhp]	Eff. [%]	Capacity [kW]	LOOP	
								Quantity	Capacity [kW]
Central Chiller	4	4,000	1,100	hp	1,050	90.0	870.33	3	2,610.99
Central Chilled Water Pump	2	4,000	500	hp	405	90.0	335.7	1	335.7
Sub-total (4.16 kV Loads)									2,946.69
Turning Gear Motor	1	460	75	hp	55.8	93.0	46.25	1	46.25
Turning Gear Oil Pump	1	460	100	hp	83.5	94.5	69.21	1	69.21
Computer Room Packaged ACU	2	480	60	kW		100.0	60	1	60
Regulating Transformer (VBPSS Inverter)	4	480	60	kVA		95.0	48.00	0	0
Guard House Distribution Panel	1	480	125	kVA		90.0	72.3	1	72.30
Compound Bldg. Non-1E 125 Vdc Battery Charger	1	480	44.11	kW		100.0	44.11	1	44.11
Non-1E 125 Vdc Battery Charger	2	480	264.7/ 235.3	kW		100.0	264.7/235.3	2	518
Non-1E 250 Vdc Battery Charger	2	480	176.5	kW		100.0	176.5	1	176.5
Compound Building Lighting Transformer	10	480	75	kVA		40	30.00	10	300.00
Fire Pump and Waste Water Treatment Building Lighting Transformer	1	480	75	kVA		80	60.00	1	60.00
Auxiliary Building Lighting Transformer	1	480	75	kVA		40	30.00	1	30.00
Turbine Building Lighting Transformer	6	480	100	kVA		45	45.00	6	270.00
Permanent Non-Safety 480V MCC Loads									870.75
Subtotal (480V Loads)									2,517.12
AAC Facility Loads									610.54
Total loads of AAC GTG									6,074.35

Table 8.3.1-6 (1 of 2)

Electrical Equipment Ratings and Component Data

13.8 kV Medium-Voltage Switchgears

13.8 kV Medium-Voltage System	Non-Class 1E
Switchgear	
- Type	Metal Clad
- Nominal voltage	13.8 kV, 3 phase, 60 Hz
- Rated current	2,000 A
Circuit Breaker	
- Maximum voltage	15 kV
- Rated short-circuit current	50 kA, rms, symmetrical
- Peak current (C and L crest)	130 kA, peak
- Control voltage	
Breaker closing coil	125 Vdc (90~140 V)
Breaker trip coil	125 Vdc (70~140 V)

4.16 kV Medium-Voltage Switchgears

4.16 kV Medium-Voltage System	Class 1E	Non-Class 1E	Permanent Non-Class 1E
Switchgear			
- Type	Metal Clad	Metal Clad	Metal Clad
- Nominal voltage	4.16 kV, 3 phase, 60 Hz	4.16 kV, 3 phase, 60 Hz	4.16 kV, 3 phase, 60 Hz
- Rated current	2,000 A	3,000 A, 2,000 A	1,200 A
Circuit Breaker			
- Maximum voltage	4.76 kV		
- Rated short-circuit current	50 kA, rms, symmetrical		
- Peak current (C and L crest)	130 kA, peak		
- Control voltage			
Breaker closing coil	125 Vdc (90~140 V)		
Breaker trip coil	125 Vdc (70~140 V)		

Table 8.3.1-6 (2 of 2)

480V Load Centers

Low-Voltage System (Load Center)	Class 1E	Non-Class 1E	Permanent Non-Class 1E
- Circuit breaker type	Air Circuit Breaker	Air Circuit Breaker	Air Circuit Breaker
- Rated short-circuit current	50 kA	50 kA, 30 kA	50 kA, 30 kA
- Rated current	3,000 A	3,000 A, 2,000 A, 1,600 A	3,000 A, 2,000 A
- Load Center transformer (AA/FA)	1,500/2,000 kVA	1,500/2,000 kVA, 1,000/1,333 kVA, 750/1,000 kVA, 500/667 kVA	1,500/2,000kVA, 1,000/1,333 kVA
- Control power	125 Vdc (90 V ~ 140 V)	125 Vdc (90 V ~ 140 V)	125 Vdc (90 V ~ 140 V)

480V Motor Control Centers

480Vac Motor Control Centers	
- Circuit Breaker Type	MCCB
- Rated short-circuit current	42 kA, 30 kA
- Rated current	600 A

4.16 kV Generators

Generators	Class 1E EDG	Non-Class 1E AAC
Generators		
- Rated voltage	4.16 kV	4.16 kV
- Rated output	9,100 kW for trains A&B 7,500 kW for trains C&D	9,700 kW

Table 8.3.1-7 (1 of 8)

Failure Modes and Effects Analysis for the Onsite AC Power System

Component	Function	Failure Mode	Failure Cause	Failure Effect and Counter Measure	Detection
1. The isolated phase bus (IPB) from the main transformer (MT) to the generator circuit breaker (GCB) or to the unit auxiliary transformer (UAT) or the UAT	Power supply to the onsite ac power system	Loss of power	• Open circuit • Short circuit • UATs fault	• The faulted equipment is isolated by protective relaying and protective equipment. • The main generator (MG) and turbine automatically trip and the GCB opens. • The other independent preferred offsite circuit remains unaffected. • The switchgears are transferred automatically from the UATs to the standby auxiliary transformers (SATs).	Annunciation by protective relays
2. Standby auxiliary transformer (SAT)	In case of a loss of power from the UAT, power supply to the onsite ac power system	Loss of power	• Open circuit • Short circuit • SATs fault	• The faulted equipment is isolated by protective relaying and protective equipment. • The other independent preferred offsite circuit remains unaffected. • No effect on unit power generation or essential safety buses since not normally connected to onsite system.	Annunciation by protective relays
3. IPB connecting the GCB and the MG or MG	Power supply to transmission network and the onsite ac power system	Loss of power	• Open circuit • Short circuit • MG fault	• The GCB opens. • The turbine and the MG are tripped automatically. • All unit and Class 1E auxiliaries continue to receive uninterrupted offsite power from the UATs.	Annunciation by protective relays
4. GCB	Supplying and breaking of the MG output power	• Breaker open by breaker malfunction • Interrupting failure at fault	• Breaker fault, failure, or pole disagreement	• The other two poles of the breaker trip. • The faulted equipment is isolated by protective relaying and protective equipment. • The other independent preferred offsite circuit remains unaffected. • Automatic reactor and turbine trips occur. • The switchgears are transferred automatically from the UATs to the SATs.	Breaker fail alarm

Table 8.3.1-7 (2 of 8)

Component	Function	Failure Mode	Failure Cause	Failure Effect and Counter Measure	Detection
5. IPB cooling system	Cooling of IPB	Loss of cooling of IPB	• Mechanical or electrical fault	• No immediate consequence. • The unit and Class 1E auxiliaries continue to receive an uninterrupted flow of power through the UATs. • The continued unit operation is dependent upon bus design capacities without forced cooling.	Cooling system fault alarm
6. UATs cooling system	Cooling of UATs	Loss of one of the cooler banks	• Mechanical or electrical fault	• No immediate consequence. • The unit and the Class 1E auxiliaries continue to receive an uninterrupted flow of power from this source. • The continued transformer and unit operation is dependent upon its rated design capacities without cooling.	Cooling system fault alarm
7. MT	Transferring of power to the transmission network and the onsite ac power system	Loss of power	• Open circuit • Short circuit • Main transformer fault	• The faulted equipment is isolated by protective relaying and protective equipment. • The MG automatically trips and the GCB opens. • The other independent preferred offsite circuit remains unaffected. • The switchgears are transferred automatically from the UATs to the SATs.	Annunciation by protective relays
8. MT cooling system	Cooling of MT	Loss of one of the cooler banks	• Mechanical or electrical fault	• No immediate consequence with the MT at full load. • The continued transformer and unit operation is dependent upon its rated design capacities without cooling.	Cooling system fault alarm
9. Power cables from the UAT (or SAT) to 4.16 kV Class 1E switchgear	Transferring of power from the UAT (or SAT) to the 4.16 kV Class 1E switchgear	Loss of switchgear power	• Cable fault (grounded, shorted)	• The associated switchgear feeder breaker trips and isolates the fault from the system. • The associated Class 1E 4.16 kV switchgear bus is de-energized. • Sufficient redundant auxiliaries remain operable from the redundant Class 1E power system for safe shutdown of the reactor.	Annunciation by protective relays

Table 8.3.1-7 (3 of 8)

Component	Function	Failure Mode	Failure Cause	Failure Effect and Counter Measure	Detection
10. 13.8 kV non-Class 1E switchgear normal incoming feeder breaker	Power supply to 13.8 kV non-Class 1E switchgear	Interrupting failure at fault	· Operating device fault · Malfunction of the protective relay	· The faulted switchgear is isolated from power source by protective relaying and protective equipment (GCB and Switchyard breaker). · Automatic turbine and generator trips occur. · All switchgears except for faulted switchgear are transferred automatically from the UATs to the SATs.	Undervoltage alarm or breaker inoperable alarm
		Breaker open by malfunction	Relay setting error	· The switchgear normal incoming breaker trips. · The associated switchgear bus is de-energized. · Required unit power reduction to the capacity supported by remaining non-Class 1E auxiliaries or may cause unit to trip. · If reactor coolant pump (RCP) switchgear bus is unavailable, the plant will experience a reactor trip due to the loss of RCPs. Turbine and generator also trip.	Undervoltage alarm or breaker trip alarm
11. 13.8 kV non-Class 1E Switchgear Bus or Feeder Breaker	Power supply for 13.8 kV Loads	Bus unavailable	· Bus insulation fail (Grounded, Shorted) · Feeder breaker interrupting fail on fault	· The switchgear normal incoming breaker trips. · The associated switchgear bus is de-energized. · Required unit power reduction to the capacity supported by remaining non-Class 1E auxiliaries or may cause unit to trip. · If RCP switchgear bus is unavailable, the plant will experience a reactor trip due to the loss of RCPs. Turbine and generator also trip.	Undervoltage alarm or breaker inoperable alarm
		Breaker open by malfunction	Relay setting error	· Switchgear Feeder Breaker trips. · The associated switchgear load is de-energized. · If RCP feeder breaker trips, the plant will experience a reactor trip due to the loss of RCPs. Turbine and generator also trip.	Undervoltage alarm or breaker inoperable alarm

Table 8.3.1-7 (4 of 8)

Component	Function	Failure Mode	Failure Cause	Failure Effect and Counter Measure	Detection
12. 4.16 kV non-Class 1E switchgear normal incoming breaker	Power supply to the switchgear bus	Interrupting failure at fault	· Operating device fault · Malfunction of the protective relay	· The faulted switchgear is isolated from power source by protective relaying and protective equipment (GCB and switchyard breaker). · Automatic turbine and generator trips occur. · All switchgears except for faulted switchgear are transferred automatically from the UATs to the SATs.	Undervoltage alarm or breaker inoperable alarm
		Breaker open by malfunction	Relay setting error	· The switchgear normal incoming breaker trips. · The associated switchgear is de-energized. · Required unit power reduction to the capacity supported by remaining non-Class 1E auxiliaries or may cause unit to trip.	Undervoltage alarm or breaker trip alarm
13. 4.16 kV non-Class 1E switchgear bus or the feeder breaker	Power supply to 4.16 kV non-Class 1E loads	Bus unavailable	· Bus insulation fail (grounded, shorted) · Feeder breaker interrupting fail	· The switchgear normal incoming breaker trips. · The associated switchgear is de-energized. · Required unit power reduction to the capacity supported by remaining non-Class 1E auxiliaries or may cause unit to trip.	Undervoltage alarm or breaker inoperable alarm
		Breaker open by malfunction	Relay setting error	· The switchgear feeder breaker trips. · The associated switchgear load is de-energized.	Breaker trip alarm

Table 8.3.1-7 (5 of 8)

Component	Function	Failure Mode	Failure Cause	Failure Effect and Counter Measure	Detection
14. The feeder cable of 13.8 kV / 480V or 4.16 kV / 480V non-Class 1E load center transformer or load center incoming breaker	Power supply to 480V load center	Load center power supply feeder unavailable	· Cable fault (grounded, shorted) · Transformer fault · Incoming breaker interrupting fail at fault	· The associated 13.8 kV or 4.16 kV feeder breaker trips and isolates the fault from the system. · The associated 480V load center bus is de-energized.	Switchgear breaker trip alarm or load center undervoltage alarm
		Breaker open by malfunction	Relay setting error	· The load center incoming breaker trips. · The associated load center bus is de-energized.	Breaker trip alarm or undervoltage alarm
15. 480V non-Class 1E load center bus or 480V non-Class 1E load center feeder breaker	Power supply to 480V load center loads	Bus unavailable	· Bus insulation fail (grounded, shorted) · Feeder breaker interrupting fail on fault	· The load center incoming breaker trips. · The associated 480V load center bus is de-energized.	Load center fault alarm
		Breaker open by malfunction	Relay setting error	· The load center feeder breaker trips. · The associated 480V load is de-energized.	Breaker trip alarm

