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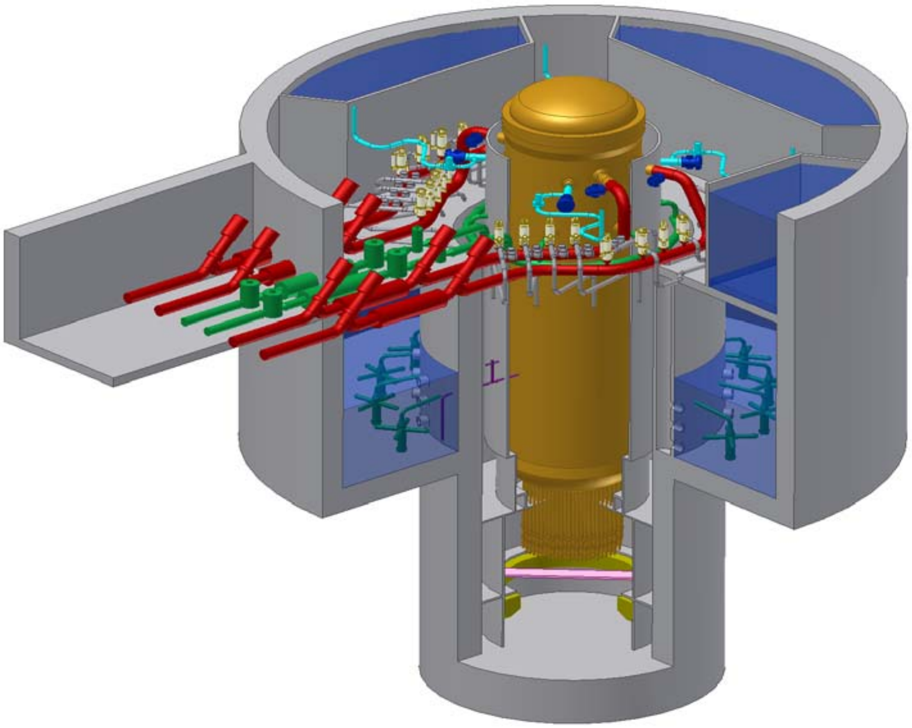


ESBWR Design Control Document
Tier 2
Chapter 8
Electric Power

(Conditional Release - pending closure of design verifications)

Contents

List of Tables

List of Illustrations

Global Abbreviations And Acronyms List

Term	Definition
10 CFR	Title 10, Code of Federal Regulations
A/D	Analog-to-Digital
AASHTO	American Association of Highway and Transportation Officials
AB	Auxiliary Boiler
ABS	Auxiliary Boiler System
ABWR	Advanced Boiling Water Reactor
ac / AC	Alternating Current
AC	Air Conditioning
ACF	Automatic Control Function
ACI	American Concrete Institute
ACS	Atmospheric Control System
AD	Administration Building
ADS	Automatic Depressurization System
AEC	Atomic Energy Commission
AFIP	Automated Fixed In-Core Probe
AGMA	American Gear Manufacturer's Association
AHS	Auxiliary Heat Sink
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AL	Analytical Limit
ALARA	As Low As Reasonably Achievable
ALWR	Advanced Light Water Reactor
ANS	American Nuclear Society
ANSI	American National Standards Institute
AOO	Anticipated Operational Occurrence
AOV	Air Operated Valve
API	American Petroleum Institute
APRM	Average Power Range Monitor
APR	Automatic Power Regulator
APRS	Automatic Power Regulator System
ARI	Alternate Rod Insertion
ARMS	Area Radiation Monitoring System
ASA	American Standards Association
ASD	Adjustable Speed Drive
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
AST	Alternate Source Term
ASTM	American Society of Testing Methods

Global Abbreviations And Acronyms List

Term	Definition
AT	Unit Auxiliary Transformer
ATLM	Automated Thermal Limit Monitor
ATWS	Anticipated Transients Without Scram
AV	Allowable Value
AWS	American Welding Society
AWWA	American Water Works Association
B&PV	Boiler and Pressure Vessel
BAF	Bottom of Active Fuel
BHP	Brake Horse Power
BOP	Balance of Plant
BPU	Bypass Unit
BPWS	Banked Position Withdrawal Sequence
BRE	Battery Room Exhaust
BRL	Background Radiation Level
BTP	NRC Branch Technical Position
BTU	British Thermal Unit
BWR	Boiling Water Reactor
BWROG	Boiling Water Reactor Owners Group
CAV	Cumulative absolute velocity
C&FS	Condensate and Feedwater System
C&I	Control and Instrumentation
C/C	Cooling and Cleanup
CB	Control Building
CBGAHVS	Control Building General Area
CBHVAC	Control Building HVAC
CBHVS	Control Building Heating, Ventilation and Air Conditioning System
CCI	Core-Concrete Interaction
CDF	Core Damage Frequency
CFR	Code of Federal Regulations
CIRC	Circulating Water System
CIS	Containment Inerting System
CIV	Combined Intermediate Valve
CLAVS	Clean Area Ventilation Subsystem of Reactor Building HVAC
CM	Cold Machine Shop
CMS	Containment Monitoring System
CMU	Control Room Multiplexing Unit
COL	Combined Operating License
COLR	Core Operating Limits Report
CONAVS	Controlled Area Ventilation Subsystem of Reactor Building HVAC

Global Abbreviations And Acronyms List

Term	Definition
CPR	Critical Power Ratio
CPS	Condensate Purification System
CPU	Central Processing Unit
CR	Control Rod
CRD	Control Rod Drive
CRDA	Control Rod Drop Accident
CRDH	Control Rod Drive Housing
CRDHS	Control Rod Drive Hydraulic System
CRGT	Control Rod Guide Tube
CRHA	Control Room Habitability Area
CRHAHVS	Control Room Habitability Area HVAC Sub-system
CRT	Cathode Ray Tube
CS&TS	Condensate Storage and Transfer System
CSDM	Cold Shutdown Margin
CS / CST	Condensate Storage Tank
CT	Main Cooling Tower
CTVCF	Constant Voltage Constant Frequency
CUF	Cumulative usage factor
CWS	Chilled Water System
D-RAP	Design Reliability Assurance Program
DAC	Design Acceptance Criteria
DAW	Dry Active Waste
DBA	Design Basis Accident
dc / DC	Direct Current
DCS	Drywell Cooling System
DCIS	Distributed Control and Information System
DEPSS	Drywell Equipment and Pipe Support Structure
DF	Decontamination Factor
D/F	Diaphragm Floor
DG	Diesel-Generator
DHR	Decay Heat Removal
DM&C	Digital Measurement and Control
DOF	Degree of freedom
DOI	Dedicated Operators Interface
DOT	Department of Transportation
dPT	Differential Pressure Transmitter
DPS	Diverse Protection System
DPV	Depressurization Valve
DR&T	Design Review and Testing

Global Abbreviations And Acronyms List

Term	Definition
DS	Independent Spent Fuel Storage Installation
DTM	Digital Trip Module
DW	Drywell
EB	Electrical Building
EBAS	Emergency Breathing Air System
EBHV	Electrical Building HVAC
ECCS	Emergency Core Cooling System
E-DCIS	Essential DCIS (Distributed Control and Information System)
EDO	Environmental Qualification Document
EFDS	Equipment and Floor Drainage System
EFPY	Effective full power years
EFU	Emergency Filter Unit
EHC	Electrohydraulic Control (Pressure Regulator)
ENS	Emergency Notification System
EOC	Emergency Operations Center
EOC	End of Cycle
EOF	Emergency Operations Facility
EOP	Emergency Operating Procedures
EPDS	Electric Power Distribution System
EPG	Emergency Procedure Guidelines
EPRI	Electric Power Research Institute
EQ	Environmental Qualification
ERICP	Emergency Rod Insertion Control Panel
ERIP	Emergency Rod Insertion Panel
ESF	Engineered Safety Feature
ETS	Emergency Trip System
FAC	Flow-Accelerated Corrosion
FAPCS	Fuel and Auxiliary Pools Cooling System
FATT	Fracture Appearance Transition Temperature
FB	Fuel Building
FBHV	Fuel Building HVAC
FCI	Fuel-Coolant Interaction
FCM	File Control Module
FCS	Flammability Control System
FCU	Fan Cooling Unit
FDDI	Fiber Distributed Data Interface
FFT	Fast Fourier Transform
FFWTR	Final Feedwater Temperature Reduction
FHA	Fire Hazards Analysis

Global Abbreviations And Acronyms List

Term	Definition
FIV	Flow-Induced Vibration
FMCRD	Fine Motion Control Rod Drive
FMEA	Failure Modes and Effects Analysis
FPS	Fire Protection System
FO	Diesel Fuel Oil Storage Tank
FOAKE	First-of-a-Kind Engineering
FPE	Fire Pump Enclosure
FTDC	Fault-Tolerant Digital Controller
FTS	Fuel Transfer System
FW	Feedwater
FWCS	Feedwater Control System
FWS	Fire Water Storage Tank
GCS	Generator Cooling System
GDC	General Design Criteria
GDCS	Gravity-Driven Cooling System
GE	General Electric Company
GE-NE	GE Nuclear Energy
GEN	Main Generator System
GETAB	General Electric Thermal Analysis Basis
G/F	NOT DEFINED
GL	Generic Letter
GM	Geiger-Mueller Counter
GM-B	Beta-Sensitive GM Detector
GSIC	Gamma-Sensitive Ion Chamber
GSOS	Generator Sealing Oil System
GWSR	Ganged Withdrawal Sequence Restriction
HAZ	Heat-Affected Zone
HCU	Hydraulic Control Unit
HCW	High Conductivity Waste
HDVS	Heater Drain and Vent System
HEI	Heat Exchange Institute
HELB	High Energy Line Break
HEP	Human error probability
HEPA	High Efficiency Particulate Air/Absolute
HFE	Human Factors Engineering
HFF	Hollow Fiber Filter
HGCS	Hydrogen Gas Cooling System
HIC	High Integrity Container
HID	High Intensity Discharge

Global Abbreviations And Acronyms List

Term	Definition
HIS	Hydraulic Institute Standards
HM	Hot Machine Shop & Storage
HP	High Pressure
HPNSS	High Pressure Nitrogen Supply System
HPT	High-pressure turbine
HRA	Human Reliability Assessment
HSI	Human-System Interface
HSSS	Hardware/Software System Specification
HVAC	Heating, Ventilation and Air Conditioning
HVS	High Velocity Separator
HWC	Hydrogen Water Chemistry
HWCS	Hydrogen Water Chemistry System
HWS	Hot Water System
HX	Heat Exchanger
I&C	Instrumentation and Control
I/O	Input/Output
IAS	Instrument Air System
IASCC	Irradiation Assisted Stress Corrosion Cracking
IBC	International Building Code
IC	Ion Chamber
IC	Isolation Condenser
ICD	Interface Control Diagram
ICS	Isolation Condenser System
IE	Inspection and Enforcement
IEB	Inspection and Enforcement Bulletin
IED	Instrument and Electrical Diagram
IEEE	Institute of Electrical and Electronic Engineers
IFTS	Inclined Fuel Transfer System
IGSCC	Intergranular Stress Corrosion Cracking
IIS	Iron Injection System
ILRT	Integrated Leak Rate Test
IOP	Integrated Operating Procedure
IMC	Induction Motor Controller
IMCC	Induction Motor Controller Cabinet
IRM	Intermediate Range Monitor
ISA	Instrument Society of America
ISI	In-Service Inspection
ISLT	In-Service Leak Test
ISM	Independent Support Motion

Global Abbreviations And Acronyms List

Term	Definition
ISMA	Independent Support Motion Response Spectrum Analysis
ISO	International Standards Organization
ITA	Inspections, Tests or Analyses
ITAAC	Inspections, Tests, Analyses and Acceptance Criteria
ITA	Initial Test Program
LAPP	Loss of Alternate Preferred Power
LCO	Limiting Conditions for Operation
LCW	Low Conductivity Waste
LD	Logic Diagram
LDA	Lay down Area
LD&IS	Leak Detection and Isolation System
LERF	Large early release frequency
LFCV	Low Flow Control Valve
LHGR	Linear Heat Generation Rate
LLRT	Local Leak Rate Test
LMU	Local Multiplexer Unit
LO	Dirty/Clean Lube Oil Storage Tank
LOCA	Loss-of-Coolant-Accident
LOFW	Loss-of-feedwater
LOOP	Loss of Offsite Power
LOPP	Loss of Preferred Power
LP	Low Pressure
LPCI	Low Pressure Coolant Injection
LPCRD	Locking Piston Control Rod Drive
LPMS	Loose Parts Monitoring System
LPRM	Local Power Range Monitor
LPSP	Low Power Setpoint
LWMS	Liquid Waste Management System
MAAP	Modular Accident Analysis Program
MAPLHGR	Maximum Average Planar Linear Head Generation Rate
MAPRAT	Maximum Average Planar Ratio
MBB	Motor Built-In Brake
MCC	Motor Control Center
MCES	Main Condenser Evacuation System
MCPR	Minimum Critical Power Ratio
MCR	Main Control Room
MCRP	Main Control Room Panel
MELB	Moderate Energy Line Break
MSS	NOT DEFINED

Global Abbreviations And Acronyms List

Term	Definition
MLHGR	Maximum Linear Heat Generation Rate
MMI	Man-Machine Interface
MMIS	Man-Machine Interface Systems
MOV	Motor-Operated Valve
MPC	Maximum Permissible Concentration
MPL	Master Parts List
MS	Main Steam
MSIV	Main Steam Isolation Valve
MSL	Main Steamline
MSLB	Main Steamline Break
MSLBA	Main Steamline Break Accident
MSR	Moisture Separator Reheater
MST	NOT DEFINED
MSV	Mean Square Voltage
MT	Main Transformer
MTTR	Mean Time To Repair
MWS	Makeup Water System
NBR	Nuclear Boiler Rated
NBS	Nuclear Boiler System
NCIG	Nuclear Construction Issues Group
NDE	Nondestructive Examination
NE-DCIS	Non-Essential Distributed Control and Information System
NDRC	National Defense Research Committee
NDT	Nil Ductility Temperature
NFPA	National Fire Protection Association
NIST	National Institute of Standard Technology
NICWS	Nuclear Island Chilled Water Subsystem
NMS	Neutron Monitoring System
NOV	Nitrogen Operated Valve
NPHS	Normal Power Heat Sink
NPSH	Net Positive Suction Head
NRC	Nuclear Regulatory Commission
NRHX	Non-Regenerative Heat Exchanger
NS	Non-seismic (non-seismic Category I)
NSSS	Nuclear Steam Supply System
NT	Nitrogen Storage Tank
NTSP	Nominal Trip Setpoint
O&M	Operation and Maintenance
O-RAP	Operational Reliability Assurance Program

Global Abbreviations And Acronyms List

Term	Definition
OBCV	Overboard Control Valve
OBE	Operating Basis Earthquake
OGS	Offgas System
OHLHS	Overhead Heavy Load Handling System
OIS	Oxygen Injection System
OLMCPR	Operating Limit Minimum Critical Power Ratio
OLU	Output Logic Unit
OOS	Out-of-service
ORNL	Oak Ridge National Laboratory
OSC	Operational Support Center
OSHA	Occupational Safety and Health Administration
OSI	Open Systems Interconnect
P&ID	Piping and Instrumentation Diagram
PA/PL	Page/Party-Line
PABX	Private Automatic Branch (Telephone) Exchange
PAM	Post Accident Monitoring
PAR	Passive Autocatalytic Recombiner
PAS	Plant Automation System
PASS	Post Accident Sampling Subsystem of Containment Monitoring System
PCC	Passive Containment Cooling
PCCS	Passive Containment Cooling System
PCT	Peak cladding temperature
PCV	Primary Containment Vessel
PFD	Process Flow Diagram
PGA	Peak Ground Acceleration
PGCS	Power Generation and Control Subsystem of Plant Automation System
PH	Pump House
PL	Parking Lot
PM	Preventive Maintenance
PMCS	Performance Monitoring and Control Subsystem of NE-DCIS
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PQCL	Product Quality Check List
PRA	Probabilistic Risk Assessment
PRMS	Process Radiation Monitoring System
PRNM	Power Range Neutron Monitoring
PS	Plant Stack
PSD	Power Spectra Density
PSS	Process Sampling System

Global Abbreviations And Acronyms List

Term	**Definition**
PSWS	Plant Service Water System
PT	Pressure Transmitter
PWR	Pressurized Water Reactor
QA	Quality Assurance
RACS	Rod Action Control Subsystem
RAM	Reliability, Availability and Maintainability
RAPI	Rod Action and Position Information
RAT	Reserve Auxiliary Transformer
RB	Reactor Building
RBC	Rod Brake Controller
RBCC	Rod Brake Controller Cabinet
RBCWS	Reactor Building Chilled Water Subsystem
RBHV	Reactor Building HVAC
RBS	Rod Block Setpoint
RBV	Reactor Building Vibration
RC&IS	Rod Control and Information System
RCC	Remote Communication Cabinet
RCCV	Reinforced Concrete Containment Vessel
RCCWS	Reactor Component Cooling Water System
RCPB	Reactor Coolant Pressure Boundary
RCS	Reactor Coolant System
RDA	Rod Drop Accident
RDC	Resolver-to-Digital Converter
REPAVS	Refueling and Pool Area Ventilation Subsystem of Fuel Building HVAC
RFP	Reactor Feed Pump
RG	Regulatory Guide
RHR	Residual heat removal (function)
RHX	Regenerative Heat Exchanger
RMS	Root Mean Square
RMS	Radiation Monitoring Subsystem
RMU	Remote Multiplexer Unit
RO	Reverse Osmosis
ROM	Read-only Memory
RPS	Reactor Protection System
RPV	Reactor Pressure Vessel
RRPS	Reference Rod Pull Sequence
RSM	Rod Server Module
RSPC	Rod Server Processing Channel
RSS	Remote Shutdown System

Global Abbreviations And Acronyms List

Term	Definition
RSSM	Reed Switch Sensor Module
RSW	Reactor Shield Wall
RTIF	Reactor Trip and Isolation Function(s)
RT_{NDT}	Reference Temperature of Nil-Ductility Transition
RTP	Reactor Thermal Power
RV	NOT DEFINED
RVC	NOT DEFINED
RW	Radwaste Building
RWBCR	Radwaste Building Control Room
RWBGA	Radwaste Building General Area
RWBHVAC	Radwaste Building HVAC
RWCU/SDC	Reactor Water Cleanup/Shutdown Cooling
RWE	Rod Withdrawal Error
RWM	Rod Worth Minimizer
SA	Severe Accident
SAR	Safety Analysis Report
SB	Service Building
S/C	Digital Gamma-Sensitive GM Detector
SC	Suppression Chamber
S/D	Scintillation Detector
S/DRSRO	Single/Dual Rod Sequence Restriction Override
S/N	Signal-to-Noise
S/P	Suppression Pool
SAS	Service Air System
SB&PC	Steam Bypass and Pressure Control System
SBO	Station Blackout
SBWR	Simplified Boiling Water Reactor
SCEW	System Component Evaluation Work
SCRRI	Selected Control Rod Run-in
SDC	Shutdown Cooling
SDM	Shutdown Margin
SDS	System Design Specification
SEOA	Sealed Emergency Operating Area
SER	Safety Evaluation Report
SF	Service Water Building
SFP	Spent fuel pool
SIL	Service Information Letter
SIT	Structural Integrity Test
SIU	Signal Interface Unit

Global Abbreviations And Acronyms List

Term	**Definition**
SJAE	Steam Jet Air Ejector
SLC	Standby Liquid Control
SLCS	Standby Liquid Control System
SLMCPR	Safety Limit Minimum Critical Power Ratio
SMU	SSLC Multiplexing Unit
SOV	Solenoid Operated Valve
SP	Setpoint
SPC	Suppression Pool Cooling
SPDS	Safety Parameter Display System
SPTMS	Suppression Pool Temperature Monitoring Subsystem of Containment Monitoring System
SR	Surveillance Requirement
SRM	Source Range Monitor
SRNM	Startup Range Neutron Monitor
SRO	Senior Reactor Operator
SRP	Standard Review Plan
SRS	Software Requirements Specification
SRSRO	Single Rod Sequence Restriction Override
SRSS	Sum of the squares
SRV	Safety Relief Valve
SRVDL	Safety relief valve discharge line
SSAR	Standard Safety Analysis Report
SSC(s)	Structure, System and Component(s)
SSE	Safe Shutdown Earthquake
SSLC	Safety System Logic and Control
SSPC	Steel Structures Painting Council
ST	Spare Transformer
STP	Sewage Treatment Plant
STRAP	Scram Time Recording and Analysis Panel
STRP	Scram Time Recording Panel
SV	Safety Valve
SWH	Static water head
SWMS	Solid Waste Management System
SY	Switch Yard
TAF	Top of Active Fuel
TASS	Turbine Auxiliary Steam System
TB	Turbine Building
TBCE	Turbine Building Compartment Exhaust
TEAS	Turbine Building Air Supply
TBE	Turbine Building Exhaust

Global Abbreviations And Acronyms List

Term	Definition
TBLOE	Turbine Building Lube Oil Area Exhaust
TBS	Turbine Bypass System
TBHV	Turbine Building HVAC
TBV	Turbine Bypass Valve
TC	Training Center
TCCWS	Turbine Component Cooling Water System
TCS	Turbine Control System
TCV	Turbine Control Valve
TDH	Total Developed Head
TEMA	Tubular Exchanger Manufacturers' Association
TFSP	Turbine first stage pressure
TG	Turbine Generator
TGSS	Turbine Gland Seal System
THA	Time-history accelerograph
TLOS	Turbine Lubricating Oil System
TLU	Trip Logic Unit
TMI	Three Mile Island
TMSS	Turbine Main Steam System
TRM	Technical Requirements Manual
TS	Technical Specification(s)
TSC	Technical Support Center
TSI	Turbine Supervisory Instrument
TSV	Turbine Stop Valve
UBC	Uniform Building Code
UDS	NOT DEFINED
UHS	Ultimate heat sink
UL	Underwriter's Laboratories Inc.
UPS	Uninterruptible Power Supply
USE	Upper Shelf Energy
USM	Uniform Support Motion
USMA	Uniform support motion response spectrum analysis
USNRC	United States Nuclear Regulatory Commission
USS	United States Standard
UV	Ultraviolet
V&V	Verification and Validation
Vac / VAC	Volts Alternating Current
Vdc / VDC	Volts Direct Current
VDU	Video Display Unit
VW	Vent Wall

Global Abbreviations And Acronyms List

Term	Definition
VWO	Valves Wide Open
WD	Wash Down Bays
WH	Warehouse
WS	Water Storage
WT	Water Treatment
WW	Wetwell
XMFR	Transformer
ZPA	Zero period acceleration

8. ELECTRIC POWER

8.1 INTRODUCTION

8.1.1 General

Description of the ESBWR Electric Power Distribution System provided herein applies to the "reference design".

Power is supplied to the plant from two independent off-site power sources. These power source connections are designed to provide reliable power sources for the plant auxiliary loads, such that any single active failure can affect only one power source and cannot propagate to the alternate power source.

The on-site AC power system consists of Class 1E and non-Class 1E power systems. The two off-site power systems provide the normal preferred and alternate preferred AC power to safety-related and nonsafety-related loads. In the event of total loss of off-site power sources, two or more on-site independent nonsafety-related standby diesel generators (or other reliable sources such as Combustion Turbine Generators) are provided to power the plant's investment protection (PIP) nonsafety-related loads (and safety-related loads through battery chargers). There are four independent Class 1E DC battery systems to provide power for the safety-related loads.

On-site Class 1E and non-Class 1E DC systems supply all the DC power requirements of the plant.

8.1.2 Utility Power Grid and Off-site Systems Description

8.1.2.1 Utility Power Grid Description

The utility power grid description is out of the ESBWR Standard Plant scope because it is site specific. However, there are combined operating license (COL) applicant/licensee items in Subsection 8.1.6.

8.1.2.2 Off-site Power System Description

The off-site power system consists of the set of electrical circuits and associated equipment that are used to interconnect the off-site transmission system with the plant main generator and the on-site electrical power distribution system, as indicated on the one-line diagram, Figure 8.1-1.

The system includes the plant switchyard, the high voltage tie lines, the unit auxiliary transformers, the reserve auxiliary transformers the generator breaker, the isolated phase bus, and the 13.8 kV and 6.9 kV bus ducts from the unit and reserve auxiliary transformers to the unit auxiliary and PIP switchgears.

The off-site power system begins at the terminals on the transmission system side of the circuit breakers that connect the switching stations to the off-site transmission systems. It ends at the connection at the input terminals of the13.8 kV and 6.9 kV switchgear main circuit breakers, which are supplied power from the unit and reserve auxiliary transformers, and at the terminals of the switchyard side of the generator circuit breaker.

Power is supplied to the plant from two electrically independent and physically separate off-site power sources as follows:

- "Normal Preferred" source through the unit auxiliary transformers; and
- "Alternate Preferred" source through the reserve auxiliary transformers.

During plant startup, normal or emergency shutdown, or during plant outages, the off-site power system serves to supply power from the off-site transmission system to the plant auxiliary and service loads.

During normal operation, the off-site power system is used to transmit generated power to the off-site transmission system and to the plant auxiliary and service loads.

