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BWRX-300 UK Generic Design Assessment (GDA) Chapter 8 – Electrical Power

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EXECUTIVE SUMMARY

The purpose of this Preliminary Safety Report (PSR) chapter is to describe the BWRX-300 Electrical Distribution System (EDS) and its associated systems, required to generate electrical power, export electrical power from the power station to the grid; to ensure safety of the nuclear plant and power station assets during normal operations and emergency conditions; to import electrical power from the grid to the power station for operations and maintenance purposes; and, how it complies with its design and safety requirements.

The chapter presents a level of detail commensurate with a 2 Step Generic Design Acceptance (GDA) and is structured in line with the high-level contents of International Atomic Energy Agency (IAEA) SSG-61.

The scope of this chapter is the EDS. The EDS is comprised of the Emergency Power System, the Standby Power System, and the Preferred Power System. The EDS extends from the switchyard extra high voltage interface with the National Grid, via transformers and power convertors, to High Voltage/Medium Voltage and Low Voltage power supplies. The EDS includes the transformers, busses, switchgear, cables, raceways, containments power conversion, batteries, electrical protection, and earthing, for the safety systems & apparatus, conventional systems & apparatus, and motive power drives. The EDS operates at a nominal system frequency of 50 Hz. The EDS interfaces with the Instrumentation and Control systems and building structures (for lightning protection and Electromagnetic Pulse/Electromagnetic Interference protection).

This chapter describes the relevant systems within the EDS, their required safety and non-safety category functions, design bases, and provides arguments as to how the functions are met by the systems. The BWRX-300 design includes Engineered Safety Features (ESFs) that mitigate the consequences of Anticipated Operational Occurrences or postulated Design Basis Accidents (DBAs) without any core damage. The ESFs associated with the EDS interfacing systems are described in PSR Ch. 6: Engineered Safety Features in relation to dependent systems, qualification, interfaces, separation, and penetrations.

System interfaces /dependencies are identified, and suitable cross references used to direct the reader to the relevant PSR chapters.

Postulated claims, arguments, and evidence to inform GDA Step 2 objectives and scope are summarised in Appendix A. Appendix B provides a Forward Action Plan which includes future work commitments and recommendations for future work where ‘gaps’ to GDA expectations have been identified, and Appendix C identifies foreseen points of interface which will be confirmed during the developing design.

ACRONYMS AND ABBREVIATIONS

Acronym	Explanation
AC	Alternating Current
ALARP	As Low As Reasonably Practicable
AOO	Anticipated Operational Occurrence
BOP	Balance of Plant
BTP	Branch Technical Position
CAE	Claims, Arguments and Evidence
CFR	Code of Federal Regulations
CIGRE	Council on Large Electric Systems
CRD	Control Rod Drive
D-in-D	Defence-in-Depth
DBA	Design Basis Accident
DC	Direct Current
DCIS	Distributed Control and Information System
EDS	Electrical Distribution System
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMIT	Examination, Maintenance, Inspection, and Testing
EPS	Emergency Power System
ESF	Engineered Safety Feature
FAP	Forward Action Plan
FLEX	Flexibly Installed Mobile Emergency Apparatus
FMCRD	Fine Motion Control Rod Drive
GDA	Generic Design Assessment
GDC	General Design Criteria
GEH	GE Hitachi Nuclear Energy
GSU	Generator Step Up Transformer
HV	High Voltage
HVAC	Heating, Ventilation, and Air Conditioning
I&C	Instrumentation and Control
IAEA	International Atomic Energy Agency
IC	Isolation Condenser
ICS	Isolation Condenser System
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IT	Information Technology

Acronym	Explanation
LfE	Learning from Experience
LG	Load Group
LOOP	Loss-of-Offsite Power
LOPP	Loss-of-Preferred Power
LV	Low Voltage
MCC	Motor Control Center
MCR	Main Control Room
MOD	Motor Operated Disconnect
MTS	Manual Transfer Switch
MV	Medium Voltage
NEMA	National Electrical Manufacturers Association
NUREG	Nuclear Regulatory Report
ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PAM	Post-Accident Monitoring
PDC	Principal Design Criterion
PSA	Probabilistic Safety Assessment
PSR	Preliminary Safety Report
RAM	Reliability, Availability, and Maintainability
RAT	Reserve Auxiliary Transformer
RB	Reactor Building
RFI	Radio Frequency Interference
RG	Regulatory Guide
RGP	Relevant Good Practice
RVT	Regulating Voltage Transformer
SC1	Safety Class 1
SC2	Safety Class 2
SC3	Safety Class 3
SCDS	Safety Case Development Strategy
SCN	Non-Safety Class
SCR	Secondary Control Room
SDG	Standby Diesel Generator
SMR	Small Modular Reactor
SSCs	Structures, Systems, and Components
TB	Turbine Building
TVSS	Transient Voltage Surge Suppressor

Acronym	Explanation
UAT	Unit Auxiliary Transformer
UK	United Kingdom
UPS	Uninterruptable Power Supply
USNRC	U.S. Nuclear Regulatory Commission

TABLE OF CONTENTS

EXECUTIVE SUMMARY ..... **iii**

ACRONYMS AND ABBREVIATIONS ..... **iv**

8. ELECTRICAL POWER **1**

8.1 Introduction 1

8.2 Description of the Electrical Power System 2

8.3 General Principles and Design Approach 8

8.4 Offsite Power Systems 14

8.5 Onsite Power Systems 19

8.6 Electrical Equipment, Cables, and Raceways 43

8.7 Grounding (Earthing), Lightning Protection and Electromagnetic Compatibility 46

8.8 Main Equipment Types 49

8.9 References 59

APPENDIX A CLAIMS, ARGUMENTS AND EVIDENCE **63**

APPENDIX B FORWARD ACTIONS **69**

APPENDIX C INTERFACES **70**

APPENDIX D BWRX-300 SYSTEM CODES AND SAFETY CLASS **74**

LIST OF TABLES

Table A-1: Claims, Arguments, Evidence Route Map 65

LIST OF FIGURES

Figure 8-1: Main Electrical One-Line Diagram 51
Figure 8-2: Typical BWRX-300 Switchyard Interface 52
Figure 8-3: Preferred Power Medium Voltage Bus A Train 53
Figure 8-4: Emergency Power System 54
Figure 8-5: Standby Power System Low Voltage Distribution Train A 55
Figure 8-6: Standby Power System – 250 VDC System 56
Figure 8-7: Preferred Power 250 VDC System Part One 57
Figure 8-8: Preferred Power 250 VDC System Part Two 58

REVISION SUMMARY

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A	All	Initial Issuance

8. ELECTRICAL POWER

8.1 Introduction

This chapter describes the BWRX-300 plant electrical system and provides its design bases.

The purpose of this Preliminary Safety Report (PSR) chapter is to describes the BWRX-300 Electrical Distribution System (EDS) and its associated systems, required to generate electrical power, export electrical power from the power station to the grid; ensure safety of the nuclear plant and power station assets during normal operations and emergency conditions; to import electrical power from the grid to the power station for operations and maintenance purposes; and, how it complies with its design and safety requirements.

The chapter presents a level of detail commensurate with a 2 Step Generic Design Assessment (GDA) and is structured in line with the high-level contents of International Atomic Energy Agency (IAEA) SSG-61, "Format and Content of the Safety Analysis Report for Nuclear Power Plants," (Reference 8-1).

System interfaces /dependencies are identified, and suitable cross references used to direct the reader to the relevant PSR chapters.

Postulated claims, arguments, and evidence to inform GDA Step 2 objectives and scope are summarised in Appendix A along with an As Low As Reasonably Practicable (ALARP) position. Appendix B provides a Forward Action Plan which includes future work commitments and recommendations for future work where 'gaps' to GDA expectations have been identified, and Appendix C identifies foreseen points of interface which will be confirmed during the developing design.

8.2 Description of the Electrical Power System

The EDS architecture is a configuration of generators, buses, transformers, and load centres that supply power to the design loads. The design described is for a 50 Hz Alternating Current (AC) power system, with 6.6 kV for the Medium Voltage (MV) level and 690 Volts Alternating Current (VAC), and 400/230 VAC for the Low Voltage (LV) level, as per 006N5115, "BWRX-300 Plant Electrical Systems Architecture Requirements and Design," (Reference 8-2).

The EDS architecture is made up of the following systems:

- Generator and Exciter System
- Preferred Power System
- Standby Power System
- Emergency Power System comprising the Emergency Power Backup Direct Current (DC) and Uninterruptable Power Supply (UPS) Electrical Systems
- Lighting and Service Power System
- Cable Raceway System
- Grounding and Lightning Protection System
- Non-Distributed Control and Information System (DCIS) communication system
- Freeze and Cathodic Protection System

In addition to describing the electrical systems and associated requirements, this chapter includes plant figures that depict the switchyard, switchyard interface, and the MV and LV AC distribution systems, including the DC battery and UPS systems. The lighting and service power system non-DCIS communication systems are covered in PSR Ch. 9A (Reference 8-3). The BWRX-300 design minimizes the reliance on electrical power to support safety category functions. The passive design of the plant is not dependent upon AC power sources, including diesel generators, to mitigate a Design Basis Accident (DBA). Safety Class 1 (SC1) power is supplied from battery-backed DC power, which has a coping period of 72 hours for all DBAs.

The Defence-in-Depth (D-in-D) concept is achieved by defined safety categories and classes that are further established below. The electrical systems provide an integral support function for Structures, Systems, and Components (SSCs) across the range of safety classes. A summary of the safety categories and description of how the electrical systems provide support is outlined below. More detailed information is provided in PSR Ch. 3 (Reference 8-4). The system safety class and system codes used on figures in this chapter are shown in Appendix D.

Alignment of codes and standards: The inclusion of International Electrotechnical Commission (IEC) standards at present is provisional, and the subject of forward actions (see Appendix B Forward Action Plans).

References to BWRX-300 chapters and associated documents are identified from NEDO-34087, "BWRX-300 United Kingdom (UK) Generic Design Assessment Master Document Submission List," (Reference 8-5).

8.2.1 Safety Category 1

BWRX-300 functions are designed to minimize reliance on electrical power. Safety Category 1 functions requiring power and control are controlled by the SC1 DCIS. Safety Category 1 functions are automatically initiated on loss of power except for Isolation Condenser System (ICS) isolation. The functions that fail to the required position upon loss of power do not require electrical power as an integral support function. Therefore, the only “energise to actuate” Safety Category 1 function supported by electrical power is “isolation of a faulted ICS line.”

In addition to the Emergency Power System, comprising the Emergency power backup Direct Current (DC) and Uninterruptable Power Supply (UPS) Electrical Systems, elements of the Cable Raceway System provide a passive Safety Category 1 function via their inclusion of the primary containment penetrations.

8.2.2 Safety Category 2

The electrical systems provide a range of Safety Category 2 functions that are powered by Standby Power System DC backed power supplies:

- Two Load Group (LG) UPSs (A and B), which provide power to the Safety Class 2 (SC2) DCIS
- Four UPSs that support the Fine Motion Control Rod Drives (FMCRDs)

8.2.3 Safety Category 3

The electrical systems provide AC or DC power to equipment supporting Safety Category 3 functions. Normal functions performing a fundamental safety function during normal plant operation or maintaining key reactor parameters (e.g., reactor pressure, reactor water level, and temperature) within normal ranges, and their integral support functions, are assigned to at least Safety Category 3.

Power for most systems with defense line functions is provided by sources backed by the Standby Diesel Generators (SDGs). Examples of AC loads serving these Safety Category 3 functions include shutdown cooling, plant cooling water, and fuel pool cooling system loads. Control power associated with these loads is derived from DC backed sources. There are a few instances where the AC power is provided by non-SDG backed sources (feedwater pump power and condensate pump power are derived from Safety Class 3 (SC3) MV buses). In such cases, the Safety Category 3 function supported (trip the pump breaker) is not required for a Loss-of-Preferred Power (LOPP) scenario.

Safety Category 3 functions also include those functions that mitigate severe accidents including Reactor Pressure Vessel vent, containment vent and emergency boron injection. These functions are powered by an electrical bus that is backed by the SDGs and the EDS infrastructure is designed to support Diverse and Flexible Coping Strategy connections for an alternate power source.