Table 8.3.1-7 (6 of 8)

Component	Function	Failure Mode	Failure Cause	Failure Effect and Counter Measure	Detection
16. 4. 16 kV Class 1E switchgear normal incoming breaker	Power supply to the 4.16 kV Class 1E bus	Interrupting failure at fault	· Operating device fault · Malfunction of protective relay	· The faulted switchgear is isolated from power source by protective relaying and protective equipment (GCB and switchyard breaker). · Automatic turbine and generator trips occur. · All switchgears except for faulted switchgear are transferred automatically from the UATs to the SATs. · Affected 4.16 kV Class 1E switchgear is de-energized. Associated 480V buses are also de-energized. · Sufficient redundant auxiliaries remain operable from the redundant Class 1E power system for safe shutdown of the reactor.	Undervoltage alarm or breaker inoperable alarm
		Breaker open by malfunction	Relay setting error	· The switchgear normal incoming breaker trips. · Affected 4.16 kV Class 1E switchgear is de-energized. Associated 480V buses are also de-energized. · Sufficient redundant auxiliaries remain operable from the redundant Class 1E power system for safe shutdown of the reactor.	Undervoltage alarm or breaker trip alarm
17. 4.16 kV Class 1E switchgear bus or feeder breakers	Power supply to Class 1E large motors and load centers	Bus unavailable	· Bus insulation fail (grounded, shorted) · Feeder breaker interrupting fail	· Incoming breakers trip and the affected 4.16 kV Class 1E switchgear is de-energized. · The associated 480V buses are also de-energized. · Sufficient redundant auxiliaries remain operable from the redundant Class 1E auxiliary power system for the safe shutdown of the reactor.	Undervoltage alarm or breaker inoperable alarm
		Breaker open by malfunction	Relay setting error	· The switchgear feeder breaker trips. · The associated switchgear load is de-energized. · Sufficient redundant auxiliaries remain operable from the redundant Class 1E auxiliary power system for the safe shutdown of the reactor.	Breaker trip alarm

Table 8.3.1-7 (7 of 8)

Component	Function	Failure Mode	Failure Cause	Failure Effect and Counter Measure	Detection
18. 4.16 kV Class 1E emergency diesel generator breaker	Power supply to the 4.16 kV Class 1E bus	Feeder breaker closing fail	Malfunction of operating device	· In case of a LOOP and a failure of EDG breaker closing, the associated 4.16 kV Class 1E switchgear is de-energized. · Sufficient redundant auxiliaries remain operable from the redundant Class 1E power system division.	Undervoltage alarm or breaker inoperable alarm
19. 4.16 kV Class 1E emergency diesel generator	Power supply to the Class 1E bus	· EDG start failure · Fault after starting · Undervoltage · Underfrequency	Electrical and mechanical fault	· If the EDG source is supplying power under offsite power failure, the affected safety division is de-energized until the fault is cleared. · Sufficient redundant auxiliaries remain operable from the redundant Class 1E power system division.	Undervoltage alarm or EDG fault alarm
20. The feeder cable of 4.16 kV/480V Class 1E load center transformer or 480V Class 1E load center incoming breaker	Power supply to the Class 1E load center bus	Load center power supply feeder unavailable	· Cable fault (grounded, shorted) · Transformer fault · Incoming breaker interrupting fail	· The associated switchgear feeder breaker trips and isolates the fault from the system. · The associated 480V load center bus is de-energized. · Sufficient redundant auxiliaries remain operable from the redundant Class 1E power system for safe shutdown of the reactor.	Switchgear feeder breaker trip alarm or load center undervoltage alarm
		Breaker open by malfunction	Relay setting error	· The load center incoming breaker trips. · The associated 480V load center bus is de-energized. · Sufficient redundant auxiliaries remain operable from the redundant Class 1E power system for safe shutdown of the reactor.	Breaker trip alarm or undervoltage alarm

Table 8.3.1-7 (8 of 8)

Component	Function	Failure Mode	Failure Cause	Failure Effect and Counter Measure	Detection
21. 480V Class 1E load center bus or 480V Class 1E load center feeder breaker	Power supply to 480V Class 1E loads	Bus unavailable	· Bus insulation fail (grounded, shorted) · Feeder breaker interrupting fail at fault	· The load center incoming breaker trips. · The associated 480V load center bus is de-energized. · Sufficient redundant auxiliaries remain operable from the redundant Class 1E power system for the safe shutdown of the reactor.	Load center breaker trip alarm or fault alarm
		Breaker open by malfunction	Relay setting error	· The load center feeder breaker trips. · The associated 480V load center bus is de-energized. · Sufficient redundant auxiliaries remain operable from the redundant Class 1E power system for the safe shutdown of the reactor.	Breaker trip alarm
22. 480V Class 1E load center feeder cable for motor control center (MCC) or 480V Class 1E MCC feeder breaker	Power supply to 480V Class 1E MCC loads	MCC bus unavailable	· Feeder cable fault (grounded, shorted) · Feeder breaker interrupting fail at fault	· The associated load center feeder breaker trips. · The associated MCC bus is de-energized. · Sufficient redundant auxiliaries remain operable from the redundant Class 1E power system for the safe shutdown of the reactor.	Load center breaker trip alarm and MCC undervoltage alarm
		Breaker open by malfunction	Relay setting error	· The MCC feeder breaker trips. · The associated MCC load is de-energized. · Sufficient redundant auxiliaries remain operable from the redundant Class 1E power system for the safe shutdown of the reactor.	MCC fault alarm

Table 8.3.2-1 (1 of 4)

Class 1E 125 Vdc Power System Loads

1. Train A

Load Description	Load Current (A) [2]				Remark
	0-1 min	1-119 min	119-120 min	121-480 min	
	1	118	1	360	
MOV Inverter (No Load Current)	20.0	20.0			
RCS Valves [1]			47.8		Random Load
Reactor Trip Switchgear System	3.0				Momentary Load
Solenoids for CVCS, SIS, MS, FW & AF Valves	21.2	21.2	21.2	4.64	
Solenoids for Miscellaneous Valves	14.7	14.7	14.7		
Lamp and Relay, Trip of SWGR and LC	49.9	4.9	4.9	4.9	
IP Inverter	389.1	389.1	389.1	104.3	
EDG-A Control Power	11.5	11.5	11.5	11.5	
TOTAL	509.5	461.5	489.3	125.3	

(1) This load is a random load of the MOV inverter.

(2) The dc loads can change during detail design.

Table 8.3.2-1 (2 of 4)

2. Train B

Load Description	Load Current (A) (2)				Remark
	0-1 min	1-119 min	119-120 min	121-480 min	
	1	118	1	360	
MOV Inverter (No Load Current)	20.0	20.0			
RCS Valves (1)			47.8		Random Load
CVCS Valves (1)			29.4		Random Load
Reactor Trip Switchgear System	3.0				Momentary Load
Solenoids for CVCS, SIS, MS, FW & AF Valves	22.5	22.5	22.5	4.64	
Solenoids for Miscellaneous Valves	15.1	15.1	15.1		
Lamp and Relay, Trip of SWGR and LC	50.0	5.0	5.0	5.0	
IP Inverter	330.6	330.6	330.6	103.7	
EDG-B Control Power	11.5	11.5	11.5	11.5	
TOTAL	452.6	404.6	461.8	124.8	

(1) This load is a random load of the MOV inverter.

(2) The dc loads can change during detail design.

Table 8.3.2-1 (3 of 4)

3. Train C

Load Description	Load Current (A) [6]										Remark
	0-1 min	1~5 min	5~60 min	60~65 min	65~480 min	480~485 min	485~957 min	957~958 min	958~959 min	959~960 min	
	1	4	55	5	415	5	472	1	1	1	
MOV Inverter (No Load Current)	25.0	25.0	25.0	25.0	25.0	25.0	25.0				
IWS Valve 1 & 2 [(1), (2)]								229.6		229.6	Random Load
RCS Valve 1 [(1)]										47.8	Random Load
RCS Valve 2 [(1)]									581.2 [(4)]	121.9 [(5)]	Random Load
AFP Turbine LCP	68.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	
Aux. Feedwater Isolation Valves	180.0 [(3)]	180 [(3)]		180 [(3)]		180 [(3)]					
Reactor Trip Switchgear System	3.0										Momentary Load
Solenoids for SIS, MS & AT Valves	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	
Solenoids for Miscellaneous Valves	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	
Lamp and Relay, Trip of SWGR and LC	39.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	
IP Inverter	259.6	259.6	259.6	259.6	259.6	259.6	259.6	259.6	259.6	259.6	
EDG-C Control Power	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	
Emergency DC Lighting	40.0	40.0	40.0								
TOTAL	634.9	536.9	356.9	496.9	316.9 (496.9 [(3)])	496.9	316.9 (496.9 [(3)])	521.5	873.1	691.2	

(1) This load is a random load of the MOV inverter.
(2) IWS Valve 1 and 2 will not be operated simultaneously.
(3) This current is loaded for the first 5 minutes every 1 hour.
(4) This current is Locked Rotor Current value of RCS Valve 2.
(5) This current is Full Load Current value of RCS Valve 2.
(6) The dc loads can change during detail design.

Table 8.3.2-1 (4 of 4)

4. Train D

Load Description	Load Current (A) (6)										Remark
	0-1 min	1~5 min	5~60 min	60~65 min	65~480 min	480~485 min	485~957 min	957~958 min	958~959 min	959~960 min	
	1	4	55	5	415	5	472	1	1	1	
MOV Inverter (No Load Current)	25.0	25.0	25.0	25.0	25.0	25.0	25.0				
IWS Valve 3 & 4 (1), (2)								229.6		229.6	Random Load
RCS Valve 3 (1)										47.8	Random Load
RCS Valve 4 (1)									581.2 (4)	121.9 (5)	Random Load
AFP Turbine LCP	68.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	
Aux. Feedwater Isolation Valves	180.0 (3)	180 (3)		180 (3)		180 (3)					
Reactor Trip Switchgear System	3.0										Momentary Load
Solenoids for SIS, MS & AT Valves	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	
Solenoids for Miscellaneous Valves	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	
Lamp and Relay, Trip of SWGR and LC	39.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	
IP Inverter	261.4	261.4	261.4	261.4	261.4	261.4	261.4	261.4	261.4	261.4	
EDG-D Control Power	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	
Emergency DC Lighting	40.0	40.0	40.0								
TOTAL	636.7	538.7	358.7	498.7	318.7 (498.7 (3))	498.7	318.7 (498.7 (3))	523.3	874.9	693.0	

(1) This load is a random load of the MOV inverter.
(2) IWS Valve 3 and 4 will not be operated simultaneously.
(3) This current is loaded for the first 5 minutes every 1 hour.
(4) This current is Locked Rotor Current value of RCS Valve 4.
(5) This current is Full Load Current value of RCS Valve 4.
(6) The dc loads can change during detail design.

Table 8.3.2-2 (1 of 5)

Non-Class 1E DC Power System Loads

1. Division I, 125 Vdc Loads

Load Description	Load Current (A) (1)			
	0~1 min	1~30 min	30~120 min	120~480 min
	1	29	90	360
Local Control Panel	74.7	74.7	74.7	
Emergency Lighting	72.4	72.4	72.4	72.4
Feedwater Pump Turbine Emergency Lube Oil Pump	200.0	136.0	136.0	
Local Alarm Box	0.5	0.5	0.5	
Personnel Air Lock	3.0	3.0	3.0	
Solenoids for CVCS, SIS, MS & FTValves	7.1	7.1	7.1	
Solenoids for Miscellaneous Valves	7.3	7.3	7.3	
EDG Speed Cubicle	7.2	7.2	7.2	
EDG DMDS Cabinet	80.0	80.0	80.0	
Lamp and Relay, Trip of SWGR and LC	119.9	19.9	19.9	
IP Inverter	969.4	969.4		
TOTAL	1541.6	1377.6	408.1	72.4

(1) The dc loads can change during detail design.