The on-site power distribution system is powered continuously by the off-site power source throughout plant startup, normal operation, and normal or emergency shutdown. When the generator breaker is tripped, power to the plant continues to be fed from the off-site power source

A detailed description of the off-site power system is provided in subsection 8.2.1.

8.1.3 On-site Electric Power System

8.1.3.1 On-site AC Power System

The on-site AC power system includes the entire system on the load side of the connection at the input terminals of the 13.8 kV and 6.9 kV switchgear main circuit breakers, which are powered from the unit and reserve auxiliary transformers, as indicated on Figure 8.1-1.

The on-site power system is divided into two power load groups at the 13.8 k V and 6.9 kV level for operational flexibility of the plant nonsafety-related systems. Separate unit and reserve auxiliary transformers feed each of the power load groups. Each power load group supplies power to a three-tier power distribution system arrangement:

(1) The first tier supplies power to nonsafety-related loads required primarily for unit operation.

(2) The second tier supplies power to PIP (nonsafety-related loads), which, on account of their specific functions, are generally required to remain operational at all times or when the unit is shut down. The second tier also supplies power to the third tier.

(3) The third tier supplies power to safety-related loads.

Both load groups of the PIP system (second tier) have a standby power supply from separate on-site standby diesel generators, in addition to their normal preferred power supply through the unit auxiliary transformers, and their alternate preferred power supply from an independent off-site source through the reserve auxiliary transformers.

Each division of the safety-related power distribution system (third tier) is provided with physically separated and electrically independent batteries sized to supply emergency power to the safety-related systems in the event of loss of all other power sources.

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

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

The third tier distributes power at 60 Hz and voltage levels of 480V and 208/120V.

A detailed description of the on-site AC power system is provided in Subsection 8.3.1.

8.1.3.2 On-site DC Power System

The on-site DC power system includes the plant batteries and battery chargers and their DC loads, except for the DC/AC inverters and the inverter loads.

The non-Class 1E 125 VDC power system, Figure 8.1-2, provides power for nonsafety-related loads, communications, lighting and other DC loads. The Non-Class 1E 250V batteries are provided to supply DC power to the plant Non-Essential Distributed Control and Information System (NE-DCIS) and non-Class 1E DC motors. The non-Class 1E 125 VDC power and Non-Class 1E 250 VDC power are normally supplied through non-Class 1E battery chargers from the non-Class 1E PIP buses. In the event that this power supply is lost, power is supplied from the non-Class 1E batteries.

The Class 1E 250 VDC power distribution system, Figure 8.1-3, provides four independent and redundant on-site sources of power for operation of safety-related DC loads including the Essential Distributed Control and Information System (E-DCIS). The Class 1E 250 VDC power is normally supplied through the Class 1E battery chargers and Isolation Power Centers, and powered from the non-Class 1E PIP buses. In the event that this power supply is lost, DC power is supplied from the Class 1E batteries. The system is physically and electrically separated into Divisions 1, 2, 3 and 4.

A detailed description of the on-site DC power system is provided in Subsection 8.3.2.

8.1.4 Safety-Related Loads

The safety-related loads utilize various Class 1E AC and/or DC sources for instrumentation, motive or control power, or both, for systems required for safety. Combinations of power sources may be involved in performing a single safety function. The control and instrumentation systems required for safety are identified in Subsection 7.1.1.

8.1.5 Design Basis

8.1.5.1 Off-site Power

Portions of the off-site power system are the responsibility of the COL applicant as defined in Subsection 8.2.1.

Electric power from the utility grid to the off-site power system is provided by two physically separated transmission lines designed and located to minimize the likelihood of simultaneous failure. One of the transmission lines serves as the main off-site power circuit (Normal Preferred Power), and the other transmission line serves as the reserve off-site power circuit (Alternate Preferred Power).

The switchyard is designed such that the equipment associated with the two transmission lines is physically separated to minimize the likelihood of simultaneous failure.

Three single-phase main step-up transformers are provided with an additional installed single phase spare. The installation of the spare transformer permits its connection and energization within 12 hours.

A single tie line connecting the plant and the switchyard constitutes the plant's main power circuit.

A second off-site (reserve) power circuit is provided through the reserve auxiliary transformers. This power circuit is electrically independent and physically separated from the main power circuit to minimize the likelihood of simultaneous failure.

Two unit auxiliary transformers are provided to supply power to the plant's auxiliary distribution system. The transformers are equal in size, and each has the capacity required to supply power to their load group of safety-related and nonsafety-related systems under conditions of maximum expected concurrent loads, including all required design margins. Unit auxiliary transformers supply power to their load group from the main off-site power circuit.

Two installed reserve auxiliary transformers serve as backup to the unit auxiliary transformers. Reserve auxiliary transformers are provided to supply power to the plant’s auxiliary distribution system. The transformers are equal in size, and each has the capacity required to supply power to its load group of safety-related and nonsafety-related systems under conditions of maximum expected concurrent loads, including all required design margins. The reserve auxiliary transformers supply power to their load groups from the second off-site power circuit.

A main generator circuit breaker is provided, which is designed to withstand the maximum RMS and crest currents, and to interrupt the maximum asymmetrical and symmetrical currents determined to be produced by a three-phase bolted fault at its location.

The off-site power system is designed to provide a continuous source of power to the on-site power system throughout plant startup, normal operation, and shutdown.

8.1.5.2 On-site Power

8.1.5.2.1 General

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

Two dedicated buses, one per power load group, are provided to feed PIP loads. The dedicated buses have three power supplies:

(1) The normal preferred power supply is provided by a unit auxiliary transformer connected to the main generator and to the main off-site power circuit.

(2) The alternate preferred power supply is provided by a reserve auxiliary transformer connected to an independent off-site source.

(3) The standby power supply is provided by an independent nonsafety-related standby diesel generator (one per power load group) of sufficient capacity such that, in the event of a loss of preferred power, each can supply enough power to achieve cold shutdown.

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

Each division is fed by a separate Isolation 480V Power Center, which is powered from a PIP nonsafety-related power supply. The non-Class 1E system ends and the Class 1E system begins at the input terminals of the main circuit breaker of the Isolation Power Centers. The input power voltage and frequency is monitored and the input breaker tripped if either voltage or frequency is out of the specified limits for a predetermined time. The Class 1E AC distribution system ends at the terminals of the Class 1E loads. The powering of the Isolation Power Centers with a nonsafety-related power supply does not jeopardize safety, because power needed during an emergency can be supplied by the safety-related batteries. The Isolation Power Centers are provided with electrical protection and isolation devices, which prevent degradation of the Class 1E power system by the non-Class 1E power system.

The redundant Class 1E electrical divisions (Divisions 1, 2, 3 and 4) are provided with separate on-site DC power supplies, electric buses, distribution cables, controls, relays and other electrical devices. Redundant divisions are physically separate and electrically independent so that in a design basis event with loss of any division's equipment resulting from a single active failure, safe plant shutdown for allowable operating modes can be accomplished with two divisions of DC power.

Separation criteria are established for preserving the independence of redundant Class 1E systems and providing isolation between Class 1E and non-Class 1E equipment.

Raceways are not shared by Class 1E and non-Class 1E cables, or Class 1E cables of a different division. Separate raceways are provided exclusively for each channel group of the Reactor Protection System solenoid wiring.

Special identification criteria, as discussed in Subsection 8.3.1.3, are applied to Class 1E equipment, cabling and raceways.

The Class 1E 480V and 120 VAC, and 250 VDC power and control systems conform to Seismic Category I requirements and are housed in Seismic Category I structures. Seismic Qualification is in accordance with IEEE Standard 344 (Section 3.10).

Class 1E equipment and systems have been designed with the capability for periodic testing.

8.1.5.2.2 Uninterruptible AC Power Supply

The Uninterruptible AC Power Supply (UPS) is divided into two subsystems, the Class 1E UPS and the Non-Class 1E UPS.

8.1.5.2.2.1 Class 1E Uninterruptible AC Power Supply

The Class 1E AC uninterruptible power supply provides redundant, reliable power of acceptable quality and availability to feed the safety-related motor operated valves and other 480 VAC safety-related loads. The Class 1E UPS support the safety-related logic and control functions during normal, upset, and accident conditions.

Each division of the Class 1E AC uninterruptible power supply system is powered through separate and independent Class 1E inverters connected to the Class 1E DC bus of the same division and from its own 480 VAC Isolation Power Center (Figure 8.1-4). Each DC bus is backed by separate Class 1E batteries.

Upon loss of AC power supply, the Class 1E UPS is powered by its respective division's Class 1E battery, switching from the AC to DC source is transparent to UPS loads. Provision is made for automatic switching to the alternate bypass supply from its division in case of a failure of the inverter power supply. The inverter normal AC power supply is synchronized in both frequency and phase with the alternate AC bypass supply, so that unacceptable voltage spikes are avoided in case of an automatic transfer from normal to alternate supply. The Class 1E uninterruptible AC power supply system complies with IEEE Standard 944 (Reference 8.1-1).

8.1.5.2.2.2 Non–Class 1E Uninterruptible AC Power Supply

Each load group of the Non-Class 1E Uninterruptible AC Power Supply is powered through separate and independent Non-Class 1E inverters connected to the Non-Class 1E DC bus and from their 480VAC Power Center (Figure 8.1-5). Each DC bus is backed by separate Non-Class 1E batteries.

Upon loss of AC power supply, the non-Class 1E UPS is powered by its respective non-Class 1E battery, switching from the AC to DC source is transparent to UPS loads. Provision is made for automatic switching to the alternate bypass supply from a 480VAC Power Center of a different load group, in case of a failure of the inverter power supply. The inverter normal AC power supply is synchronized in both frequency and phase with the alternate AC bypass supply, so that unacceptable voltage spikes are avoided in case of an automatic transfer from normal to alternate supply. The 480VAC Power centers that provide the normal and alternate AC sources are backed by the on-site standby diesel generators.

The Non-Class 1E uninterruptible power supply complies with IEEE Standard 944 (Reference 8.1-1).

8.1.5.2.3 I&C Power Supply System

The I&C Power Supply System consists of regulating stepdown transformers providing 208/120 VAC power to those loads not requiring uninterruptible power, and to those loads requiring an alternate, clean power source. The I & C Power Supply System buses are shown in Figure 8.1-6.

Each of the Isolation Power Center powers a separate, independent I&C bus for providing an alternate power source to certain (E-DCIS) equipment.

The non-Class 1E equipment (NE-DCIS) requiring I&C power is supplied by the non-Class 1E swing bus power center through regulating transformers.

8.1.5.2.4 Regulatory Requirements

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

General Design Criteria:

- GDC 2, "Design Bases for Protection against Natural Phenomena"
- GDC 4, "Environmental and Missile Design Bases"
- GDC 5, "Sharing of Structures, Systems and Components" – The ESBWR is a single-unit plant design. Therefore, this GDC is not applicable.
- GDC 17, "Electric Power Systems"
- GDC 18, "Inspection and Testing of Electrical Power Systems"

- GDC 50, "Containment Design Bases"

NRC Regulatory Guides:

- Regulatory Guide 1.6, "Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems" – The ESBWR Standard Plant does not need or have safety-related standby AC power sources; however, portions pertaining to the safety-related DC system are addressed within Subsection 8.3.2. Also, the nonsafety-related Standby AC Power Supply System for the ESBWR is designed with physical separation of redundant load groups.
- Regulatory Guide 1.9, "Selection, Design, Qualification and Testing Emergency of Emergency Diesel-Generator Units Used as Class 1E Onsite Electric Power Systems at Nuclear Power Plants" – The ESBWR diesel-generator units are not safety-related, nor is AC power needed for the ESBWR to achieve safe shutdown.
- Regulatory Guide 1.32, "Criteria for Safety-Related Electric Power Systems for Nuclear Power Plants." Safety-related DC power sources are provided to support passive core cooling and containment integrity safety functions. No offsite or diesel-generator-derived AC power is required for 72 hours after an abnormal event.
- Regulatory Guide 1.47, "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems"
- Regulatory Guide 1.53, "Application of Single-Failure Criterion to Nuclear Power Plant Protection Systems."
- Regulatory Guide 1.63, "Electric Penetration Assemblies in Containment Structures for Light-Water-Cooled Nuclear Power Plants"
- Regulatory Guide 1.75, "Physical Independence of Electric Systems." Safe shutdown relies only upon DC-derived power and will meet the design requirements for physical independence.
- Regulatory Guide 1.81, "Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants" – The ESBWR Standard Plant is designed as a single-unit plant. Therefore, this Regulatory Guide 1.81 is not applicable.
- Regulatory Guide 1.106, "Thermal Overload Protection for Electric Motors on Motor-Operated Valves"
- Regulatory Guide 1.108, "Periodic Testing of Diesel Generator Units Used as Onsite Electric Power Systems at Nuclear Power Plants" – The ESBWR Standard Plant does not need or have safety-related diesel generator units or standby power sources; therefore this Regulatory Guide 1.108 is not applicable.
- Regulatory Guide 1.118, "Periodic Testing of Electric Power and Protection Systems" (see Subsection 8.3.4.12 for COL information).
- Regulatory Guide 1.128, "Installation Design and Installation of Large Lead Storage Batteries for Nuclear Power Plants"
- Regulatory Guide 1.129, "Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Nuclear Power Plants" – the ESBWR design allows for periodic testing,

maintenance and replacement of batteries. Refer to Subsection 8.3.4.14 for COL information.

- Regulatory Guide 1.153, "Criteria for Power Instrumentation, and Control Portions of Safety Systems"
- Regulatory Guide 1.155, "Station Blackout" – The ESBWR does not require AC power to achieve safe shutdown. Thus, ESBWR meets the intent of Regulatory Guide 1.155. The Station Blackout evaluation is provided in Section 15.5.
- Regulatory Guide 1.160, "Monitoring of Effectiveness of Maintenance at Nuclear Power Plants" - Maintenance Rule development is addressed by the COL applicant (see Subsection 8.3.4.15 for COL information).

Branch Technical Positions:

- BTP ICSB 4 (PSB), "Requirements on Motor-Operated Valves in the ECCS Accumulator Lines" – This BTP is written for pressurized water reactor (PWR) plants only and is therefore not applicable to the ESBWR.
- BTP ICSB 8 (PSB), "Use of Diesel-Generator Sets for Peaking" – The ESBWR can achieve safe shutdown without AC power, and the diesel-generator sets are not safety-related. Therefore, this criterion is not applicable.
- BTP ICSB 11 (PSB), "Stability of Offsite Power Systems" (see Subsection 8.2.1 for COL information).
- BTP ICSB 18 (PSB), "Application of the Single Failure Criterion to Manually-Controlled Electrically-Operated Valves"
- BTP ICSB 21, "Guidance for Application of Regulatory Guide 1.47"
- BTP PSB 1, "Adequacy of Station Electric Distribution System Voltages" (see Subsection 8.3.4.4 for COL information).
- BTP PSB 2, "Criteria for Alarms and Indications Associated with Diesel-Generator Unit Bypassed and Inoperable Status"

Other SRP Criteria:

- NUREG/CR 0660, "Enhancement of Onsite Diesel Generator Reliability" – The ESBWR diesel-generator units are not safety-related, nor is AC power needed for to achieve safe shutdown; therefore, the NUREG is not directly applicable. However, defense-in-depth principles such as redundancy and diversity are incorporated in the design and integration of ESBWR systems.
- NUREG/CR 0737, "TMI Lessons Learned"
- TMI Action Item II.E.3.1, "Emergency Power Supply for Pressurizer Heater" – This criteria is applicable only to PWRs and does not apply to the ESBWR.
- TMI Action Item II.G.1, "Emergency Power for Pressurizer Equipment" – This criteria is applicable only to PWRs and does not apply to the ESBWR.

8.1.6 COL Information

8.1.6.1 Utility Power Grid Description

The COL applicant is to provide a description of the utility power grid, and address the stability of the off-site power system in accordance with Branch Technical Position BTP ICSB 11 (PSB).

8.1.6.2 Offsite Power System Description

The COL applicant is to revise, as necessary, the description of the off-site power system (Subsections 8.1.2.2 & 8.1.5.1).

8.1.6.3 Compliance to Regulatory Requirements and Guidelines

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

8.1.7 References

8.1-1 IEEE Standard 944, "IEEE Application and Testing of Uninterruptible Power Supplies for Power Generating Stations."

Table 8.1-1

On-Site Power System SRP Criteria Applicability Matrix

Applicable Criteria		IEEE Standard	Notes	Off-site Power System	AC (On-site) Power System	DC (On-site) Power System
GDC	2				X	X
GDC	4				X	X
GDC	5		1			
GDC	17			X	X	X
GDC	18			X	X	X
GDC	50				X	X
10 CFR	50.34(f)(2)(v)		6	X	X	X
10 CFR	50.34(f)(2)(xiii)		2		X	
10 CFR	50.34(f)(2)(xx)		2		X	
10 CFR	50.63			X	X	
RG	1.6		3		X	X
RG	1.9	387	3		X	
RG	1.32	308		X	X	X
RG	1.47			X	X	X
RG	1.53	379			X	X
RG	1.63	317			X	X
RG	1.75	384			X	X
RG	1.81		1			
RG	1.106				X	X
RG	1.108		3		X	
RG	1.118	338	4		X	X
RG	1.128	484				X
RG	1.129	450	4			X
RG	1.153	603		X	X	X
RG	1.155					X
RG	1.160		4			
BTP	ICSB 4	279	2			
BTP	ICSB 8	308			X	
BTP	ICSB 11		4	X		
BTP	ICSB 18				X	
BTP	ICSB 21			X	X	X
BTP	PSB 1		4		X	
BTP	PSB 2				X	
NUREG-0718			6	X	X	X
NUREG	0737		5			
NUREG/CR-0660			3		X	

Notes:

(1) Noted criteria are applicable to multi-unit plants only, and are not applicable to single-unit ESBWR.

(2) The criterion is only applicable to PWRs, and thus, is not applicable to the ESBWR.

(3) The ESBWR Standard Plant does not have safety-related diesel generators, and thus, this criterion is not applicable to the ESBWR.

(4) To be addressed in a COL application.

(5) Covered by 10 CFR 50.34(f)(2)(xiii) and 50.34(f)(2)(xx).

(6) Not applicable to the ESBWR: 10 CFR 50.34 (f) and NUREG 0718 apply only to the pending applications at February 16, 1982.