Safety Category 3 includes normal lighting, emergency lighting, and control room lighting in addition to providing service power throughout the plant. Security and yard lighting are outside the scope of this document.

Overall safety strategy and critical elements are discussed further in PSR Ch. 3.

Figure 8-1 depicts the main BWRX-300 plant electrical one-line and shows the Generator and Exciter System, Standby Power System and Preferred Power System.

For further explanation on the overall safety classes and safety categories, refer to PSR Ch. 3 (Reference 8-4).

8.2.4 Overview of Offsite Power System

The BWRX-300 has two connections to the switchyard. The Preferred Power System provides the interconnecting EDS elements between the plant main generator, onsite power system, and the offsite power source. The preferred power sources for the plant are the two switchyard connections. Note that for the BWRX-300 design, a LOPP or a Loss-of-Offsite Power (LOOP) are the same and can be used interchangeably to represent a loss of the switchyard as a power source to the plant.

The BWR-300 switchyard design allows significant flexibility. Because of the passive safety design of the BWRX-300 plant, only a single Preferred Power System connection between the plant and switchyard is required. However, two sources of offsite power are provided to improve reliability and operational flexibility.

8.2.5 Offsite Power System Design Basis

Safety Category Function

Offsite power has no Safety Category 1 function due to the passive design of the BWRX-300. Therefore, offsite power supplies are not required based on Principal Design Criterion (PDC) 17, "Electric Power Systems," and IAEA-TECDOC-1770, "Design Provisions for Withstanding Station Blackout at Nuclear Power Plants," (Reference 8-6).

8.2.6 Overview of Onsite Power Systems

The onsite AC power system starts at the Generator Step Up Transformer (GSU) and Reserve Auxiliary Transformer (RAT) motor operated disconnects, and transitions from there to include the main generator, the main generator circuit breaker, the Unit Auxiliary Transformer (UAT), and the rest of the plant AC distribution as depicted on Figure 8-1. The typical BWRX-300 switchyard interface is depicted on Figure 8-2.

The BWRX-300 has two connections to the switchyard. One connection is to the High Voltage (HV) side of the GSU. The LV side of the GSU is connected to the main generator breaker via isolated phase bus duct and includes a branch to the UAT. The GSU provides transmission of the main generator output to the grid when the plant is online and can provide power to the plant when the main generator is offline. When the generator breaker is open, the switchyard can "backfeed" power to the plant through the GSU and the UAT. The other switchyard connection is to the HV side of the RAT. The UAT and RAT secondaries are connected to the plant MV buses.

The MV bus configuration and load allocation are such that buses can be shut down for maintenance during outages and can be shut down one at a time in normal operation while minimizing the effect to plant power generation.

The MV buses are normally aligned to the UAT. The MV buses can be aligned to the RAT while offline or during power generation, either manually or via automatic transfer. The RAT is normally energised and ready to accept the plant load. The MV buses have protective relays and are designed to automatically bus transfer (break before make) between the UAT and the RAT. The bus transfer is automatically initiated on loss of source to the MV buses or a faulted circuit in the normal Preferred Power System supply. The intent of this automatic action is to minimize the potential for a loss of power to the plant EDS. The transfer logic occurs if power is available from the RAT, preventing a transfer to a dead source. To avoid the possibility of cycling between the preferred sources, the automatic bus transfer is one-directional (i.e., there is no possibility of an automatic transfer from the RAT to the UAT). Transfer from the RAT to the UAT for the Preferred Power System source is performed manually with sufficient permissives to avoid transferring into a faulted or out of sync source.

8.2.7 Onsite Power System Design Basis

Safety Category Functions

The BWRX-300 design includes passive safety features that do not require AC power to support core cooling or containment integrity. Safety functions are automatically initiated on loss of power except for isolation of a faulted ICS line. Therefore, the only Safety Category 1 function that requires electrical power is ICS isolation.

Emergency Power System batteries provide 72-hours worth of power to loads supporting Safety Category 1 functions and Post-Accident Monitoring (PAM). A loss of AC voltage, degraded voltage, and a loss of phase condition on the Emergency Power System does not adversely affect the performance of plant Safety Category 1 functions.

The Standby Power System includes the SDGs and the interconnecting AC system that is derived from it. Additionally, the Standby Power System includes the SC2 UPS distribution system. The primary purpose of this system is to provide backup power in the event of a LOPP for loads which have a function required during a LOPP (or loads which require power for plant investment protection).

8.2.8 Licensing Requirements: Design Criteria, Regulatory Guides, and Standards

The BWRX-300 electrical system design meets the requirements of IAEA Safety Standards Series No. SF-1 Safety Fundamentals and complies with the requirements except as indicated. The BWRX-300 electrical system is designed to meet IAEA and U.S. Nuclear Regulatory Commission (USNRC) requirements.

Although the BWRX-300 shutdown and heat removal functions can be initiated by active SC1, SC2, and SC3 control systems, loss of offsite, and onsite electrical power, including battery-backed Uninterruptable Power Supplies (UPSs), automatically causes control rod insertion/plant shutdown and initiates decay heat removal through the ICS. In any DBA and Beyond Design Basis Accident, electricity is required for monitoring, alarms, and communications. The heat removal functions can be provided passively by ICS or actively by equipment powered by the SDGs, which can operate autonomously for one week before requiring refuelling.

As per IAEA-TECDOC-1791, “Considerations on the Application of the IAEA Safety Requirements for the Design of Nuclear Power Plants,” (Reference 8-7) and Office for Nuclear Regulation (ONR) “Licence Condition Handbook,” (Reference 8-8), and requirements specified in IAEA SSG-34, “Design of Electrical Power Systems for Nuclear Power Plants,” (Reference 8-9) are to be addressed. These requirements for the BWRX-300 electrical systems are discussed below.

8.2.9 IAEA-TECDOC-1791 and ONR Requirements

IAEA-TECDOC-1791 (Reference 8-7) and ONR Licence Condition Handbook (Reference 8-8) define requirements for safety support systems. Noting that the Licence Condition Handbook (Reference 8-8) contains legal requirements that a UK site licensee must comply with, which is beyond the scope of GDA to consider.

The BWRX-300 electrical system meets the requirements of IAEA-TECDOC-1791 (Reference 8-7) with normal plant power provided via the main generator or offsite power, backup power provided via SDGs, and SC1 emergency power provided by UPSs. The electrical system is designed with sufficient capacity to meet load requirements to support fundamental safety functions. The design incorporates an appropriate D-in-D strategy to ensure availability and reliability of the supported systems.

For BWRX-300, the SC1 Emergency Power System provides at least 72 hours of battery-backed AC and DC power, after which it is supported by the SDGs for at least one week, or alternatively, is supported by connection of portable generators. In a complete loss-of-offsite/generator AC power, batteries are charged via the SDGs or the portable generator connections while also powering the required loads for safety category functions.

Capacity margin for the batteries is established by meeting the IEC 61225 “Nuclear power plants — Instrumentation, control, and electrical power systems — Requirements for static uninterruptible DC and AC power supply systems,” (Reference 8-10).

The SC1 Emergency Power System have been designed to:

- Be independent of normal and standby systems.

- Support continuity of the fundamental safety functions until long-term (normal or standby) service is re-established:
  - Without the need for operator action to connect temporary onsite services for at least eight hours.
  - Without the need for offsite services and support for at least 72 hours.
- Have a capacity margin that allows for future increases in demand.
- Be testable under design load conditions, where practicable.

8.2.10 Specific Safety Requirements and the Design of Electrical Power Systems for Nuclear Power Plants

IAEA SSR-2/1, "Safety of Nuclear Power Plants: Design," (Reference 8-11) and IAEA SSG-34 (Reference 8-9) defines requirements for EDSs.

The Emergency Power System performs the Safety Category 1 functions. The Preferred Power System and the Standby Power System perform the Safety Category 2 and Safety Category 3 functions. The design of these systems ensures sufficient capacity to support associated safety category functions, and that availability and reliability of the system is commensurate with the safety significance of the connected loads.

The BWRX-300 electrical systems are designed to accommodate grid disturbances within the range of those shown to be possible by transmission operator studies at the point of interconnect. Such studies include maximum and minimum transient and steady-state grid voltages, available fault current, and consideration of the effect of geomagnetic induced currents resulting from coronal mass ejections. The design includes appropriate mitigations based on the results of studies such as the application of automatic load tap changes, surge suppression, transformer zero sequence current monitoring, and blocking capacitors.

However, in contrast to the guidance of in IAEA SSG-34 (Reference 8-9), the BWRX-300 design is not required to include two or more independent connections between the plant and the grid because the BWRX-300 plant does not require offsite electrical power to achieve safe shutdown, nor does it require electrical power to protect the public from severe accidents. All SC1 power is provided by three divisions of SC1 batteries and UPSs. The batteries are sized for 72 hours, which allows for either of the two SC3 SDGs to start, external portable generators to be connected, or offsite power to be restored. Although the BWRX-300 is not committed to the requirement in the aforementioned regulatory documents that the plant have two offsite power sources, two sources of offsite power are typically used to improve reliability and operational flexibility, as shown in Figure 8-1 and Figure 8-2.

8.2.11 Specific Safety Requirements and Design Provisions for Withstanding Station Blackout

The BWRX-300 design complies with Specific Safety Requirements IAEA SSR-2/1 (Reference 8-11) and IAEA-TECDOC-1770 (Reference 8-6) further defines design requirements for EDSs with a focus on standby and Emergency Power Systems.

The BWRX-300 electrical systems are designed to meet IAEA SSR-2/1 (Reference 8-11). Although the BWRX-300 does not require any onsite or offsite AC power for safety, the permanently installed SDGs provide standby AC power and generally meet all requirements of IAEA SSR-2/1 (Reference 8-11). Restoring power as soon as possible is desirable. Following a plant LOOP, the SDGs are expected (although not credited) to automatically start and achieve rated voltage and frequency within 30 seconds. The completion of automatic sequencing is expected (but not credited) to take no longer than two minutes. The permanently installed batteries provide the emergency power required for the SC1, SC2, and SC3 loads to meet plant needs for 72 hours. If offsite power is not restored, AC power is provided via the SDGs or via permanently installed external connections for use with portable generators.

8.2.12 Specific Safety Requirements for Electrical Power Systems, DC and Uninterruptible Power Systems

The BWRX-300 design complies with IAEA SSG-34 (Reference 8-9) (including Section 7.83), which further defines requirements for electrical power systems with a focus on DC and uninterruptible power systems.

The BWRX-300 DC systems use two battery chargers, but only a single battery per division (contrary to SSG-34, (Reference 8-9), Section 7.84). The chargers are arranged such that one can carry the DC loads directly while the other applies an equalizing charge such that the loads do not have to be exposed to the equalizing voltage. It is important to note that this operational feature is optional and is not required to be used. Use of this feature removes the battery from the division. Additionally, the various DC loads are designed for equalizing voltages, if required. Additional guidance in IAEA SSG-34 (Reference 8-9) Section 2.9 (c) recommends the uninterruptible power system include a normal AC supply to the inverter and a bypass AC supply with an automatic switchover. The divisional electrical systems use two redundant UPSs, the bypass line breakers are kept open, and automatic swap over to the bypass AC is not provided. The reason for operating without the bypass breaker closed is in response to the Forsmark event (USNRC ML102070360, "Lessons from Forsmark Electrical Event," (Reference 8-12)).

8.2.13 Requirements for Alternate AC Power Supplies

IAEA-TECDOC-1770 (Reference 8-6) defines requirements for EDSs with a focus on alternate AC power supplies. The BWRX-300 electrical systems are designed to meet the equivalent of requirements for alternate AC power supplies. Permanently installed electrical connections/disconnects are provided for connection of portable generators as required. Onsite portable, transportable, or fixed power sources, or offsite portable or transportable power sources, or a combination of these, are provide for this purpose by the utility operator of the power plant.

8.3 General Principles and Design Approach

The BWRX-300 is designed in accordance with the following criteria. Any exceptions or clarifications are noted below.

8.3.1 General Design Criteria

The BWRX-300 is designed for compliance with 10 Code of Federal Regulations (CFR) 50, Appendix A General Design Criteria (GDCs) and PDCs as follows:

GDC 2 – Design bases for protection against natural phenomena – This GDC was considered in the design of the Offsite Power Systems and Onsite Power Systems. The Emergency Power System is SC1 and is designed to retain the capability to perform its Safety Category 1 functions during and after design basis natural phenomena events. Therefore, the Emergency Power System meets the requirements of this GDC.