Table 8.3.2-2 (2 of 5)

2. Division II, 125 Vdc Loads

Load Description	Load Current (A) [1]			
	0~1 min	1~30 min	30~120 min	120~480 min
	1	29	90	360
Local Control Panel	43.4	43.4	43.4	
Emergency Lighting	59.4	59.4	59.4	59.4
Feedwater Pump Turbine Emergency Lube Oil Pump	100.0	68.0	68.0	
Personnel Air Lock	3.0	3.0	3.0	
Solenoids for CVCS, MS & FT Valves	3.9	3.9	3.9	
Solenoids for Miscellaneous Valves	5.3	5.3	5.3	
EDG Speed Cubicle	7.2	7.2	7.2	
EDG DMDS Cabinet	80.0	80.0	80.0	
Lamp and Relay, Trip of SWGR and LC	129.9	19.9	19.9	
IP Inverter	1021.8	1021.8		
TOTAL	1453.9	1311.9	290.1	59.4

(1) The dc loads can change during detail design.

Table 8.3.2-2 (3 of 5)

3. Division II, 250 Vdc Loads

Load Description	Load Current (A) [1]		
	0~1 min	1~30 min	30~120 min
	1	29	90
T/G Emergency Bearing Oil Pump	1060.0	265.0	265.0
T/G Emergency Seal Oil Pump	257.5	103.0	103.0
UPS Load Current	115.1	115.1	
TOTAL	1432.6	483.1	368.0

(1) The dc loads can change during detail design.

Table 8.3.2-2 (4 of 5)

4. 125 Vdc Loads, Compound Building

Load Description	Load Current (A) [1]		
	0~30 min	30~120 min	120~480 min
	30	90	360
Liquid Radwaste Control Panel	1.4	1.4	
Gaseous Radwaste Control Panel	2.0	2.0	
Radioactive Laundry System Control Panel	0.3	0.3	
GRS Control Cabinet	12.5	12.5	
Local Alarm Box	1.0	1.0	
Plant Chilled Water System Control Panel	0.3	0.3	
Emergency Lighting Panel	24.0	24.0	24.0
Miscellaneous Valves	5.6	5.6	
Lamp and Relay, Trip of Load Center	3.0	3.0	
UPS Load Current	139.9		
TOTAL	189.9	50.0	24.0

(1) The dc loads can change during detail design.

Table 8.3.2-2 (5 of 5)

5. 125 Vdc Loads, AAC GTG Building

Load Description	Load Current (A) [1]	
	0~1 min	1~120 min
	1	119
AAC GTG DMDS Cabinet	40.0	40.0
AAC GTG Control Power	13.6	13.6
Lamp and Relay, Trip of SWGR and LC	8.1	3.1
UPS Load Current	13.7	13.7
TOTAL	75.4	70.4

(1) The dc loads can change during detail design.

Table 8.3.2-3 (1 of 4)

Class 1E 120 Vac I&C Power System Loads

Train A

Description	Capacity (kVA)
Auxiliary Process Cabinet (APC)	0.16
Plant Protection System (PPS) Cabinets	1.08
Core Protection Calculator System (CPCS) Cabinet and Test Simulator	1.02
Maintenance and Test Panel (MTP-A1)	0.6
ESF-CCS Group Controller Cabinets	1.2
ESF-CCS Loop Controller Cabinets	13.5
Safety Console	1.02
Ex-core Neutron Flux Monitoring System (ENFMS)	0.4
Safety-Related Divisionalized Cabinet (SRDC)	0.51
Radiation Monitoring System Local Unit	5.66
QIAS-P Display Processor	0.42
Remote Shutdown Console	0.36
Transducer for 4.16 kV Switchgear and dc control center	0.1
Pilot Operated Safety Release Valve Master Control Cabinet (PMCC) (Channel A)	0.43
Total	26.46

(1) The I&C loads can change during the design.

Table 8.3.2-3 (2 of 4)

Train B

Description	Capacity (kVA)
Auxiliary Process Cabinet (APC)	0.11
Plant Protection System (PPS) Cabinets	1.08
Core Protection Calculator System (CPCS) Cabinet and Test Simulator	1.02
Maintenance and Test Panel (MTP-B1)	0.6
ESF-CCS Group Controller Cabinets	1.2
ESF-CCS Loop Controller Cabinets	14.63
Safety Console	1.02
Ex-core Neutron Flux Monitoring System (ENFMS)	0.4
Safety-Related Divisionalized Cabinet (SRDC)	0.51
Radiation Monitoring System Local Unit	0.6
QIAS-P Display Processor	0.42
Remote Shutdown Console	0.36
Transducer for 4.16 kV Switchgear and dc control center	0.1
Pilot Operated Safety Release Valve Master Control Cabinet (PMCC) (Channel B)	0.43
Total	22.48

(1) The I&C loads can change during the design.

Table 8.3.2-3 (3 of 4)

Train C

Description	Capacity (kVA)
Auxiliary Process Cabinet (APC)	0.09
Plant Protection System (PPS) Cabinets	1.08
Core Protection Calculator System (CPCS) Cabinet and Test Simulator	1.02
ESF-CCS Group Controller Cabinets	1.2
ESF-CCS Loop Controller Cabinets	6.75
Maintenance and Test Panel (MTP-C1)	0.6
Safety Consoles	2.2
Shift Technical Advisor Console	0.54
Reactor Operator Console	0.36
Turbine/Electrical Operator Consoles	0.72
Shift Supervisor Console	0.54
Remote Shutdown Console	1.08
Digital Rod Control System (DRCS) Remote I/O Cabinet	0.54
Ex-core Neutron Flux Monitoring System (ENFMS)	0.4
Transducer for 4.16 kV Switchgear and dc control center	0.1
Pilot Operated Safety Release Valve Master Control Cabinet (PMCC) (Channel C)	0.43
Total	17.65

(1) The I&C loads can change during the design.

Table 8.3.2-3 (4 of 4)

Train D

Description	Capacity (kVA)
Auxiliary Process Cabinet (APC)	0.09
Plant Protection System (PPS) Cabinets	1.08
Core Protection Calculator System (CPCS) Cabinet and Test Simulator	1.02
QIAS-N Display Processor	0.48
ESF-CCS Group Controller Cabinets	1.2
ESF-CCS Loop Controller Cabinets	6.75
Maintenance and Test Panel (MTP-D1)	0.6
Safety Consoles	1.84
Shift Technical Advisor Console	0.54
Reactor Operator Console	0.36
Turbine/Electrical Operator Consoles	0.72
Shift Supervisor Console	0.54
Remote Shutdown Console	1.08
Digital Rod Control System (DRCS) Remote I/O Cabinet	0.54
Ex-core Neutron Flux Monitoring System (ENFMS)	0.4
Transducer for 4.16 kV Switchgear and dc control center	0.1
Pilot Operated Safety Release Valve Master Control Cabinet (PMCC) (Channel D)	0.43
Total	17.77

(1) The I&C loads can change during the design.

Table 8.3.2-4 (1 of 2)

Electrical Equipment Ratings – Component Data

Non-Class 1E DC and I&C Power System

Component	Description	Specification
Battery Charger	AC input	Three phase, 480 Vac ± 10 %, 60 Hz ± 5 %
	DC output	± 0.5 % regulation
	Float voltage range	124-130/248-260 V (125/250 Vdc system)
	Equalizing voltage range	130-140/260-280 V (125/250 Vdc system)
	DC output current rating	1,800 A (auxiliary building, division I) 1,600 A (auxiliary building, division II) 300 A (compound building) 200 A (AAC GTG building), 600 A (TG building)
Battery	Type	Lead Acid
	Number of cells	116 cell for 125 Vdc (auxiliary building) 58 cell for 125 Vdc (compound and AAC GTG building) 116 cell for 250 Vdc (TG building)
	Nominal voltage	125 Vdc/250 Vdc
	Float voltage	2.15-2.17 V/cell
	Equalizing voltage	2.25-2.40 V/cell
	Minimum operating voltage	1.81 V/cell
	Voltage range	105-140 V for 125 Vdc System 210-280 V for 250 Vdc System
	Battery capacity	4,000 AH (division I) 3,600 AH (division II) 700 AH (compound building) 500 AH (AAC GTG building) 3,200 AH (TG building)
Inverter	Rating	60 kVA
	DC input voltage	100-140 V
	Nominal output ac voltage	120 V
	Output voltage regulation	± 2 %
	Output frequency	60 Hz ± 0.5 %
	Efficiency	85 %
Regulating Transformer	Rating	60 kVA
	Input nominal voltage	1 phase 480 V
	Output nominal voltage	1 phase 120 V

Table 8.3.2-4 (2 of 2)

Class 1E DC and I&C Power System

Component	Description	Specification
Battery Charger	AC input	Three phase, 480 Vac ± 10 %, 60 Hz ± 5 %
	DC output	± 0.5 % regulation
	Float voltage range	124-130/248-260 V (125/250 Vdc system)
	Equalizing voltage range	130-140/260-280 V (125/250 Vdc system)
	DC output current rating	700 A (trains A&B), 1,200 A (trains C&D)
Battery	Type	Lead acid
	Number of cells	58 cell × 2 (parallel)
	Nominal voltage	125 Vdc
	Float voltage	2.15-2.17 V/cell
	Equalizing voltage	2.25-2.40 V/cell
	Minimum operating voltage	1.81 V/cell
	Voltage range	105-140 V for 125 Vdc System
	Battery capacity	2,800 AH (trains A&B) 8,800 AH (trains C&D)
Inverter	Rating	40 kVA
	DC input voltage	100-140 V
	Nominal output ac voltage	120 V
	Output voltage regulation	± 2 %
	Output frequency	60 Hz ± 0.5 %
	Efficiency	85 %
Regulating Transformer	Rating	40 kVA
	Input nominal voltage	1 phase 480 V
	Output nominal voltage	1 phase 120 V

Table 8.3.2-5 (1 of 2)

Electrical Equipment Status Information of
Class 1E 125 Vdc and 120 Vac Power Systems

MCR and RSR

Description	Status	
	Alarm	Indication
Battery charger output voltage low	○	
Battery charger output voltage high	○	
Loss of ac input to battery charger	○	
Loss of battery charger output power	○	
Battery charger output circuit breaker open	○	○
DC control center main circuit breaker open	○	○
Battery circuit breaker open	○	○
Battery current (Charge and Discharge)		○
Battery test panel feeder breaker close	○	
125 Vdc control center undervoltage	○	
125 Vdc control center ground	○	
125 Vdc control center voltage		○
Inverter 125 Vdc input failure	○	
Inverter failure	○	
Inverter ac output voltage low	○	
120 Vac inverter distribution panel undervoltage	○	
120 Vac inverter distribution panel ground	○	

Table 8.3.2-5 (2 of 2)

Local

Description	Status	
	Alarm	Indication
DC bus undervoltage	○	
DC bus ground	○	
Charger dc voltage low	○	
Charger dc voltage high	○	
Battery charger ac power failure	○	
Battery charger dc power failure	○	
Battery current(Ammeter-Charge/Discharge)		○
Battery charger output current (Ammeter)		○
DC bus voltage (Voltmeter)		○
Battery charger output voltage (Voltmeter)		○
DC bus ground detector		○
Battery charger ac on indication		○
Charger high dc voltage shutdown relay (Main ac supply breaker to the charger open)		○

Table 8.3.2-6 (1 of 2)

Failure Modes and Effects Analysis for the 125 V dc and Class 1E Vital Power System

Component	Function	Failure Mode	Failure Cause	Failure Effect and Countermeasure	Detection
1. 480 Vac supply to chargers	Power supply to charger	Loss of ac input power	• Loss of 480 V load center power • Power supply feeder fault	• Power supply failure to dc MCC from charger • Power from battery is available to supply power without interruption.	Annunciation by charger undervoltage relay
2. Battery chargers	Power supply to 125 Vdc load and charge of battery	• Loss of output power • Opening of output breaker • Undervoltage of output power • Overvoltage of output power	Component failure	• Power supply failure to dc MCC from charger • Severe internal faults may cause high short-circuit currents to flow with resulting voltage reduction on the 125 Vdc bus until the fault is cleared by the isolating circuit breakers. • The 125 Vdc bus receives power from its respective battery without interruption. • If the battery circuit breakers open, the complete loss of voltage on one 125 Vdc bus may result but other redundant system can function as alternative.	• Annunciation by charger trouble detection • Annunciation by charger undervoltage / overvoltage relay
3. 125 Vdc batteries	Back-up power supply to dc MCC	Battery circuit breaker open	Battery failure	• Back-up power loss • In case a charger is available, even though the battery fails to supply to dc MCC, the battery charger allows continued supply of power to dc MCC. • In case both battery and charger are unavailable, other redundant system can function as alternative.	Annunciation by breaker trip