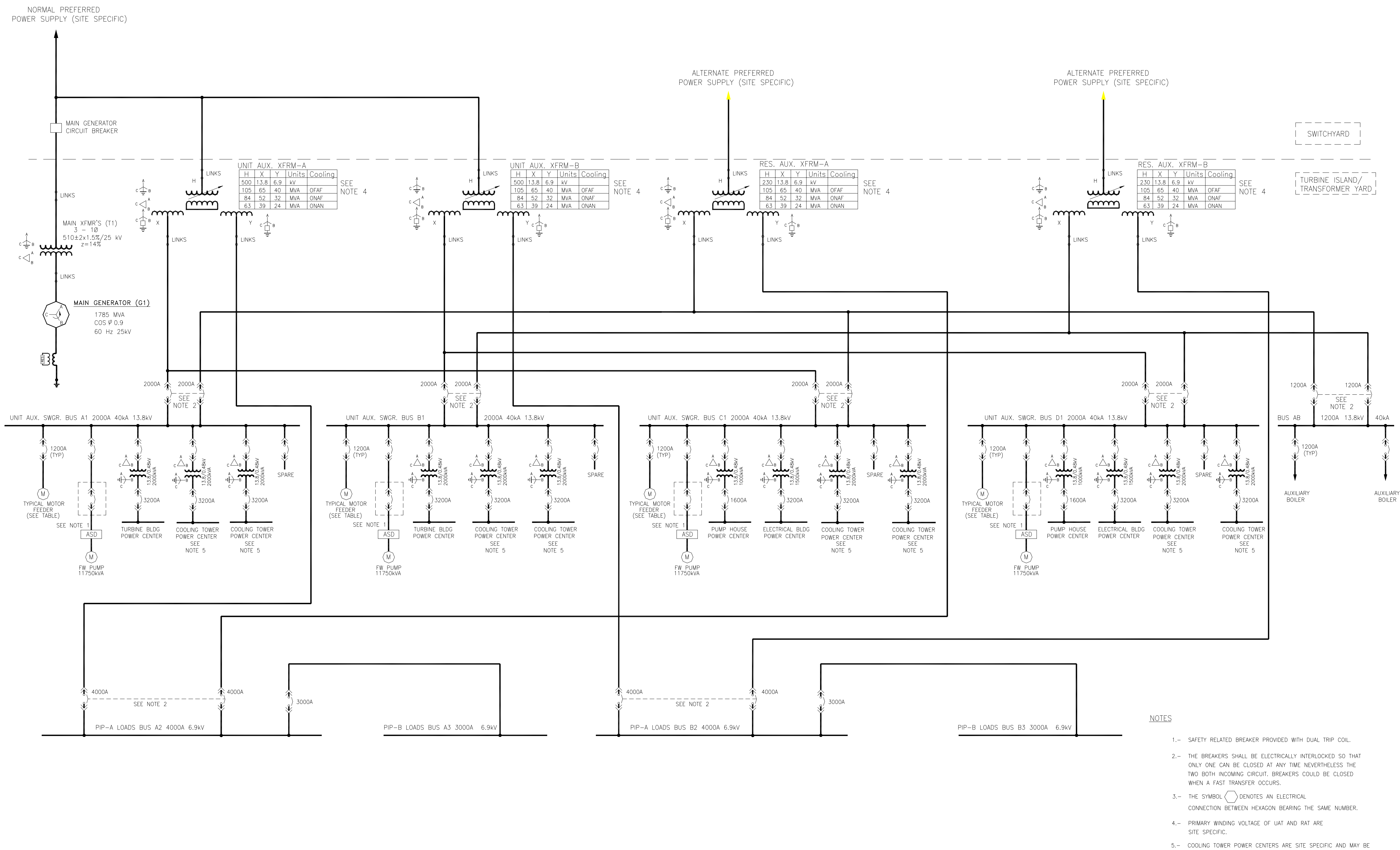


Figure 8.1-1. Electrical Power Distribution System - One Line Diagram
Sh 1 of 3

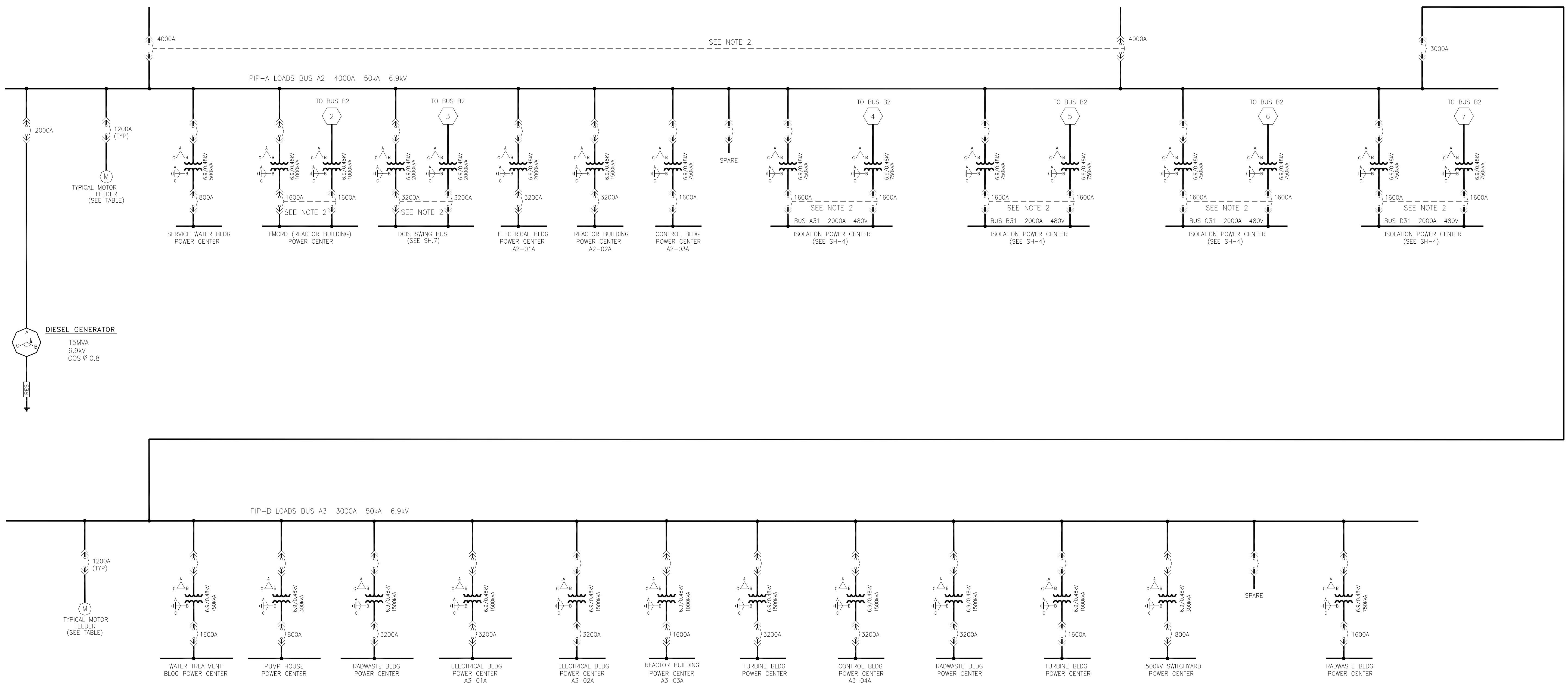


Figure 8.1-1. Electrical Power Distribution System - One Line Diagram
Sh 2 of 3

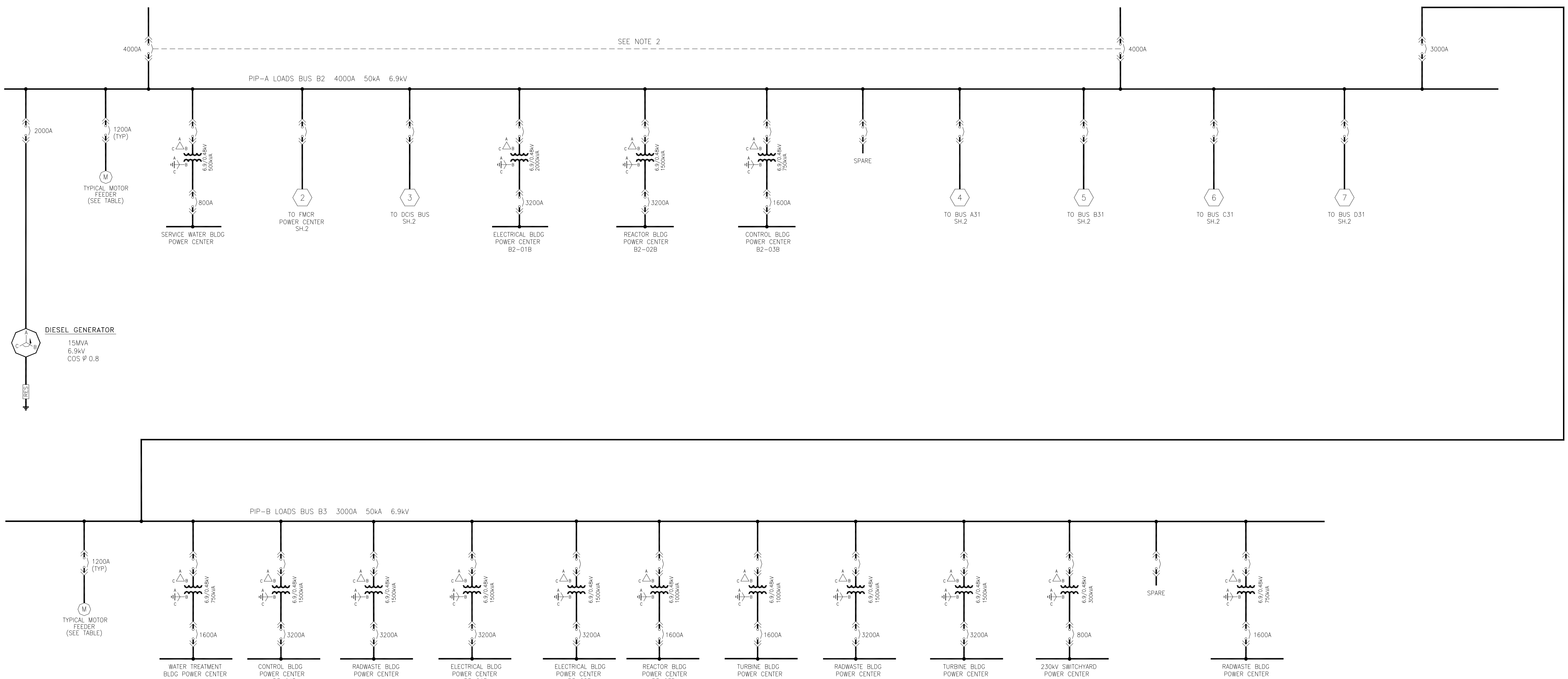


Figure 8.1-1. Electrical Power Distribution System - One Line Diagram
Sh 3 of 3

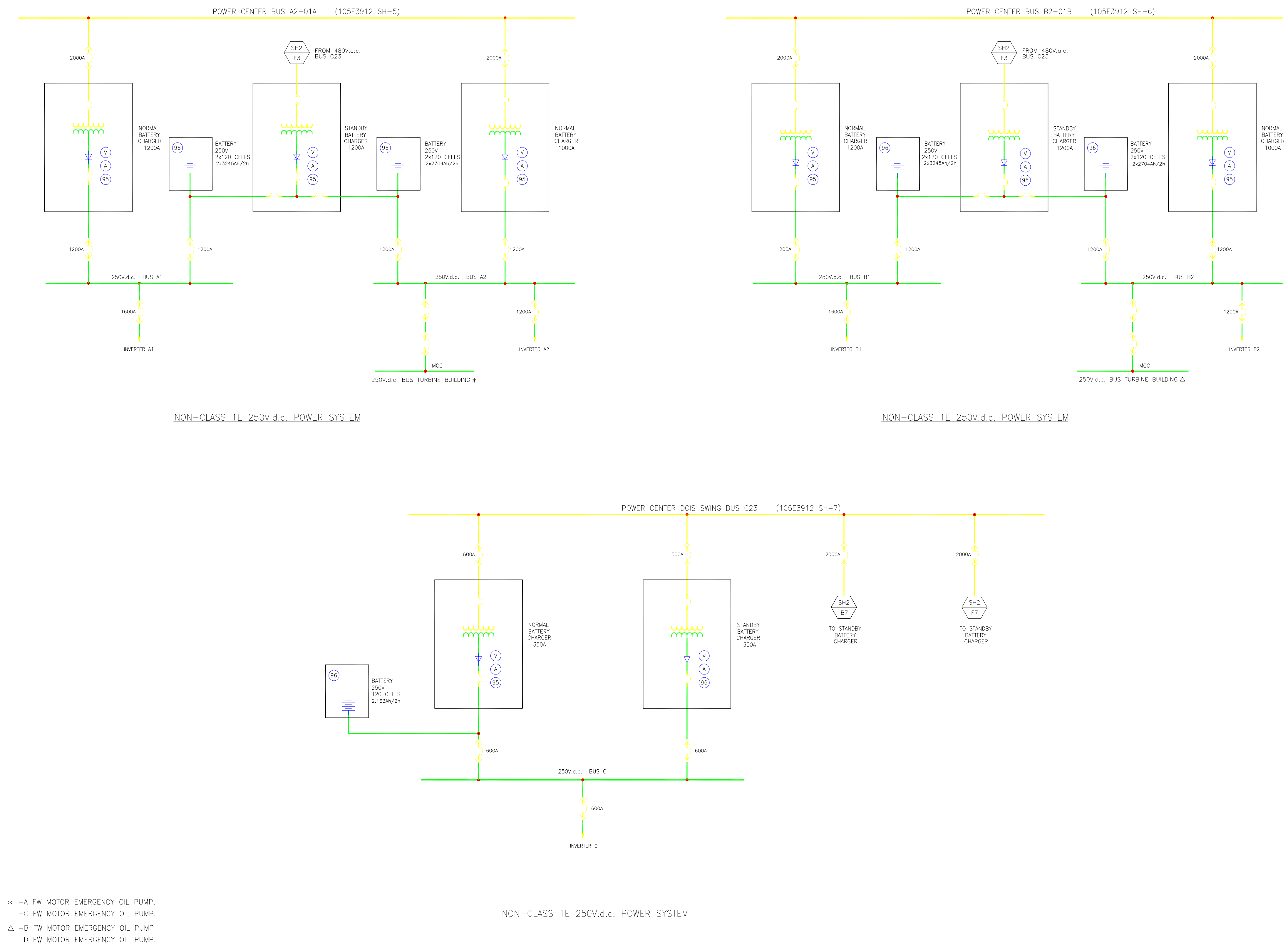


Figure 8.1-2. Direct Current Power Supply (Non-Class 1E) - One Line Diagram
Sh 1 of 2

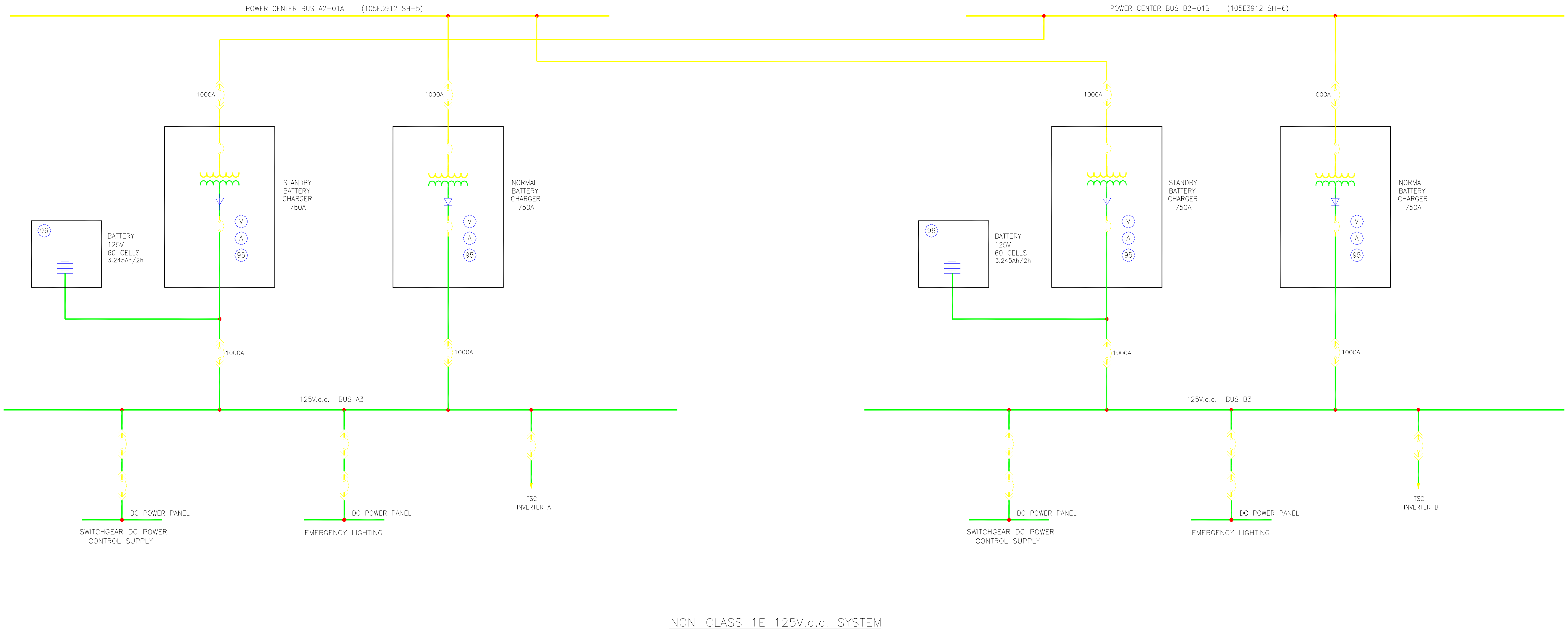


Figure 8.1-2. Direct Current Power Supply (Non-Class 1E) - One Line Diagram
Sh 2 of 2

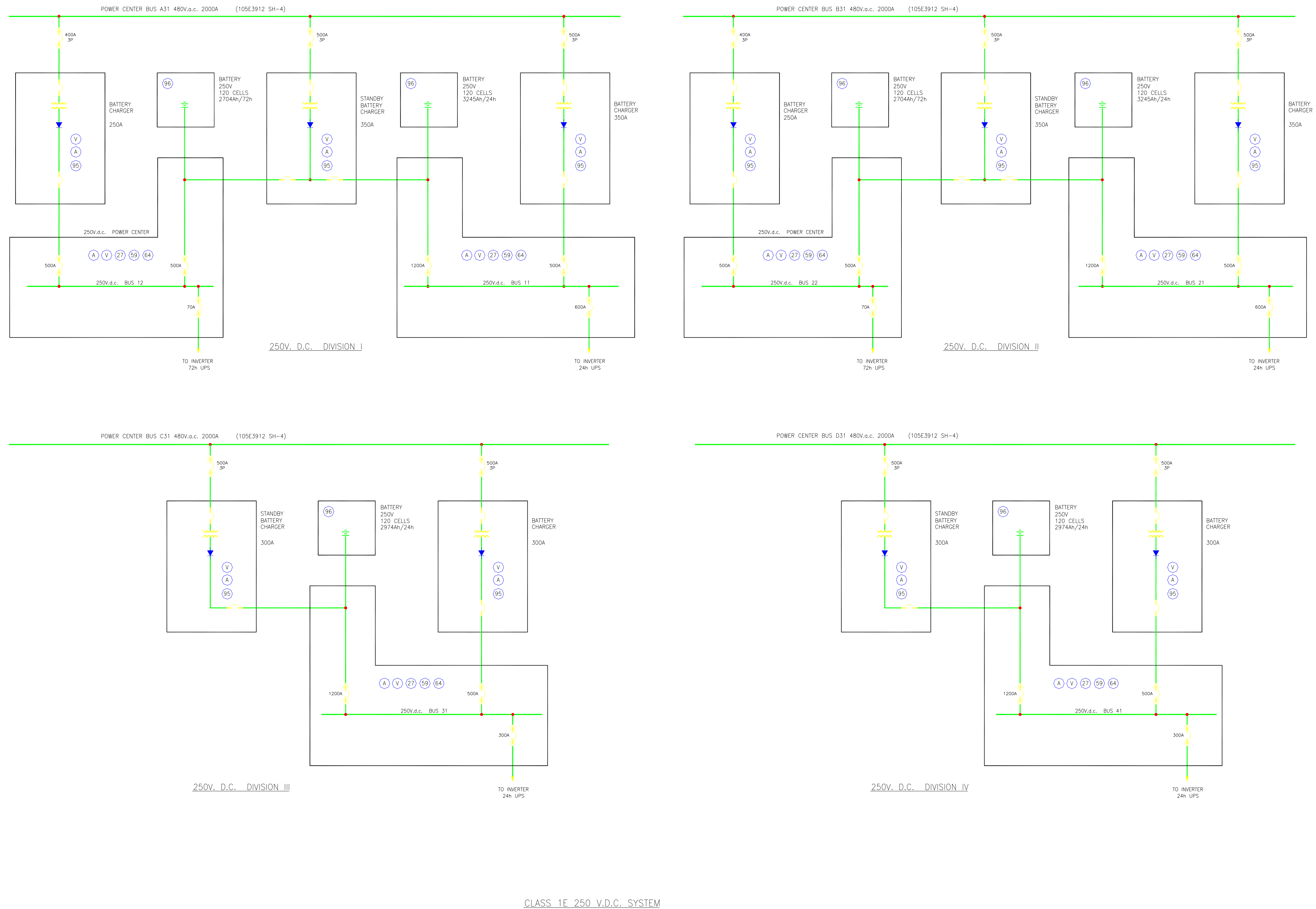


Figure 8.1-3. Direct Current Power Supply (Class 1E) - One Line Diagram

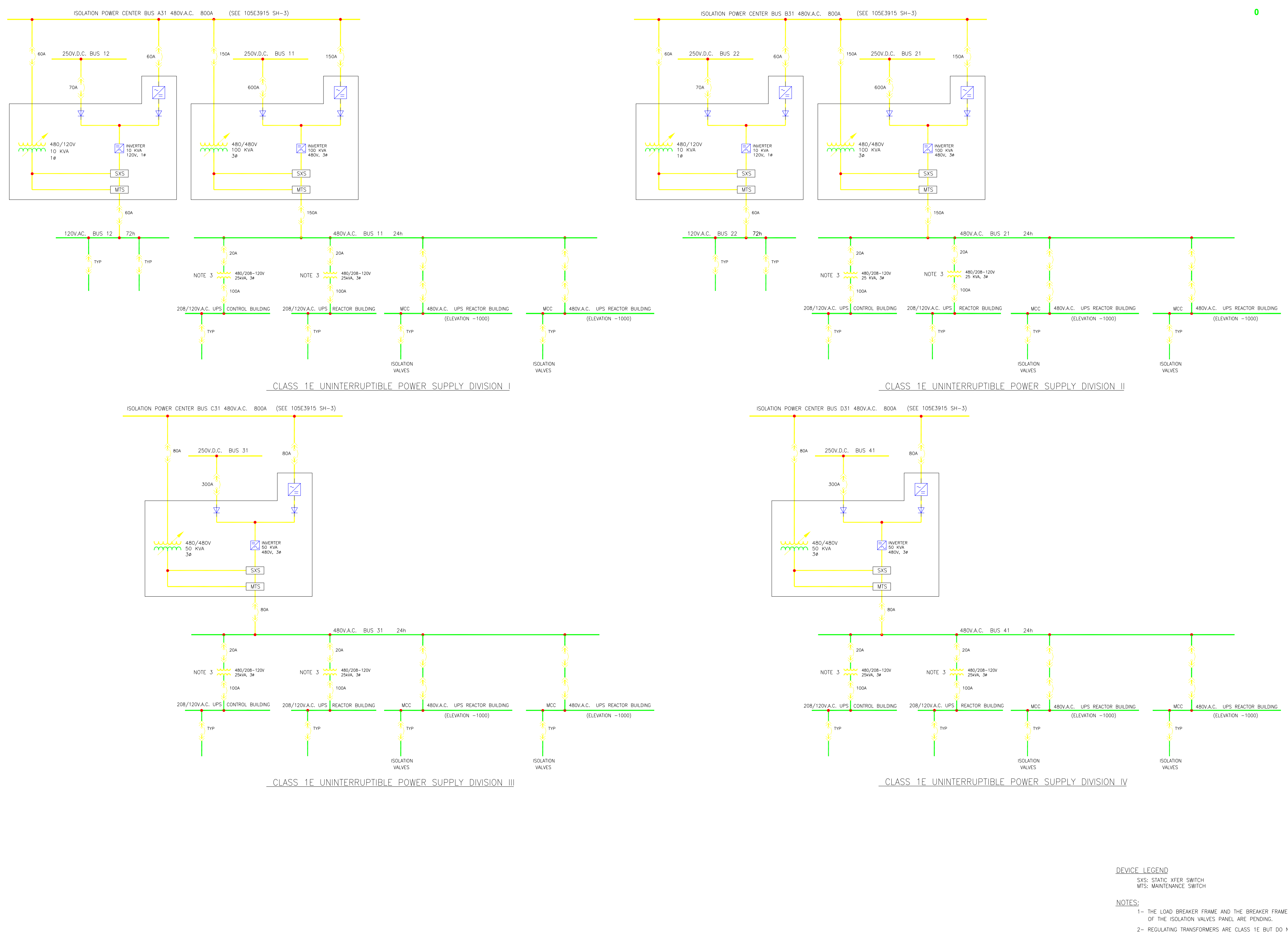


Figure 8.1-4. Uninterruptible AC Power Supply (Class 1E) - One Line Diagram

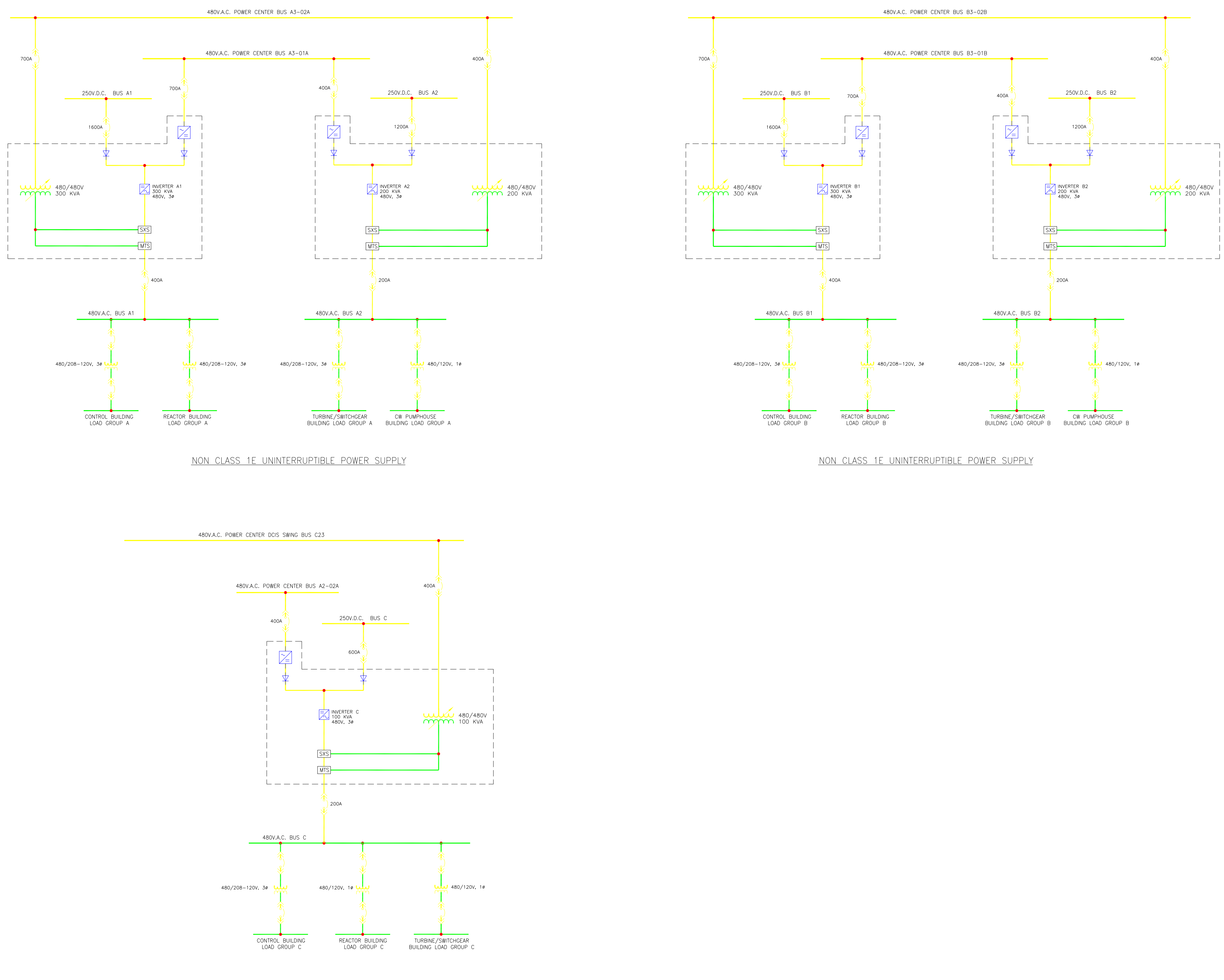


Figure 8.1-5. Uninterruptible AC Power Supply (Non-Class 1E) - One Line Diagram
Sh 1 of 2