No Safety Category 1 functions rely on AC power or DC power from the Standby Power System or Preferred Power System. Therefore, these systems are not required to meet the requirements of this GDC.

GDC 4 – Environmental and dynamic effects design bases – This GDC was considered in the design of the Offsite Power Systems and Onsite Power Systems. The Emergency Power System is SC1 and is designed to be compatible with environmental conditions associated with normal operation, maintenance, testing, and postulated pipe failure accidents including Loss-of-Coolant Accidents (LOCAs). Design requirements specify the duration that Safety Class 1 SSCs must survive the environmental conditions following a LOCA. The SC2 and SC3 SSCs that mitigate postulated initiating events are confirmed to be compatible with the environmental and dynamic effects present during the event scenarios where these functions are credited. Additionally, the failure of non-SC1 equipment due to environmental and dynamic effects does not impair SC1 equipment. No Safety Category 1 functions rely on offsite AC power. Therefore, the Offsite Power System is not required to meet the requirements of this GDC.

GDC 5 – Sharing of structures, systems, and components – The BWRX-300 is designed as a single unit and does not share any SSCs with other nuclear power units.

PDC 17 – Electric Power Systems – The BWRX-300 plant design supports PDC 17 compliance for offsite circuits by providing SC1 passive systems for core cooling and containment integrity. No offsite or diesel-generator-derived AC power is required for 72-hours after a DBA.

The basis for eliminating the need for reliance on an offsite electric power system described in PDC 17 also applies to the offsite power requirements of GDCs 18, 34, 35, 38, 41, and 44.

GDC 18, "Inspection and Testing of Electric Power Systems" – SC1 DC power sources are provided to support passive core cooling and containment Safety Category 1 functions. The SC1 DC power system has the capability for testing each battery, rectifier, battery charger and inverter without disrupting power to SC1 loads. Therefore, the design of the SC1 DC power system meets the requirements of this GDC. No offsite or diesel-generator-derived AC power is required for 72-hours after a DBA. Therefore, GDC 18 does not apply to the AC power systems or non-SC1 DC power systems.

GDC 33, Reactor coolant makeup – The high-pressure Control Rod Drive (CRD) system pumps can provide reactor coolant makeup using either onsite electric power (assuming offsite power is not available) backed up by SC3 standby diesel generators or offsite electric power (assuming onsite power is not available). Leaks larger than the CRD system pump capacity or if CRD pumps are not available are mitigated by ICS, which requires no AC power. Therefore, the electrical power requirements of GDC 33 are met.

GDC 34, Residual heat removal – The residual heat removal function for DBAs is performed passively by the ICS system. Neither offsite nor onsite power supplies are utilized in performance of the function. Therefore, there are no electrical power requirements for this GDC.

GDC 18, "Inspection and Testing of Electric Power Systems" – SC1 DC power sources are provided to support passive core cooling and containment Safety Category 1 functions. The SC1 DC power system has the capability for testing each battery, rectifier, battery charger and inverter without disrupting power to SC1 loads. Therefore, the design of the SC1 DC power system meets the requirements of this GDC. No offsite or diesel-generator-derived AC power is required for 72-hours after a DBA.

GDC 35, Emergency core cooling – The emergency core cooling function is performed passively by the ICS system. Neither offsite nor onsite power supplies are utilized in performance of the function. Therefore, there are no electrical power requirements for this GDC.

GDC 38, Containment heat removal – The containment heat removal function is performed passively by the Passive Containment Cooling System (PCCS). Neither offsite nor onsite power supplies are utilized in performance of the function. Therefore, there are no electrical power requirements for this GDC.

GDC 41, Containment atmosphere cleanup – The containment atmosphere is maintained as inerted such that cleanup systems, and therefore electrical power systems, are not required. Therefore, there are no electrical power requirements for this GDC.

GDC 44, Cooling water – The ICS and PCCS systems transfer heat to their associated pools passively, without the need for electrical power systems. Therefore, there are no electrical power requirements for this GDC.

GDC 50, Containment design basis – The containment electrical penetrations are designed to minimize leakage such that the containment does not exceed leakage limits. Therefore, the containment electrical penetrations meet the requirements of this GDC.

The EDS architecture is a configuration of generators, buses, transformers, and load centres that supply power to the design loads. The BWRX-300 Standard Design was developed to operate on a 60 Hz electrical grid although it accommodates potential 50 Hz deployment options for which technical studies have been completed to demonstrate feasibility. The UK GDA electrical design reference point is 006N5115 (Reference 8-2), which has been updated to address the UK grid operation at 50 Hz. GEH is evaluating the potential gaps in the ability of the BWRX-300 to operate in accordance with the UK Grid Code. GEH will report the results of this evaluation during Step 2 and will be implemented in a subsequent stage, see Appendix B for inclusion of Grid code matters in the Forward Action Plan (FAP).

The BWRX-300 Design Reference is defined in NEDC-34154P, "BWRX-300 UK GDA Design Reference Report," (Reference 8-13), which includes the Electrical Power System design reference definition.

8.3.2 U.S. Nuclear Regulatory Commission Regulatory Guides and Nuclear Regulatory Reports (NUREGs)

USNRC endorsed standards are used to show compliance to applicable USNRC Regulatory Guides (RGs).

RG 1.6, "Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems." The BWRX-300 does not need or have SC1 standby AC power sources. However, portions pertaining to the Emergency Power System meet Institute of Electrical and Electronics Engineers (IEEE) 603-2018.

RG 1.32, "Criteria for Power Systems for Nuclear Power Plants." SC1 DC power sources are provided to support passive core cooling and containment integrity safety functions. No offsite or standby diesel-generator-derived AC power is required for the initial 72-hours after a DBA. The Emergency Power System meets RG 1.32 by conformance with the guidance in IEEE 308-2020.

RG.1.47, "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems." The design of the Emergency Power System conforms to the applicable requirements given in IEEE 603-2018, as supplemented by the requirements included in RG 1.47.

RG 1.53, "Application of the Single-Failure Criterion to Safety Systems." The Emergency Power System complies with this guidance and meets IEEE 379-2014 and IEEE 603-2018.

RG 1.63, "Electric Penetration Assemblies in Containment Structures for Nuclear Power Plants." Electrical penetrations conform with this guidance and meet IEEE 317-2013.

RG 1.75, "Criteria for Independence of Electrical Safety Systems." Equipment and cable separation, and electrical isolation are in accordance with the requirements of IEEE 384-2018 and IEC 60709:2018.

RG 1.118, "Periodic Testing of Electric Power and Protection Systems." The design of the Emergency Power System is designed to accommodate required surveillance testing in accordance with the requirements of IEEE 338-2022 as supplemented by the guidance in RG 1.118.

RG 1.128, "Installation Design and Installation of Large Lead-Acid Storage Batteries for Nuclear Power Plants." The Emergency Power System batteries are designed with consideration of the recommended practices in IEEE 484-2019 as supplemented by the guidance of RG 1.128.

RG 1.129, "Maintenance, Testing, and Replacement of Large Lead-Acid Storage Batteries for Nuclear Power Plants." The SC1 batteries meet the requirements of IEEE 450-2020.

RG 1.153, "Criteria for Safety Systems." The Emergency Power System is single failure tolerant in accordance with the guidance in IEEE 603-2018.

RG 1.155, "Station Blackout." The BWRX-300 meets Station Blackout by having a 72-hour coping capability. Therefore, the intent of RG 1.155 is met, however, much of the guidance is not applicable due to the passive nature of the BWRX-300 safety systems.

RG 1.204, "Guidelines for Lightning Protection of Nuclear Power Plants." Refer to Section 8.7 for conformance to applicable standards.

RG 1.211, "Qualifications of Safety-Related Cables and Field Splices for Nuclear Power Plants." Conformance with guidance is met by compliance with IEEE 383-2023.

RG 1.212, "Sizing of Large Lead–Acid Storage Batteries." See Section 8.5.27 for conformance with applicable standards.

NUREG/CR 0660, "Enhancement of Onsite Diesel Generator Reliability." The BWRX-300 SDGs are not SC1, nor is AC power needed to achieve safe shutdown. Therefore, the NUREG is not directly applicable. However, D-in-D principles such as redundancy and diversity are incorporated in the design and integration of BWRX-300 systems.

8.3.3 General Principles and Design Approach Applicable to the EU and the UK

The BWRX-300 is designed in accordance with the following EU and UK criteria, including:

8.3.4 General Principles

The EDS architecture is a configuration of generators, buses, transformers, and load centres that supply power to the design loads. The design described in this document is for AC power at 50 Hz frequency, as identified in 006N5115 (Reference 8-2) (*Note: This section represents the EU and UK context equivalent to 8.2.1 above. It is acknowledged that some text is duplicated*).

For the BWRX-300, the Emergency Power System (EPS) safety functions are informed by PSR Ch. 3 (Reference 8-4).

Refer to IAEA SSG-34 (Reference 8-9) for:

- Independence between redundant standby (onsite) power sources and between their distribution systems. The BWRX-300 does not need or have SC1 standby AC power sources. Though this is applicable to SC1 DC systems.
- As AC power is not needed for the BWRX-300 to achieve safe shutdown, Application and Testing of the Safety-Related Diesel Generators, the BWRX-300 SDG units are not SC1.
- SC1 DC power sources are provided to support passive core cooling and containment integrity safety functions. No offsite or standby diesel-generator-derived AC power is required for the initial 72 hours after a DBA.
- Bypassed and inoperable status indication.
- Single failure criterion.
- Penetration assemblies' independence of electrical safety systems.
- Shared emergency and shutdown electric systems for multi-unit nuclear power plants. The BWRX-300 standard plant is designed as a single-unit plant.
- Availability of electric power sources. (The BWRX-300 passive plant design supports offsite power circuits by providing SC1 passive systems for core cooling and containment integrity. The plant design only requires one offsite circuit.)
- Protection for electric motors on motor-operated valves. The BWRX-300 does not require electric motors or motor operated valves to perform a Safety Category 1 function.
- Periodic testing of electric power and protection systems.
- Design and installation of lead-acid storage batteries.
- Maintenance, testing, and replacement of large lead-acid storage batteries.
- Design considerations imposed by criteria.
- Station blackout. (The BWRX-300 does not require AC power to achieve safe shutdown.)
- Qualification.
- Storage Batteries.

8.3.5 IAEA, IEC, and Other Relevant Codes and Standards

The BWRX-300 design complies with the following:

- Stability of offsite power systems
- Open phase conditions

- Generator reliability
- "Application of the Single-Failure Criterion"

IEC 62855, "Nuclear Power Plants — Electrical Power Systems — Electrical Power Systems Analysis," (Reference 8-14).

IEC 63046, "Nuclear Power Plants — Electrical Power System — General Requirements," (Reference 8-15).

IAEA Safety Series 50-SG-D3, "Protection System and Related Features in Nuclear Power Plants," (Reference 8-16).

IAEA Safety Series No. 50-SG-D7, "Emergency Power Systems at Nuclear Power Plants," (Reference 8-17).

IEC 60364-8-2, "Low-Voltage Electrical Installations - Part 8-82: Functional Aspects - Prosumer's Low-Voltage Electrical Installations," (Reference 8-18).

IAEA Safety Standards Series, DS 252, "Instrumentation and Control Systems Important to Safety in Nuclear Power Plants," (Reference 8-19).

IAEA SSG-39, "Design of Instrumentation and Control Systems for Nuclear Power Plants," (Reference 8-20).

- Also to include the capability of assuring its operable status during normal plant operation such that the indicating and annunciating function can be verified.

Chapters 5 and 7 of IAEA SSG-74, "Maintenance, Testing, Surveillance, and Inspection in Nuclear Power Plants," (Reference 8-21).

IAEA SSG-34, "Design of Electrical Power Systems for Nuclear Power Plants," (Reference 8-9).

BS 7671, "IET Wiring Regulations, Eighteenth Edition," (UK context) (Reference 8-22).

HSR25, "The Electricity at Work Regulations," (UK context) (Reference 8-23).