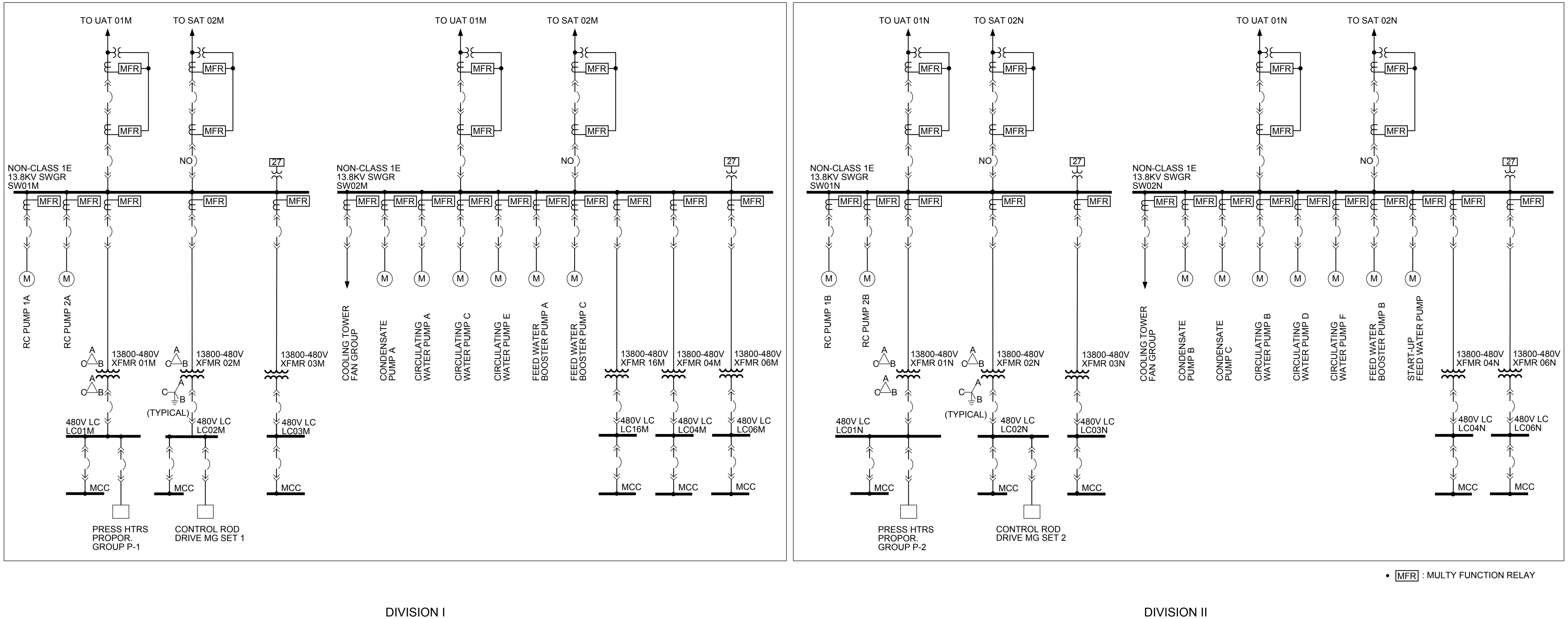
Table 8.3.2-6 (2 of 2)

Component	Function	Failure Mode	Failure Cause	Failure Effect and Countermeasure	Detection
4. 125 Vdc control centers	Power supply to dc loads	Ground fault	Grounding of a single bus	· The 125 Vdc system is an ungrounded electrical system and therefore, ground detector is under surveillance and causes alarms. · A single ground does not cause any malfunction or prevent operation of any safety feature.	Annunciation by dc MCC ground detector
		Undervoltage	Charger failure and battery discharge	· The 125 V bus is monitored to detect the voltage decay on the bus and initiate an alarm at a voltage setting where the battery can still deliver power for safe and orderly shutdown of the unit. · Upon detection, power can be restored either by correcting the deficiency or by switching to a redundant source.	Annunciation by dc MCC undervoltage relay
5. 125 Vdc distribution panel	Power supply to dc loads	Main circuit breaker open	Bus shorted	· Voltage on the shorted 125 Vdc bus system of the affected unit decays until isolated by the isolating circuit breakers. · Remaining redundant channels are available for the safe operation of the unit.	Annunciation by breaker trip [(Local Only)]

Table 8.3.2-7

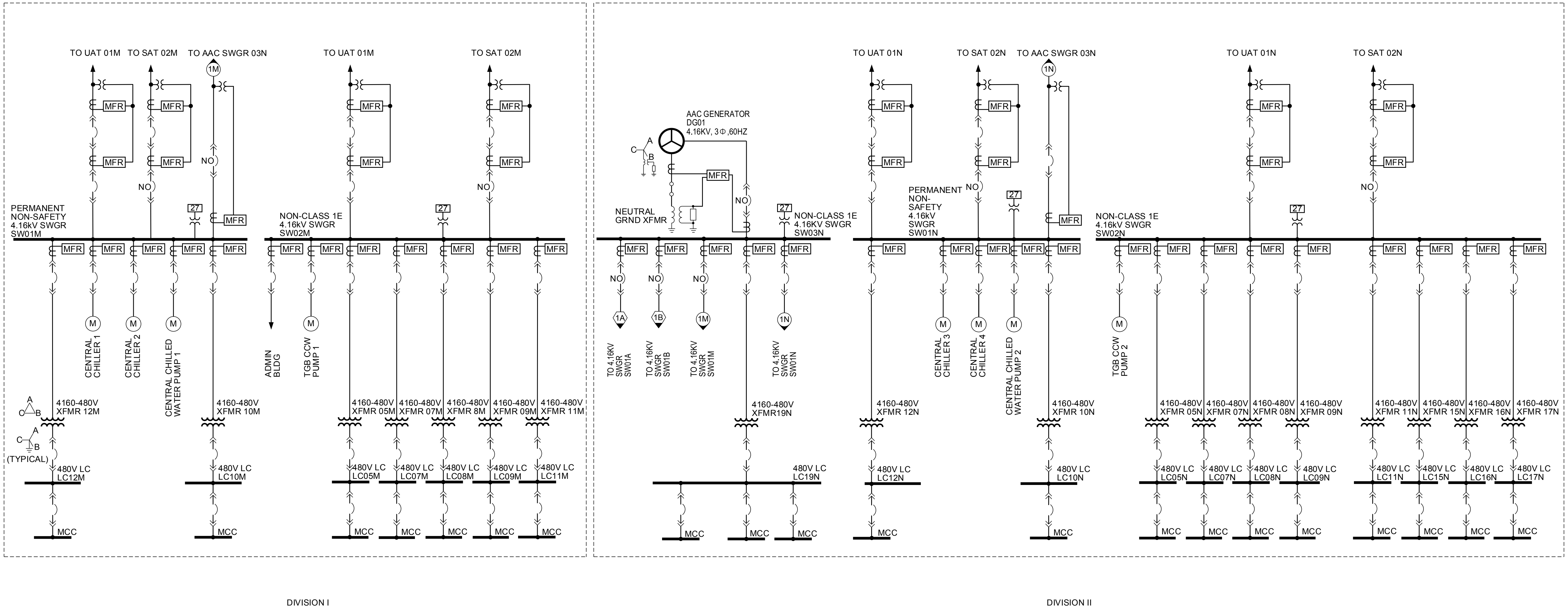
Failure Modes and Effects Analysis for the 120 Vac Class 1E Vital Instrumentation and Control Power System

Component	Function	Failure Mode	Failure Cause	Failure Effect and Countermeasure	Detection
1. Inverter	Power supply to vital bus panelboards	· Loss of output power · Loss of input power · Inverter failure	Component failure	· Input power loss of 120 V vital bus distribution panel · Regulating transformer supply back-up power · Redundant system is available for the function	Annunciation by inverter undervoltage relay
2. ac instrument and control power distribution panel	Power supply to vital instrument loads	Undervoltage	Bus shorted	· Power supply loss of 120 V vital instrument loads · Sufficient redundant system provides adequate protection.	Annunciation by power loss



Non-Class 1E 13.8 kV AC Power System

Figure 8.3.1-1 Onsite AC Electrical Power System (1 of 3)



Non-Class 1E 4.16 kV AC Power System

Figure 8.3.1-1 Onsite AC Electrical Power System (2 of 3)

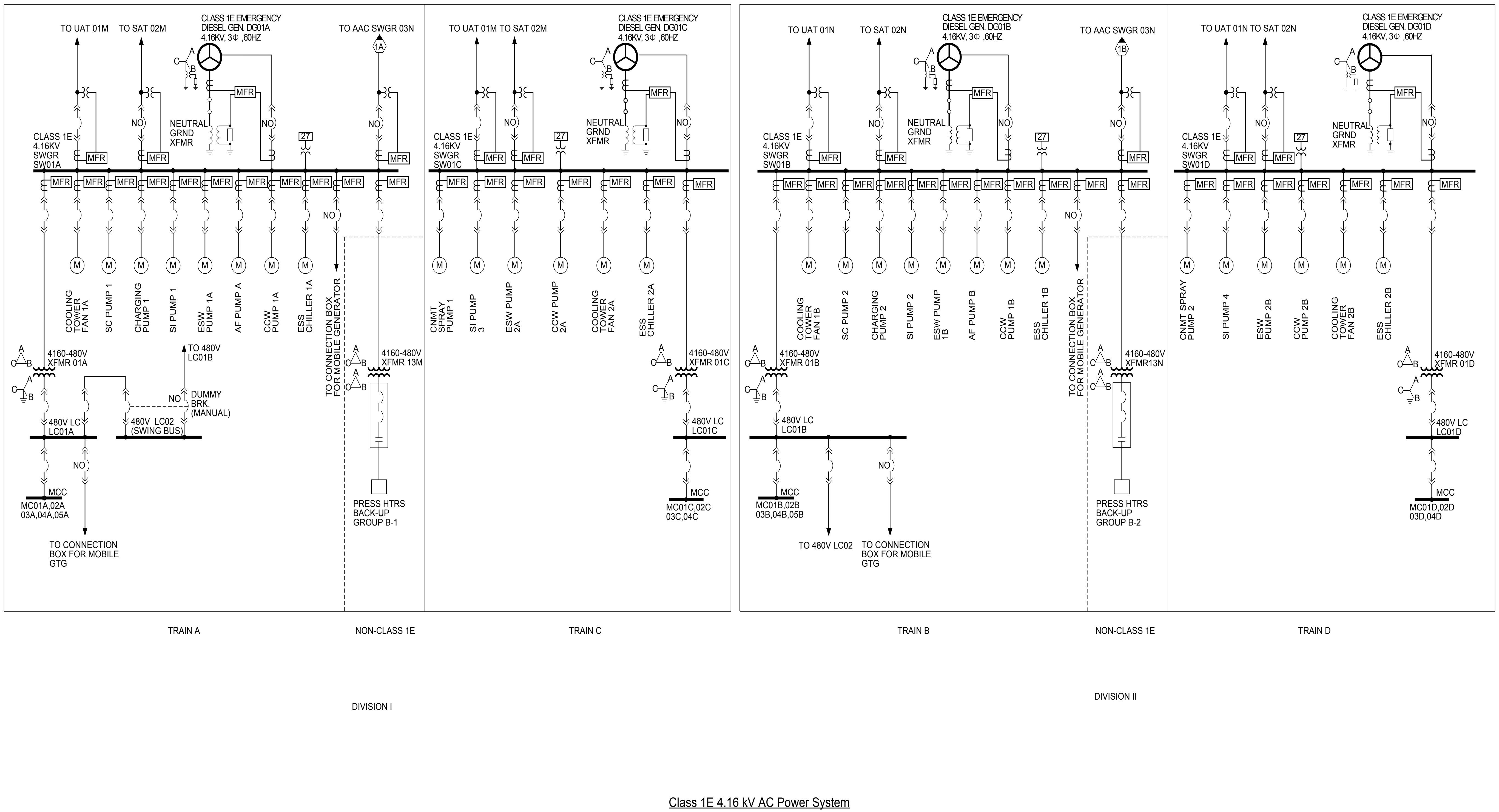


Figure 8.3.1-1 Onsite AC Electrical Power System (3 of 3)