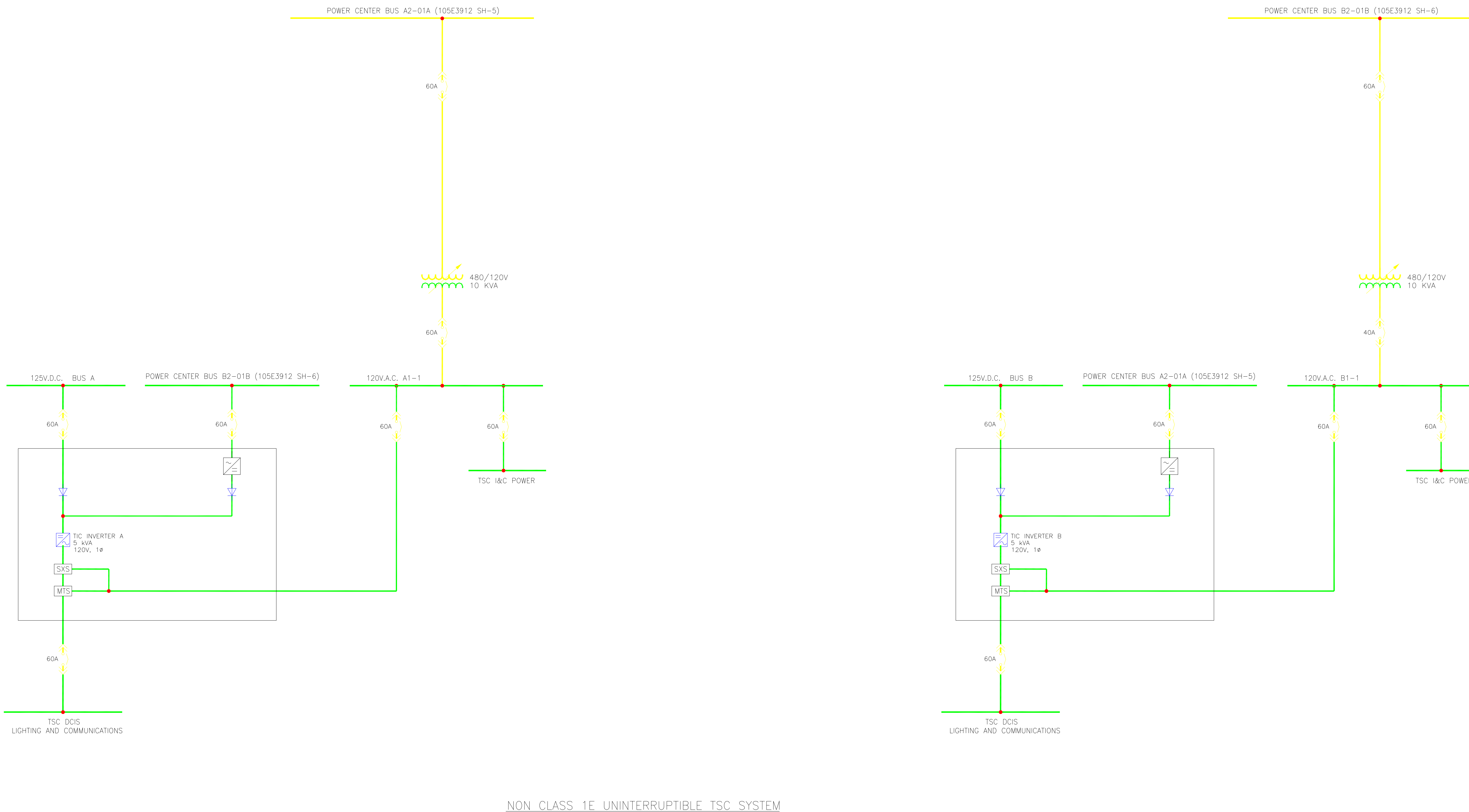
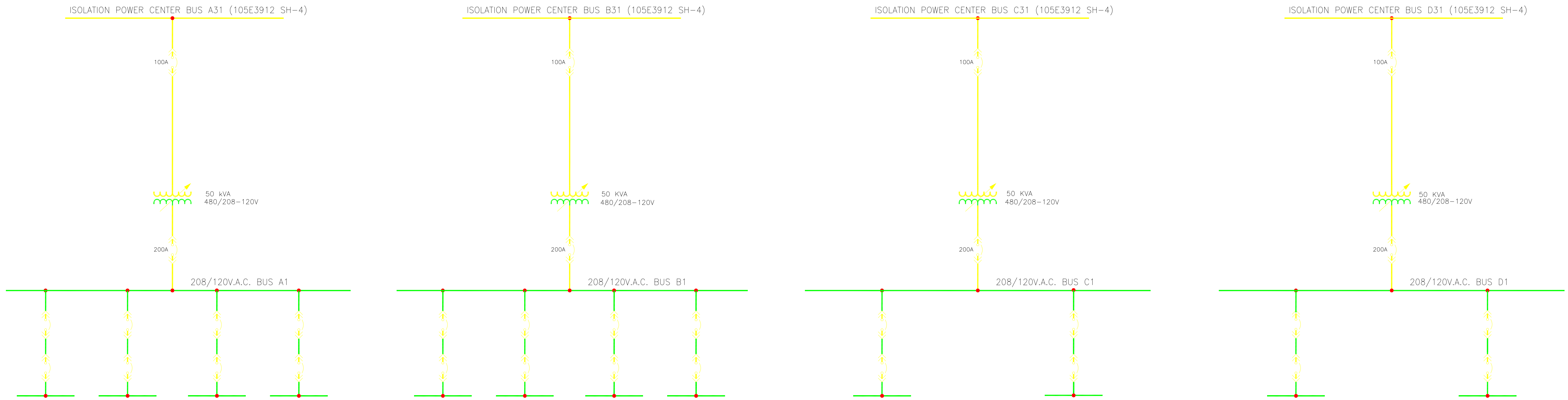


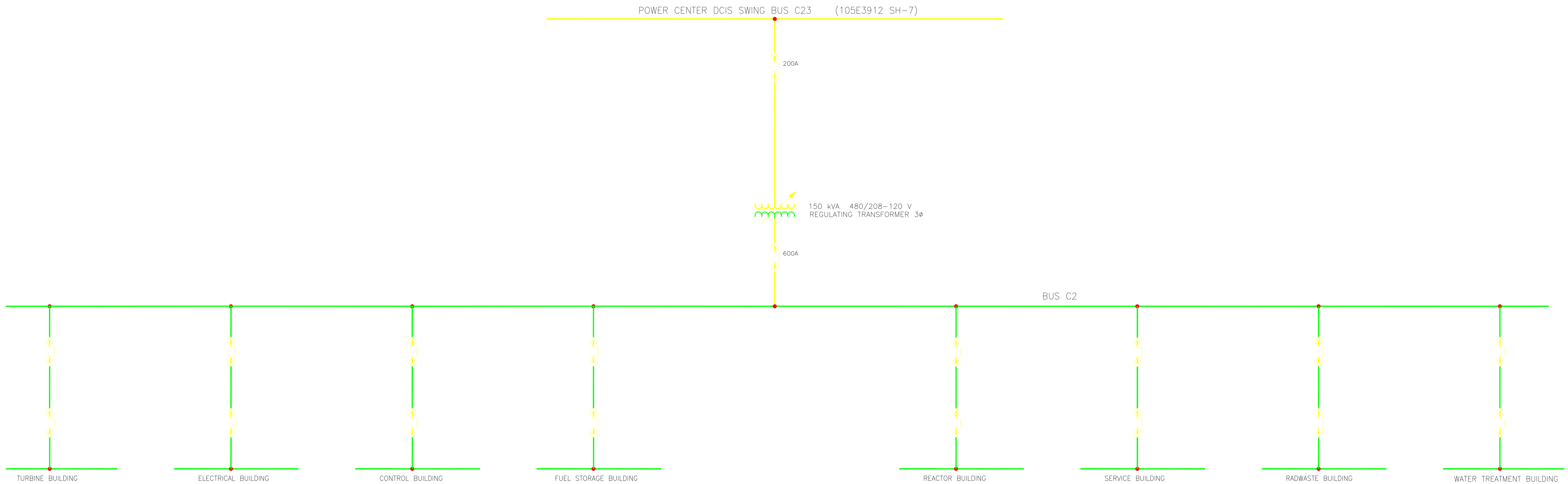
Figure 8.1-5. Uninterruptible AC Power Supply (Non-Class 1E) - One Line Diagram
Sh 2 of 2



Alternate Power Supply to Class 1E I&C

NOTES:
1 – THE NUMBER OF FEEDERS ARE PRELIMINARY.
2 – ADDITIONAL REGULATING TRANSFORMERS WILL BE PROVIDED IF SIGNIFICANT VOLTAGE DROP APPEARS.
3 – ALTERNATE POWER SUPPLY SYSTEM FEEDS CLASS 1E I&c LOADS, BUT DO NOT PERFORM ANY SAFETY FUNCTION.

Figure 8.1-6. Instrumentation and Control Power Supply System - One Line Diagram
Sh 1 of 2



Alternate Power Supply to Class 1E I&C

Figure 8.1-6. Instrumentation and Control Power Supply System - One Line Diagram
Sh 2 of 2

8.2 OFF-SITE POWER SYSTEMS

8.2.1 Description

8.2.1.1 Transmission System

The transmission system description is out of the ESBWR Reference Plant scope; however, there are design bases (interface requirements) contained in Subsection 8.2.3, and COL applicant/licensee items contained in Subsection 8.2.4.

8.2.1.2 Off-site Power System

The off-site power system is a nonsafety-related system. Power is supplied to the plant from two electrically independent and physically separate off-site power sources:

The "Normal Preferred" power source is supplied through the unit auxiliary transformers. The normal preferred power source serves the total plant load consisting of nonsafety-related loads, plant investment protection (PIP) nonsafety-related loads and safety-related loads.

The "Alternate Preferred" power source is supplied through the reserve auxiliary transformers. The alternate preferred power source, as an alternate power source to the plant load, may be utilized in the event of unavailability of the normal preferred power source.

The main power transformers consist of three single-phase transformers and an installed spare.

The unit auxiliary transformers consist of two three-phase transformers. The unit auxiliary transformers provide normal preferred power to each of the plant's two power generation load groups and the two PIP non-Class 1E power load groups.

The reserve auxiliary transformers consist of two three-phase transformers fed from the second off-site source. The reserve auxiliary transformers provide alternate preferred power to the plant's two power generation load groups and the two PIP non-Class 1E power load groups.

The reserve auxiliary transformers are of the same size as the unit auxiliary transformers, and each function as a backup power source in the event of a unit auxiliary transformer failure.

The main power transformers, unit and reserve auxiliary transformers, are designed and constructed to withstand the mechanical and thermal stresses produced by external short circuits, and meet the corresponding requirements of IEEE Standard C57.12.00 (Reference 8.2-1).

A switchyard-located generator circuit breaker is provided with capability of interrupting the maximum available fault current. The generator circuit breaker is sized and designed in accordance with IEEE Standard C37.06 (Reference 8.2-2). The generator circuit breaker allows the generator to be taken off line and the main grid to be utilized as an immediate access power source for the on-site AC power system (i.e., power is fed from the off-site source through the unit auxiliary transformers). Start-up power is provided through the unit auxiliary transformers from the off-site power system.

Unit synchronization is normally through the main generator circuit breaker. A coincidental three-out-of-three logic scheme and synchrocheck relays are used to ensure proper synchronization of the unit to the off-site system. Dual trip coils and redundant protective relaying schemes are provided for the generator circuit breaker, and control power is supplied from redundant load groups of nonsafety-related 125 VDC power.

The isolated phase bus duct provides the electrical interconnection between the main generator output terminals and the low voltage terminals of the main transformers.

The non-segregated phase bus ducts provided for the electrical interconnection between the unit auxiliary transformers and the 13.8 kV and 6.9 kV unit auxiliary switchgear buses (which are associated with each two power generation load groups and two PIP non-Class 1E power load groups) are physically separated to minimize the likelihood of simultaneous failure.

The non-segregated phase bus duct provided for the electrical interconnection between the reserve auxiliary transformers and the 13.8 kV and 6.9 kV unit auxiliary switchgear buses are physically separated from the bus ducts provided for the interconnection of the unit auxiliary transformers and the unit auxiliary switchgear buses to minimize the likelihood of simultaneous failure.

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

Disconnect links are provided for the unit auxiliary transformers so that a failed transformer may be taken out of service, and the installed reserve auxiliary transformer connected to the alternative preferred source. Thus, a reserve auxiliary transformer can replace the failed unit auxiliary transformer.

Disconnect links are provided for the reserve auxiliary transformers so that a failed transformer may be taken out of service. Power is supplied to the plant through the two unit auxiliary transformers. Thus, the two reserve auxiliary transformers remain connected. Each of the connected reserve auxiliary transformers has the capability to replace one unit auxiliary transformer.

There will always be both a normal and an alternate preferred power path to the safety-related electrical system, even if the plant is operating with a reserve or unit auxiliary transformer out of service.

8.2.1.2.1 Switchyard

The switchyard description is out of the ESBWR Reference Plant scope, however, there are design bases (interface requirements) contained in Subsection 8.2.3, and COL applicant/licensee items contained in Subsection 8.2.4.

8.2.2 Analysis

In accordance with the NRC Standard Review Plan (NUREG-0800), Table 8-1 and Section 8.2, the preferred off-site power distribution system is designed consistent with the following criteria, so far as it applies to non-Class 1E equipment. Any exceptions or clarifications are so noted.

Applicable Criteria:

- GDC 5, "Sharing of Structures, Systems and Components," and Regulatory Guide 1.81, "Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power

Plants" – The ESBWR Reference Plant is designed as a single-unit plant. Therefore, GDC 5 and Regulatory Guide 1.81 are not applicable.

- GDC 17, "Electric Power Systems" –The ESBWR Reference Plant complies with GDC 17 as it applies to non-Class 1E power systems.
- GDC 18, "Inspection and Testing of Electric Power Systems" – The ESBWR Reference Plant is in compliance with GDC 18 except for the testing of generator circuit breaker. This breaker cannot be tested during normal operation of the plant. Generator breakers are extremely reliable with published test results showing a high reliability. This high reliability compares favorably with the probability of failure of the normal preferred power supply due to other causes.

  All other equipment can either be tested during normal plant operation or it is continually tested by virtue of its operation during normal plant operation.
- 10 CFR 50.63, "Loss of All Alternating Current Power" – The ESBWR 10 CFR 50.2 *Design Bases* do not rely upon any off-site power system to achieve and maintain safe shutdown. See the Station Blackout evaluation in Section 15.5.
- Regulatory Guide 1.32, "Criteria for Power Systems for Nuclear Power Plants" – The off-site power system is non-Class 1E. Therefore, Regulatory Guide 1.32 is not applicable to the ESBWR off-site power system.
- Regulatory Guide 1.47, "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems," and BTP ICSB 21, "Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems" – The off-site power system is non-Class 1E. Therefore, Regulatory Guide 1.47 and BTP ICSB 21 are not applicable to the ESBWR off-site power system.
- BTP ICSB 11, "Stability of Offsite Power Systems" – This topic is site specific, see Subsection 8.2.4.10 for COL information.

8.2.3 Design Bases (Interface Requirements)

The off-site power system of the ESBWR Reference Plant is based on certain design bases (10 CFR 52 interface requirements). These design requirements follow:

- In case of failure of the normal preferred power supply circuit, the alternate preferred power supply circuit shall remain available through the reserve auxiliary transformers.
- The normal preferred circuit shall be electrically independent and physically separated from the alternate preferred circuit. The normal preferred and alternate preferred circuits may be connected to the same transmission systems provided the switchyard is fed by at least two transmission lines that can each supply the shutdown electrical loads and provided that both transmission lines are sufficiently separated. If the normal preferred and alternated preferred circuits are fed from separate transmission systems, each system shall be individually capable of supplying the shutdown electrical loads. They may use a common switchyard provided adequate separation exists.
- The switching station to which the main off-site circuit is connected shall have two full capacity main buses arranged such that:

- Any incoming or outgoing transmission line can be switched without affecting another line.
- Any circuit breaker can be isolated for maintenance without interrupting service to any circuit.
- Faults of a single main bus are isolated without interrupting service to any circuit.

- The main, unit auxiliary and reserve auxiliary transformers shall meet the requirements of IEEE Standard C57.12.00 (Reference 8.2-1).
- Circuit breakers and disconnecting switches are sized and designed in accordance with IEEE Standard C37.06 (Reference 8.2-2).
- It is required that a minimum clearance of 12.7 m (50 ft) or two hour fire barrier exists between the reserve auxiliary transformers and the unit auxiliary transformers. In addition, the physical separation between transformers and oil collection systems shall be as stated in Section 9A.5.
- It is required that cables associated with the normal preferred and alternate preferred circuits be routed separately and in separate raceways apart from each other and on-site power system cables. However, they may share a common underground duct bank as indicated below.
- It is required that the alternate preferred circuit be separated from the normal preferred circuit by a minimum clear distance of 12.7m (50 ft) as measured from a plan view or by a two hour fire barrier. The associated control, instrumentation, and miscellaneous power cables of the reserve circuit shall, if located underground in the same duct bank as the cables associated in the normal preferred circuit between the switchyard and the power block, be routed in separate conduits or raceways and shall have separate manholes.
- It is required that cables associated with the alternate preferred circuit be routed in separate trenches within the switchyard from those associated with the normal preferred circuit, provided there is a common switchyard.
- The applicant shall review the proposed site specific configuration of power lines coming to the station and the characteristics of the transmission system to which the plant is connected to determine the reliability of the off-site power system and verify that it is consistent with the probability risk analysis of Chapter 19.
- It is required that provisions be made to permit disconnection of a failed auxiliary transformer and energizing of the rest of the auxiliary transformers in no more than 12 hours.
- It is required that the applicant provide a station ground grid consisting of a ground mat below grade at the switchyard. The station ground grid shall be connected with the foundation embedded loop grounding system provided for the remaining plant buildings including, but not limited to, the reactor and turbine buildings, cooling towers, unit auxiliary transformers, and the standby power source buildings.

8.2.4 COL Information

8.2.4.1 Transmission System Description

The transmission system is site-specific and under the responsibility of the COL applicant.

8.2.4.2 Switchyard Description

The switchyard is site-specific and under the responsibility of the COL applicant.

8.2.4.3 Normal Preferred Power

The Normal Preferred Power interface occurs at high voltage terminals of the unit auxiliary transformers. The rated conditions for this interface are 210 MVA at a 0.9 power factor and 500 kV. It is a requirement that the utility provide sufficient impedance in the main power transformer and the high voltage circuit to limit the primary side maximum available fault current contribution from the system to no more than 63 kA symmetrical and 170 kA asymmetrical peak at 1/2 cycle from inception of the fault. These values should be acceptable to most utilities. When all equipment and system parameters are known, a refined calculation based on the known values with a fault located at the generator output may be made. This may allow a lower impedance for the main power transformer, if desired. The voltage and frequency are the utility's standard ones with the actual values to be determined at contract award.

8.2.4.4 Alternate Preferred Power

The Alternate Preferred Power interface occurs at the high voltage terminals of the reserve auxiliary transformers. The rated load is 210 MVA at a 0.9 power factor. The voltage and frequency are the utility's standard with the actual values to be determined at contract award. The reserve off-site power circuit is required to be of an underground cable design unless determined not to be feasible because of specific site conditions.

8.2.4.5 Unit Synchronization

Unit synchronization shall normally be through the generator circuit breaker. A coincidental three-out-of-three logic scheme and auto-synchronizing relay with voltage and frequency matching relays preclude faulty synchronizations. Provisions to synchronize the unit through the switching circuit breakers are required.

8.2.4.6 Protective Relaying

Protective relaying interfaces for the two power system interfaces are to be defined during the detail design phase following contract award. All relay schemes used for the protection of the off-site power circuits and the switching station's equipment are required to be redundant and shall include backup protection features. All breakers are required to be equipped with dual trip coils. Each redundant protection circuit, which supplies a trip signal, is required to be powered from its redundant load group of DC power and connected to a separate trip coil. All equipment and cabling associated with each redundant system is required to be physically separated from its redundant counterpart.

8.2.4.7 Switchyard DC Power

The DC power needed to operate redundant protection and control equipment of the off-site power system shall be supplied from two separate, dedicated switchyard batteries, each with a battery charger fed from separate AC bus. Each battery is required to be capable of supplying the DC power required for normal operation of the switching station's equipment.

8.2.4.8 Switchyard AC Power

Two redundant low voltage AC power supply systems shall be provided to supply AC power to the switching station's auxiliary loads. Each system is required to be supplied from separate, independent AC buses. The capacity of each system is required to be adequate to meet the AC power requirements for normal operation of the switching station's equipment.

8.2.4.9 Transformer Protection

Each off-site power system transformer shall be provided with primary and backup protective devices. The DC power to the primary and backup devices shall be supplied from separate DC sources.

8.2.4.10 Stability of Off-Site Power Systems

Detailed analyses will be provided for the plant's primary and secondary off-site sources. The analyses shall define the pre-fault and post-fault load flow and transient stability with and without the plant on-line. Load flow simulations and stability calculations are to be examined to evaluate the transient and post-transient system conditions after the most severe network faults and after the sudden tripping of the ESBWR power plant. System minimum and maximum values of voltage and fault current are to be provided.

8.2.4.11 Transmission System Reliability

Demonstrate the reliability of the transmission systems to which the plant is connected; in particular, address unscheduled outages.

8.2.4.12 Generator Circuit Breaker

The generator circuit breaker meets Appendix A to Standard Review Plan (SRP) Section 8.2.

8.2.4.13 Degraded Voltage

The COL applicant is to provide undervoltage protection criteria in order to define whether the non Class 1E 6.9 kV buses powered from the Standby On-site AC Power Supply System have to be provided with undervoltage protection to take precautions against degraded voltage condition in the off-site power system.

8.2.4.14 Interface Requirements

The COL applicant/licensee shall confirm that the interface requirements of Subsection 8.2.3 are met.

8.2.5 References

8.2-1 IEEE Standard C57.12.00, "General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers."

8.2-2 IEEE Standard C37.06, "AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis."

8.3 ON-SITE POWER SYSTEMS

8.3.1 AC Power Systems

8.3.1.1 Description

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

The on-site AC power system is configured into two separate power load groups. Each power load group is fed by a separate unit auxiliary transformer, each with a redundant reserve auxiliary transformer for backup, and consists of two types of buses:

- **Power Generation (PG) nonsafety-related buses** - are those buses that are not directly backed by standby on-site AC power sources and have connections to the main or second off-site source through the unit or reserve auxiliary transformers, respectively. Backfeed from the plant investment protection (PIP) nonsafety-related buses is prevented by reverse power relaying. The PG nonsafety-related buses are the 13.8 kV unit auxiliary switchgear and associated lower voltage load buses.
- **Plant Investment Protection (PIP) nonsafety-related buses** - are those buses that are backed by the Standby On-site AC Power Supply System and have connections to the normal preferred and alternate preferred off-site sources through the unit and auxiliary reserve transformers, respectively. The PIP nonsafety-related buses are the 6.9 kV PIP buses and associated lower voltage load buses exclusive of the safety-related buses.

The PG nonsafety-related buses feed nonsafety-related loads that are required exclusively for unit operation and are normally powered from the normal preferred power source through the unit auxiliary transformers (UATs). These buses are also capable of being powered from the alternate preferred power source through the reserve auxiliary transformers (RATs) in the event that the normal preferred power source is unavailable.

The PIP nonsafety-related buses feed nonsafety-related loads that, because of specific functions, are generally required to remain operational at all times or when the unit is shut down. In addition, the PIP nonsafety-related buses supply AC power to the safety-related buses. The PIP nonsafety-related buses are backed up by a separate standby on-site AC power supply system in each power load group. These buses are also connected to the normal preferred and alternate preferred power sources through the unit and reserve auxiliary transformers, respectively.

Refer to Subsection 8.3.4 for COL items.

8.3.1.1.1 Medium Voltage AC Power Distribution System

The medium voltage AC power distribution system consists of the on-site electric power distribution circuits that operate at 13.8 kV and 6.9 kV. The system begins at the connection at the input terminals of the 13.8 kV and 6.9 kV main circuit breakers that supply power from the UATs and RATs, and at the output terminals of the plant on-site standby AC power sources.

The system ends at the input terminals of medium voltage loads and at the high voltage terminals of the low voltage power center (P/C) transformers. The system includes switchgear buses and circuit breakers as well as their associated local instrumentation, controls, and protective relays. It also includes cables interconnecting the switchgear buses to their sources and loads.

Power is supplied from the unit and reserve auxiliary transformers at 13.8 kV and 6.9 kV to the PG and PIP buses. There are four PG buses, each being powered from one of the two UATs, or if the UATs are unavailable, from one of the two RATs. The source breakers for each PG bus are electrically interlocked to prevent simultaneous connection of the UATs and RATs to the PG buses. The PG buses distribute power at 13.8 kV to motor loads of approximately 250 kW and larger and power center transformers.

Four 6.9 kV PIP buses (two per load group) provide power for the non-Class 1E PIP loads. Each two of these four buses is assigned to one of the two power load groups and is backed by the standby on-site AC power supply system. Each PIP bus is normally powered from the normal preferred power source through the UAT of the same load group. Additionally, in the event of unavailability of the normal preferred power source, each PIP bus has connections to and can be powered from the alternate preferred power source through the RAT of the same load group. The source breakers of the normal and alternate preferred power sources are electrically interlocked to prevent paralleling of the two power supplies. The PIP buses distribute power at 6.9 kV to motor loads of approximately 250 kW and larger and to power center transformers.

Standby AC power for the PIP non-Class 1E buses is supplied by standby diesel generators at 6.9 kV and distributed by the non-Class 1E power distribution system. The 6.9 kV PIP buses are automatically transferred to the standby diesel generators when the normal and alternate preferred power supplies to these buses are lost.

Each 13.8 kV and 6.9 kV bus has a safety grounding circuit breaker, not shown on one-line, designed to protect personnel during maintenance operations. During periods when the buses are energized, these breakers are racked out (i.e., in a disconnected position). A control room alarm annunciates whenever any safety grounding breaker is racked in.

The bus power supply breakers are interlocked with the safety grounding breakers such that they cannot be closed unless their associated grounding breaker is racked out. The grounding breakers cannot be closed unless: (1) the bus undervoltage relays are actuated, (2) the power supply breakers to the bus are in a disconnected position, and (3) bus instrumentation power is available.

8.3.1.1.2 Low Voltage AC Power Distribution System

The low voltage AC power distribution system consists of the on-site electric power distribution circuits that operate at 480V through 120V exclusive of plant lighting. For a discussion of the plant 120V systems refer to Subsections 8.3.1.1.3 and 8.3.1.1.4. The low voltage system begins at the high voltage terminals of the power center transformers and the input terminals of the DC/AC inverters. The system ends at the input terminals of loads (motors, heaters, etc.), at the input terminals of the battery chargers, and at the primary terminals of lighting transformers.

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

Power is supplied from the power center transformers to the 480V power centers. The power centers supply power to motor loads of approximately 100 kW through 249 kW, and to the 480V MCCs. The power centers are of the single-fed or double-ended type depending on the redundancy requirements of the loads powered by a given power center. The power supplies to the double-ended power center transformers of the PIP nonsafety-related buses are supplied from different power load groups. Each double-ended power center is normally powered by its normal power source through its normal source main breaker, with the alternate source main breaker open. The power center normal and alternate source main breakers are electrically interlocked to prevent simultaneous powering of the power center by normal and alternate sources.