ONR Licence Condition Handbook (Reference 8-8).

IEC 60364, "Low-voltage electrical installations," (EU context) (Reference 8-24).

IAEA NG-T-3.8, "Electric Grid Reliability and Interface with Nuclear Power Plants," (Reference 8-25).

The BWRX-300 design will be assessed against the National Energy System Operator Grid Code. The Grid Code provides technical requirements for connecting to and using the National Electricity Transmission System. Confirmation of compliance or gaps and mitigations and further work will be included in further revisions of this document or a supplemental report (see Appendix B).

8.3.6 GEH Primary References

006N5200, "BWRX-300 Plant Electrical Systems Nuclear Regulations and Standards Compliance Plan," (Reference 8-26) lists the codes and standards that were used in the development of the BWRX-300 electrical system design. The information in this report demonstrates that the BWRX-300 electrical system design complies with relevant regulatory documents and specific national and international codes and standards, including but not limited to IAEA, CSA Group, IEC, and IEEE.

006N5115 (Reference 8-2). This document provides an overview of the EDS architecture, which is a configuration of generators, buses, transformers, and load centers that supply power to the BWRX-300 design loads. The design presented in this document encompasses global installations, with specific applications of 50 Hz AC power system aspects where applicable.

8.4 Offsite Power Systems

8.4.1 System and Equipment Functions

The BWRX-300 switchyard design is customer dependent, but the plant design allows significant flexibility. Because of the passive safety design of the BWRX-300 plant, only a single power feed between the plant and switchyard is required. Therefore, the utility is only required to provide one transmission line to the BWRX-300 switchyard from offsite sources. However, two sources of offsite power are typically used to improve reliability and operational flexibility, as shown in Figure 8-1.

Connection of the plant to the grid with only a single transmission line may be satisfactory for passive plants, see Section 1.10 of IAEA SSG-34 (Reference 8-9).

8.4.2 Safety Design Basis

The offsite power system is designed to provide a continuous source of power to the onsite power system throughout plant startup, normal operation (including shutdown), and abnormal operations. The offsite power system provides no credited safety category function. The BWRX-300 safety design does not require offsite power to be present to mitigate any DBAs. As a result, the total LOOP results in no effect on nuclear safety.

8.4.3 Documents Informing the EDS Safety Design

The EDS design is informed by:

- PSR Ch. 15.8: Safety Analysis - External Hazards (Reference 8-27) and mitigates external hazards
- PSR Ch. 15.5: Deterministic Safety Analysis including SAA (Reference 8-28)
- PSR Ch. 15.7: Deterministic Safety Analyses – Analysis of Internal Hazards (Reference 8-29) and mitigates internal hazards
- PSR Ch. 1: Introduction (Reference 8-30)
- PSR Ch. 3: Safety Objectives and Design Rules for SSCs (Reference 8-4)
- 005N3558, “BWRX-300 Fault Evaluation,” (Reference 8-31)

8.4.4 Conformance and Guidance

The passive plant water supplies in the ICS and fuel pools provide a cooling function for at least seven days without any active intervention. Isolation Condenser (IC) isolation valves fail as-is, and battery backed UPSs are needed to close isolation valves if an IC leak occurs. After seven days refilling of cooling pools and the reactor can be accomplished using the onsite diesel with SC3 systems, flex connections, portable pumps, and other available sources. PDC 17 states that offsite power is not required for mitigation of Anticipated Operational Occurrences (AOOs) and postulated accidents. The BWRX-300 does not require AC power sources for mitigating DBAs; PSR Ch. 15 (Reference 8-32) describes the design bases assumptions utilized for analysis.

The AC power system is designed such that plant auxiliaries can be powered from the grid under all modes of operation. During LOOP, AC power is supplied by the onsite SDGs or portable generators via Flexibly Installed Mobile Emergency Apparatus (FLEX) connections. Preassigned loads and equipment are automatically loaded on the SDGs in a predetermined sequence. Additional loads can be manually added as required.

8.4.5 Design Criteria, Regulatory Guides, and Standards Applicable Criteria

PDC 17, "Electric Power Systems." The BWRX-300 plant design supports PDC 17 compliance for offsite circuits by providing SC1 passive systems for core cooling and containment integrity. No offsite or diesel-generator-derived AC power is required for 72-hours after a DBA.

The basis for eliminating the need for an offsite electric power system described in PDC 17 also applies to the offsite power requirements of GDCs 18, 33, 34, 35, 38, 41, and 44.

GDC 18, "Inspection and Testing of Electric Power Systems." SC1 DC power sources are provided to support passive core cooling and containment Safety Category 1 functions. No offsite or diesel-generator-derived AC power is required for 72-hours after a DBA.

10 Code of Federal Regulations (CFR) 50.63, "Loss of All Alternating Current Power." The BWRX-300 design does not rely upon offsite power, onsite AC power, or operator action for the first 72-hours to achieve and maintain safe shutdown. As such, the passive design meets the requirements of the regulation.

RG 1.32, "Criteria for Power Systems for Nuclear Power Plants." The offsite power system is not SC1. Therefore, RG 1.32 is not applicable to the BWRX-300 offsite power system.

RG 1.47, "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems," and Branch Technical Position (BTP) ICSB 21, "Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems." The offsite power system is not SC1. Therefore, RG 1.47 and BTP ICSB 21 are not applicable to the BWRX-300 offsite power system.

BTP ICSB 11, "Stability of Off-site Power Systems." This topic is addressed in Section 8.3.3 and Section 8.4.10.

IEEE/IEC 62271-37-013 "International Standard for High-Voltage Switchgear and Control Gear – Part 37-013: Alternating Current Generator Circuit-Breakers," (Reference 8-33).

8.4.6 Description of the Offsite Power System

A local switchyard is designed and constructed to consolidate power output from the BWRX-300 Small Modular Reactor (SMR) facility and connect it with UK electrical power grid, see Figure 8-1.

The local switchyard will be operated via the Main Control Room (MCR) in the SMR facility. The SMR facility has two high-voltage connections with the local switchyard at a 400 kV or 275 kV voltage level. One line to output power from the GSU and one line to supply the RAT. The local switchyard has two redundant 400 kV or 275 kV connections with the transmitter.

The local switchyard is an indoor gas insulated switchgear type, following a breaker and half arrangement with two redundant busses (Figure 8-2). The local switchyard is designed to have local and remote-control capability to meet National Grid Electricity Transmission codes and standards.

Power is supplied to the plant from the switchyard connected to the transmission grid offsite power sources. The BWRX-300 has two connections to the switchyard. One connection is to the HV side of the GSU. The LV side of the GSU is connected to the main generator breaker via isolated phase bus duct and includes a branch to the UAT. The other connection is to the HV side of the RAT. The UAT and RAT secondaries are connected to the plant MV buses. The configuration is shown in Figure 8-1.

The GSU provides transmission of the main generator output to the grid when the plant is online and can provide power to the plant when the main generator is offline. When the generator breaker is closed and the plant is synchronized with the grid, the generator gross power output is approximately 300 MWe. When the generator breaker is open, the switchyard can "backfeed" power to the plant through the GSU and the UAT. The generator breaker is designed to perform its intended function during steady-state operation, power system transients, and major faults. The ratings and required capabilities of the generator circuit breaker are the designated limits of operating characteristics based on definite conditions as defined in IEEE/IEC 62271-37-013 (Reference 8-33).

The normally energised RAT interface provides a supplemental power path from the grid to the plant power distribution system. Like the UAT, the RAT is sized for 100% of the plant loading in both normal and abnormal operating conditions. The purpose of the preferred power source from the RAT is to provide operational Reliability, Availability, and Maintainability (RAM) to the system.

8.4.7 Design Requirements for the Offsite Power Systems

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

The switchyard, to which the main offsite circuits are connected, has two full-capacity main busses.

The switchyard main busses are designed such that any circuit breaker can be isolated for maintenance without interrupting service to any circuit.

Circuit breakers used in the switchyard and connected to the BWRX-300 plant are sized and designed in accordance with IEEE/IEC 62271-37-013 (Reference 8-33).

Disconnecting switches used in the switchyard and connected to the BWRX-300 plant are sized and designed in accordance with IEEE/IEC 62271-37-013 (Reference 8-33).

Transmission

The transmission system provides electric power from the utility grid to the offsite power system. The system is designed and located to minimize the likelihood of simultaneous failure during DBAs and adverse environmental conditions. The transmission system design bases requirements are contained in Section 8.3.2.

8.4.8 Transmission Switchyard

The switchyard is planned to be a breaker-and-a-half design unless interconnection studies warrant a more robust configuration. All line and bus relaying has sufficient redundancy and diversity to ensure that a failure of a breaker to open does not cause a loss of the switchyard and total offsite power to the plant. The switchyard breaker control and protective relaying is in a weather-enclosed switchyard house with its own power source for control and protection.

Control of the generator breaker is provided in the MCR. The control of all yard breakers is controlled by the transmission authority. Line status indication for the switchyard is provided in the MCR.

Operational experience has shown that an open phase condition on the high side of the large power transformers connecting the transmission network to the onsite power system is difficult to detect and has the potential to adversely affect downstream equipment. NUREG-0800 BTP 8-9, “Open Phase Conditions in Electrical Power Systems,” includes a detailed description of the issue and requirements for how to address it. The BWRX-300 complies with the requirements provided within BTP 8-9 for new reactors by including open phase detection. The open phase detection detects an open phase during all operational electrical system configurations and plant load conditions. Following detection of an open phase an alarm is generated in the MCR.

8.4.9 Transformer Area

The transformer area contains the GSU, the UAT, and the RAT. One feeder connects the transformer area with the switchyard to supply power to/from the GSU for the unit. A separate switchyard feeder supplies power to the RAT. The arrangement is shown in Figure 8-2.

Fire protection for the transformers is in accordance with Council on Large Electric Systems (CIGRE) Reference 537, "Guide for Transformer Fire Safety Practices," (Reference 8-34).

8.4.10 Grid Stability

The BWRX-300 has passive systems for core cooling and containment integrity and, therefore, does not depend on the electric power grid for mitigating DBAs. This feature significantly reduces the importance of the grid connection and the importance of grid stability for anything other than for power production. An Interconnection study will be performed during plant specific licensing to ensure that the transmission interface is adequate to meet the National Energy System Operator Grid Code.

8.4.11 Materials

Materials are expected to be suitable and compatible for use in the switchyard environment. Appropriate national standards and appropriate international standards are met. The switchyard is a typical switchyard design with commercially available equipment designed for this type of service.

8.4.12 Interfaces With Other Equipment or Systems

Interfaces with the switchyard are hard input/output with no network connections.

The offsite power system connects to the plant, via the Switchyard, through two transmission lines, one connected to the GSU, and one connected to the RAT. The monitoring parameters available in the MCR include breaker position, voltages, currents, power, and alarms.

The AC and DC power required by the switchyard equipment are separated from plant onsite power systems.

8.4.13 System and Equipment Operation

Switchyard breakers for the plant connections include design features that allow for remote operation by the plant operators.

8.4.14 Instrumentation and Control

Switchyard Instrumentation and Control (I&C) is provided in the MCR to monitor and control the breakers that interface with the plant.

8.4.15 Monitoring, Inspection, Testing and Maintenance

Monitoring of the offsite power system (i.e., switchyard parameters and the switchyard breakers) is made available to the plant operator and the grid operator through separate communication systems. Switchyard monitoring parameters available in the MCR include breaker position, voltages, currents, power, and associated alarms.

Most inspections are primarily visual, or infrared but individual breakers can be isolated for more intrusive inspections if needed.

Required electrical system testing is governed by the plant technical specification and industry standards. The electrical systems are designed to allow required tests to be performed with minimal disturbance to the balance of the system. Specific steps and alignments necessary for the successful performance of testing are to be controlled by plant procedures.

The switchyard system has been designed to be upgraded if necessary, using conventional techniques for upgrading software, or upgrading equipment. Replacement of major equipment (e.g., transformers, breakers) could require a significant outage to repair, modify or replace the equipment. The switchyard main busses are designed such that any circuit breaker can be isolated for maintenance without interrupting service to any circuit.