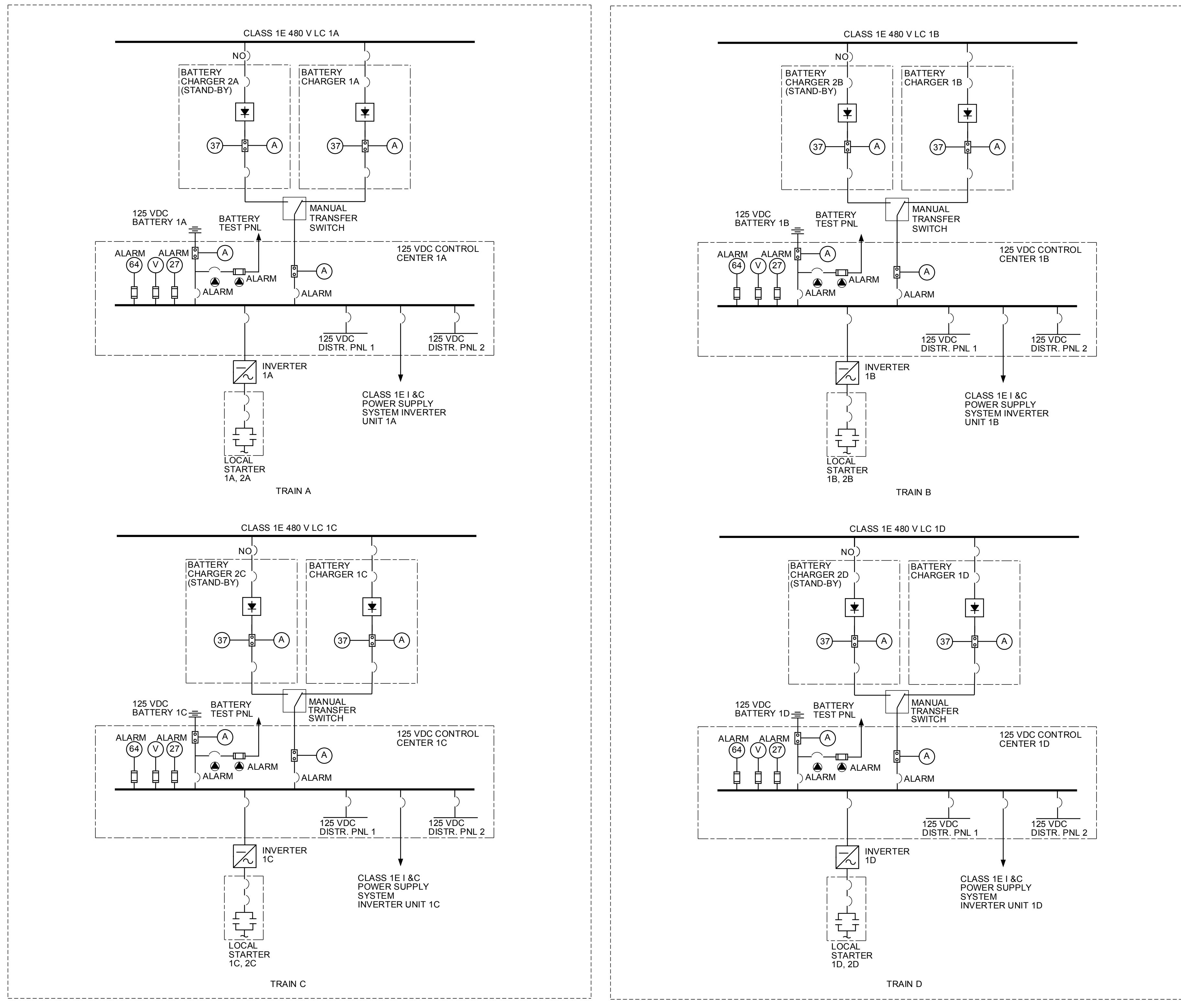


Figure 8.3.2-1 Class 1E DC Power System

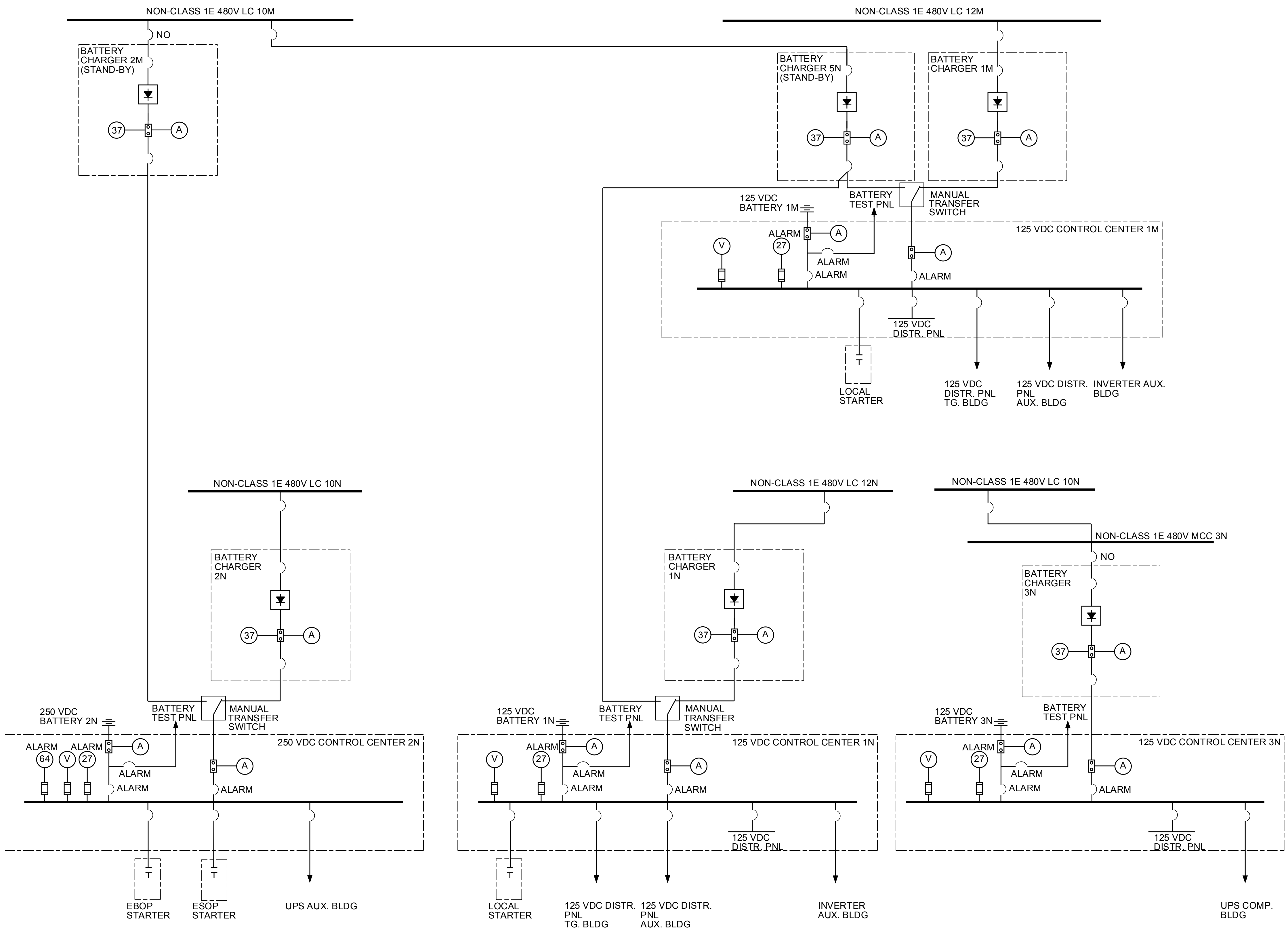


Figure 8.3.2-2 Non-Class 1E DC Power System

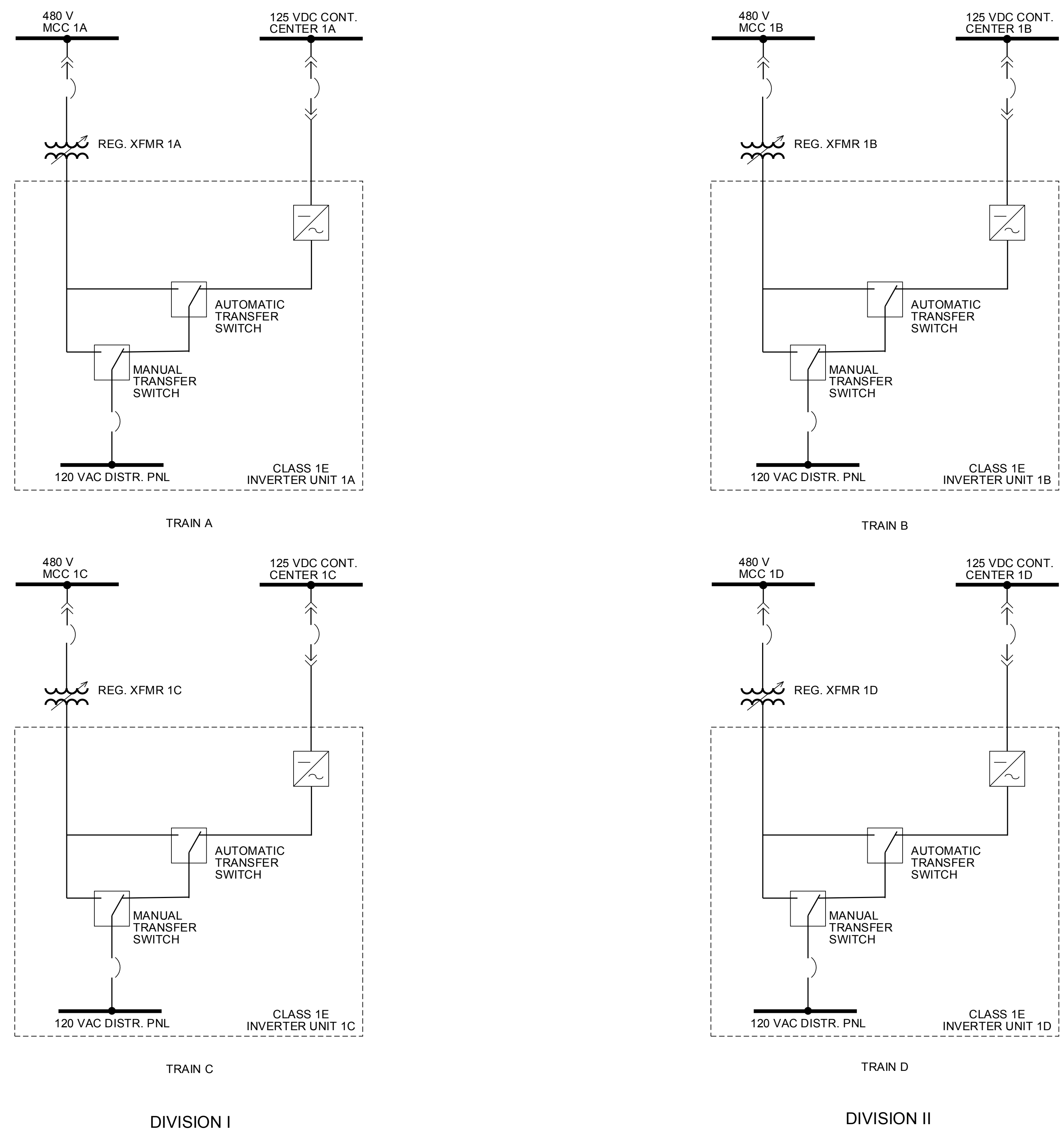


Figure 8.3.2-3 Class 1E 120 Vac Instrumentation and Control Power System

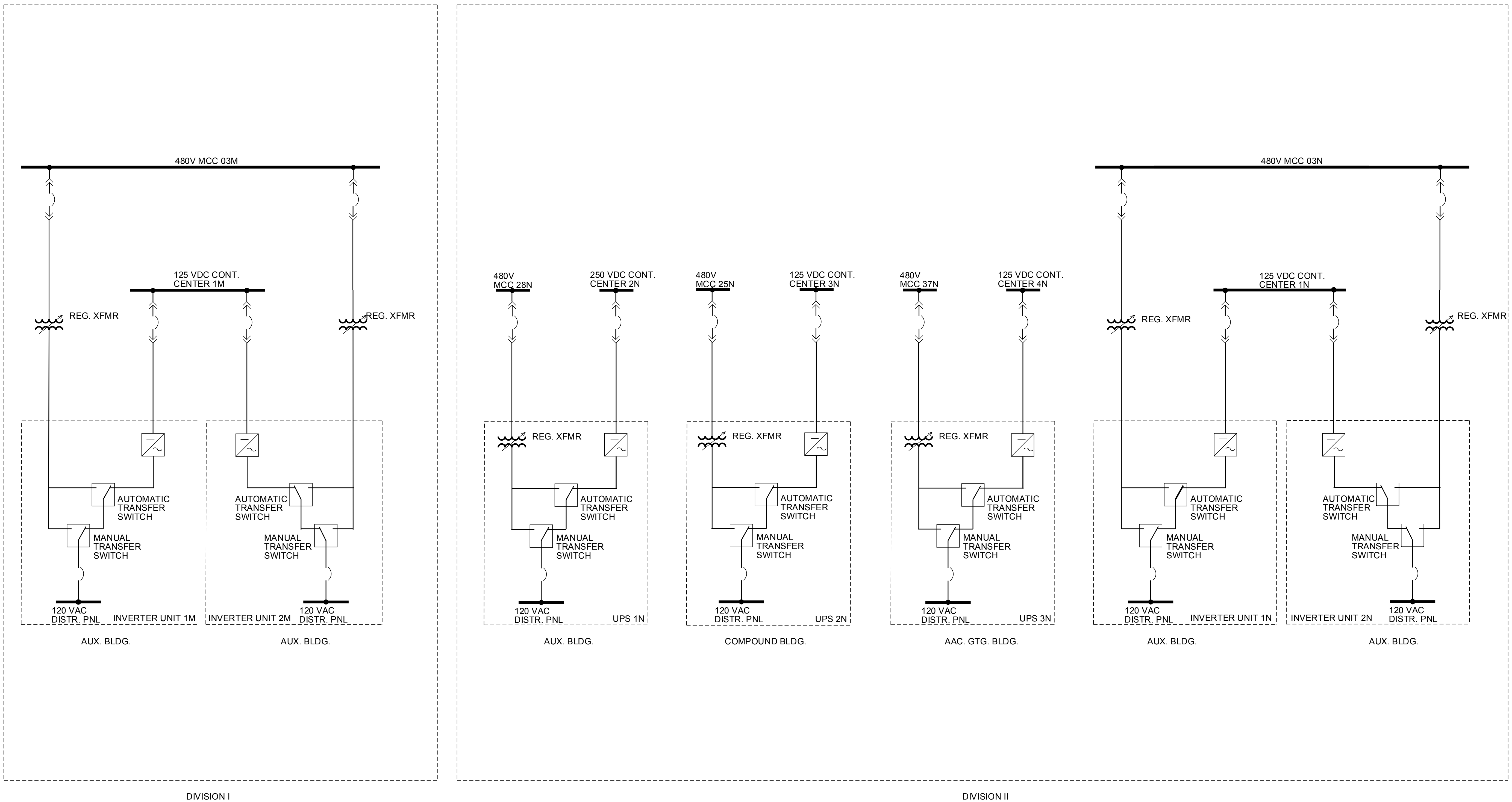


Figure 8.3.2-4 Non-Class 1E 120 Vac Instrumentation and Control Power System

8.4 Station Blackout

8.4.1 System Description

Station blackout (SBO) is the complete loss of alternating current (AC) electric power to the Class 1E and non-Class 1E switchgear buses in the APR1400. The SBO involves the loss of offsite power (LOOP) concurrent with a turbine trip and failure of the onsite emergency ac power system, but it does not include the loss of available ac power to buses fed by station batteries through inverters or the loss of the power from the alternate ac (AAC) source.

8.4.1.1 Description

The offsite and onsite power systems are designed with sufficient independence, capacity, and capability to meet the requirements of General Design Criterion (GDC) 17 (Reference 1). The offsite and onsite systems are also designed to permit periodic inspection and testing in accordance with GDC 18 (Reference 2). The electrical connections between the offsite power system and onsite power systems are described in Section 8.2. The onsite power system is described in Section 8.3.

During an SBO, a non-Class 1E AAC gas turbine generator (GTG) with sufficient capacity, capability, and reliability provides power for the set of required shutdown loads (non-design-basis accident) to bring the plant to safe shutdown. The AAC GTG is started and manually connected to the shutdown bus within 10 minutes in accordance with Position C.3.2.5 of NRC RG 1.155 (Reference 3). The application of the AAC GTG to cope with an SBO meets 10 CFR 50.63 (Reference 4) and SECY-90-016 (Reference 8).

Conformance of APR1400 with NRC RG 1.155 regulatory position C.3.3 is addressed as shown in Table 8.4.1-1.

Training and procedures necessary to cope with an SBO for APR1400 plant operators are described in Section 13.2 and Section 13.5.

8.4.1.2 Station Blackout Coping Duration

The SBO coping duration is determined by the following four design factors as specified in 10 CFR 50.63 and NRC RG 1.155 Position C.3.1.

a. The first design factor is the redundancy of the onsite emergency alternating current (EAC) power system. The onsite EAC power system for the APR1400 consists of two redundant systems that have four independent Class 1E EDGs. One Class 1E EDG (train A or B) is required to operate the ac-powered decay heat removal systems. Therefore, the EAC power configuration group selected for the APR1400 is group "C" in accordance with Table 3 of NRC RG 1.155.

b. The second design factor is the reliability of the onsite EAC power sources. The APR1400 selects a target EDG reliability of 0.95. The reliable operation of the EAC power sources is provided reasonable assurance by a reliability program that is in accordance with NRC RG 1.9 (Reference 5) and NRC RG 1.155 Position C.1.2.

c. The third design factor is the expected frequency of a LOOP. The offsite power system is site-specific and not part of the APR1400. Therefore, the offsite power design characteristic group for the APR1400 is selected as "P3" for conservatism in accordance with Table 4 of NRC RG 1.155.

d. The fourth design factor is the probable time needed to restore offsite power. This factor is incorporated into the "P3" grouping addressed previously.

Based on the above condition, the SBO coping duration for the APR1400 is 16 hours in accordance with Table 2 of NRC RG 1.155. The AAC GTG is capable of supplying power for the shutdown loads required to bring the plant to the hot shutdown condition during an SBO.

However, since the preceding factors are subject to change as per the site conditions and site-specific design, the COL applicant is to validate the SBO coping duration according to the method specified in NRC RG 1.155 (COL 8.4(1)).

8.4.1.3 Alternate AC Power Source

The 4.16 kV non-Class 1E AAC GTG is provided as an AAC source to mitigate the SBO in accordance with Position C.3.3 of NRC RG 1.155. The AAC GTG has sufficient capacity to operate the system necessary for coping with the SBO for the time required to bring and maintain the plant in a safe shutdown condition. This design meets the requirements of Criterion 4 for NRC RG 1.155, Position C.3.3.5. The reliability of the AAC power system meets or exceeds 95 percent as determined in accordance with NSAC-108 (Reference 6).

The SBO loads for the AAC GTG are shown in Table 8.3.1-4. The AAC power source for the APR1400 is designed to meet the requirements of 10 CFR 50.63, NRC RG 1.155, and NUMARC 87-00 (Reference 7).

The AAC GTG is designed to attain rated voltage and frequency within 2 minutes after receipt of a starting signal. The loads required for plant safe shutdown are manually connected by the operator in the main control room (MCR) and remote shutdown room (RSR) in accordance with the emergency operating procedures (EOPs) described in Subsection 13.5.2. Normally, the AAC GTG is not directly connected to both the preferred offsite power sources and any onsite Class 1E 4.16 kV switchgear buses. One normally open non-Class 1E circuit breaker is provided between the AAC GTG and the non-Class 1E AAC 4.16 kV switchgear and two normally open circuit breakers in series are provided between the non-Class 1E AAC switchgear and each Class 1E 4.16 kV switchgear (train A and train B). The connection between the AAC power source and the onsite or offsite ac power systems meets the requirements of Criterion 1 for NRC RG 1.155, Position C.3.3.5. The AAC GTG is manually connected to the designated Class 1E 4.16 kV switchgears (train A or train B) by the operator within 10 minutes from the beginning of the SBO event. This operation meets the requirements of Criterion 3 for NRC RG 1.155, Position C.3.3.5. The isolation between the Class 1E and the non-Class 1E system is provided by two circuit breakers in series in accordance with the Appendix B requirements of NRC RG 1.155 and with NUMARC 87-00.