Isolation Power Centers

The isolation power centers are powered from the PIP nonsafety-related buses, which are backed up by the standby diesel generators. There are four isolation power centers, one each for Divisions 1, 2, 3 and 4. Each isolation power center is double-ended and can be powered from either of the PIP load group buses. The normal and alternate source main breakers of each isolation power center are electrically interlocked to prevent powering the isolation power center from the normal and alternate sources simultaneously. The isolation power centers are shown in Figure 8.3-1.

The isolation power centers supply power to safety-related loads of their respective division. These loads consist of the Class 1E battery chargers, Class 1E inverters and Class 1E regulating transformers as discussed in Subsection 8.3.2, 8.3.1.1.3, and 8.3.1.1.4 respectively. In addition, there is no Class 1E lighting that operates directly from the 480 VAC (or higher voltage) in the ESBWR design. The lighting system is discussed in Chapter 9. There are no Class 1E actuators (pumps, valves, etc.), which operate directly from 480VAC (or higher) in the ESBWR design.

Isolation power centers are protected against degraded voltage and frequency conditions by way of voltage and frequency relays installed in 6.9 kV PIP buses. Refer to Subsection 8.3.4 for COL applicant/licensee items.

In addition, each isolation power center has provisions for connecting a transportable AC generator via plug-in connections, capable of supplying certain Class 1E loads while recharging the Class 1E batteries. The emergency power main circuit breaker provided in connection with these provisions is normally locked open. An interlock is provided so that only one main breaker may be closed at any time. The plug-in connections are located in a locked box. The position of the emergency main breaker and the doors to the plug-in connections are alarmed in the control room when not in the normal position. All keys are under administrative control.

Motor Control Centers

MCCs supply 99 kW and smaller motors, control power transformers, process heaters, motor-operated valves and other small electrically operated auxiliaries, including 480 to 208/120V and 480 to 240/120V transformers. MCCs are assigned to the same load group as the power center that supplies their power.

Starters for the control of 460V motors smaller than 100 kW are MCC-mounted, across-the-line magnetically operated, air break type. MCC circuits feeding loads within the containment have a backup protective device in series with the primary overcurrent protective device. Refer to Subsection 8.3.1.4.1 for further discussion, and to Subsection 8.3.4 for COL applicant/licensee items.

8.3.1.1.3 Uninterruptible AC Power Supply System

Figure 8.1-4 shows the overall Class 1E Uninterruptible AC Power Supply (UPS) system. The Class 1E UPS for each of the four divisions is supplied from a 480V isolation power center in the same division. The isolation power centers are connected to PIP nonsafety-related buses, which are backed by standby diesel generators. Divisions I and II each have two inverters. One inverter receives 480 VAC normal power from the isolation power center of that division and has a Class 1E 72-hour battery of that division supplying 250 VDC emergency power, with an inverter output at 120 VAC single phase. The second inverter receives 480 VAC normal power from the isolation power center of that division and has a Class 1E 24-hour battery of that division supplying 250 VDC emergency power, with an inverter output at 480 VAC three phase.

Divisions III and IV each have one inverter which receives 480 VAC normal power from the Isolation Power Center of that division and has a Class 1E 24-hour battery of that division supplying 250 VDC emergency power, with an inverter output at 480 VAC three phase.

Power is distributed to the individual loads from distributions transformers and associated distribution panels, and to logic level circuits through the control room logic panels.

Class 1E motor operated valves and other Class 1E motors are powered from the Class 1E UPS. The design requirements imposed by this type of load, as the starting current, are considered in the design of the Class 1E UPS.

The plant design and circuit layout of the UPS provide physical separation of the equipment, cabling, and instrumentation essential to plant safety. Equipment of each division of the Class 1E UPS distribution system is located in an area separated physically from the other divisions. No provisions exist for the interconnection of the Class 1E UPS buses of one division with those of another division or non-division. All components of Class 1E AC systems are housed in Seismic Category I structures.

Refer to Subsection 8.3.4 for COL applicant/licensee items.

Class 1E Uninterruptible AC Power Supply System

Four divisions of Class 1E UPS provide 120VAC power for the Safety System Logic and Control (SSLC), the Reactor Protection System (RPS), and other safety-related loads requiring uninterruptible power.

The four divisions of Class 1E UPS are shown in Figure 8.1-4. The Class 1E UPS buses are each supplied independently from their divisional Class 1E inverters, which, in turn, are powered from one of the independent and redundant DC buses of the same division and from their isolation power center. The divisional DC bus is powered through a battery charger connected to its divisional isolation power center, and backed by the division's Class 1E batteries. A static bypass switch is provided for transferring Class 1E UPS AC load from the Class 1E inverter output to a direct AC feed from the divisional isolation power center through a regulating transformer should an inverter failure occur. A manual bypass switch is provided for transferring Class 1E UPSS AC loads from the Class 1E inverter output to a direct AC feed from the divisional isolation power center through a regulating transformer in order to perform inverter maintenance without removing Class 1E UPS AC loads from service.

The Class 1E UPS power supply buses are designed to provide logic and control power for the independent trip systems of the SSLC that operates the RPS. [The SSLC for the Emergency Core Cooling System (ECCS) derives its power from the Class 1E 250 VDC power system (Figure 8.1-3)]. The Class 1E portion of the Instrumentation and Control Power Supply System provides an additional supply to SSLC for the RPS and ECCS. The Class 1E UPS buses also supply power to the Neutron Monitoring System and parts of the Process Radiation Monitoring System and main steam isolation valve (MSIV) function in the Leak Detection System. Power distribution is arranged to prevent inadvertent operation of the reactor scram initiation or MSIV isolation upon loss of any single power supply.

Two (2) divisions of the Class 1E UPS provide power to the RPS scram and MSIV solenoid valves. The RPS A solenoids are supplied by Division 1, and the RPS B solenoids are supplied from Division 2. For the outboard MSIVs, the #1 (test solenoid) and #2 solenoids are powered from Division 1, and the #3 solenoids are powered from Division 2. For the inboard MSIVs, the #1 (test solenoid) and #2 solenoids are powered from Division 2, and the #3 solenoids are powered from Division 1.

Routine maintenance can be conducted on equipment associated with the Class 1E UPS power supply. Inverters and solid state switches can be inspected, serviced and tested channel by channel without tripping the RPS logic.

UPS Components - Each of the four Class 1E UPS divisions includes the following components:

- A solid-state UPS inverter, to convert 250 VDC and 480 VAC power to 480 VAC power;
- A solid-state transfer switch to sense inverter failure and automatically switch to alternate 480VAC power;
- A manual bypass switch for inverter maintenance;
- Power distribution components including MCCs, distribution transformers, and distribution panelboards to provide power to all Class 1E loads requiring uninterruptible AC power; and
- Circuits between Class 1E UPS components and from Class 1E UPS components to Class 1E UPS loads.

Operating Configuration - The four divisions of Class 1E UPS operate independently, providing power to all Class 1E loads within their division requiring uninterruptible AC power. The normal power source for each division’s inverter is the same division’s isolation power center, which provides AC power to the inverter. Transfer from the 480VAC power supply to the 250VDC bus is done automatically and passively in case of loss of the normal power source. Transfer from the inverter to the alternate AC source (provided via the division’s isolation power center through a regulating transformer) is done automatically in case of inverter failure. An alarm is provided in the control room for any of the alternate operating lineups.

Non-Class 1E Uninterruptible Power Supply System

Figure 8.1-5 shows the overall non-Class 1E UPS. The non-Class 1E UPS for each of the two plant power distribution load groups is supplied from a 480V power center in the same load group, with standby on-site AC power of the same load group providing backup power should a failure of the normal supply occur. Emergency power of the same load group from 250 VDC batteries is provided should loss of normal and standby on-site AC power sources occur.

A third non-Class 1E UPS load group is provided to supply the non-Class 1E DCIS loads. This load group's non-Class 1E UPS is normally powered from a 480 VAC double-ended power center, which can receive power from either of the two power load groups. The power center normal and alternate source main breakers are electrically interlocked to prevent the normal and alternate sources from simultaneously providing power to the power center. Additionally, standby on-site AC power from either of the two load groups provides backup power should a failure of the normal and alternate supplies occur. Emergency power of the same load group from 250 VDC batteries is provided should loss of normal, alternate, and standby on-site AC power sources occur.

Two dedicated non-Class 1E UPS are provided for the Technical Support Center (TSC), also in a two-load group configuration. Power for each TSC non-Class 1E UPS is normally supplied from a 480 VAC power center in the same load group, with standby on-site AC power of the same load group providing backup power should a failure of the normal supply occur. Emergency power of the same load group from 125 VDC batteries is provided should loss of normal and standby on-site AC power sources occur.

The non-Class 1E UPS provides reliable, uninterruptible AC power for important nonsafety-related equipment required for continuity of power plant operation. Each non-Class 1E UPS load group includes a solid-state inverter, solid-state transfer switch, manual transfer switch, and distribution transformers with associated distribution panels (Figure 8.1-5).

The normal power supply for each load group of the non-Class 1E UPS is through a non-Class 1E 480 VAC power center, with backup power provided by the standby on-site AC power supply system PIP bus of the same load group. In case of failure of the 480 VAC power supply, transfer from the 480 VAC power center to the non-Class 1E 250 VDC bus is automatic and passive. Transfer from the normal AC power source through the inverter to the alternate AC power source occurs by automatic transfer should an inverter failure occur. An alarm in the main control room sets off when an alternate lineup of the non-Class 1E UPS occurs.

The 480VAC power centers, which provide power to the non-Class 1E battery chargers, are connected to PIP nonsafety-related buses that are backed up by standby diesel generators.

8.3.1.1.4 Instrumentation and Control Power Supply System

Figure 8.1-6 shows the overall Instrumentation and Control Power Supply System.

Regulating step-down transformers provide 208/120VAC power to those loads not requiring uninterruptible power. The non-vital AC control power buses are shown in Figure 8.1-6. The Instrumentation and Control buses are each supplied independently from separate 480VAC power centers.

Four of these Instrumentation and Control (I&C) buses power Class 1E I&C loads, and they are supplied independently from isolation power centers A31, B31, C31 and D31. These provide an alternative power source to certain Class 1E Distributed Control and Information System (E-DCIS) equipment.

Other instrumentation and control buses are supplied from the DCIS SWING BUS power center to supply non-Class 1E I&C loads. This system supplies AC loads of the Non-Essential Distributed Control and Information System (NE-DCIS), solenoid valves and other I&C loads.

The Instrumentation and Control Power Supply System does not perform any safety function

8.3.1.1.5 Class 1E Electric Equipment Considerations

The following guidelines are utilized for Class 1E equipment.

Physical Separation and Independence:

- Electrical equipment is separated in accordance with IEEE Standard 384, Regulatory Guide 1.75 and General Design Criterion 17.
- To meet the provisions of Policy Issue SECY-89-013, which relates to fire tolerance, 3 hour rated fire barriers are provided between areas of different safety-related divisions throughout the plant except in the primary containment and the control room complex. Refer to Subsection 9.5.1 for a description of how the provisions of the policy issue are met.
- The overall design objective is to locate the divisional equipment and its associated control, instrumentation, electrical supporting systems, and interconnecting cabling such that separation is maintained among all divisions. Redundant divisions of electric equipment and cabling are located in separate rooms or fire areas wherever possible.
- Electric equipment and wiring for the Class 1E systems which are segregated into separate divisions are separated so that no design basis event is capable of disabling more than one division of any engineered safety feature (ESF) total function.
- The safety-related electrical equipment (MCCs, batteries, distribution panels, etc.) are located in separate seismic Category I rooms in the reactor building to ensure electrical and physical separation among the divisions. Separation is provided among divisional cables being routed between various equipment rooms, the main control room, containment, and other processing areas. Separation of safety-related equipment in these areas is achieved by separate safety-related structures, barriers, or a combination thereof. The equipment is located to facilitate divisional separation of cable trays and to provide access to electrical penetration assemblies. Exceptions to this separation objective are identified and analyzed as to equivalency and acceptability in the fire hazard analysis (see Section 9A.6 Special Cases). For separation requirements relating to the main control room and relay room panels, refer to "Main Control Room and Relay Room Panels" in Subsection 8.3.1.4.
- For separation requirements relating to the wiring and components within control, relay, and instrument panels/racks, refer to "Control, Relay, and Instrument Panels/Racks" in Subsection 8.3.1.4

- For additional separation requirements relating to RPS and ESF systems refer to “System Separation Requirements” in Subsection 8.3.1.4. Containment electrical penetrations are dispersed around the periphery of the containment and are physically separated in accordance with the requirements of Section 6.5 of IEEE 384. Each penetration carries circuits of a single voltage class and division. Penetrations serving safety-related loads are not used for nonsafety-related circuits and are only used for circuits belonging to the same safety-related division.
- Wiring for all Class 1E equipment indicating lights is an integral part of the Class 1E cables used for control of the same equipment and are considered to be Class 1E circuits.
- Associated cables are treated as Class 1E circuits and routed in their corresponding divisional raceways. Separation requirements are the same as for Class 1E circuits. Associated cables shall be identified and justified per Subsection 8.3.4.6.

Class 1E Electric Equipment Design Bases and Criteria:

- Motors are sized in accordance with National Electrical Manufacturers’ Association (NEMA) standards. The manufacturers' ratings are large enough to produce the starting, pull-in and driving torque required by the driven load under normal running, runout, or discharge valve or damper closed condition.
- Plant design specifications for electrical equipment require such equipment be capable of continuous operation with equipment terminal voltage fluctuations of plus or minus 10% of rated, and be capable of accelerating their loads as required with a minimum of 80% rated terminal voltage.
- Motor starting torque is capable of starting and accelerating the connected load to normal speed within sufficient time to perform its safety function for all expected operating conditions.
- Power sources, distribution systems, and branch circuits are designed to maintain voltage and frequency within acceptable limits.
- The selection of motor insulation such as Class F, H or B is a design consideration based on service requirements and environment. All Class 1E motors are qualified by tests in accordance with IEEE Standard 334.
- Interrupting capacity of motor control centers and distribution panels is at least equal to the maximum available fault current to which it is exposed to under all modes of operation. Circuit breaker and applications are in accordance with ANSI Standards. (Refer to Subsection 8.3.4.1 for COL applicant/licensee items.)

Testing:

The design provides for periodically testing the chain of system elements from sensing devices through driven equipment to ensure that Class 1E equipment is functioning in accordance with design requirements, and to ensure the requirements of Regulatory Guide 1.118 and IEEE 338 are met.

8.3.1.1.6 Circuit Protection

Philosophy of Protection

Simplicity of load grouping facilitates the use of conventional, protective relaying practices for isolation of faults. Emphasis has been placed on preserving function and limiting loss of Class 1E equipment function in situations of power loss or equipment failure.

Circuit protection of the Class 1E buses contained within the nuclear island is interfaced with the design of the overall protection system outside the nuclear island.

Protective relay schemes and direct acting trip devices on primary and backup circuit breakers are provided throughout the on-site power system to:

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

Grounding

The medium voltage (13.8 kV and 6.9 kV) system is low resistance grounded except that each standby on-site AC power source is high resistance grounded to maximize availability.

The low voltage (480V and lower) AC system is solidly grounded.

Bus Protection

Bus protection is as follows:

- The 13.8 kV and 6.9 kV bus incoming circuits have inverse-time overload, ground fault, bus differential and undervoltage protection;
- The 13.8 kV and 6.9 kV feeders for power centers have instantaneous, inverse-time overload and ground fault protection;
- The 13.8 kV and 6.9 kV motor feeders have instantaneous, inverse-time overload and ground fault protection;
- The 480V feeders for MCC buses have long-time and short-time overload and ground fault protection;
- The 480V Isolation Power Center buses have inverse-time overload and ground fault protection. In addition, low voltage and frequency relay protective functions are provided which isolate these buses from the non-Class 1E system upon degraded source conditions; and
- The 480V MCC loads have instantaneous and inverse time overload protection.

See Subsection 8.3.4.2 for COL applicant\licensee items.

Protection Requirements

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

8.3.1.1.7 Load Shedding and Sequencing on PIP Buses

Load shedding, bus transfer and sequencing on the 6.9 kV PIP buses is initiated on loss of bus voltage. Only loss of preferred power (LOPP) signals are used to trip the loads.

Diesel Generators are sized conservatively to accommodate expected loads to be served by them with an acceptable starting sequence. Details of loads and starting sequences will be established during the COL phase (see Subsection 8.3.4.3 for COL applicant/licensee items).

Load shedding and bus ready-to-load signals are generated by the control system for the Electric Power Distribution System. Individual timers for each required load are reset and started by their Electric Power Distribution Systems signals.

LOPP

The 6.9 kV PIP buses are normally energized from the normal preferred power supply. When the normal preferred power supply is lost, a fast transfer from the normal preferred power supply to the alternative preferred power supply is done.

Should the bus voltage decay to below 70% of its nominal rated value for a predetermined time a standard dead bus transfer is automatically initiated to the standby on-site AC power source. The signal trips the supply breaker, starts the standby on-site AC power source, and closes the standby power supply breaker after the standby on-site AC power source has returned a ready to load signal (i.e., voltage and frequency are within normal limits and no lockout exists, and the normal and alternate preferred supply breakers are open). As the bus voltage decays, large pump motor breakers are tripped and low voltage motor starters are opened because of undervoltage. After bus voltage has been reestablished, large motor loads are sequence started as required. Transfer back to the preferred source is done manually.

Loss-of-Coolant Accident (LOCA)

When a LOCA occurs, with or without a LOPP, the load sequence timers are started if the 6.9 kV PIP bus voltage is greater than 70% and loads are applied to the bus at the end of preset times.

Each load has an individual load sequence timer that starts if a LOCA occurs and the 6.9 kV PIP bus voltage is greater than 70%, regardless of whether the bus voltage source is normal preferred power, alternate preferred power or the standby on-site AC power source. The load sequence timers are part of the low level circuit logic for each LOCA load and do not provide a means of common mode failure that would render both on-site and off-site power unavailable. If a timer fails, the LOCA load could be applied manually provided the bus voltage is greater than 70%.

LOPP Following LOCA

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

LOCA Following LOPP

If a LOCA occurs following loss of the normal and alternate preferred power supplies, the LOCA signal starts the standby on-site AC power source if not already started from low bus voltage. Automatic load sequencing assures that the standby diesel generator will not be overloaded.

LOCA When the Standby On-site AC Power Source is parallel to the Power Source During Testing.

If a LOCA occurs when the standby diesel generator is paralleled with either the normal preferred power or the alternate preferred power source, the standby diesel generator automatically disconnects from the 6.9 kV PIP bus regardless of whether the test is being conducted from the local control panel or the main control room. Loads are applied as described in (2) above.

LOPP During Standby On-site Power Source Paralleling Test

If the normal preferred power supply is used for load testing the standby on-site AC power source and is lost during the standby on-site AC power source paralleling test, the normal preferred power supply breaker is automatically tripped and the standby on-site AC power source continues to power the bus loads. Transfer to the normal or alternate preferred power supply may then be accomplished manually.

If the alternate preferred supply is used for load testing the standby on-site AC power source, and the alternate preferred source is lost, the alternate preferred power supply breaker is automatically tripped and the standby on-site AC power source continues to power the bus loads. Transfer to the normal or alternate preferred power supply may then be accomplished manually.

Restoration of Off-Site Power

Upon restoration of off-site power, the 6.9 kV PIP buses can be transferred back to the off-site source by manual operation only.

Protection Against Degraded Voltage

For protection of the PIP buses against the effects of a sustained degraded voltage condition, the 6.9 kV PIP bus voltages are monitored. When the bus voltage degrades to 90% or below of its rated value for a predetermined time (to prevent triggering by transients), the undervoltage is annunciated in the control room. Simultaneously a 5-minute timer is started, to allow the operator to take corrective action. After 5 minutes, the respective feeder breaker with the undervoltage is tripped. Should a LOCA occur during the 5-minute time delay, the power supply breaker with the undervoltage is tripped instantly. Subsequent bus transfer is described above.

See Subsection 8.3.4 for COL items.

8.3.1.1.8 Standby On-site AC Power Supply System[EAE61]

The standby AC power supply system is not within the ESBWR 10 CFR 50.2 Design Bases, is not relied upon to perform any safety-related function, and thus, is classified as nonsafety-related. It includes the standby on-site AC power sources and associated power supply circuits up to the source breakers of the on-site PIP buses to which they are connected.

The standby on-site AC power sources consist of the prime movers and AC generators, the auxiliary systems (starting, lubrication, cooling, fuel supply, excitation, etc.), the fuel storage and transfer systems and the associated local instrumentation and control systems.

The on-site standby AC power supply system is designed to supply AC power to the PIP nonsafety-related buses. The PIP buses provide power for various auxiliary and investment protection load groups, and isolation power centers when the normal and alternate preferred power supplies are not available. Operation of the system is not required to ensure nuclear safety.

Figure 8.1-1 shows the interconnections between the preferred power sources, alternate preferred power sources, and the standby on-site AC power sources.

Redundant (nonsafety) Standby AC Power Supplies

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

Ratings and Capability

Each of the standby on-site AC power sources is sized to serve its load and conforms to the following criteria:

- Each standby on-site AC power source is capable of starting, accelerating, and supplying its loads in the sequence necessary for plant investment protection.
- Each standby on-site AC power source is capable of starting, accelerating, and supplying its loads in their proper sequence without exceeding a 20% voltage drop at its output terminals.
- Each standby on-site AC power source is capable of starting, accelerating and running its largest motor at any time after the automatic loading sequence is completed, assuming that the motor had failed to start initially.
- Each standby on-site AC power source is capable of reaching full speed and voltage within 1 minute after receiving a signal to start, and capable of being fully loaded within the next 600 seconds [EAE62].
- Each standby on-site AC power source has a short-term power rating greater than the sum of the loads of its load group of PIP loads and safety-related battery chargers that could be powered concurrently during hot standby, normal plant cooldown, or plant outages.
- Each standby on-site AC power source is capable of recovering from a load step 110% greater than the most severe load step in its profile, as follows:
  - Voltage and frequency at no time drop below 80 and 95% of nominal, respectively;
  - Voltage and frequency are restored to within 10 and 20%, respectively, in no more than 60% of the planned load sequence time interval.

- Each standby on-site AC power source is capable of load rejection up to its maximum short time power rating without exceeding either 75% of the difference between the nominal speed and the over-speed trip set-point or 15% above nominal.
- Each standby on-site AC power source is capable of operating at no load for a minimum of 8 hours without detrimental effects on subsequent operating performance at full or partial load.
- Each standby on-site AC power source is capable of operating without an external cooling supply for a minimum of 3 minutes at no load and for 1 minute at full load during its normal operation.
- Each standby on-site AC power source is provided with a backup mechanical-hydraulic portion of the governor designed to provide full speed control for startup and normal operation in case of failure of the electronic portion.

Refer to Subsection 8.3.4 3 for COL applicant/licensee items.

Starting Circuits and Systems

The standby on-site AC power sources start automatically on loss of bus voltage. Undervoltage relays are used to start each standby on-site AC power source in the event of a drop in bus voltage below preset values for a predetermined period of time.

Upon loss of preferred AC power to the PIP buses the transfer of these buses to the standby on-site AC power sources is automatic as described in Subsection 8.3.1.1.7. After the breakers connecting the buses to the preferred power supply (or alternate preferred power supply, depending upon system configuration) are opened and when the required standby on-site AC power source generator voltage and frequency are established the standby on-site AC power source breaker is closed.

The standby on-site AC power sources are designed to start and attain rated voltage and frequency within 1 minute of receiving a start signal. The generator and voltage regulator are designed to permit the generating unit to accept the load and to accelerate the motors in the sequence within the time requirements. The voltage drop caused by starting the large motors does not exceed the requirements set forth in Subsection 8.3.1.1.8 Ratings and Capability. Control and timing circuits are provided, as appropriate, to ensure that each load is applied automatically at the correct time.

Automatic Shedding, Loading and Isolation

The standby on-site AC power source is connected to its PIP bus only when the incoming preferred or alternate preferred source breakers have been tripped (Subsection 8.3.1.1.7). Under this condition, major loads are tripped from the 6.9 kV PIP bus, except for the 480V power center feeders, before closing the standby on-site AC power source breaker.

The large motor loads are then reapplied sequentially and automatically to the bus after closing of the standby on-site AC power source breaker.

Protection Systems

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

- Generator overspeed trip; and
- Generator differential relay trip.

These and other protective functions (alarms and trips) of the standby on-site AC power source or the generator breaker and other off-normal conditions are annunciated in the main control room and/or locally as shown in Table 8.3-1. Local alarm/annunciation points have auxiliary isolated switch outputs which provide inputs to alarm/annunciator refresh units in the main control room that identify the standby on-site AC power source and the anomaly concerned. Those anomalies, which cause the respective standby on-site AC power source and/or generator to become inoperative, are so indicated in accordance with Regulatory Guide 1.47 and BTP PSB-2.

Local and Remote Control

Each standby on-site AC power source is capable of being started or stopped manually from the main control room. Start/stop control and bus transfer control may be transferred to a local control station in the standby on-site AC power source room by operating key switches at the local station.

Engine Mechanical Systems and Accessories

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

Interlocks and Testability

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

When the plant is in cold shutdown conditions, the on-site standby power supply system can also be used to supply plant power during maintenance of the off-site power supply system.