8.4.16 Radiological Aspects

The offsite electrical systems are not normally exposed to radiological environments. Accident doses are expected to be within the normal range of operating envelope, refer to PSR Ch. 2 (Reference 8-35), and 007N3183, "Annual Occupational Collective Radiation Dose for BWRX-300," (Reference 8-36).

8.4.17 Performance and Safety Evaluation

While there are no safety category functions for the offsite power system function, the offsite power systems provide net 300 MW of power to the grid and utilizes offsite power to power plant loads during normal and abnormal operating conditions. Therefore, no performance or safety evaluation is necessary. As stated previously, the total LOOP results in no effect on nuclear safety.

8.5 Onsite Power Systems

Onsite power systems provide power to the plant loads during all modes of plant operation. The onsite power systems include AC power systems and DC power systems.

The onsite AC power systems are described in Section 8.5.1. The DC power systems are described in Section 8.5.27. SSCs classification methodology is provided in PSR Ch. 3 (Reference 8-4).

The Onsite Power Systems comprise the Emergency Power System, the Standby Power System, and the Preferred Power System.

8.5.1 Alternating Current Power Systems (Onsite)

8.5.2 System and Equipment Functions

The onsite AC power system consists of a 50 Hz standby onsite AC power supply system and electrical distribution equipment. Figure 8-1 shows the plant main one-line diagram. The onsite power distribution system has multiple nominal bus voltage ratings. Equipment utilization voltages are designated as 6.6 kV, 690 VAC and 400/230 VAC.

The onsite AC power system starts at the GSU and RAT high side transformer bushings and transitions from there to include the GSU, the main generator, the main generator circuit breaker, the UAT, the RAT, and the rest of the plant AC distribution as depicted on Figure 8-1.

8.5.3 Safety Design Basis

The BWRX-300 has two connections to the switchyard. The normal power source is connected to the primary side Motor Operated Disconnect (MOD) of the GSU; the secondary side of the GSU is connected to the main generator breaker and includes a branch to the UAT of the plant. The power source can also be aligned to the MODs at the RAT primary side. The UAT and RAT secondaries are connected to the plant MV busses. The onsite AC power systems are not designed to perform any safety category functions to mitigate a DBA.

Battery-backed uninterruptible power is provided to post accident monitoring equipment in the control rooms for at least 72 hours.

(Note: The DC systems and batteries are designed to provide AC power (AC Distribution Panels 1A and 1B) to post accident monitoring equipment to the control rooms for at least 72 hours.)

8.5.4 System Design Requirements for Onsite AC Power Systems

The Onsite AC Power Systems are:

A. The Preferred Power System MV and LV busses and distribution, see Figure 8-3
B. The Standby Power System LV busses and Distribution, see Figure 8-5
C. AC power (AC Distribution Panels 1A and 1B), as above, see Figure 8-7 and Figure 8-8 (Note panels stated as “E” and “F” in these Figures are designated 1A and 1B in 006N5115 (Reference 8-2)).

The generic system design requirements for the AC electrical systems are listed below:

1. The LV AC distribution systems are solidly earthed.
2. Load assignments within the plant electrical systems are evenly distributed between the MV busses, to the extent practical, to maintain a reasonable load balance on the UAT and RAT secondary windings.
3. Current-carrying cables in the plant electrical systems are qualified to meet IAEA SSG-34 (Reference 8-9).

4. The equipment can perform correctly when exposed to worst-case environmental conditions of the applicable room/building.
5. The equipment and components in the plant electrical systems are classified to the seismic category appropriate for the safety classification and location of the system.
6. The equipment and components in the plant electrical systems are mounted to maintain the applicable seismic qualification.
7. Standby lighting with a safety category is powered from busses backed by a standby power source of the same (or higher) safety classification.
8. Normal lighting is powered from the Non-Safety Class (SCN) power generation busses to the extent practical.

In addition to the generic system design requirements listed above, the following design requirements are applicable for the EDS:

1. The UAT is sized to support 100% of the station loads for the worst-case operating scenario.
2. The UAT includes two secondary windings, both rated at 6.6 kV.
3. The UAT complies with IEC 60076 (all parts), configured (including vector group) for UK applications with two secondaries.
4. The UAT includes an automatic load tap changer, with a sensing voltage corresponding to the average voltage of the secondary feeds.
5. The main generator circuit breaker is sized and designed in accordance with IEEE/IEC 62271-37-013 (Reference 8-33).
6. The GSU is a single three -phase transformer.
7. The GSU complies with IEC 60076 (all parts), configured (including vector group) for UK applications.
8. The RAT is sized to support 100% of the station loads for the worst-case operating scenario.
9. The RAT and GSU each have a dedicated MOD connected to the primary winding.
10. The RAT includes two secondary windings, both rated at 6.6 kV.
11. The RAT includes an automatic load tap changer, with a sensing voltage corresponding to the average voltage of the secondary feeds.
12. EDS MV busses are used to supply loads required exclusively for power generation.
13. Fast bus transfer between the UAT and the RAT is initiated when bus voltage is lost to the A2 and B2 busses, during a faulted UAT bus, and during a unit trip.
14. The fast bus transfer is sufficiently fast to prevent downstream loads from dropping off the bus.
15. The fast bus transfer logic prevents transfer to a dead bus.
16. The fast bus transfer is one-directional from the normal preferred source to the alternate preferred source.
17. Unit substation transformers winding configuration is Delta primary to Wye secondary.
18. Unit substation transformers secondary Wye winding is solidly earthed.

In addition to the generic system design requirements listed above, the following design requirements are applicable for the EDS Preferred Power System:

1. Provides redundant LV power feeds to each Emergency Power System division, with each feed designed to provide the full power of the respective division.
2. Two Standby Power System SDGs provide backup power to the LV A21 and B21 busses for plant mechanical systems, investment protection, and the plant DCIS.
3. Each Standby Power System SDG is sized to supply 100% of the required Emergency Power System divisional loads in all three divisions while also supplying power to the required Preferred Power System safety categorised loads during a LOOP event.
4. The Standby Power System SDGs provide adequate voltage and frequency regulation during load sequencing and steady-state conditions.
5. The Standby Power System SDGs can accept a step change corresponding to the size of the largest load and remain within frequency and voltage limits.
6. The Standby Power System SDGs are controllable from the MCR, the Secondary Control Room (SCR) and locally.
7. Once started, Standby Power System SDGs are capable of synchronizing to the plant electrical system for test purposes.
8. The Standby Power System SDGs operate without requiring any plant services other than fuel, with the capability of continuous operation for at least one week without any offsite resources.
9. The SDGs incorporate protective relaying for protection and control.

The onsite AC power systems (Preferred Power System, Standby Power System, and SCN systems) have appropriate levels of hardware and software quality corresponding to the functions and systems receiving power. The systems provide reliable power to various plant functions (electrical loads) and provide an electrical pathway for the main generator to the utility switchyard/grid. The electrical systems are appropriately protected, monitored, recorded, and controlled by the plant operators. Various segments of the plant electrical system can operate independently.

8.5.5 Description

Power is supplied to the plant from the switchyard connected to the transmission grid offsite power sources. The BWRX-300 has two connections to the switchyard. One connection is to the HV side of the GSU. The LV side of the GSU is connected to the main generator breaker via isolated phase bus duct and includes a branch to the UAT. The other connection is to the HV side of the RAT. The configuration is shown in Figure 8-1.

The GSU provides transmission of the main generator output to the grid when the plant is online and can provide power to the plant when the main generator is offline via backfeed. When the generator breaker is closed and the plant is synchronized with the grid, the generator gross power output is approximately 300 MWe. When the generator breaker is opened, the switchyard can “backfeed” power to the plant through the GSU and the UAT. The UAT is sized to support 100% of the plant normal operating loads. The UAT is protected by breakers on both the primary and secondary side. Protection is provided for fault conditions and includes both transient and steady-state overvoltage protection. If a UAT fault occurs, the primary side breaker opens to prevent drawing fault current from the main generator and the grid.

The RAT interface provides a power path from the grid to the plant power distribution system. Like the UAT, the RAT is sized to support 100% of the plant normally operating power generation and safety categorized loads. The RAT interface provides operational flexibility and reliability to the system. For example, in the event of a failed UAT during power operation, the system isolates the failed UAT and automatically fast transfers to the RAT to supply plant loads.

Although the plant transformers are to be monitored by a condition monitoring system, it is expected that the transformer life is approximately 30 years. The design specifically supports changing the transformer during a long outage in 25 to 30 years, before the transformer end of life. The UAT and RAT are equipped with automatic load tap changers that assure the plant busses maintain nominal voltage under all grid or main generator voltage conditions and when the house loads change from power operation to outages. All other onsite transformers in load centres have manual tap changers. However, after initial setup, these should not have to be readjusted. Figure 8-1 depicts the A1 and B1 MV bus configuration for the EDS. The bus configuration and load allocation are such that these busses can be shut down for maintenance during outages and can be shut down one at a time in normal operation while minimizing the effect on plant power generation.

With the plant online providing power to the switchyard, the MV busses A1, A2, B1, and B2 busses are normally aligned to the UAT. With the plant offline, the MV busses are normally aligned to the RAT. The MV busses could also be aligned to the RAT during power generation, either manually or via fast transfer. Another possible alignment is with the plant offline supplying power to the MV busses via the UAT and GSU with the generator breaker open in a backfeed configuration.

The MV busses A1, A2, B1, and B2 protective relays are designed to automatically fast bus transfer between the UAT and the RAT. The fast bus transfer is automatically initiated on loss of power to busses A2 and B2, a faulted circuit in the normal Preferred Power System, and on a unit trip. The intent of this automatic action is to minimize the potential for a loss of power to the plant EDS and to minimize entrance into the backfeed operation alignment. The transfer logic is configured in such a way that it only occurs if power is available from the RAT. This prevents a transfer to a dead source. Additionally, to avoid the possibility of cycling between the normal and alternate preferred source, the fast bus transfer is one-directional (i.e., there is no possibility of an automatic transfer from the alternate preferred to the normal preferred source).

8.5.6 Station Blackout

The BWRX-300 design minimizes the reliance on electrical power to support safety class functions. The passive design of the plant is not dependent upon off site AC power sources or diesel generators to mitigate a DBA. For the evaluation of a LOPP with no reliance on the SDGs see PSR Ch. 15.8 (Reference 8-27), PSR Ch. 15.5 (Reference 8-28), PSR Ch. 15.7 (Reference 8-29), PSR Ch. 15 (Reference 8-32), PSR Ch. 15.1 (Reference 8-37), PSR Ch. 15.2 (Reference 8-38), PSR Ch. 15.3 (Reference 8-39), PSR Ch. 15.4 (Reference 8-40), PSR Ch. 15.6 (Reference 8-41), and PSR Ch. 15.9 (Reference 8-42). The Emergency Power System is supplied from battery backed DC power which has a coping period of 72 hours for all DBAs. Emergency Power System DC power sources are provided to support passive core cooling and containment safety category functions. This complies with the requirements station blackout rule as described in 10 CFR 50.63, “Loss of All Alternating Current Power,” and in accordance with IAEA-TECDOC-1770 (Reference 8-6). For GDC and PDC compliance, see Section 8.3.1.

8.5.7 Electric Circuit Protection

Load grouping facilitates the use of conventional protective relaying practices for isolation of faults. Protective relay schemes and direct acting trip devices are provided throughout the onsite power system to:

- Isolate faulted equipment and/or circuits from the power system

- Prevent damage to equipment
- Protect personnel
- Minimize system disturbances
- Maintain continuity of the power supply

8.5.8 Preferred Power System

The Preferred Power System provides the interconnecting EDS elements between the plant main generator, onsite power system, and the offsite power source. In addition, the Preferred Power System includes the entirety of the Balance of Plant (BOP) distribution system required for power generation. The Preferred Power System boundaries start at the high side bushings of the GSU and RAT and continue to the terminals of the Main Generator and downstream to the terminals of the BOP equipment. The system also includes protective relaying associated with the GSU, RAT, UAT and main generator, and a 250 Volts Direct Current (VDC) and UPS System.