The non-Class 1E AAC 4.16 kV switchgear has connection provisions to two permanent non-safety (PNS) 4.16 kV switchgear (divisions I and II). During a LOOP condition, the AAC GTG is manually aligned to power two PNS 4.16 kV switchgear. The configuration of the electrical connections between the AAC GTG, Class 1E, and non-Class 1E switchgear are shown in Figures 8.1-1 and 8.3.1-1. To minimize the potential for common-cause failures with Class 1E EDGs, the AAC GTG is provided with a gas turbine engine with a diverse starting and cooling system. The independence of the AAC GTG from the offsite power source and EAC power sources is realized by physical separation, electrical isolation of power and control circuits, and control and protection scheme of the AAC power source.

The AAC GTG, including the related auxiliary equipment, is located in the AAC GTG building and the Class 1E switchgear are located in the auxiliary building. The circuits between the AAC GTG and Class 1E switchgear are separated from the circuits connecting the Class 1E switchgear to the offsite power source as practicable such that impact on the connections of the AAC GTG is minimized for events that affect the offsite power source. The power and control circuits of the Class 1E switchgear are isolated by using isolation devices from the non-Class 1E AAC switchgear to prevent malfunctions in the non-Class 1E switchgear causing unacceptable impacts to the Class 1E switchgear.

The two circuit breakers in series between the non-Class 1E AAC switchgear and Class 1E switchgear are provided with interlock and permissive schemes and there is no control interface between the load shedding and sequencing schemes of the Class 1E EDGs and the AAC GTG control schemes. Therefore, no single-point vulnerability exists in which a weather-related event or single active failure disables any portion of the onsite EAC sources or the offsite power sources and simultaneously fails the AAC source. The design factors for the AAC GTG meet the requirements of Criterion 2 for NRC RG 1.155, Position C.3.3.5.

The COL applicant is to identify local power sources and transmission paths that could be made available to resupply power to the plant following the loss of a grid or an SBO (COL 8.4(2)).

The power supply from the AAC GTG and the recovery from the SBO are described in Subsections 8.4.1.4 and 8.4.1.5.

8.4.1.3.1 AAC Instrumentation and Control

Various monitoring and control devices are provided to provide the operator with control and operational status information for the AAC system. The COL applicant is to specify the specific parameters for monitoring, alarms, mechanical and electrical trip for testing, and emergency trips (COL 8.4(3)). Generally, parameters described in this Subsection are used.

The following mechanical trips are provided to protect the AAC GTG during testing:

a. Low lube oil pressure

b. Low lube oil level in lube oil tank or sump

c. High pressure in crank case

d. High high lube oil temperature

e. low fuel oil pressure

These mechanical trips are bypassed during the operation of the AAC GTG in the emergency mode. The following electrical trips are provided to protect the AAC GTG during testing:

a. Generator electrical protection

b. Electronic governor failure

All signals of the protective relay trip, except the trip signals listed below, are bypassed during the operation of the AAC GTG in the emergency mode.

a. Engine over speed

b. Generator differential protection

c. Manual trip

The following parameters are monitored in the MCR, RSR, and local control panel.

a. Lube oil temperature and pressure

b. Engine bearing temperatures

c. Engine speed

d. Air pressure (if air is used for starting)

The status of each Class 1E 4.16 kV breaker position is indicated in the MCR, RSR, and the circuit breaker cubicle. The instrumentation for the AAC GTG provides the following indicators in the MCR and RSR:

a. Output voltage

b. Output frequency

c. Output ampere

d. Output watts

e. Output vars

f. Power factor

g. Output watt-hours

The following status indication are provided in local control panel.

a. Engine over speed

b. Low oil pressures

c. Low air pressure (if air is used for starting)

d. GTG output breaker position

e. Loss of control power

f. Generator fault

8.4.1.4 Power Supply from AAC GTG

The power supply from the AAC GTG to the dedicated train of the onsite Class 1E switchgear buses (train A or train B) is accomplished with the following operating procedures:

a. The undervoltage signals on the PNS 4.16 kV buses automatically initiate the starting of the AAC GTG and the tripping of incoming circuit breakers from the offsite power supply sources.

b. The AAC GTG circuit breaker in the AAC switchgear is closed manually after the AAC GTG attains the rated voltage and frequency. The power supply from the AAC GTG is restored to the PNS 4.16 kV buses manually. The loads on the PNS 4.16 kV buses are started manually by operator action.

c. The Class 1E bus tie circuit breaker in the AAC switchgear and the AAC bus tie circuit breaker in the Class 1E 4.16 kV switchgear are normally open.

d. All loads on the Class 1E 4.16 kV buses except the 480V load centers are tripped automatically by undervoltage signals on the Class 1E 4.16 kV bus. All loads on the PNS buses, as shown in Table 8.3.1-5, are tripped by manually opening the respective tie breakers.

e. The dedicated Class 1E 4.16 kV bus is energized from the AAC GTG by manually closing the associated Class 1E bus tie circuit breaker in the AAC switchgear and the AAC bus tie circuit breaker in the Class 1E 4.16 kV bus.

f. The SBO loads for the AAC GTG, as shown in Table 8.3.1-4, are energized by manual operation. Power factors of 0.8 for the AAC GTG and 0.85 for the SBO loads were conservatively used for calculating the capacity of the AAC GTG since the specific load data will be determined at the time of procurement. The resulting capacity of the AAC GTG was established to be 12,125 kVA and the SBO loads 10,228 kVA.