8.3.1.2 Analysis

8.3.1.2.1 General Design Criteria and Regulatory Guidance Compliance

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

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

GDC 2, Design Basis for Protection Against Natural Phenomena

GDC 4, Environmental and Dynamic Effects Design Bases

The requirements of the GDC 2 and 4 are met, in that all components of the Class 1E power system are housed in seismic Category I structures designed to protect them from natural phenomena. These components have been qualified to the appropriate seismic, hydrodynamic, and environmental conditions as described in Chapter 3.

GDC 17, Electric Power Systems

The requirements of GDC 17 are met, in that an on-site electric power system is provided to permit the functioning of safety-related structures, systems and components. With total loss of off-site power, the on-site power system provides sufficient capacity and capability to ensure that:

- Specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of anticipated operational occurrences.
- The core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents.

Section 3.2 contains a list of safety-related structures, systems, and components. The on-site electric power system includes four redundant load divisions. Sufficient independence is provided between redundant load divisions to ensure that postulated single active failures affect only a single load division and are limited to the extent of total loss of that load division. The remaining redundant load divisions provide for the measures stated above.

During a total loss of off-site power, the Class 1E system is automatically powered from the on-site nonsafety-related standby diesel generators. If, however, these standby diesel generators are not available, each division of the Class 1E system independently isolates itself from the non-Class 1E system, and power to safety-related loads of each safety-related load division is provided uninterrupted by the Class 1E batteries of each division. Divisions 1 and 2 each have a Class 1E 24-hour and 72-hour battery, and Divisions 3 and 4 each have a Class 1E 24-hour battery. The divisional batteries are sized to provide power to required loads for a minimum of 24 or 72 hours, depending on the division and the load requirement, without the need for recharging.

In addition, each division of the Class 1E system is protected by devices that monitor the input voltage and frequency from the non-Class 1E system, and automatically isolate the division on degraded conditions.

The combination of these factors in the design minimizes the probability of losing electric power from on-site power supplies as a result of the loss of power from the transmission system or any disturbance of the non-Class 1E AC system.

The on-site power distribution system is normally powered from the main generator through the main transformer during normal operation and following a separation of the plant from the transmission system without a turbine trip. Therefore, the loss of the transmission system does not affect the ability of the main generator or the on-site power supplies to provide power to the Class 1E system.

Following a turbine trip, the turbine-generator is automatically isolated from the plant and transmission system by the generator circuit breaker. This allows the plant auxiliary loads to be powered continuously and unswitched throughout plant startup, normal operation, and normal or emergency shutdown. Therefore, the loss of the main generator does not affect the ability of the transmission system or the on-site power supplies to provide power to the Class 1E system.

GDC 18, Inspection and Testing of Electric Power Systems

The Class 1E system is designed to permit the following:

- during equipment shutdown, periodic inspection and testing of wiring, insulation, connections, and the condition of components;
- during normal plant operation, periodic testing of the operability and functional performance of on-site power supplies, circuit breakers, and their associated control circuits, relays, and buses; and
- during plant shutdown, testing of the operability of the Class 1E system as a whole. Under conditions, as close to design as practicable, the full operational sequence that brings the system into operation, including operation of signals of the safety-related systems and the transfer of power between off-site and on-site power system, is tested.

GDC 50, Containment Design Basis

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

8.3.1.2.2 Quality Assurance Requirements

The Quality Assurance program is provided in Chapter 17. This program includes a comprehensive system to ensure that the purchased material, manufacture, fabrication, testing, and quality control of the equipment in the emergency electric power system conforms to the evaluation of the emergency electric power system equipment vendor Quality Assurance programs and preparation of procurement specifications incorporating quality assurance requirements. The administrative responsibility and control provided are also described in Chapter 17.

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

A necessary condition for receipt, installation and placing of equipment in service has been the sighting and auditing of Quality Assurance/Quality Control (QA/QC) verification data and the placing of this data in permanent on-site storage files.

8.3.1.2.3 Environmental Considerations

In addition to the effects of operation in normal service environment, all Class 1E equipment is designed to operate during and after any design basis event, in the area in which it is located. All Class 1E electric equipment is qualified to IEEE 323. Detailed information on all Class 1E equipment that must operate in a hostile environment during and/or subsequent to an accident is provided in Section 3.11.

8.3.1.3 Physical Identification of Safety-Related Equipment

8.3.1.3.1 Power, Instrumentation and Control Systems

Electrical and control equipment, panels and racks, and cables and raceways grouped into separate divisions are identified so that their electrical divisional assignment is apparent, and so that an observer can visually differentiate between Class 1E equipment and wiring of different divisions, and between Class 1E and non-Class 1E equipment and wiring. The identification method is color coding. All markers within a division have the same color. For associated cables (if any) treated as Class 1E,[1] there will be an identification criterion to identify them as associated cables and to which division they are associated. The identification criterion will allow associated circuits to be differentiated from Class 1E circuits. Divisional separation requirements of individual pieces of hardware are shown in the system elementary diagrams. Identification of raceways, cables, etc., is compatible with the identification of the Class 1E equipment with which it interfaces. Location of the identification is such that points of change of circuit classification (at isolation devices, etc.) are readily apparent (Refer to Subsection 8.3.4.6 for COL information).

Equipment Identification

Equipment (panels, racks, junction or pull boxes) of each division of the Class 1E electric system are identified as follows:

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

Cable Identification

All cables for Class 1E systems and circuits (except those routed in conduits) are tagged every 1.5 m (5 ft) prior to (or during) installation. All cables are tagged at their terminations with a unique identifying number (cable number), in addition to the marking characteristics shown below.

All Class 1E cables are marked in a manner of sufficient durability to be legible to facilitate initial verification that the installation is in conformance with the separation criteria.

Such markings are colored to uniquely identify the division (or non-division) of the cable. Generally, individual conductors are also color-coded or color-tagged at intervals not exceeding 30cm (12 in.) so that their division is discernible. Within cabinets or panels with circuits of more than one division, individual conductors are color-coded or color-tagged at intervals not exceeding 30cm (12 in.) so that the division they belong to is clearly discernible. Any non-

[1] Associated circuits added beyond the certified design must be specifically identified and justified per Subsection 8.3.4.6. Associated circuits are defined in Subsection 5.5.1 of IEEE 384, with the clarification for items (3) and (4) that non-Class 1E circuits being in an enclosed raceway without the required physical separation or barriers between the enclosed raceway and the Class 1E or associated cable(s) makes the circuits (related to the non-Class 1E cable in the enclosed raceway) associated circuits.

divisional cable within such cabinets is appropriately marked to distinguish it from the divisional cables.

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

Type of Special Cables	Unique Voltage Class
Neutron monitoring	VN
Scram solenoid cables	VS

Raceway Identification

All conduit is similarly tagged with a unique conduit number, in addition to the marking characteristics shown below, at 4.5m (15 ft) intervals, at discontinuities, at pull boxes, at points of entrance and exit to rooms, and at origin and destination of equipment. Conduits containing cables operating at voltages above 600V (i.e., 6.9 kV) are also tagged to indicate the operating voltage. These markings are applied prior to the installation of the cables.

All Class 1E cable trays are marked with the division color, and with the their raceway identification at 4.5m (15 ft) intervals on straight sections, at turning points and at points of entry and exit of enclosed areas. Cable trays are marked prior to the installation of cables.

Neutron monitoring cables, local power range monitor cables and startup range neutron monitor cables [EAE63]are run in their own divisional conduits and cable trays, separately from all other power, instrumentation and control cables. Scram solenoid cables are run in a separate conduit for each rod scram group.

Redundant Class 1E equipment and circuits, assigned to redundant Class 1E divisions, are readily distinguishable from each other and non-Class 1E system equipment and circuits without the necessity for consulting reference materials. This is accomplished by color coding of equipment, nameplates, cables, and raceways, as described above.

Sensory Equipment Grouping and Designation Letters

Redundant sensory logic/control and actuation equipment for safety-related systems shall be identified.

8.3.1.4 Independence of Redundant Systems

8.3.1.4.1 Power Systems

The Class 1E on-site electric power systems and major components of the separate power divisions are shown in Figure 8.1-3 and 8.1-4.

Independence of the electric equipment and raceway systems, between the different divisions, is maintained primarily by firewall-type separation, where feasible, and by spatial separation, in accordance with criteria given in Subsection 8.3.1.4.1 Class 1E Electric Equipment Arrangement. Exceptions are analyzed in Subsection 9A.6.4.

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

The physical independence of electric power systems complies with the requirements of IEEE Standards 308, 379, 384, 603 GDC 17 and 18 and NRC Regulatory Guides 1.6 and 1.75.

Class 1E Electric Equipment Arrangement

Class 1E electric equipment and wiring are segregated into separate divisions so that no single credible event is capable of disabling enough equipment to hinder reactor shutdown, removal of decay heat from the core, or isolation of the containment in the event of an accident. Separation requirements are applied to control power and motive power for all systems involved.

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

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

An independent raceway system is provided for each division of the Class 1E electric system. The raceways are arranged, physically, top to bottom, as follows (based on the function and the voltage class of the cables):

V3 = Low voltage power including 480 VAC, 120 VAC, 250 VDC power and all instrumentation and control power supply feeders (600V insulation class).

V2 = High level signal and control, including 250 VDC and 120 VAC controls which carry less than 20 amps current and 250 VDC or AC for relay contacter control.

V1 = Low level signal and control, including fiber optic cables, and metallic cables with analog signals up to 55 VDC and digital signals up to 12 VDC.

Electric Cable Installation

Cable derating and cable tray fill — Base ampacity rating of cables is established as described in Subsection 8.3.3.2. Electric cables of a discrete Class 1E electric system division are installed in a cable tray system provided for the same division. Cables are installed in trays in accordance with their voltage ratings and as described in Subsection 8.3.1.4.1. Tray fill is as established in Subsection 8.3.3.2.

Cable routing in potentially harsh environmental areas — Circuits of different safety-related divisions are not routed through the same potentially harsh environmental area, with the exception of main steam line instrumentation and control circuits and main steam line isolation valves circuits, which are exposed to possible steam line break and turbine missiles, respectively. Cable routing in the drywell is discussed in association with the equipment it serves in Section 9A.5.

Sharing of cable trays — All divisions of Class 1E AC and DC systems are provided with independent raceway systems.

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

Cable and raceway markings — All cables (except lighting and non-vital communications) are tagged at their terminations with a unique identifying number. The marking of cables and raceways for divisional identification is discussed in Subsection 8.3.1.3.

Spacing of wiring and components in control boards, panels and relay racks — Separation is accomplished by mounting the redundant devices or other components on physically separated control boards if, from a plant operational point of view, this is feasible. When operational design dictates that redundant equipment be in close proximity, separation is achieved by a barrier or enclosure to retard internal fire or by a maintained air space in accordance with criteria given in Subsection 8.3.1.4.1 Class 1E Electric Equipment Arrangement.

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

Electric penetration assembly — Electric penetration assemblies of different Class 1E divisions are separated by 3-hour rated fire barriers, separate rooms and/or locations on separate floor levels. Separation by distance without barriers is allowed only in the inerted containment. Separation between divisional and non-divisional penetrations is in accordance with IEEE 384. Grouping of circuits in penetration assemblies follows the same raceway voltage groupings as described in Subsection 8.3.1.4.1 Class 1E Electric Equipment Arrangement.

Redundant overcurrent interrupting devices are provided for all electrical circuits going through containment penetrations, if the maximum available fault current (including failure of upstream devices) is greater than the continuous rating of the penetration. This avoids penetration damage in the event of failure of any single overcurrent device to clear a fault within the penetration or beyond it. Refer to Subsection 8.3.4.7 for COL applicant/license items.

Control of Compliance with Separation Criteria During Design and Installation

Compliance with the criteria that ensure independence of redundant systems is a supervisory responsibility during both the design and installation phases. The responsibility is discharged by:

- identifying applicable criteria;
- issuing working procedure to implement these criteria;
- modifying procedures to keep them current and workable;
- checking the manufacturer's drawings and specifications to ensure compliance with procedures; and
- controlling installation and procurement to assure compliance with approved and issued drawings and specifications.

The equipment nomenclature used on the ESBWR standard design is one of the primary mechanisms for ensuring proper separation. Each equipment and/or assembly of equipment carries a single number (e.g., the item numbers for motor drivers are the same as the machinery driven). Based on these identification numbers, each item can be identified as safety-related or nonsafety-related, and each safety-related item can further be identified to its division. This is carried through and dictates appropriate treatment at the design level during preparation of the manufacturer's drawings. Non-Class 1E equipment is separated where desired to enhance power generation reliability, although such separation is not a safety consideration.

Once the safety-related equipment has been identified with a Class 1E safety-related division, the divisional assignment dictates a characteristic color (Subsection 8.3.1.3) for positive visual identification. Likewise, the divisional identification of all ancillary equipment, cable and raceways matches the divisional assignment of the system it supports.

Independence of Redundant Safety-Related Instrumentation and Control Systems

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

General

Separation of the equipment for the safety-related systems referred to in Chapter 7 is accomplished so that they are in compliance with IEEE 603, 10 CFR 50 Appendix A, GDC 3 and 17, and NRC Regulatory Guides 1.75 (IEEE 384) and 1.53 (IEEE 379).

Independence of mutually redundant and/or diverse Class 1E equipment, devices, and cables is achieved by 3-hour rated fire barriers and electrical isolation. This protection is provided to maintain the independence of nuclear safety-related circuits and equipment so that the protective function required during and following a design basis event including a single fire anywhere in the plant or a single active failure in any circuit or equipment can be accomplished. The exception to this are the cases which are analyzed in Section 9A.6.

Separation Techniques

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

Safety Class Structure — The basic design consideration of plant layout is such that redundant circuits and equipment are located in separate safety-related areas and fire areas insofar as possible. The separation of Class 1E circuits and equipment is such that the required independence is not compromised by the failure of mechanical systems served by the Class 1E electrical system. For example, Class 1E circuits are routed or protected so that failure of related mechanical equipment of one system cannot disable Class 1E circuits or equipment essential to the operation of a redundant system.

Spatial Separation and/or Protective Barriers — Spatial (distance) separation and/or protective barriers shall be such that no locally generated force or missile resulting from a design basis event (DBE) or from random failure of equipment can disable a safety-related function.

Separation in all safety-related equipment and cable areas shall equal or exceed the requirements of IEEE 384. The exceptions to this are the cases analyzed in Section 9A.6.

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

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

(1) Certain operator interface control panels may have operational considerations that dictate that redundant protection system or ESF system circuits or devices be located in a single panel. These circuits and devices are separated horizontally and vertically by the minimum distance required in IEEE 384 Subsection 6.6.2, or by steel barriers or enclosures.

(2) Class 1E circuits and devices are also separated from the non-Class 1E circuits and devices that are present inside a panel. These circuits and devices are separated from each other horizontally and vertically by the minimum distance required in IEEE Subsection 6.6.2, or by steel barriers or enclosures.

(3) Where electrical interfaces between Class 1E and non-Class 1E circuits or between Class 1E circuits of different divisions cannot be avoided, Class 1E isolation devices are used (see Subsection 8.3.1.4.).

(4) If two panels containing circuits of different separation divisions are less than 91.5 cm (3 ft) apart, there is a steel barrier between the two panels. Panel ends closed by steel end plates are considered to be acceptable barriers provided that terminal boards and wireways are spaced a minimum of 2.5 cm (1 inch) from the end plate.

(5) Penetration of separation barriers within a subdivided panel is permitted, provided such penetrations are sealed or otherwise treated so that fire generated by an electrical fault could not reasonably propagate from one section to the other and disable a protective function.

(6) If two or more divisions of fiber optic cable are brought to a fiber bypass switch separation shall not be necessary in the immediate vicinity of the switch

Isolation Devices — Where electrical interfaces between Class 1E and non-Class 1E circuits or between Class 1E circuits of different divisions cannot be avoided, Class 1E isolation devices are used. Isolation is provided by the isolation devices defined in IEEE Section 7.

Wiring from Class 1E equipment or circuits which interface with non-Class 1E equipment circuits (i.e., annunciators or data loggers) is treated as Class 1E and retains its divisional identification up to and including its isolation device (usually fiber optic). The output circuits from this isolation device are classified as non-Class 1E and shall be physically separated from the Class-1E wiring.

System Separation Requirements

The separation requirements pertaining to the RPS and ESF systems are given in the following subsections.

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

(1) RPS sensors, sensor input circuit wiring, trip channels, and trip logic equipment are arranged in four functionally independent and divisionally separate groups designated Divisions 1, 2, 3 and 4. The trip channel wiring associated with the sensor input signals for each of the four divisions provides inputs to divisional logic cabinets which are in the same divisional group as the sensors and trip channels and which are functionally independent and physically separated from the logic cabinets of the redundant divisions.

(2) Where trip channel data originating from sensors of one division are required for coincident trip logic circuits in other divisions, Class 1E isolation devices are used as interface elements for signals sent from one division to another such as to maintain electrical isolation between divisions.

(3) Sensor wiring for several trip variables associated with the trip channels of one division may be run together in the same conduits or in the same raceways of that same and only division. Sensor wiring associated with one division is not routed with, or in close proximity to, any wiring or cabling associated with a redundant division.

(4) The scram solenoid circuits, from the actuation devices to the solenoids of the scram pilot valves of the CRD hydraulic control units, are run in grounded steel conduits, with no other wiring contained within the conduits, so that each scram group is protected against a hot short to any other wiring by a grounded enclosure. Short sections [less than 1 m (3.28 ft)] of flexible metallic conduit are permitted for making connections within panels and the connections to the solenoids.

(5) Separate grounded steel conduits are provided for the scram solenoid wiring for each of four scram groups. Separate grounded steel conduits are also provided for both the A solenoid wiring circuits and for the B solenoid wiring circuits of the same scram group.

(6) Scram solenoid conduits have a unique identification and are separately routed as Division 1 and 2 conduits for the A and B solenoids of the scram pilot valves, respectively. This corresponds to the divisional assignment of their power sources. The conduits containing the scram solenoid group wiring of any one scram group are also be physically separated by a minimum separation distance of 2.5 cm (1 in.) from the conduits of any other scram group, and from raceways which contain either divisional or non-divisional circuits. The scram group conduits are not routed within the confines of any other raceway. The RPS conduits containing the scram group wiring for the A and B solenoids of the scram pilot valves (associated with Divisions 1 and 2, respectively) are separated from non-enclosed raceways associated with any of the four electrical divisions or non-divisional cables in accordance with IEEE 384 and Regulatory Guide 1.75.

(7) Any scram group conduit may be routed alongside any cable or raceway containing either safety-related circuits (of any division), or any cable or raceway containing nonsafety-related circuits, as long as the conduit itself is not within the boundary of any raceway

which contains either the divisional or the nonsafety-related circuits and is physically separated from said cables and raceway boundaries as stated in item (6) above. Any one scram group conduit may also be routed along with scram group conduits of any of the three other scram groups as long as the minimum separation distance of 2.5 cm (1 in.) is maintained.

(8) The startup range neutron monitoring (SRNM) subsystem cabling of the Neutron Monitoring System (NMS) cabling under the vessel is treated as divisional. The SRNM cables are assigned to Divisions 1, 2, 3 and 4. Under the vessel, cables are enclosed as described in Subsection 9A.6.4.

Other Safety-Related Systems

(1) Separation of redundant systems or portions of a system is such that no single active failure can prevent initiation and completion of a safety-related function.

(2) The Standby Liquid Control system redundant Class 1E controls are run as Division 1 and Division 2 so that no failure of standby liquid control function results from any single electrical failure.

(3) Inboard and outboard isolation valves are redundant to each other so they are made independent of and protected from each other to the extent that no single active failure can prevent the operation of at least one of an inboard/outboard pair.

(4) Isolation valve circuits require special attention because of their function in limiting the consequences of a pipe break outside the primary containment. Isolation valve control and power circuits are required to be protected from the pipe lines that they are responsible for isolating.

Safety-related isolation valve wiring in the vicinity of the outboard (downstream) valve is installed in conduits and routed to take advantage of the mechanical protection afforded by the valve operator or other available structural barriers not susceptible to disabling damage from the pipe line break. Additional mechanical protection (barriers) is placed as necessary between wiring and potential sources of disabling mechanical damage consequential to a break downstream of the outboard valve.

(5) The two systems Automatic Depressurization System (ADS) and Gravity Driven Cooling System (GDCS) comprising the ECCS have their various sensors, logics, actuating devices and power supplies assigned to divisions, so that no single active failure can disable a redundant ECCS function.

a. The wiring to the ADS solenoid valves within the drywell is run in rigid conduits. The conduits for ADS solenoid A shall be divisionally separated from ADS solenoid B conduits and contain no other cable. Short lengths [less than 1 m (3.28 ft)] of flexible conduit are used to make the final raceway connection to the ADS valve solenoids.

b. The conduits for ADS depressurization valve booster assemblies are run in rigid conduits. The conduits are divisionally separated and contain only cable(s) associated with the depressurization valve booster assemblies. Short lengths [less than 0.6 m (2 ft)] of flexible conduit are used to make the final raceway connection to the depressurization valve booster assemblies.

c. The wiring to the GDCS squib valve initiators is run in rigid conduits. The conduits are divisionally separated and contain only cable(s) associated with the squib valve initiators. Short lengths [less than 1 m (3.28 ft)] of flexible conduit are used to make the final raceway connection to the GDCS squib valve initiators.

d. Electrical equipment and raceways for safety-related systems are either not located in close proximity to primary steam piping (steam leakage zone), or designed for short-term exposure to the high temperature and humidity associated with a steam leak.

e. Class 1E electrical equipment located in the suppression pool level swell zone is limited to the suppression pool temperature monitors, which have their terminations sealed such that operation would not be impaired by submersion caused by pool swell or LOCA. These devices are qualified to the requirements of IEEE 323 for the environment in which they are located.

f. Containment penetrations are arranged so that no design basis event can disable cabling in more than one division. Penetrations do not contain cables of more than one divisional assignment.

g. Annunciator and computer inputs from Class 1E equipment or circuits are treated as Class 1E and retain their divisional identification up through their Class 1E isolation device. The output circuit from this isolation device is classified as non-Class 1E.

(6) Annunciator and computer inputs from non-Class 1E equipment or circuits do not require isolation devices.

8.3.2 DC Power Systems

8.3.2.1 Description

Completely independent Class 1E (i.e., safety-related) and non-Class 1E (i.e., nonsafety-related) DC power systems are provided. The Class 1E DC system is shown in Figure 8.1-3. The non-Class 1E DC system is shown in Figure 8.1-2.

Four independent Class 1E 250 VDC systems are provided, one each for Divisions 1, 2, 3 and 4. They supply normal and emergency DC power for station emergency auxiliaries and for control and switching during all modes of operation.

Five independent non-Class 1E DC systems are provided consisting of three 250VDC systems and two 125 VDC systems. The non-Class 1E DC systems supply power for control and switching, switchgear control, TSC, instrumentation, and station auxiliaries.

Refer to Subsection 8.3.4.8 for COL applicant/licensee items.

8.3.2.1.1 Class 1E Station Batteries and Battery Chargers

250V Class 1E DC Systems Configuration

Figure 8.1-3 shows the overall 250 VDC system provided for Class 1E Divisions 1, 2, 3 and 4. Divisions 1 and 2 consists of two separate battery sets for each division. One set supplies power to selected safety loads for at least 72 hours following a licensing basis event, and the other set supplies power to other loads for a period of at least 24 hours without load shedding. ‘Divisions 3 and 4 each have one battery set which can supply loads for at least 24 hours without load shedding. The DC systems are operated ungrounded for increased reliability. Each of the Class 1E battery system has a 250 VDC battery, a battery charger a main distribution panel, and a ground detection panel. One divisional battery charger is used to supply each group DC distribution panel bus and its associated battery. The divisional battery charger is normally fed from its divisional 480V Isolation Power Center. The main DC distribution bus feeds the local DC distribution panels, UPS inverter, and DC motor control center. Each division has a standby charger to equalize the battery charging of that division.

The four safety-related divisions are supplied power from four independent Isolation Power Centers. The 250 VDC systems supply DC power to Divisions 1, 2, 3 and 4, respectively, and are designed as Class 1E equipment in accordance with IEEE Std 308 and IEEE 946 (Reference 8.3-1). The Class 1E DC system is designed so that no single active failure in any division of the 250 VDC system results in conditions that prevent safe shutdown of the plant.

The plant design and circuit layout of the DC systems provide physical separation of the equipment, cabling, and instrumentation essential to plant safety. Each 250VDC battery is separately housed in a ventilated room apart from its charger, distribution, and ground detection panels. Equipment of each division of the DC distribution system is located in an area separated physically from the other divisions. All the components of Class 1E 250 VDC systems are housed in Seismic Category I structures.

Class 1E Batteries

In divisions 1 and 2, there are two separate 250 volt Class 1E batteries rated for 72-hour and 24-hour station blackout conditions, respectively. In divisions 3 and 4, there are only 24-hour batteries. The DC system minimum battery terminal voltage at the end of the discharge period is 210 volts. The maximum equalizing charge voltage for Class 1E batteries is 280VDC.

The Class 1E batteries have sufficient stored capacity without their chargers to independently supply the safety-related loads continuously for the time periods stated above. Each distribution circuit is capable of transmitting sufficient energy to start and operate all required loads in that circuit. The batteries are sized so that the sum of the required loads does not exceed 80% of the battery ampere-hour rating, or warranted capacity at end-of-installed-life with 100% design demand. Batteries are sized for the DC load in accordance with IEEE Standard 485 (Reference 8.3-2). The battery banks are designed to permit the replacement of individual cells.