The GSU provides transmission of the main generator output to the grid when the plant is online and can provide power to the plant when the main generator is offline. When the generator breaker is closed and the plant is synchronized with the grid, the generator gross power output is approximately 300 MWe. When the generator breaker is open, the switchyard can “backfeed” power to the plant through the GSU and the UAT. The UAT is sized to support 100% of the plant loading in both normal and abnormal operating conditions. Protection is provided for fault conditions and includes both transient and steady-state overvoltage protection. If a UAT fault occurs, the switchyard breaker, generator breaker, and secondary side breakers open, isolating the faulted transformer and causing automatic transfer to the RAT Preferred Power System path.

The normally energised RAT interface provides a supplemental power path from the grid to the plant power distribution system. Like the UAT, the RAT is sized for 100% of the plant loading in both normal and abnormal operating conditions. The purpose of this Preferred Power System source is to provide operational RAM to the system.

The GSU, UAT, and RAT are monitored by a condition monitoring system.

As shown on Figure 8-1, the onsite power system includes four 6.6 kV MV buses. The normal power system supply is connected through the UAT to the MV buses. The alternate supply to the buses is connected through the RAT to the MV buses and serves as backup to the UAT.

The MV bus configuration and load allocation is such that buses can be removed from service for maintenance during outages and can be removed from service one at a time in normal operation while minimizing the effect to plant power generation.

With the plant online providing power to the switchyard, the MV buses are normally aligned to the UAT. The MV buses can also be aligned to the RAT during power generation, either manually or via automatic transfer. The RAT is normally energised and ready to accept the plant load. With the plant offline and the generator breaker open, power is back fed through the GSU to the UAT supplying power to the MV buses.

8.5.9 Standby Power System

The Standby Power System includes the SDGs and the interconnecting AC system that is derived from it. Additionally, the Standby Power System includes the Standby Power System DC and UPS distribution system. The primary purpose of this system is to provide backup power in the event of a LOPP for loads which have a function required during a LOPP or loads which require power for plant investment protection.

Safety categorized functions supported by power from the Standby Power System have battery backed UPS power sources. These include functions associated with the FMCRDs and the DCIS. The non-battery backed portion of the system supports equipment that relies upon an SDG-backed power source. These include functions such as shutdown cooling, plant cooling water, and boron injection. A FLEX connection is provided to ensure power can be provided from a portable power source.

SDGs are the backup source of power to the Emergency Power System. However, when the associated bus loses power, the SDG automatically starts after a short delay. Specific loads on the LV buses (and the derivative Motor Control Center (MCC)) are automatically sequenced after the SDG successfully starts. Load sequencing is based on relative importance and coordinates with the dropout of battery chargers and UPS. The SDGs can be manually started/controlled from the MCR, the SCR, and locally.

8.5.10 Onsite Standby Power Performance

The Standby Power System provides redundant LV power feeds to each Emergency Power System division.

Each train of the Standby Power System is designed to supply the full load of all three Emergency Power System divisions, inclusive of a single charger per division operating at rated load.

The Standby Power System provides two SDGs for 690 VAC backup power to the LV buses for plant mechanical systems, investment protection, and the plant DCIS.

The SDGs meet the following requirements:

- Sized to supply 100% of the required Emergency Power System divisional loads in all three Emergency Power System divisions while also supplying power to the required Emergency Power System loads during a LOOP event.
- Can be controlled from the MCR, SCR, and locally.
- Provide voltage and frequency regulation within the 50 Hz limits required by IEC 60038, “IEC standard voltages,” (Reference 8-43) and BS EN 50160, “Voltage characteristics of electricity supplied by public electricity networks,” (Reference 8-44).
- Capable of closing into a dead bus.
- Once started, operate without requiring any plant services other than those required to store and transfer fuel, with the capability of continuous operation for at least 7 days at rated power without any offsite resources.

8.5.11 Electrical Equipment Layout

The Preferred Power System GSU, UAT, and RAT are located outside the Turbine Building (TB) at the generator end of the building.

The Emergency Power System divisions are in the Reactor Building (RB), which is a Seismic Category 1A structure. Each of the three Emergency Power System divisions have an independent and physically separate power feed from each of the Standby Power System LV SDG backed buses. Each of the three Emergency Power System divisions are independent and physically separate from other Emergency Power System divisions and from other electrical systems of the plant.

8.5.12 Analysis

Emergency Power System includes battery chargers, batteries, and UPSs. The UPSs supply AC power to the loads required for 72 hours after a DBA or loss of onsite and offsite AC power.

(Note: The Preferred Power System and Standby Power System do not contain SC1 components.)

The configuration and system designs for the BWRX-300 electrical systems must provide acceptable power and voltage to station loads for all configurations and plant modes of operation. The system is designed to meet the following criteria:

- The minimum and maximum allowable steady state voltages for connected equipment.
- The minimum and maximum allowable transient voltages for connected equipment.
- The maximum allowable voltage drop across connecting equipment.
- The maximum allowable short circuit current for major electrical equipment.
- Allowable configurations for the electrical systems.
- The required modes or operation for the electrical systems.
- Established margins consistent with IEEE standards for equipment sizing and operation.
- Frequency and voltage tolerance for systems and equipment.

8.5.13 Environmental Considerations

The Emergency Power System equipment is capable of performing under worst case conditions when required to perform its safety category function. This equipment that must operate in a harsh environment during and subsequent to an accident is provided in PSR Ch. 15.8 (Reference 8-27), PSR Ch. 15.5 (Reference 8-28), PSR Ch. 15.7 (Reference 8-29), PSR Ch. 15 (Reference 8-32), PSR Ch. 15.1 (Reference 8-37), PSR Ch. 15.2 (Reference 8-38), PSR Ch. 15.3 (Reference 8-39), PSR Ch. 15.4 (Reference 8-40), PSR Ch. 15.6 (Reference 8-41), and PSR Ch. 15.9 (Reference 8-42), including Seismic Qualification.

8.5.14 Freeze and Cathodic Protection System

The freeze protection system provides environmental protection to plant equipment to prevent freezing. The electric heat tracing system provides freeze protection where required for outdoor service components and warming of process fluids if required, either indoors or outdoors.

The cathodic protection system uses an electrical process that reverses the basic corrosion reaction by applying a DC current to counteract the corrosion current and thus prevent or decrease the rate of corrosion of a metal in an electrolyte.

The freeze and cathodic protection system are classified as SCN.

8.5.15 Containment Building Electrical Penetrations

Primary electrical containment penetrations meet the requirements of IEEE 317-2013 and IEEE 741-2022, which meets the intent of IAEA SSG-34 (Reference 8-9).

8.5.16 Motor Operated Valve and Thermal Overload Bypass

There are no motor operated valves supplied by the Emergency Power System in the BWRX-300 design.

8.5.17 Cables Subject to Submergence

The underground duct banks used in the plant design have sufficient drainage to minimize any potential for long term submergence.

8.5.18 Bypass and Inoperable Status Indication for Engineered Safety Features Systems

The Emergency Power System design includes provisions for bypass and inoperable status indications in accordance with NUREG-0800 BTP 8-5.

8.5.19 Cable Raceway System

The Cable Raceway System includes raceway and supports necessary to route cable in and between buildings and equipment using cable trays, conduits, duct banks, or tunnels.

The cabling and raceways are designed to meet the following design requirements:

1. Equipment, cabling separation, and electrical isolation are based on IEC 60709, "Instrumentation, Control and Electrical Power Systems Important to Safety – Separation," (Reference 8-45). This supports compliance with IAEA SSG-34 (Reference 8-9).
2. Fire protection and fire safe shutdown program requirements are supported by cable separation, fire barriers, limiting cable tray fill, 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, in accordance with BS EN 61034, "Measurement of smoke density of cables burning under defined conditions - Test procedure and requirements," (Reference 8-46) and BS EN 60754-1 + A1 "Test on gases evolved during combustion of materials from cables raceway and cable routing," (Reference 8-47).

Cable Separation

The Cable Raceway Systems are separated on the basis of function, division, and voltage class. The raceways are physically arranged top to bottom based on the function and the voltage class of the cables.

<u>Voltage Level Segregation</u>

Cable systems have electrical segregation according to voltage levels, signal levels, and vulnerability to electrical noise pickup.

LV power and control cable classifications have compatible operating temperatures and voltage (690V or less) ratings when installed in the same raceway.

<u>Protection Group Separation</u>

Cabling for separate protection groups and tele protections protecting the same system element are physically separated.

The use of fibre optics for separate protection groups and tele protections protecting the same system element does not result in a common mode failure.

Wiring for separate protection groups and tele protections protecting the same system element are not located in the same cable or terminated in the same panel.

Raceways containing the cabling of two protection groups protecting the same element are sufficiently separated, in both horizontal and vertical planes to allow enough time to isolate the affected facility subsequent to a failure in one raceway while maintaining operation of one protection group.

<u>Scram Solenoid Cables</u>

Scram solenoid cables are routed in dedicated conduit from each Division 1 and Division 2 DCIS cabinet to each hydraulic control unit group 1, 2, 3, and 4 cabinet. The Emergency Power System consists of three divisions and 4 scram groups. The Emergency Power System cables comply with RG 1.75 above, and IAEA SSG-34 (Reference 8-9).

Non-safety systems maintain spatial separation as required in IAEA SSG-34 (Reference 8-9) to meet common mode failure redundancy such as fires, flooding, and other events determined by risk evaluation.

Cable Derating and Cable Tray Fill

Cable tray fill is limited to a percentage of cross-sectional area. The tray fill is justified and documented.

Cable Tray and Cable Routing

Cables are routed in horizontal and vertical runs of steel trays or through steel conduits. Trays or conduits are supported at intervals by appropriately designed supports. The supports are attached to walls, floors, and ceilings of structures as required by the arrangement. The type of support and spacing is determined by allowable tray or conduit spans which are governed by rigidity and stress. Underground raceways have limited application for the BWRX-300. When underground raceways are required, they are appropriately sloped and drained to minimize the potential for long term cable submergence.

8.5.20 Materials

Materials to be used are specified and evaluated by GEH for design and commissioning. Materials are expected to be suitable and compatible for use in the environment, and that appropriate international standards are identified and met. The design utilizes materials typical for this type of service with commercially available equipment. Materials are associated with the safety category of the individual systems. SSCs are evaluated based on the safety category and functions. Materials are evaluated and selected based on the environmental conditions and safety category of the equipment as per PSR Ch. 6 (Reference 8-48).

8.5.21 Interfaces With Other Equipment or Systems

Interfaces between the EDS and I&C systems are in accordance with the requirements of IEC 61513, "Nuclear Power Plants – Instrumentation and Control Important to Safety – General Requirements for Systems," (Reference 8-49).

The BWRX-300 standard plant design utilizes a safety classification approach versus a safety-related approach. The UK/European classification approach follows IAEA SSG-34 (Reference 8-9). There is no safety significant AC power for ICS systems, thus this discussion is not applicable to the BWRX-300.

The onsite AC power system, interfaces primarily with the following:

1. The offsite AC power system
2. The onsite DC power systems
3. Plant loads

The SDGs are electric start and radiator cooled and do not require plant mechanical support services for operation (such as plant auxiliary cooling or instrument air). Either of the SDGs can support all the Preferred Power System loads and Emergency Power System loads (three divisions) that require power for completion of safety functions (i.e., either SDG can support active decay heat removal). There is onsite fuel storage in large storage tanks and day tanks for each SDG. The large storage tanks hold enough fuel for at least seven days of full power operation of the SDGs at rated load. The local day tanks are in addition to the seven-day supply of fuel to support online testing; the day tanks alone provide up to eight hours of full power operation at rated load. The most important loads on the A21 and B21 busses are the Emergency Power System UPS, battery chargers, and Regulating Voltage Transformers (RVTs). Next in line as a matter of importance are the Standby Power System LGs that provide power to the UPSs, battery chargers, and RVTs. Along with these two LGs, the four FMCRD UPSs are of high importance.

8.5.22 System and Equipment Operation

The onsite AC power system starts at the GSU and RAT MODs and transitions from there to include the GSU, the main generator, the main generator circuit breaker, the UAT, the RAT and the rest of the plant AC distribution as depicted on Figure 8-1. The onsite power system includes four 6.6 kV MV busses A1, A2, B1, and B2. The UAT powers MV busses A2 and B2 from either the main generator or backfeed from the GSU if the generator is not operating. If the UAT is unavailable or for operational flexibility, the MV busses can be powered from the RAT.

The A1 and B1 MV busses are normally supplied by A2 and B2 busses during power operation.