The COL applicant is to develop detailed procedures for manually aligning the alternate AC power supply when two (Trains A and B) of the four diesel generators are unavailable during a loss of offsite power event (COL 8.4(4)).

The manual operation on the above procedures meets Appendix B requirements of NUMARC 87-00.

8.4.1.5 Recovery from SBO

Power is restored to the Class 1E buses from the onsite Class 1E EDGs or the offsite power sources within the SBO coping duration:

a. Restore onsite power system from offsite power sources

   1) The output of AAC GTG is adjusted to synchronize with the offsite power source.

   2) If the offsite source from UATs (or SATs) is available, the incoming breakers from the UATs (or SATs) to the Class 1E 4.16 kV buses are closed after synchronizing the AAC GTG with the offsite power source.

   3) The AAC bus tie circuit breaker in the Class 1E 4.16 kV switchgear and the Class 1E bus tie circuit breaker in the AAC switchgear are tripped to isolate the Class 1E bus from the AAC GTG.

b. Restore onsite power system from the EDGs

   1) The AAC bus tie circuit breaker in the Class 1E 4.16 kV switchgear and the Class 1E bus tie circuit breaker in the AAC switchgear are tripped to isolate the Class 1E bus from the AAC GTG.

   2) The EDG is connected to required loads by EOP.

8.4.1.6 Periodic Testing and Inspection

Periodic testing and inspection of the AAC meets the requirement of Criterion 5 for NRC RG 1.155 Position C.3.3.5 to demonstrate equipment operability and reliability.

As specified in NUMARC 87-00 Appendix B, the AAC power source is started and brought to operating conditions that are consistent with its function as an AAC power source at least every 3 months. The AAC GTG is started once every refueling outage to verify its availability within 10 minutes and the rated load capacity test is performed. The portions of the AAC GTG and its support systems subjected to maintenance activities will be tested before returning the AAC GTG and its support systems to service.

8.4.2 Analysis

8.4.2.1 Conformance with 10 CFR Part 50

10 CFR 50.63 – Loss of All Alternating Current Power

The AAC power systems, including the AAC GTG support systems, which are provided to mitigate an SBO conform to the Maintenance Rule requirements in 10 CFR 50.65 since they are included in the emergency operation procedures (EOPs).

The APR1400 is designed to be able to withstand or cope with and recover from an SBO for a specified duration as defined in 10 CFR 50.63. Conformance with 10 CFR 50.63 is described in Subsections 8.4.1.2, 8.4.1.3, and 8.4.1.4.

10 CFR 50.65 – Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants

The AAC GTG performance monitoring is included as a part of the reliability assurance program and the maintenance rule program described in Section 17.4 and Section 17.6.

Appendix A to 10 CFR Part 50, General Design Criterion 17 and 18

Conformance with GDC 17 and 18 is described in Subsection 8.4.1.1.

8.4.2.2 Conformance with NRC Regulatory Guides

NRC Regulatory Guide 1.9

The guideline of NRC RG 1.9 is related to the design application and testing program of the Class 1E EDG in the nuclear power plant.

Conformance with NRC RG 1.9 is described in Subsection 8.3.1.2.2.

NRC Regulatory Guide 1.155

The following requirements of NRC RG 1.155 are related to the AAC GTG and the loads applied for SBO coping conditions.

a. NRC RG 1.155 requires that each nuclear power plant have the capability to withstand and recover from an SBO lasting a specified minimum duration. The specified duration of SBO is based on the four factors as described in Subsection 8.4.1.2. Conformance with NRC RG 1.155 Position C.3.1 is described in Subsection 8.4.1.2.

b. There are two SBO coping methods. The first method is the "AC-Independent" approach. In this approach, nuclear power plants rely on available process steam, dc power, and compressed air to operate equipment necessary to achieve safe shutdown conditions until offsite power sources or EAC power sources are restored. The second method is the "Alternate AC" approach. This method is named for its use of equipment that is capable of being electrically isolated from the preferred offsite and emergency onsite ac power sources. The APR1400 selects the "Alternate AC" approach. NRC RG 1.155 specifies that no coping analysis is needed if the AAC power source is available within 10 minutes of the onset of an SBO. Therefore, the APR1400 is not required to perform an SBO coping analysis. Conformance with NRC RG 1.155 Position C.3.2.5 and C.3.3 is described in Subsection 8.4.1.

c. NRC RG 1.155 Position C.3.4 is related to the training and procedures for all operator actions necessary to cope with an SBO, Position C.1.3 is related to the procedure for the action to restore emergency ac power when the emergency ac power system is unavailable, and Position C.2 is related to the procedure for the actions to restore offsite power when offsite power is unavailable. The procedures that address NRC RG 1.155 Positions C1.3, C.2 and C3.4 are included in the emergency operating procedures (EOPs), which are to be developed and implemented by the COL applicant as specified in COL 13.5(5).

The training per NRC RG 1.155 Position C.3.4 is included in the licensed plant staff training program, which is to be provided by the COL applicant as specified in COL 13.2(3).

d. NRC RG 1.155 Position C.3.5 is related to the quality assurance (QA) activities and specification for a non-safety-related AAC that is installed to meet an SBO. The non-safety equipment installed to meet an SBO does not degrade the existing safety-related systems. The QA guidance for the AAC GTG is described in Chapter 17. The AAC GTG follows the quality requirements in accordance with regulatory position 3.5 and Appendix A in NRC RG 1.155. Appendix B to NRC RG 1.155 will be considered as a criteria to the technical specifications for the AAC GTG and its support systems.

e. The AAC GTG is designed and installed to meet the station blackout rule and has its own independent support systems not subject to a water source, instrument air or water delivery system of any other safety related system described in NRC RG 1.155, Appendix B. Thus, system and station equipment specifications for such functions as water source, instrument air, and water delivery system do not need to account for the AAC GTG. Conformance or justification of AAC Sources (AAC GTG) with NRC RG 1.155 Appendix B is addressed as shown in Table 8.4.2-1.

8.4.2.3 Conformance with 10 CFR 52.47(b)(1) and 10 CFR 52.80(a)

See Subsection 8.2.2.4.

8.4.2.4 Conformance with NUREG-0800

Standard Review Plan, Section 8.4.III.3, Criteria D to I and K to M

Conformance of APR1400 design with the NUREG-0800, Section 8.4.III.3, Criteria D to I and K to M is addressed as shown in Table 8.4.2-2.

8.4.3 Combined License Information

COL 8.4(1) The COL applicant is to validate the SBO coping duration according to the method specified in NRC RG 1.155.

COL 8.4(2) The COL applicant is to identify local power sources and transmission paths that could be made available to resupply power to the plant following the loss of a grid or the SBO.

COL 8.4(3) The COL applicant is to specify the specific parameters for monitoring, alarms, mechanical and electrical trip for testing, and emergency trips.

COL 8.4(4) The COL applicant is to develop detailed procedures for manually aligning the alternate AC power supply when two (Trains A and B) of the four diesel generators are unavailable during a loss of offsite power event.

8.4.4 References

1. 10 CFR Part 50, Appendix A, General Design Criterion 17, "Electric Power Systems," U.S. Nuclear Regulatory Commission.

2. 10 CFR Part 50, Appendix A, General Design Criterion 18, "Inspection and Testing of Electric Power Systems," U.S. Nuclear Regulatory Commission.

3. Regulatory Guide 1.155, "Station Blackout," U.S. Nuclear Regulatory Commission, August 1988.

4. 10 CFR 50.63, "Loss of All Alternating Current Power," U.S. Nuclear Regulatory Commission.

5. Regulatory Guide 1.9, "Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants," Rev. 4, U.S. Nuclear Regulatory Commission, March 2007.

6. NSAC-108, "Reliability of Emergency Diesel Generators at U.S. Nuclear Power Plants," Electric Power Research Institute, September 1986.

7. NUMARC 87-00, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," Rev. 1, Nuclear Energy Institute, August 1991.

8. SECY-90-016, "Evolutionary Light Water Reactor (LWR) Certification Issues and Their Relationship to Current Regulatory Requirements, " U.S. Nuclear Regulatory Commission, January 12, 1990.

Table 8.4.1-1 (1 of 5)

Conformance with NRC RG 1.155 Regulatory Position C.3.3

Regulatory Position of NRC RG 1.155	Conformance or Justification
If the plant's station blackout capability, as determined according to the guidance in Regulatory Position 3.2, is significantly less than the minimum acceptable plant-specific station blackout duration (as developed according to Regulatory Position 3.1 or as justified by the licensee or applicant on some other basis and accepted by the staff), modifications to the plant may be necessary to extend the time the plant is able to cope with a station blackout. If modifications are needed, the following items should be considered:	APR1400 design conformance to each regulatory position is described below.
3.3.1 If, after considering load shedding to extend the time until battery depletion, battery capacity must be extended further to meet the station blackout duration recommended in Regulatory Position 3.1, it is considered acceptable either to add batteries or to add a charging system for the existing batteries that is independent of both the offsite and the blacked-out unit's onsite emergency ac power systems, such as a dedicated diesel generator.	The battery duty cycles of the APR1400 are 8 hours for Train A and Train B, and 16 hours for Train C and Train D. In the event of an SBO, since the AAC GTG will energize the shutdown bus (Train A or B) within 10 minutes of the onset of SBO, and the shutdown bus provides power for the DC loads necessary for the SBO coping duration via the battery charger and distribution bus, no additional DC equipment is required.
3.3.2. If the capacity of the condensate storage tank is not sufficient to remove decay heat for the station blackout duration recommended in Regulatory Position 3.1, a system meeting the requirements of Regulatory Position 3.5 to resupply the tank from an alternative water source is an acceptable means to increase its capacity provided any power source necessary to provide additional water is independent of both the offsite and the blacked-out unit's onsite emergency ac power systems.	The APR1400 design utilizes two (one per division) auxiliary feedwater (AFW) storage tanks for decay heat removal instead of a condensate storage tank. During an SBO, the auxiliary feedwater system (AFWS) provides decay heat removal by supplying makeup water to the steam generator through operation of a turbine driven AFW pump or a motor driven AFW pump. The motor driven AFW pumps can be powered from the AAC-GTG and made available within 10 minutes from the onset of an SBO. As stated in Subsection 10.4.9, each AFW storage tank provides the required water volume to provide sufficient flow to the steam generator(s) and has 100% capacity water volume to achieve a safe cold shutdown. Thus, no additional make-up water source to the AFW storage tanks is required.

Table 8.4.1-1 (2 of 5)

Regulatory Position of NRC RG 1.155	Conformance or Justification
3.3.3. If the compressed air capacity is not sufficient to remove decay heat and to maintain appropriate containment integrity for the station blackout duration recommended in Regulatory Position 3.1, a system to provide sufficient capacity from an alternative source that meets Regulatory Position 3.5 is an acceptable means to increase the air capacity provided any power source necessary to provide additional air is independent of both the offsite and the blacked-out unit's onsite emergency ac power systems.	A loss of compressed air during an SBO causes all pneumatically operated safety-related valves and control dampers served by the instrument air system to fail to the safe position. No alternative sources of compressed air are necessary to support an SBO condition for the APR1400. Therefore, unavailability of compressed air does not affect the capability to remove decay heat or to maintain containment integrity. Related descriptions are mentioned in Subsection 9.3.1.3.
3.3.4. If a system is required for primary coolant charging and makeup, reactor coolant pump seal cooling or injection, decay heat removal, or maintaining appropriate containment integrity specifically to meet the station blackout duration recommended in Regulatory Position 3.1, the following criteria should be met: 1. The system should be capable of being actuated and controlled from the control room, or if other means of control are required, it should be demonstrated that these steps can be carried out in a timely fashion, and 2. If the system must operate within 10 minutes of a loss of all ac power, it should be capable of being actuated from the control room.	The MCR and RSR contain all of the control and/or monitoring provision for the operator to manually actuate the components of the systems necessary to cope with an SBO condition.
3.3.5. If an AAC power source is selected specifically for satisfying the requirements for station blackout, the design should meet the following criteria: 1. The AAC power source should not normally be directly connected to the preferred or the blacked-out unit's onsite emergency ac power system.	The APR1400 design is compliant with the requirement. The design considerations of AAC power source and its periodic testing are described in Subsections 8.4.1.3, and 8.4.1.6.