The Class 1E batteries meet the qualification requirements of IEEE 535 (Reference 8.3-3), and are installed in accordance with IEEE 484 (Reference 8.3-9).

Class 1E Battery Chargers

The Class 1E battery chargers are full wave, silicon-controlled rectifiers. The housings are freestanding, NEMA Type 1, and are ventilated. The chargers are suitable for float charging the batteries. The chargers operate from a 460 volt, 3 phase, 60 Hz supply. The power for each divisional battery charger is supplied by that division's dedicated Isolation Power Center. While the standby battery charger is used to equalize its associated battery off-line, the normal charger associated with that battery is utilized to provide power to its associated DC bus.

Standby chargers are supplied from the same Isolation Power Center as the normal charger.

Each battery charger is capable of recharging its battery from the design minimum charge to 95% of fully charged condition within 12 hours.

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

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

Ventilation

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

Inspection, Maintenance, and Testing

An initial composite test of the on-site DC power systems is called for as a prerequisite to initial fuel loading. This test verifies that each battery capacity is sufficient to satisfy a safety load demand profile under the conditions of a LOCA and loss of preferred power. Battery capacity tests are conducted in accordance with IEEE Std. 450. These tests ensure that the battery has the capacity to meet safety load demands.

In-service tests, inspections, and resulting maintenance of the DC power systems including the batteries, chargers, and auxiliaries are specified in the plant-specific Technical Specifications.

Station Blackout

The station blackout scenario (defined in 10 CFR 50.63, Regulatory Guide 1.155 and Appendix B to SRP 8.2) includes the complete loss of all off-site and on-site AC power, but not the loss of available AC power buses fed by station batteries through inverters, as with the ESBWR. The ESBWR 10 CFR 50.2 Design Bases rely upon battery power to achieve and maintain safe shutdown. The batteries are adequately sized for the station blackout loads. The Station Blackout evaluation is provided in Section 15.5.

8.3.2.1.2 Non-Class 1E Station Batteries and Battery Chargers

125V and 250V Non-Class 1E DC Systems Configuration

Figure 8.1-2 shows the overall 125V and 250V non-Class 1E DC systems. The DC systems are operated ungrounded for increased reliability. Each of the DC systems has battery, a battery charger, main DC distribution panel, and ground detection panel. The main DC distribution buses feed the local DC distribution panels, UPS inverter and/or DC motor control center.

The plant design and circuit layout of the non-Class 1E DC systems provide physical separation of the equipment, cabling and instrumentation associated with the load groups of non-Class 1E equipment. Each 125V and 250 VDC battery is separately housed in a ventilated room apart from its charger, distribution, and ground detection panels. Equipment of each load group of the DC distribution system is located in an area separated physically from the other load groups.

The non-Class 1E DC power is required for standby lighting, control and switching functions such as the control of 6.9 kV and 480V switchgear, DC motors, control relays, meters and indicators.

Non-Class 1E Batteries

The 125 volt non-Class 1E batteries are sized for 2-hour duty cycles at a discharge rate of 2 hours, based on a terminal voltage of 1.75 volts per cell at 25°C (77°F). The DC system minimum battery terminal voltage at the end of the discharge period is 105 volts. The maximum equalizing charge voltage for 125V batteries is 140 VDC.

The 250 volt non-Class 1E batteries are sized for 2-hour duty cycles at a discharge rate of 2 hours, based on a terminal voltage of 1.75 volts per cell at 25°C (77°F). The DC system minimum battery terminal voltage at the end of the discharge period is 210 volts. The maximum equalizing charge voltage for 250V batteries is 280 VDC.

The non-Class 1E batteries have sufficient stored capacity without their chargers to independently supply their loads continuously for at least 2 hours. Each distribution circuit is capable of transmitting sufficient energy to start and operate all required loads in that circuit.

The batteries are sized so that the sum of the required loads does not exceed 80% of the battery ampere-hour rating, or warranted capacity at end-of-installed-life with 100% design demand. The battery banks are designed to permit replacement of individual cells without loss of availability or capability.

Non-Class 1E Battery Chargers

The non-Class 1E battery chargers are full wave, silicon-controlled rectifiers. The housings are freestanding, NEMA Type 1, and are ventilated. The chargers are suitable for float charging the batteries. The chargers operate from a 460 volt, 3 phase, 60 Hz supply. Each train charger is supplied from a separate power center, which is backed by the standby diesel generator.

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

Each battery charger is capable of recharging its battery from the design minimum charge to 95% of fully charged condition within 12 hours.

The battery chargers are the constant voltage type, with the 125 VDC system chargers having a voltage adjustable between 120 and 145 volts and the 250 VDC system chargers having a voltage adjustable between 240 and 290 VDC, with the capability of operating as battery eliminators. The battery eliminator feature is incorporated as a precautionary measure to protect against the effects of inadvertent disconnection of the battery. The battery chargers are designed to function properly and remain stable on the disconnection of the battery. Variation of the charger output voltage is less than ± 1 percent with or without the battery connected. The maximum output ripple for the charger is 30 millivolts rms with the battery, and less than 2% rms without the battery.

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

Ventilation

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

8.3.2.2 Analysis

8.3.2.2.1 Class 1E DC Power Systems

The 480 VAC power supplies for the divisional battery chargers are from the individual Isolation Power Centers to which the particular 250VDC system belongs (Figure 8.1-3). These Isolation Power Centers are fed directly from the PIP nonsafety-related buses, which are backed up by the standby diesel generators. In addition, these Isolation Power Centers have a hard-wired connection to a terminal box where a portable emergency generator may be connected in the event that power is not available from the PIP buses. In this way, separation between the independent systems is maintained and the AC power provided to the chargers can be from either preferred or standby AC power sources.

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

The AC and DC switchgear circuit breakers in each division receive control power from the batteries in the respective load groups ensuring the following:

- The unlikely loss of one 250 VDC system does not jeopardize the supply of preferred and standby AC power to the Class 1E buses of the other load groups.
- The differential relays in one division and all the interlocks associated with these relays are from one 250 VDC system only, thereby eliminating any cross connections between the redundant DC systems.

8.3.2.2.2 Regulatory Requirements

The following analyses demonstrate compliance of the Class 1E Divisions 1, 2, 3 and 4 DC power systems to NRC GDC, NRC Regulatory Guides, and other criteria consistent with the standard review plan. The analyses establish the ability of the system to sustain credible single active failure and retain their capacity to function.

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

GDC:

GDC 2, 4, 17, 18 and 50 - The DC power system complies with these GDC, which are generically addressed in Subsection 3.1.2.

Regulatory Guides:

Regulatory Guide 1.6 — "Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems." The ESBWR Standard Plant does not need or have any safety-related standby AC power sources. Moreover, the nonsafety-related Standby AC power Supply System for the ESBWR is designed with physical separation of redundant load groups. Safety-related loads groups are supplied from redundant and independent electrical distribution systems designed with physical separation.

Regulatory Guide 1.32 — "Criteria for Power Systems for Nuclear Power Plants." Safety-related DC power sources are provided to support passive core cooling and containment integrity safety functions. No offsite or diesel-generator-derived AC power is required for 72 hours.

Regulatory Guide 1.47 — "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems."

Regulatory Guide 1.53 – "Application of the single failure criteria in nuclear power plants."

Regulatory Guide 1.63 — "Electric Penetration Assemblies in Containment Structures for Nuclear Power Plants."

Regulatory Guide 1.75 — "Physical Independence of Electric Systems." Safe shutdown relies only upon DC-derived power and will meet the design requirements for physical independence.

The DC safety-related standby lighting system circuits up to the lighting fixtures are Class 1E and are routed in Seismic Category I raceways. However, the lighting fixtures themselves are not seismically qualified, but are seismically supported. The cables and circuits from the power source to the lighting fixtures are Class 1E. The lamps cannot be seismically qualified. This is an exception to the requirement that all Class 1E equipment be seismically qualified. The lamps can only fail open and therefore do not represent a hazard to the Class 1E power sources.

Associated circuits added beyond the certified design must be specifically identified and justified per Subsection 8.3.4.6. Associated circuits are defined in Subsection 5.5.1 of IEEE 384, with the clarification for items (3) and (4) that non-Class 1E circuits being in an enclosed raceway without the required physical separation or barriers between the enclosed raceway and the Class 1E or associated cables makes the circuits (related to the non-Class 1E cable in the enclosed raceway) associated circuits.

Regulatory Guide 1.106 – "Thermal Overload Protection for Electrical Motors and Motor Operated Valves."

Regulatory Guide 1.118 — "Periodic Testing of Electric Power and Protection Systems." (See Subsection 8.3.4.12 for COL requirements.)

Regulatory Guide 1.128 — "Installation Designs and Installation of Large Lead Storage Batteries for Nuclear Power Plants."

Regulatory Guide 1.129 — "Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Nuclear Power Plants."

The Class 1E DC power system is designed in accordance with these Regulatory Guides. It is designed with sufficient capacity, independence and redundancy to ensure that the required power support for core cooling, containment integrity and other vital functions are maintained in the event of a postulated accident, assuming a single active failure.

The batteries consist of industrial type storage cells, designed for the type of service in which they are used. Ample capacity is available to serve the loads connected to the system for the duration of the time that alternating current is not available to the battery charger. Each division of Class 1E equipment is provided with a separate and independent 250 VDC system. The DC power system is designed to permit inspection and testing of all important areas and features, especially those which have a standby function and whose operation is not normally demonstrated. (See Subsection 8.3.4.14 for COL applicant/licensee items.)

Regulatory Guide 1.153 — "Criteria for Safety Systems."

Regulatory Guide 1.155 — "Station Blackout," the ESBWR uses battery power to achieve and maintain safe shutdown. Thus, the ESBWR meets the intent of Regulatory Guide 1.155. The Station Blackout evaluation is provided in Section 15.5.

Branch Technical Positions (BTPs):

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

The DC power system is designed consistent with this criterion.

Other SRP Criteria:

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

8.3.3 Fire Protection of Cable Systems

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

8.3.3.1 Resistance of Cables to Combustion

The electrical cable insulation is designed to resist the onset of combustion by choice of insulation and jacket materials, which have flame-resistive and self-extinguishing characteristics. Polyvinyl chloride and neoprene cable insulation are not used in the ESBWR. Each coaxial cable, each single conductor cable, each fiber optic cable sheath, [EAE64]and each conductor in multi-conductor cable are specified to pass the vertical flame test in accordance with UL-44. In addition, each power, control, and instrumentation cable is specified to pass the vertical tray flame test in accordance with IEEE 383 (Reference 8.3-4). All cable trays are fabricated from noncombustible material.

8.3.3.2 Cables and Raceways

Power and control cables are specified for continuous operation at conductor temperature not exceeding 90°C (194°F) and to withstand an emergency overload temperature of up to 130°C (266°F) in accordance with IPCEA S-66-524/NEMA WC-7 (Reference 8.3-5) Appendix D. The base ampacity rating of the cables was established as published in IEEE 835 (Reference 8.3-6) and IPCEA-54-440/NEMA WC-51 (Reference 8.3-7).

Cables are specified to continue to operate at 100% relative humidity with a service life expectancy of 60 years. Class 1E cables are designed to survive the LOCA ambient condition at the end of the 60-year life span. Refer to Subsection 8.3.4.5 for COL applicant/licensee items.

Cable tray fill is limited to 40% cross-sectional area for trays containing power cables; and 50% cross-sectional area for trays containing control and instrumentation cables. If tray fill exceeds the above maximum fills, the tray fill is justified and documented.

Cable splices in raceways are prohibited. Cable splices are only made in manholes, boxes or suitable fittings. Splices in cables passing through the containment penetration assemblies are made in terminal boxes located adjacent to the penetration assembly. (See Regulatory Guide 1.175 for splice exception.)

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

8.3.3.3 Localization of Fires

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

In any given fire area, equipment is typically from only one safety-related division. This design objective is not always met due to other overriding design requirements. IEEE Standard 384 and Regulatory Guide 1.75 are always complied with, however. In addition, an analysis is made and documented in Appendix 9A to ascertain that the requirement of being able to safely shut down the plant with complete burnout of the fire area without recovery of the equipment is met. The fire detection, fire suppression, and fire containment systems provided, however, assure that a fire of this magnitude does not occur.

Maximum separation of equipment is provided through location of redundant equipment in separate fire areas. Local instrument panels and racks are located to facilitate adequate separation of cabling. Clear access to and from the main switchgear rooms is provided. Separation is provided between divisional cables; between divisional cables and non-divisional cables; and between the two load groups of non-divisional equipment and cable/raceway systems being routed throughout the plant by way of separate fire rated compartments or embedments. Cable chases are ventilated and smoke removal capability is provided. Local instrument panels and racks are separated by division and located to facilitate the required separation of cabling.

8.3.3.4 Fire Detection and Protection Systems

All areas of the plant are covered by a fire detection and alarm system. Double manual hose coverage is provided throughout the buildings. Sprinkler systems are provided based on equipment arrangement and combustible loadings in each fire area. The standby diesel generator rooms and day tank rooms are protected by foam sprinkler systems. The foam sprinkler systems are dry pipe systems with pre-action valves that are actuated by compensated rate of heat rise and ultraviolet flame detectors. Individual sprinkler heads are opened by their thermal links.

8.3.4 COL Information

8.3.4.1 Interrupting Capacity of Electrical Distribution Equipment

The interrupting capacity of the switchgear and circuit interrupting devices must be shown to be compatible with the magnitude of the available fault current based on the final selection of the batteries, battery chargers, etc. (See Subsection 8.3.1.1.5).

8.3.4.2 Defective Refurbished Circuit Breakers

NRC Bulletin No. 88-10 and NRC Information Notice No. 88-46 identify problems with defective refurbished circuit breakers. To ensure that refurbished circuit breakers shall not be used in safety-related or nonsafety-related circuitry of the ESBWR design, it is a COL licensing requirement that new breakers be specified in the purchase specifications (Subsection 8.3.1.1.6).

8.3.4.3 Non-safety Standby Diesel Generator Load Table Changes

The diesel generator loads and the load sequencing for the standby on-site AC power sources shall be defined. Furthermore, changes may be needed for specific plant applications (see Subsection 8.3.1.1.8).

8.3.4.4 Minimum Starting Voltages for Class 1E Motors

"BTP PSB1" (Subsection 8.1.5.2.4), BTP PSB1 requires protection against degraded voltage for Class 1E systems. Provide an analysis showing compliance with BTP1. In particular, include the minimum required starting voltages for Class 1E motors; compare these minimum required voltages to the voltages that are supplied at the motor terminals during the starting transient when operating on off-site power and when operating on the standby diesel generators.

Degraded voltage in the off-site power system does not affect the Class 1E systems as all Class 1E systems are powered from batteries. Nevertheless, the COL applicant is to provide undervoltage protection criteria in order to define whether the non Class 1E 6.9 kV buses powered from the Standby On-site AC Power Supply System have to be provided with undervoltage protection to protect it against degraded voltage conditions in the off-site power system.

8.3.4.5 Certified Proof Tests on Cable Samples

Subsection 8.3.3.2 requires certified proof tests on cables to demonstrate 60-year life, and resistance to radiation, flame, and the environment. Demonstrate the testing methodology to assure such attributes are acceptable for the 60-year life.

All cables specified for Class 1E systems and circuits are moisture and radiation resistant, are highly flame resistant and evidence little corrosive effect when subjected to heat or flame, or both. Certified proof tests are performed on cable samples to:

- certify 60-year life by thermal aging;
- prove the radiation resistance by exposure of aged specimens to integrated dosage;
- prove mechanical/electrical tests of cable for environmental conditions specified;
- prove flame resistance by the vertical tray, 70,000 Btu/hr flame test for 8 minutes (minimum); and
- show acceptable levels of gas evolution by an acid gas generation test.

8.3.4.6 Associated Circuits[EAE65]

Subsections 8.3.1.1.5 and 8.3.1.3.1 commit to the identification and justification for all associated circuits added beyond the certified design.

Prior to the final design there were no "associated circuits," as defined by IEEE 384, known to exist in the ESBWR Standard Plant design. In the final design, provide: (1) assurance that no "associated circuit" exists, or (2) specifically identify and justify each such circuit in the COL documentation, and show it meets the requirements of Regulatory Guide 1.75, Position C.4.

8.3.4.7 Electrical Penetration Assemblies

Subsections 8.3.1.1.5 and 8.3.1.4.1 specify design requirements for electrical penetration assemblies. Provide fault current clearing-time curves of the electrical penetrations' primary and secondary current interrupting devices plotted against the thermal capability (I^2t) curve of the penetration (to maintain mechanical integrity). Provide an analysis showing coordination of these curves. Also, provide a simplified one-line diagram showing the location of the protective devices in the penetration circuit, and indicate the maximum available fault current of the circuit.

Provide specific identification and location of power supplies used to provide external control power for tripping primary and backup electrical penetration breakers (if utilized).

Provide an analysis demonstrating the thermal capability of all electrical conductors within penetrations is preserved and protected by one of the following:

(1) Show that the maximum available fault current (including failure of upstream devices) is less than the maximum continuous current capacity of the conductor within the penetration; or

(2) Show that the redundant circuit protection devices are provided, and are adequately designed and set to interrupt current, in spite of a single active failure, at a value below the maximum continuous current capacity of the conductor within the penetration. Such devices must be located in separate panels or be separated by barriers; and must be

independent such that failure of one does not adversely affect the other. Furthermore, they must not be dependent on the same power supply.

8.3.4.8 DC Voltage Analysis

Provide a DC voltage analysis showing battery terminal voltage and worst case DC load terminal voltage at each step of the Class 1E battery loading profile (Subsection 8.3.2.1).

Provide the manufacturer's ampere-hour rating of the batteries at the 2-hour rate and at the 8-hour rate, and provide the 1-minute ampere rating of the batteries (see Subsections 8.3.2.1.1 and 8.3.2.1.2).

8.3.4.9 Administrative Controls for Bus Grounding Circuit Breakers

Bus grounding circuit breakers are intended to provide safety grounds during maintenance operations. Administrative controls exist to (1) lock these circuit breakers in a racked- in (i.e., in the connected) position after bus de-energization and prior to maintenance, and (2) lock these circuit breakers in a racked out (i.e., in the disconnected) position prior to bus energization. Furthermore, show that annunciation is provided to alarm in the control room whenever these breakers are racked in for service.

8.3.4.10 Testing of Thermal Overload Bypass Contacts for Motor Operated Valves

Thermal overload protection for Class 1E Motor Operated Valves (MOVs) is active at all times except under LOCA conditions. Describe the means implemented for testing the bypass function, in accordance with the requirements of Regulatory Guide 1.106.

8.3.4.11 Emergency Operating Procedures for Station Blackout[EAE66]

Applicants referencing the ESBWR Standard Plant will provide instructions in their Emergency Operating Procedures for operator actions during a postulated station blackout event. Specifically, two divisions may be shut down, provided the remaining two redundant divisions of instrumentation are functioning properly, in order to: (1) reduce heat dissipation in the control room while HVAC is lost, and (2) conserve battery energy for additional SRV operations, or other specific functions, as needed, throughout the event.

8.3.4.12 Periodic Testing of Power and Protection Systems

The program for periodic testing of electric power and protection systems in accordance with Regulatory Guide 1.118 and IEEE 338 are addressed by the COL applicant.

8.3.4.13 Common Industrial Standards Referenced in Purchase Specifications

In addition to the regulatory codes and standards required for licensing, purchase specifications shall contain a list of common industrial standards, as appropriate, for the assurance of quality manufacturing of both safety-related and nonsafety-related equipment. Such standards would include ANSI, ASTM, IEEE, NEMA, UL, etc., a few of which are identified in Table 8.3-2.

8.3.4.14 Periodic testing of batteries

The periodic testing of batteries in accordance with Regulatory Guide 1.129 and IEEE 450 is addressed by the COL applicant.

8.3.4.15 Regulatory Guide 1.160

Maintenance Rule development is addressed by the COL applicant/licensee.

8.3.5 Additional Industry Standards

Table 8.3-2 provides a partial listing of other (acceptable) industry standards, which may be used.

8.3.6 References

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

8.3-2 IEEE 485, "Recommended Practice for Sizing Large Lead Storage Batteries for Nuclear Power Generating Stations."

8.3-3 IEEE 535, "Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations."

8.3-4 IEEE 383, "Type Test of Class 1E Cables, Field Splices, and Connections for Nuclear Power Generating Stations."

8.3-5 IPCEA S-66-524/NEMA WC-7, "Cross-Linked Thermosetting Polyethylene Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy."

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

8.3-7 ICEAP-54-440/NEMA WC-51, "Ampacities of Cables in Open-top Cable Trays."

8.3-8 IEEE 450, "Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications."

8.3-9 IEEE 484, "Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications."

Table 8.3-1
Diesel Generator Alarms

Annunciation points

DESCRIPTION	ANNUNCIATION	
	LOCAL	REMOTE
Diesel engine running	X	X
D/G trouble		X
D/G controls not in Auto	X	X
G main breaker trip	X	X
D/G in maintenance mode	X	X
D/G in parallel mode	X	X
D/G overspeed	X	X
Engine failed to start	X	X
Generator Differential relay	X	X
Reverse power relay	X	X
Field relay	X	X
Overcurrent relay	X	X
Lock-out relay operated	X	X
Overvoltage relay	X	X
Ground relay	X	X
Overtemperature relay	X	X
Undervoltage relay	X	X
Frequency relay	X	X

Indication

DESCRIPTION	ANNUNCIATION	
	LOCAL	REMOTE
Engine speed	X	X
Engine hour meter	X	X
Generator output voltage	X	X
Current	X	X
Active power output	X	X
Reactive power output	X	X

Table 8.3-2

Acceptable Industry Standards

(Note: There are many more standards referenced in the standards listed below.)

Motor Control Centers

- NEMA ICS-2 — Standards for Industrial Control Devices, Controllers and Assemblies
- Underwriter's Laboratories Standard No. 845

Low Voltage Circuit Breakers

- IEEE C37.13 — Low Voltage Power Circuit Breakers
- IEEE C37.16 — Preferred Ratings and Related Requirements for Low Voltage AC Power Circuit Breakers and AC Power Service Protectors
- IEEE C37.17 — Trip Devices for AC and General-Purpose DC Low Voltage Power Circuit Breakers
- ANSI C37.50 — Test Procedures for Low Voltage AC Power Circuit Breakers Used in Enclosures

Molded Case Circuit Breakers

- UL 489 — Branch Circuit and Service Circuit Breakers
- NEMA AB-1 — Molded Case Circuit Breakers

Metalclad Switchgear[EAE69]

- IEEE C37.04 — AC Power Circuit Breaker Rating Structure
- IEEE C37.06 — Preferred Ratings of Power Circuit Breakers
- IEEE C37.09 — Test Procedure for Power Circuit Breakers on a Symmetrical Current Basis
- IEEE C37.010 — Application Guide for AC High-Voltage Circuit Breakers on a Symmetrical Current Basis
- IEEE C37.11 — Power Circuit Breaker Control Requirements
- IEEE C37.20 — Switchgear Assemblies and Metal-Enclosed Bus
- IEEE C37.100 — Definitions for Power Switchgear

Transformers

- IEEE C57.12 — General Requirements for Distribution, Power, and Regulating Transformers
- IEEE C57.12.11 — Guide for Installation of Oil-Immersed Transformers (10mVA and Larger, 69-287 kV rating)
- IEEE C57.12.80 — Terminology for Power and Distribution Transformers
- IEEE C57.12.90 — Test Code for Distribution, Power, and Regulating Transformers

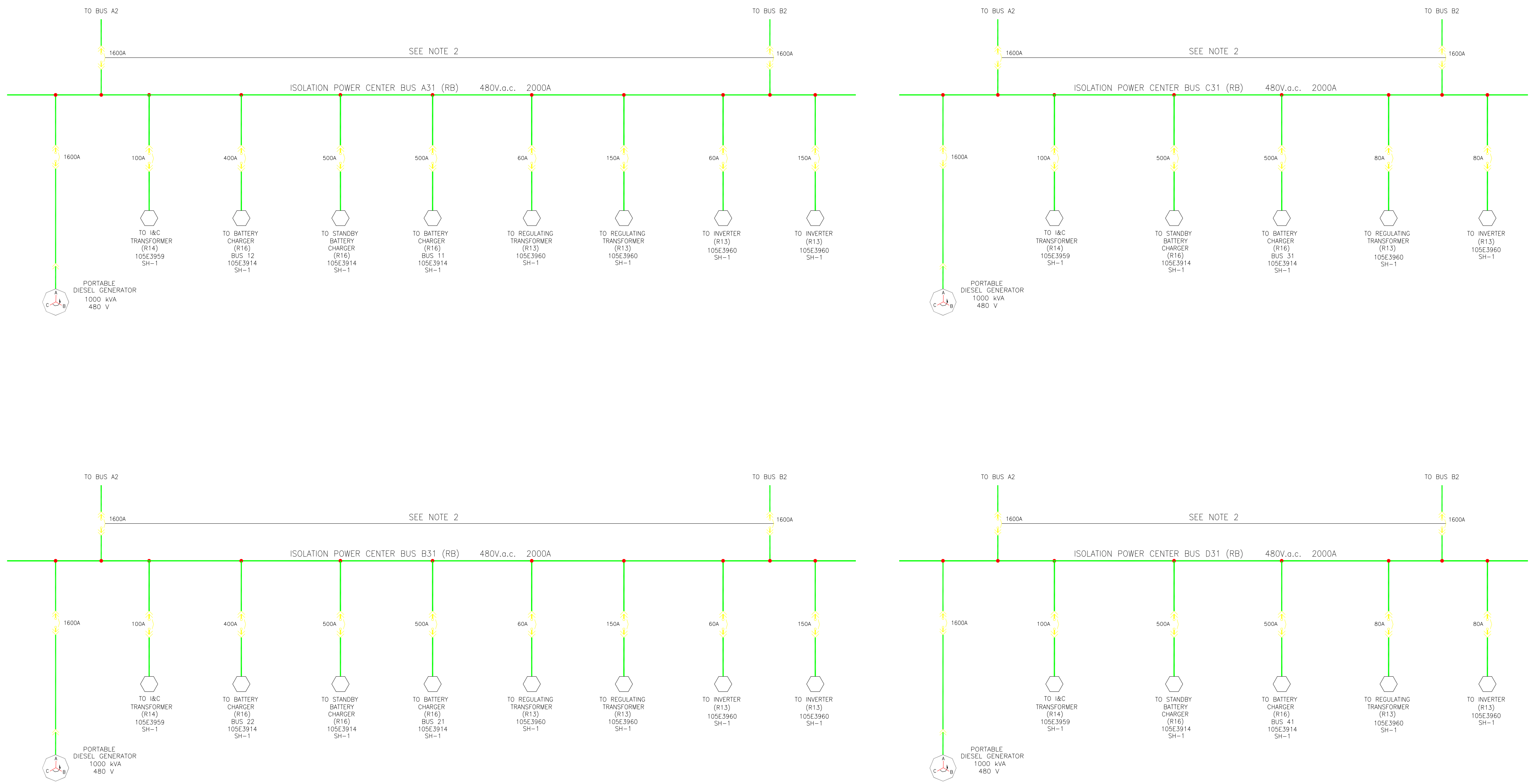
Batteries

- IEEE 450 — Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.
- IEEE 484 — Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications.
- IEEE 485 — Recommended Practice for Sizing Large Lead Storage Batteries for Nuclear Power Generating Stations.