The A2 and B2 MV busses supply power to LV 690 VAC load centres A21 and B21. The A21 and B21 LV busses can be aligned to the MV busses A1 and B1.

If power is lost from the MV busses, busses A21 and B21 are powered by dedicated and physically separated SDGs.

The A21 and B21 LV busses are normally aligned through the MV busses to separate windings of the UAT. The A21 LV bus is normally supplied by MV Bus A2 connected directly to the UAT. Bus A21 can be powered from Bus B21 through a normally open crosstie breaker arrangement.

The A21 and B21 LV busses can also be supplied by the Standby Power System SDGs. The SDGs are electric start and radiator cooled and do not require plant mechanical support services for operation. Either of the SDGs has sufficient capacity to support all Emergency Power loads (three divisions) and Standby Power loads. The SDGs can also provide power to loads required to provide active decay heat removal. There is onsite fuel storage for each SDG for at least a week of full power at rated load. Refer to PSR Ch. 9A (Reference 8-3).

The A21 and B21 LV SDG backed busses are in separate fire-barrier separated rooms. A21 and B21 busses provide normal power to the following critical loads:

- Emergency Power UPSs and battery chargers
- The Standby Power LGs
- The FMCRD UPSs

A21 and B21 and derivative busses, SDGs, digital protection relays, and other components are designed, selected, and qualified to the requirements applicable to their safety categorization.

During a LOOP, the busses A21 and B21 are automatically powered by the associated SDG. The SDG supply breakers to the busses are interlocked with the normal offsite source breakers to prevent the undesired paralleling of sources, while allowing periodic SDG testing by synchronizing to and loading into either normal power feed.

8.5.23 Instrumentation and Control

The BWRX-300 onsite AC power systems are monitored and controlled by DCIS equipment of a corresponding safety classification. Generally, the DCIS control systems are expected to operate and monitor the plant transformers and feeder breakers, including load breakers for pumps, adjustable speed drives, or other plant equipment.

8.5.24 Monitoring, Inspection, Testing and Maintenance

If electrical equipment is found to be inoperable or failing, operators would be alerted, and an inspection of the equipment would be initiated. Operators would make the decision based on inspection to replace or repair or monitor the equipment for any further degradation.

The design of the plant electrical systems accommodates online testing and inspection to the extent practical. Condition monitoring equipment is included where appropriate.

Periodic starting and loading of the SDGs is expected to be required by plant technical specifications.

To the extent practical, the design of the plant electrical systems includes the capability to isolate, maintain, and test individual components and equipment while the plant is online.

Nuclear power plant commissioning usually involves three types of testing, in order of plant completion:

- Construction tests
- Preoperational tests
- Startup/power ascension tests

The first two test types may overlap, but the last test type requires that the first two be completed before fuel loading is allowed. The plant electrical system is to be involved in all testing but note that no significant plant testing can be done until the plant electrical system is operational. In this context, "operational" implies that the system powers mechanical loads that need testing and power the plant DCIS loads needed to monitor, control, and record the plant systems to be tested. This implies that the plant electrical system should be among the first operational installed systems:

- The design on the onsite AC power systems includes provisions for connection to construction power.
- The plant electrical system switchgear and distribution equipment include access points in the front, back, and sides as needed to support efficiency in constructability.

Where possible, it is intended to purchase electrical components that do not require maintenance for a 60-year plant lifetime. The large BWRX-300 plant transformers (GSU, UAT, and RAT) have a realistic 30-year lifetime. Condition monitoring of the transformers and other important equipment is provided to assist in determining appropriate maintenance and replacement intervals.

NOTE: The transformers are expected to be conservatively rated to reduce heat and maximize longevity.

The BWRX-300 plant is designed to meet a 60-year design life assuming required maintenance, operational program requirements, and equipment replacements, as needed, are accomplished. Replacement frequencies follow manufacturer guidance and in combination with available monitoring data if available.

Standby Diesel Generator Capacity Testing

The SDGs are tested periodically to verify that anticipated loads can be satisfactorily loaded and supported. The SDG supply breakers are interlocked with the normal supply breakers to prevent the undesired paralleling of sources, while allowing paralleling of sources to allow periodic SDG testing by synchronizing and loading to the normal power feed. Protective features are provided to separate the diesel under test from the grid in the event of a LOOP. The testing is to ensure that the function of the SDGs can operate under the anticipated loads.

There is no requirement for the SDG to operate following a DBA.

The SDGs are automatically started and loaded upon a LOPP. The SDGs are designed and sized to carry the loads for plant recovery from DBA and LOPP events. The SDGs are tested periodically to verify that anticipated loads can be satisfactorily loaded and supported. This testing is to ensure the SDGs can be auto started and then auto loaded by the sequencer.

Cable and Raceway Inspection and Testing

Normally the cabling and raceways are designed to not require any inspections once they have passed installation and commissioning testing. If special inspection considerations are required, they are performed under plant inspection programs.

Cabling and raceways testing is based on preventive and predictive maintenance programs. Site testing requirements are used for post installation testing and inspection.

The cables and raceways are designed for their location to maintain their required function. The cables and raceways are qualified for the anticipated environment during the lifetime of the plant. If a shorter in-service life is required, it is controlled under the environmental qualification program.

8.5.25 Radiological Aspects

The onsite AC power system is qualified for the safety category function, and corresponding locations, see PSR Ch. 2 and PSR Ch. 15 (Reference 8-32) and Chapters 15.1 to 15.9, PSR Ch. 15.8 (Reference 8-27), PSR Ch. 15.5 (Reference 8-28), PSR Ch. 15.7 (Reference 8-29), PSR Ch. 15.1 (Reference 8-37), PSR Ch. 15.2 (Reference 8-38), PSR Ch. 15.3 (Reference 8-39), PSR Ch. 15.4 (Reference 8-40), PSR Ch. 15.6 (Reference 8-41), and PSR Ch. 15.9 (Reference 8-42) for Environmental Qualification.

8.5.26 Performance and Safety Evaluation

The onsite AC EDS is expected to perform their design functions in normal and abnormal conditions. The reliability of any safety significant item is to be commensurate with its safety significance.

8.5.27 Direct Current Power Systems

8.5.28 System and Equipment Functions

The onsite DC power system is divided into three subsystems. The system and equipment functions are described below:

Emergency Power System

- The Emergency Power System is shown in Figure 8-4.
    - The Emergency Power System DC power system powers the DCIS equipment responsible for automatic shutdown and decay heat removal. The Safety Category 1 DCIS functions are executed in a fail-safe manner through removal of power with exception of the IC leak detection and isolation. See PSR Ch. 7 (Reference 8-50).
    - The Emergency Power System DC power system powers inverters to provide AC power (AC Distribution Panels 1A and 1B) to post accident monitoring equipment for the control rooms for at least 72 hours.
    - As a seismically qualified DC power source, the Emergency Power System DC power system also supplies power to loads required during or following a seismic event.

Standby Power System

- The Standby Power System is shown in Figure 8-5 and Figure 8-6.
  - The loads assigned to the Standby Power System UPSs and batteries are those required for the BWRX-300 to achieve safe shutdown and include the equipment that provides a diverse, active alternative to Safety Category 1 functions.

Preferred Power System

- The Preferred Power System is shown in Figure 8-7 and Figure 8-8.
  - The Preferred Power System DC power is designed to provide power to DC loads, such as DCIS, protective relaying, and breaker control power.

8.5.29 Safety Design Bases

The safety design basis criteria are provided below for each of the three DC subsystems.

- Emergency Power System DC power
  - The design of the DC Emergency Power System conforms to the applicable requirements given in IAEA SSR-2/1 (Reference 8-11), and IAEA SSG-34 (Reference 8-9).
  - The Emergency Power System batteries meet the qualification requirements of IEC/IEEE 60780-323, "IEC/IEEE International Standard - Nuclear facilities -- Electrical equipment important to safety – Qualification," (Reference 8-51) and IEC/IEEE 60980-344, "IEEE/IEC International Standard - Nuclear facilities - Equipment important to safety - Seismic qualification," (Reference 8-52).
  - A single failure in the Emergency Power System that results in a loss of any single divisional AC output does not result in loss of both AC outputs within that division's DC power system.
  - The Emergency Power System batteries have enough stored capacity without chargers to independently supply loads continuously for at least 72 hours with a minimum final discharge voltage sufficient to support the associated loads.
  - Each of the Emergency Power System UPSs are able to supply 100% of the divisional load.
  - The Emergency Power System divisions are electrically separate such that no electrical connection exists between a UPS in one Emergency Power System division and a component in another Emergency Power System division.
- Standby Power System DC power
  - The Standby Power System batteries have enough stored capacity without chargers to independently supply loads continuously for at least 72 hours with a minimum final discharge voltage sufficient to support the associated loads.
  - The DC Standby Power System supplies power to SC2 loads.

Safety Design Bases UPS and Batteries

1. All Emergency Power System batteries and equipment are physically separated and electrically independent in accordance with the requirements given in IEC 60709 (Reference 8-45).
2. All battery chargers and UPSs disconnect from the AC input whenever that input varies outside the range of +/-15% voltage from nominal for greater than 60 seconds.

3. All battery chargers are able to function as battery eliminators.
4. All battery chargers produce a filtered DC output that meets the requirements of IEC 61000-4, “Electromagnetic Compatibility Testing and Measurement Package,” (Reference 8-53).
5. All battery chargers are housed in National Electrical Manufacturers Association (NEMA) Type 1 ventilated enclosures.
6. All battery chargers include overvoltage protection on the output that shuts down the charger upon actuation.
7. All battery chargers are of a current limiting design.
8. All battery banks are designed to permit replacement of individual cells. The plant DC systems consist of an un-Earthed system with ground detection.
9. All UPSs maintain rated output voltage +/-5% from zero to rated load.
10. All UPSs are sized to provide the current of a single faulted load in addition to all other normal loads, while still providing normal output voltage.
11. The UPS bypass RVTs maintain a nominal output voltage within +/-5% over an input voltage variation of +10% and -15%.
12. The battery chargers, UPS, lighting, and convenience power all work continuously without operator intervention.
13. Category B, Transient voltage surge suppressors are used on the input circuit to battery chargers, UPSs, and associated bypass circuits to protect against voltage surges.
14. In accordance with IEC 61225 (Reference 8-10) adequate filtering is provided by the battery charger.
15. Provisions for maintenance and testing are in accordance with IEC 62040-5-3, “Uninterruptible power systems (UPS) Part 5-3: DC output UPS — Performance and test requirements,” (Reference 8-54).

Physical Identification of the Emergency Power System Safety Class 1 Equipment

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 equipment and wiring of different divisions, and safety categorized / non safety categorized equipment and wiring. The identification method is colour-coding. All markers within a division have the same colour. The BWRX-300 equipment, cabling separation and electrical isolation are based on function and performed in accordance with the requirements of IEC 60709 (Reference 8-45), and RG 1.75. Divisional separation requirements of individual pieces of hardware are shown in the system elementary diagrams. Identification of raceways and cables is compatible with the identification of the safety categorization of equipment with which it interfaces. Location of the identification is such that points of change of circuit classification (at isolation devices) are readily apparent.

Independence of Redundant Systems

Each of the Emergency Power System divisional rooms in the RB are physically separate from and individually fire-barriered and flood-barriered from the other Emergency Power System divisional rooms.

Safety Class 1 to Non-Safety Class 1 Isolation

Anticipated electrical faults are selectively isolated by protective devices. Such isolation is accomplished by ensuring acceptable coordination between protective devices in accordance with the requirements of IEC 60255, "Measuring Relays and Protection Equipment," (Reference 8-55) and IEC 62855 (Reference 8-14).

Bus arrangement, load allocation, and equipment and cable separation ensures that for any single fault, the performance of the safety class functions is not compromised.

Non-Safety Class 1 Direct Current and Uninterruptable Power Supply System

The onsite DC power system description for each of the two subsystems is provided below.

8.5.30 Description

Standby Power System Direct Current Power System

The most important loads on the Standby Power System 690 VAC buses are the Emergency Power System UPS, battery chargers, and RVTs. Next in line as a matter of importance are the Standby Power System LGs for the UPSs, battery chargers, and RVTs. Along with the two Standby Power System LGs, the four FMCRD UPSs are of high importance. Refer to Figure 8-5.