Table 8.4.1-1 (3 of 5)

Regulatory Position of NRC RG 1.155	Conformance or Justification
2. There should be a minimum potential for common -cause failure with the preferred or the blacked-out unit's onsite emergency ac power sources. No single-point vulnerability should exist whereby a weather-related event or single active failure could disable any portion of the blacked-out unit's onsite emergency ac power sources or the preferred power sources and simultaneously fail the AAC power source. 3. The AAC power source should be available in a timely manner after the onset of station blackout and have provisions to be manually connected to one or all of the redundant safety buses as required. The time required for making this equipment available should not be more than 1 hour as demonstrated by test. If the AAC power source can be demonstrated by test to be available to power the shutdown buses within 10 minutes of the onset of station blackout, no coping analysis is required. 4. The AAC power source should have sufficient capacity to operate the systems necessary for coping with a station blackout for the time required to bring and maintain the plant in safe shutdown. 5. The AAC power system should be inspected, maintained, and tested periodically to demonstrate operability and reliability. The reliability of the AAC power system should meet or exceed 95 percent as determined in accordance with NSAC-108 (Ref. 11) or equivalent methodology. An AAC power source serving a multiple-unit site where onsite emergency ac sources are not shared between units should have, as a minimum, the capacity and capability for coping with station blackout in any of the units.	

Table 8.4.1-1 (4 of 5)

Regulatory Position of NRC RG 1.155	Conformance or Justification
At sites where onsite emergency sources are shared between units, the AAC power sources should have the capacity and capability to ensure that all units can be brought to and maintained in safe shutdown (i.e., those plant conditions defined in plant technical specifications as Hot Standby or Hot Shutdown, as appropriate). Plants have the option of maintaining the RCS at normal operating temperatures or at reduced temperatures. Plants that have more than the required redundancy of emergency ac sources for loss-of-offsite-power conditions, on a per nuclear unit basis, may use one of the existing emergency sources as an AAC power source provided it meets the applicable criteria for an AAC source. Additionally, emergency diesel generators with 1-out-of-2-shared and 2-out-of-3-shared ac power configurations may not be used as AAC power sources.	
3.3.6. If a system or component is added specifically to meet the recommendations on station blackout duration in Regulatory Position 3.1, system walk downs and initial tests of new or modified, systems or critical components should be performed to verify that the modifications were performed properly. Failures of added components that may be vulnerable to internal or external hazards within the design basis (e.g., seismic events) should not affect the operation of systems required for the design basis accident.	The APR1400 design includes the AAC GTG as the AAC power source for SBO mitigation. A test program will be conducted by the manufacturer / equipment vendor to verify the major equipment performance objectives (e.g., start time, rated speed and voltage times, stable voltage outputs, etc.). These tests will be conducted prior to the AAC GTG installation at the plant site. Prior to plant operation, the AAC power source and support components will be subject to pre-operational testing to demonstrate that the AAC GTG will perform its intended function.

Table 8.4.1-1 (5 of 5)

Regulatory Position of NRC RG 1.155	Conformance or Justification
	Failure of the AAC power source or associated components due to operational events (internal or external hazards) will not affect the operation of safety-related systems required for the design basis accidents. The AAC GTG is located in an independent building from the power block that contains the plant safety systems. The effects caused by failure of the AAC power source due to operational events are limited since the AAC power source is physically, mechanically and electrically isolated from the design basis engineered safety features in the power block. The independence of the AAC power source from the PPS and Class 1E power sources is realized by physical separation of the AAC power source, electrical isolation of power and control circuits, and control and protection scheme for the AAC power source. These measures for independence of the AAC power source ensures that the AAC power source and failures of the AAC power source components do not adversely affect the function of PPS and the Class 1E onsite power systems. Further discussion on the independence and separation of the AAC GTG components from system required for DBAs is provided in Subsection 8.4.1.3.
3.3.7. A system or component added specifically to meet the recommendations on station blackout duration in Regulatory Position 3.1 should be inspected, maintained, and tested periodically to demonstrate equipment operability and reliability.	This regulatory position is covered by Criterion 5 of Regulatory Position 3.3.5, which pertains to the AAC power source. The AAC GTG will be subject to periodic testing and inspection in order to verify the operability and reliability goals in the plant reliability assurance program as mentioned in Subsection 8.4.1.6. Periodic maintenance of the AAC GTG and its support systems will be planned and implemented under the framework of the Maintenance Rule program.

Table 8.4.2-1 (1 of 2)

Conformance to NRC RG 1.155 Appendix B, Alternate AC Sources

NRC RG 1.155, Appendix B, Alternate AC Sources		Conformance or Justification
Safety-Related Equipment (Compliance with IEEE Std. 279)	Not required, but the existing Class 1E electrical systems must continue to meet all applicable safety-related criteria.	The AAC is non-safety-related, but the existing onsite emergency power sources, buses and loads will continue to meet all applicable safety-related criteria since the AAC source is independent of the Class 1E electrical systems as noted in Table 1 Items E, G, I, and K.
Diversity from Existing EDGs	See Regulatory Position 3.3.5 of this guide.	The APR1400 design will utilize an AAC power source that is diverse from that of the EDGs. A qualified gas turbine generator will be used as the AAC source.
Independence from Existing Safety-Related Systems	Required if connected to Class 1E buses. Separation to be provided by 2 circuit breakers in series (1 Class 1 E at the Class 1E bus and 1 non-Class 1E).	The two breakers in series, which are nor+mally open, are provided between the Class 1E SWGR buses and AAC SWGR bus (one Class 1E at the Class 1E buses and anther non-Class 1E at the AAC SWGR bus).
Environmental Consideration	If normal cooling is lost, needed for station blackout event only and not for design basis accident (DBA) conditions. Procedures should be in place to effect the actions necessary to maintain acceptable environmental conditions for the required equipment. See Regulatory Position 3.2.4.	Equipment and environment cooling loss will be limited to 10 minutes (SBO duration). Normal plant cooling loads will be restored after shutdown loads are reestablished. Temperature rise conditions will be on the order of minutes rather than hours and no additional equipment or measures are necessary to supply interim cooling. Therefore, associated procedures are also not required.
Capacity	Specified in § 50.63 and Regulatory Position 3.3.5.	The AAC GTG has the sufficient capacity to supply required shutdown loads to bring and maintain the plant in a safe shutdown condition.
Quality Assurance	Indicated in Regulatory Position 3.5.	The AAC GTG follows the quality requirements in accordance with regulatory position 3.5 and Appendix A in NRC RG 1.155.

Table 8.4.2-1 (2 of 2)

NRC RG 1.155, Appendix B, Alternate AC Sources		Conformance or Justification
Technical Specification for Maintenance, Limiting Condition, FSAR, etc.	Should be consistent with the Interim Commission Policy Statement on Technical Specifications (Federal Register Notice 52 FR 3789) as applicable.	The AAC GTG and its support systems conform to the maintenance rule (MR) requirements in 10 CFR 50.65. The Interim Commission Policy Statement on Technical Specifications will be considered as applicable.
Instrumentation and Monitoring	Must meet system functional requirements.	The AAC power source instrumentation, controls and monitoring will be of sufficient number, type and quality to assure that the AAC GTG reliability goals are met.
Common Cause Failure (CCF)	Design should, to the extent practicable, minimize CCF between safety-related and non-safety-related systems.	The AAC power source will be physically, mechanically and electrically independent of the offsite and onsite power systems to the extent practicable in order to minimize CCF between safety-related and non-safety-related systems.

Table 8.4.2-2 (1 of 3)

Conformance to NUREG-0800, Section 8.4.III.3 Criteria D to I and K to M

NUREG-0800, Section 8.4.III.3 Criteria	Conformance or Justification
D. Plant staff in the control room monitor the performance of the AAC power source. As a minimum, monitoring should include the voltage, current, frequency, and circuit breaker position.	The performance monitoring parameters of the AAC power source from the control room consist of the voltage, current, frequency, VARs, watts, watt-hour, and power factor. Also, the status of the circuit breaker position is monitored from the main control room and remote shutdown room.
E. The AAC source components are enclosed within structures that conform to the Uniform Building Code. Electrical cables connecting the AAC power source to the shutdown buses are protected against the events that affect the preferred ac power system. Buried cables or other appropriate methods can be used to accomplish this.	The structure of AAC GTG building, in which the AAC source components are located, will be designed to conform to the Uniform Building Code. The AAC power source components are located in the AAC GTG building and the Class 1E (shutdown buses) are located in the auxiliary building. The non-Class 1E AAC power source SWGR (3N) has connection provisions each to the Class 1E SWGRs 1A and 1B. The connections between the AAC power source and Class 1E SWGR 1A and 1B are made by cables, which run through an underground common tunnel (UCT) installed between the AAC GTG building and the auxiliary building. The connections, between the AAC power source and each Class 1E SWGR 1A and 1B, are appropriately separated from the cables connecting the Class 1E SWGR 1A and 1B to the preferred ac power system (PPS) as practicable such that impact on the connections of the AAC power source is minimized for the events that affect the PPS.
F. Non safety-related AAC power source(s) and associated dedicated dc system(s) should meet the QA guidance in Section 3.5, Appendix A, and Appendix B to NRC RG 1.155.	The AAC GTG follows the quality requirements in accordance with regulatory position 3.5 and Appendix A in NRC RG 1.155. Compliance with Appendix B to NRC RG 1.155 is provided as following Table "Conformance to NRC RG 1.155, Appendix B, Alternate AC Sources."

Table 8.4.2-2 (2 of 3)

NUREG-0800, Section 8.4.III.3 Criteria	Conformance or Justification
G. The AAC power system is equipped with a dedicated dc power system that is electrically independent from the blacked-out unit's preferred and Class 1E power systems and is of sufficient capability and capacity for operation of dc loads associated with the AAC source for the maximum necessary duration of AAC source operation.	A dedicated non-Class 1E 125 Vdc power system is provided in the AAC GTG building to supply the dc power necessary to start and operate the AAC GTG. The system consists of a battery, battery chargers, a dc control center, and distribution panels. The battery is sized based on the worst-case duty cycle of dc loads for the AAC system. The sizing of the battery is performed in accordance with IEEE Std. 485. The battery capacity for AAC system is 500 AH.
I. The AAC power system is provided with a fuel supply that is separate from the fuel supply for the onsite EAC power system. A separate day tank, supplied from a common storage tank, is acceptable if the fuel is sampled and analyzed using methods consistent with applicable standards before its transfer to the day tank.	The AAC GTG has a diesel fuel oil storage tank and a day tank separate from the onsite EDG system. Related descriptions are described in DCD, Tier 2 Subsection 9.5.9.2
K. The AAC power system is capable of operating during and after an SBO without any support system receiving power from the preferred power supply or the blacked-out unit's EAC power sources. The capability of the AAC to start on demand depends on the availability of the necessary support systems to fulfill their required function. These support systems may need varying combinations of dc or ac power for varying periods to maintain operational readiness. Information Notice (IN) 97-21 (Ref. 17) discusses two examples of a failure of the AAC to start on demand because of an extended loss of auxiliary electrical power sources.	The AAC GTG will be manually started to supply the electric power of Class 1E SWGR bus without receiving any externally provided AC or DC power source. DC power necessary for establishing the electric field excitation of generator and for control and protection of AAC power system is supplied from the dedicated battery set for the AAC power system.

Table 8.4.2-2 (3 of 3)

NUREG-0800, Section 8.4.III.3 Criteria	Conformance or Justification
L. The portions of the AAC power system subjected to maintenance activities are/will be tested before returning the AAC power system to service.	As specified in NUMARC 87-00 Appendix B, the AAC power source is started and brought to operating conditions that are consistent with its function as an AAC power source at least every 3 months. The AAC GTG is started once every refueling outage to verify its availability within 10 minutes and the rated load capacity test is performed. In addition, the portions of the AAC GTG and its support systems subjected to maintenance activities will be tested before returning the AAC GTG and its support systems to service.
M. Plant-specific technical guidelines and emergency operating procedures will be implemented (or are in place, as applicable) that identify those actions necessary for placing the AAC power source in service.	All operator actions necessary for SBO coping including placing the AAC power source in service will be identified in the emergency operating procedures (EOPs) and associated technical guidelines. The COL applicant is to provide a program for developing the EOPs as specified in COL 13.5(5).