Table 8.3-3

Battery Duty Cycles

Safety-related	**Division/train**	**Rated voltage** (V)	**Duty cycles** (h)
Y	1	250	72
Y	1	250	24
Y	2	250	72
Y	2	250	24
Y	3	250	24
Y	4	250	24
N	A	250	2
N	A	250	2
N	B	250	2
N	B	250	2
N	C	250	2
N	A	125	2
N	B	125	2



NOTES

2.- THE BREAKERS SHALL BE ELECTRICALLY INTERLOCKED SO THAT ONLY ONE CAN BE CLOSED AT ANY TIME NEVERTHELESS THE TWO BOTH INCOMING CIRCUIT. BREAKERS COULD BE CLOSED WHEN A FAST TRANSFER OCCURS.

Figure 8.3-1. 480 Volt Power Centers - One Line Diagram

Sh 1 of 4

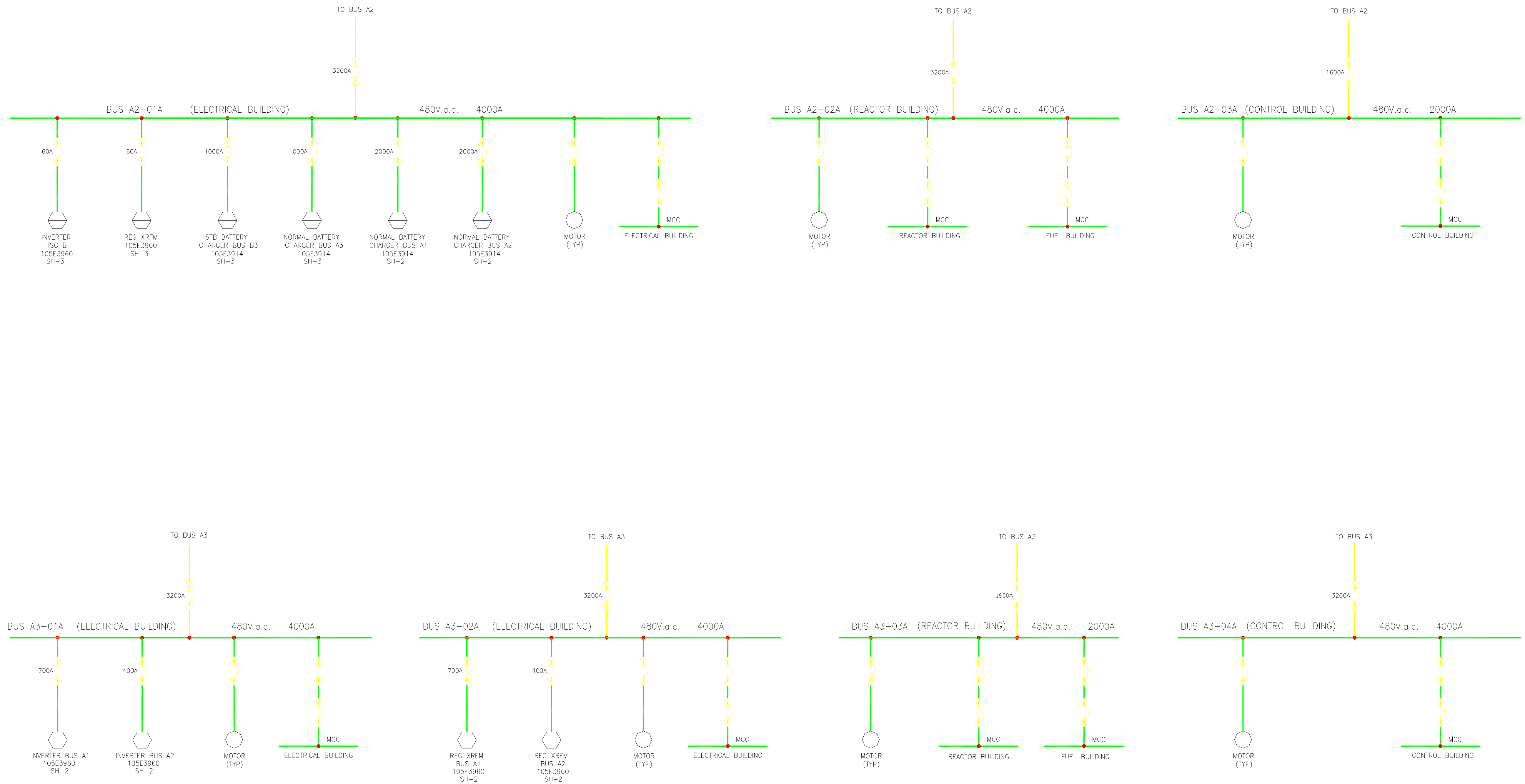


Figure 8.3-1. 480 Volt Power Centers - One Line Diagram

Sh 2 of 4

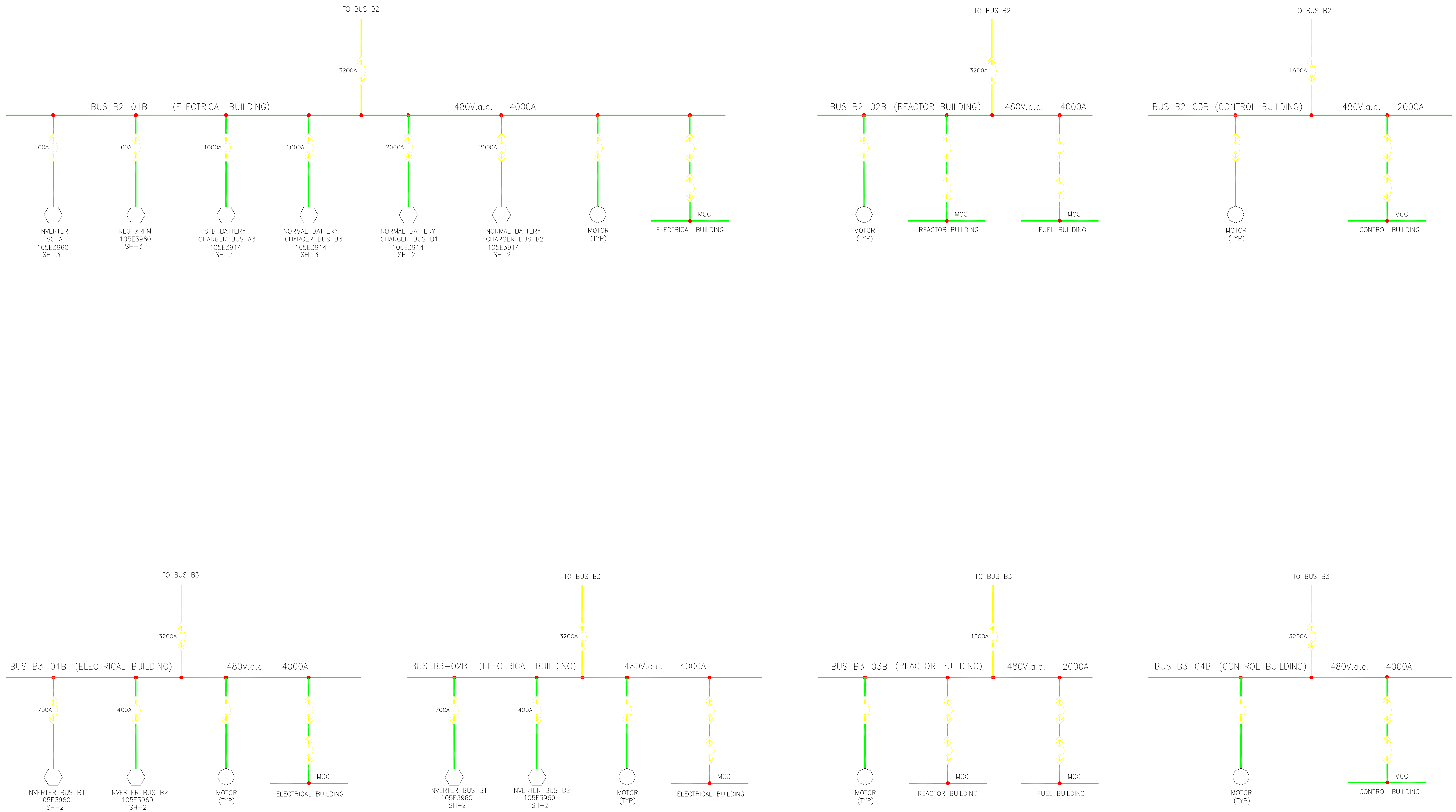


Figure 8.3-1. 480 Volt Power Centers - One Line Diagram

Sh 3 of 4

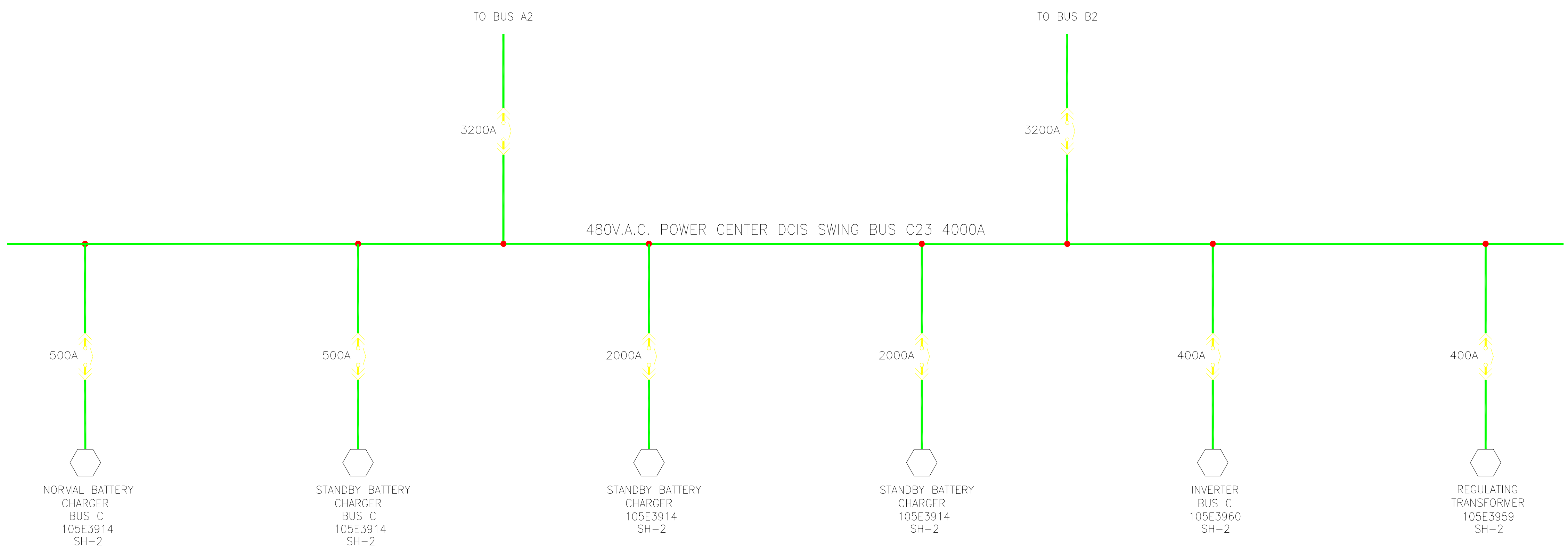


Figure 8.3-1. 480 Volt Power Centers - One Line Diagram

Sh 4 of 4

8A MISCELLANEOUS ELECTRICAL SYSTEMS

8A.1 STATION GROUNDING AND SURGE PROTECTION

8A.1.1 Description

The electrical grounding system is comprised of:

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

The plant instrumentation is grounded through a separate insulated radial grounding system comprised of buses and insulated cables. The instrumentation grounding systems are connected to the station grounding grid at only one point and are insulated from all other grounding circuits. Separate instrumentation grounding systems are provided for plant analog (i.e., relays, solenoids, etc.) and digital instrumentation systems.

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

A plant grounding grid consisting of bare copper cables is provided to limit step and touch potentials to safe values under all fault conditions. The buried grid is located at the switchyard and connected to systems within the buildings by a 500 MCM bare copper loop, which encircles all buildings (Figure 8A-1).

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

The plant's main generator is grounded with a neutral grounding device. The impedance of that device limits the maximum phase current under short-circuit conditions to a value not greater than that for a three-phase fault at its terminals. Provisions are included to ensure proper grounding of the isophase buses when the generator is disconnected.

The onsite, medium-voltage AC distribution system is resistance grounded at the neutral point of the low-voltage windings of the unit auxiliary and reserve auxiliary transformers. The neutral point of the generator windings of the onsite Standby On-site AC Power Supply is through distribution-type transformers and loading-neutral resistors, sized for continuous operation in the event of a ground fault.

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

The target value of ground resistance is one ohm or less for the Reactor, Turbine, Control, Service and Radwaste buildings. This is consistent with Section 12.1 of IEEE-80. If the target grounding resistance is not achieved by the ground grid, auxiliary ground grids, shallow buried ground rods or deep buried ground rods will be used in combination as necessary to meet the target ground resistance value.

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

8A.1.2 Analysis

No SRP or regulatory guidance is provided for the grounding and lightning protection system. It is designed and required to be installed to the applicable sections of the following codes and standards.

(1) IEEE-80, Guide for Safety in AC Substation Grounding (Reference 8A-1);

(2) IEEE-81, Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System (Reference 8A-2);

(3) IEEE-665, Guide for Generation Station Grounding (Reference 8A-3); and

(4) NFPA-78, National Fire Protection Association's Lightning Protection Code (Reference 8A-4).

This code is utilized as recommended practices only. It does not apply to electrical generating plants.

8A.1.3 COL Information

It is the responsibility of the COL applicant to perform ground resistance measurements to determine that the required value of one ohm or less has been met and to make additions to the system if necessary to meet the target resistance.

8A.2 CATHODIC PROTECTION

8A.2.1 Description

A cathodic protection system is provided. Its design is plant unique as it must be tailored to the site conditions. The COL applicant must provide a design meeting the requirements listed in Subsection 8A.2.3.

8A.2.2 Analysis

There are no SRP or regulatory requirements nor any national standards for cathodic protection systems. The system is designed to the requirements listed in Subsection 8A.2.3.

8A.2.3 COL Information

The COL applicant is required to meet the following minimum requirements for the design of the cathodic protection systems. These requirements are the same as those called for in Chapter 11, Section 9.4 of the Utility Requirements Document (Reference 8A-5).

The need for cathodic protection on the entire site, portions of the site, or not at all shall be determined by analyses. The analyses shall be based on soil resistivity readings, water chemistry data, and historical data from the site gathered from before commencement of site preparation to the completion of construction and startup.

(1) Where large protective currents are required, a shallow interconnected impressed current system consisting of packaged high silicon alloy anodes and transformer-rectifiers, shall normally be used. The rectifiers shall be approximately 50% oversized in anticipation of system growth and possible higher current consumption.

(2) The protected structures of the impressed current cathodic protection system shall be connected to the station grounding grid.

(3) Localized sacrificial anode cathodic protection systems shall be used where required to supplement the impressed current cathodic protection system and protect surfaces which are not connected to the station grounding grid or are located in outlying areas.

(4) Prepackaged zinc type Reference electrodes shall be permanently installed near poorly accessible protected surfaces to provide a means of monitoring protection level by measuring potentials.

(5) Test stations above grade shall be installed throughout the station adjacent to the areas being protected for termination of test leads from protected structures and permanent Reference electrodes.

8A.3 ELECTRIC HEAT TRACING

8A.3.1 Description

The electric heat tracing system provides freeze protection where required for outdoor service components and fluid warming of process fluids if required, either in or out doors. If the operation of the heat tracing is required for proper operation of a safety-related system, the heat tracing for the safety-related system is required to be Class 1E. Power for heat tracing is supplied from the on-site distribution system buses. Non-Class 1E heat tracing has access to the combustion turbine generator through the same load group is supplied from the same Power Center or Motor Control Center as the components protected. Class 1E heat tracing is assigned to the appropriate division of Class 1E power.

8A.3.2 Analysis

There are no SRP or regulatory guidance provided for electric heat tracing systems. They are required to be designed and installed to the applicable sections of the following codes and standards.

- IEEE-622, Recommended Practice for the Design and Installation of Electric Heat Tracing Systems in for Nuclear Power Generating Stations (Reference 8A-6).
- IEEE-622A, Recommended Practice for the Design and Installation of Electric Pipe Heating Control and Alarm Systems in Nuclear for Power Generating Stations (Reference 8A-7).

8A.3.3 COL Information

No COL applicant information is required.

8A.4 REFERENCES

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

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

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

8A-4 NFPA-78, "National Fire Protection Association's Lightning Protection Code."

8A-5 Electric Power Research Institute, "Utility Requirements Document, Advanced Light Water Reactor, Volume II, ALWR Evolutionary Plant."

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

8A-7 IEEE-622A, "Recommended Practice for the Design and Installation of Electric Pipe Heating Control and Alarm Systems in Nuclear for Power Generating Stations."

8B REALISTIC STATION BLACKOUT EVALUATION

8B.1 INTRODUCTION

The performance evaluation for Station Blackout (SBO) based on TRACG is presented in the following section.

8B.2 ACCEPTANCE CRITERIA

The design shall meet the following acceptance criteria:

Reactor Vessel Coolant Integrity - Adequate reactor coolant inventory shall be maintained such that reactor water level is maintained above the core (i.e., top of active fuel).

Hot Shutdown Condition – Achieve and maintain the plant to those shutdown conditions specified in plant Technical Specifications as Hot Shutdown

Containment Integrity – If containment isolation is involved, the maximum containment and suppression pool pressures and temperatures shall be maintained below their design limits.

8B.3 ANALYSIS ASSUMPTIONS

The analysis assumptions and inputs are summarized below.

(1) Reactor is operating initially at 100% of rated power/100% rated nominal core flow, nominal dome pressure and normal water level.

(2) The nominal ANSI/ANS 5.1-1994 decay heat model is assumed.

(3) SBO starts with loss of all alternating current (AC) power, which occurs at time zero.

(4) Loss of AC power trips reactor feedwater pumps at event initiation.

(5) The reactor scrams occurs at 2.0 seconds due to loss of power supply to feedwater pumps. It is considered that when feedwater flow is lost, there is a new scram signal with a conservative delay time of 2.0 seconds.

(6) Feedwater is ramped down linearly to zero in 5.0 seconds after event initiation.

(7) Closure of all Main Steam Isolation Valves (MSIVs) is automatically initiated when the reactor water level reaches Level 2 with a 30.0 second delay, and the valves are fully closed at 5.0 seconds.

(8) A single failure is assumed. The systems available for initial vessel inventory and pressure control, containment pressure/temperature control and suppression pool temperature control are:

   a. Isolation Condensers (ICs);

   b. Control Rod Drive (CRD) pumps;

   c. Safety Relief Valves (SRVs);

   d. Depressurization Valves (DPVs);

   e. Gravity-Driven Cooling System (GDCS) squib valves;

   f. GDCS loops; and

g. Passive Containment Cooling System (PCCS) loops.

(9) 3 ICs (assuming single failure of one IC) are automatically initiated upon the closure of MSIVs to stabilize the plant. Operators control ICs to assure the maximum cooldown rate not exceeding 100°F/hr, if necessary.

(10) 2 CRD pumps are automatically initiated to provide vessel inventory makeup. The maximum delayed time is 145 seconds upon restoring AC power through nonsafety-related standby diesel generators (DGs). CRD pumps shall keep the water level above Level 0.5 to avoid any Automatic Depressurization System (ADS) initiation to blow down the vessel.

(11) ICs and CRD flow stabilize the plant. SRVs, DPVs, PCCS and GDCS can be utilized if IC does not stabilize the plant, which is most unlikely.

(12) The event is terminated after an 8-hour coping period.

8B.4 ANALYSIS RESULTS

The analysis results are presented in this section. As shown in Figure 8B-1, with operation of IC and CRD systems, the minimum reactor water level is about 4.67 m above the top of active fuel (about 12.12 m above vessel zero). The water level recovers above Level 1 lower analytical limit and upper analytical limit within about 5 minutes and 20 minutes into the event, respectively. Therefore the requirement for reactor vessel coolant integrity is satisfied. Additionally this minimum water level is well above Level 0.5, which is 10 m above vessel zero, and thus, ADS initiation can be avoided.

Subsequent to a SBO event, hot shutdown condition can be achieved and maintained by operation of IC and CRD systems. Therefore, the requirement for achieving and maintaining hot shutdown condition is met.

ICs and CRD flow can stabilize the plant without SRV actuation or ADS blowdown, consequently there is no heat-up in the suppression pool and containment. Therefore, the integrity for containment is maintained.

As demonstrated above each acceptance criterion in Section 8B.2 is met. Therefore ESBWR can successfully mitigate a SBO event.

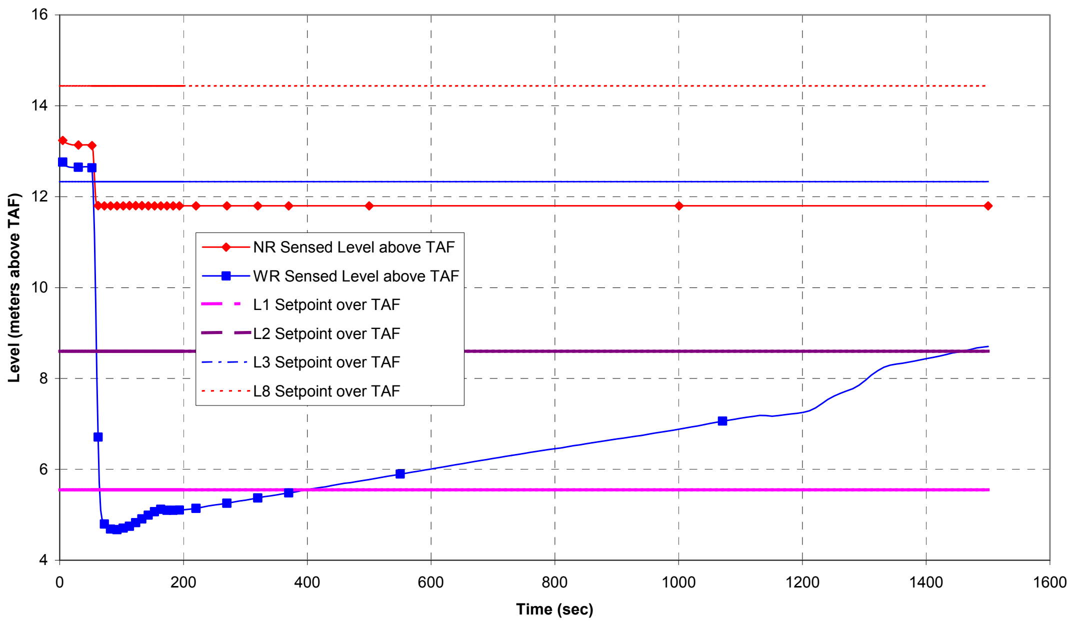


Figure 8B-1. Water Level Response for SBO