The loads assigned to the Standby Power System UPSs and batteries are those required for the BWRX-300 to achieve shutdown and include the equipment that provides a diverse, active path to Safety Category 1 functions. The DC Standby Power System, depicted in Figure 8-6, is designed to carry the loads via dedicated batteries, independent of offsite or diesel AC power. The Standby Power System LV LGs include surge protection via a Transient Voltage Surge Suppressors (TVSSs) to prevent HV spikes propagating to the battery chargers, UPSs, and RVTs. The Standby Power System includes two LGs. Each LG has an individual UPS in support of the respective Standby Power System DCIS division, along with other loads. The LG UPSs provide three-phase 400/230 VAC outputs. Redundant circuits are provided from separate UPSs to support redundant power sources to the DCIS.

Additionally, the Standby Power System includes four separate rod group UPSs for the FMCRDs.

The Standby Power System DC subsystem includes the following design features:

1. Any load requiring power for completion of a Safety Category 2 function is powered from the Standby Power System UPSs, batteries or RVTs and cannot be powered directly from the upstream Standby Power System AC buses. The Standby Power System is designed with redundancy such that the failure of a single electrical bus or MCC has no adverse effect on the redundant counterpart.
2. Battery banks are sized such that the sum of the required loads does not exceed the battery ampere hour rating over the rated discharge period or 80% warranted capacity at the end of the installed life with 100% design demand.
3. Batteries have enough stored capacity without chargers to independently supply loads continuously with a minimum final discharge voltage sufficient to support the associated loads.
4. Redundant LG battery chargers support equalization and battery testing without effects to downstream loads.
5. LG UPS outputs provide a three-phase nominal AC voltage of 400/230 VAC, 50 Hz.
6. LG battery banks are designed to supply DC power at 250 VDC nominal.
7. DC and UPS systems are powered from diesel-backed sources.

Preferred Power 250 VDC Power System

The Preferred Power System DC subsystem system is designed to provide Preferred Power to DC loads, such as protective relaying and breaker control power. As shown in Figure 8-7, two independent 250 VDC batteries are provided, supplying power to two independent 250 VDC buses. The redundant configuration is compliant with North American Electric Reliability Corporation and Northeast Power Coordinating Council requirements for separate backup power for bulk power systems. A battery mission time of eight hours is selected to align with typical designs for bulk power systems substations. Each DC bus and each battery is normally supplied power and charging current from its associated charger. A standby charger capable of being aligned to either bus or battery is provided in case any given charger is out of service. Each charger is designed to supply 100% of the required load of a single bus while charging the battery. The two primary chargers derive LV AC power from separate 690 VAC Preferred Power System buses. The standby charger is supplied through a transfer switch, which can derive power from either SDG backed LV buses. The standby charger connection to the SDG buses provides operational flexibility in the event of an extended bus outage.

As shown in Figure 8-8, two independent UPSs are provided that provide a three-phase 400/230 VAC 50 Hz output to independent buses. The UPSs derive power from their associated 250 VDC bus. The UPSs are equipped with both static and manual transfer switches aligned to an RVT. The RVTs are normally energised and derive power from a separate AC source than that which supplies the associated battery charger. The static transfer switch operates automatically as needed for UPS output faults.

The following design features are applicable to the preferred power DC subsystem:

1. The Preferred Power System UPS outputs provide a three-phase nominal AC voltage 400/230 VAC, 50 Hz.
2. The Preferred Power System battery banks are designed to supply DC power at 250 VDC nominal.
3. The Preferred Power System batteries have enough stored capacity without chargers to independently supply loads continuously for at least eight hours, with a minimum final discharge voltage sufficient to support the associated loads.
4. Preferred Power System batteries are physically separated and electrically independent in accordance with the applicable requirements of the grid connection authority having jurisdiction.

8.5.31 Materials

Materials are associated with the safety categorization of the individual systems. Materials are evaluated and selected based on the environmental conditions to which the cables/raceways are exposed in conjunction with the safety categorization of the equipment being served. The safety categorization of the equipment is as per PSR Ch. 6 (Reference 8-48).

8.5.32 Interfaces with Other Equipment or Systems

The BWRX-300 standard plant design utilizes a safety classification approach versus a safety-related approach as defined by IEEE 384-2018 and in accordance with IAEA SSG-34 (Reference 8-9). There is no SC1 AC power for the ICS system, thus this discussion is not applicable to the BWRX-300.

8.5.33 System and Equipment Operation

The onsite DC power system description for each of the Emergency Power System DC and UPS subsystems is provided below.

Like the three-division I&C DCIS, the Emergency Power System consists of three separate and independent divisions of power. With the design of the I&C DCIS, only two of the three of emergency power backed divisions are required when a DBA occurs, and the plant safety category functions are still achieved. Similarly, only two of the three corresponding Emergency Power System divisions are required to mitigate a DBA. Within each Emergency Power System division, there are two UPSs, and each divisional load can be powered from either UPS, such that either UPS source can fulfil the divisional safety category function.

Figure 8-4 represents a typical design of one of three divisions of the Emergency Power System. Each division contains two battery chargers, each with the capacity to power loads while providing the maximum battery charge current. The 250 VDC batteries are sized to provide 72 hours of emergency power to ensure all functions requiring power are available and sufficient PAM is provided over the 72-hour period. The 72-hour requirement is consistent with the overall plant design basis and regulatory requirements including USNRC NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Plants: LWR Edition, Section 8.4 for Station Blackout.

As shown in the main electrical one-line diagrams in Figure 8-1 and Figure 8-4, the Standby Power System provides separate feeds from a Preferred Power System LV bus to the three divisions of Emergency Power System. Each Emergency Power System division can be continuously energised from multiple sources: offsite power (normal supply), SDG power (backup supply), portable generator power (external building connections), or individual division battery power (emergency supply). Each Standby Power System supply train (diesel generator and associated equipment) is sized to supply all three Emergency Power System divisions. By division, SDG sizing considers one charger operating at rated capacity. Independent of offsite or standby power each division can be supplied by the Emergency Power System batteries (emergency supply). In the unlikely event that AC power provided by the LV buses is of insufficient quality, the battery chargers and UPS automatically isolate from the station EDS and the Emergency Power System loads are supplied by the batteries. Additionally, external connections are provided for connection of FLEX as needed.

Loading on each of three divisions is similar with a few exceptions such as lighting, which is distributed on only two of three divisions. Each division is designed to the maximum load and mission time of the three divisions.

The Emergency Power System batteries, battery chargers, UPSs, and associated components are in the RB, which is a Seismic Category 1A structure. Divisional components are in separated rooms that are fire- and flood-barriered from each other by division. The electrical components and equipment in these areas are qualified to environmental and seismic conditions.

The following design requirements are applicable to the Emergency Power System:

The design of the Emergency Power System conforms to IEC 60255 (Reference 8-55), IEC 62855 (Reference 8-14), IEC 63332-387, "Nuclear Facilities - Electrical Power Systems, Part 387: Diesel Generator Units Applied As Standby Power Sources," (Reference 8-56), IAEA SSG-39 (Reference 8-20) and IEC 61513 (Reference 8-49).

The design of the Emergency Power System conforms to IAEA SSG-34 (Reference 8-9).

The design of the Emergency Power System is designed to accommodate required surveillance testing in accordance with IEC 60671, "Nuclear power plants - Instrumentation and control systems important to safety - Surveillance testing," (Reference 8-57) and comply with RG 1.118.

The Emergency Power System batteries are designed in accordance with IEC 61225 (Reference 8-10), IEC 62485-1, "Safety Requirements For Secondary Batteries and Battery Installations," (Reference 8-58) and IEC 62040-5-3 (Reference 8-54).

Emergency Power System battery banks are sized such that the sum of the loads required in support of functions and PAM does not exceed 80% (aging factor) of the battery ampere hour rating over the rated 72-hour discharge period or warranted capacity at the end of the installed life with 100% design demand.

The Emergency Power System is single failure tolerant in accordance with IAEA SSG-34 (Reference 8-9), Section 7, “Application of the Single-Failure Criterion.”

The Emergency Power System design supports the recommended practices of IEC 60896-11, “Stationary lead-acid batteries,” (Reference 8-59).

The Emergency Power System design includes provisions for bypassing an inoperable status indication in accordance with Chapters 5 and 7 of IAEA SSG-34 (Reference 8-9). For bypassing inoperable status indication, refer to Chapter 7 of IAEA SSG-61 (Reference 8-1).

All battery chargers and UPSs disconnect from the AC input whenever that input varies outside the range of voltage from nominal for a set period of time.

All battery chargers are able to function as battery eliminators.

All battery chargers produce a filtered DC output that meets the requirements of IEC 61000-4 (Reference 8-53).

All battery chargers include overvoltage protection on the output that shuts down the charger upon actuation. This meets the recommendations of IEC 61225 (Reference 8-10) and IEC 60709 (Reference 8-45), IEC 62040-5-3 (Reference 8-54), and IEC 60896-11, (Reference 8-59).

All battery chargers are of a current limiting design to provide additional overload protection for DC loads, including the batteries, and prevents the AC source from becoming a load on the batteries.

For DC system grounding, See Section 8.7.1.

The plant DC systems consist of an ungrounded system with ground detection, IEC 62485 (Reference 8-58), IEC 60896-11 (Reference 8-59), and IET Technical Briefing, “Practical Considerations for d.c. Installations,” (Reference 8-60) for station battery systems and on sound engineering practice for DC systems to prevent interruption of DC power when a single line-to-ground fault occurs.

All UPSs maintain rated output voltage from zero to rated load. This value meets the range of 50 Hz service voltages provided in IEC 60038 (Reference 8-43).

All branch circuit protective devices supplied by the UPS is evaluated to ensure coordination with the UPS short circuit shutoff magnitude and time. This requirement ensures that a faulted branch circuit does not result in the complete loss of all circuits supplied by the UPS.

The UPS bypass RVTs maintain a nominal output voltage over a varied input voltage for a given range. This requirement ensures that a well-conditioned and regulated output voltage is provided even when the UPSs are bypassed.

Category B, TVSSs are used on the input circuit to battery chargers, UPSs, and associated bypass circuits to protect against voltage surges in accordance with BS 7671 (Reference 8-22), IEC 62305, “Protection against lightning,” (Reference 8-61), and BSI PD IEC/TR 62066, “Surge Over-voltages and Surge Protection in Low-Voltage A.C. Power Systems - General Basic Information,” (Reference 8-62).

For I&C grounding, filtering, and electromagnetic interference (EMI), see 8.6.1.2.

The Emergency Power System design meets the recommended practices in IAEA SSG-34 (Reference 8-9), International Atomic Energy Agency for design of DC power systems for stationary applications) and IAEA SSR-2/1 (Reference 8-11) and IAEA-TECDOC-1770 (Reference 8-6), and IAEA-TECDOC-1791 (Reference 8-7).

A single failure in any individual Emergency Power System division does not adversely affect the other Emergency Power System divisions in accordance with IAEA SSG-34 (Reference 8-9), IAEA Safety Standards Series, DS 252 (Reference 8-19), IAEA SSG-39 (Reference 8-20), IEC 61513 (Reference 8-49), IEC/IEEE 60780-323 (Reference 8-51), and IEC 63332-387 (Reference 8-56).

A single failure in the DC portion of the Emergency Power System does not result in conditions that prevent safe shutdown of the plant coincident with a separate Emergency Power System division being out of service, in accordance with IAEA SSG-34 (Reference 8-9), IAEA Safety Standards Series, DS 252 (Reference 8-19), IAEA SSG-39 (Reference 8-20), IEC 61513 (Reference 8-49), IEC/IEEE 60780-323 (Reference 8-51), and IEC 63332-387 (Reference 8-56).

Emergency Power System divisions are physically and electrically separated and isolated from each other without electrical crosstie to other divisions or battery systems.

The Emergency Power System batteries meet the qualification requirements of IEC/IEEE 60780-323 (Reference 8-51), IEC/IEEE 60980-344 (Reference 8-52) and IEC 60896-11 (Reference 8-59).

The Emergency Power System divisional batteries are sized with an expected service life of 10 years in accordance with IEC 60896-11 (Reference 8-59).

The Emergency Power System batteries have enough stored capacity to independently supply loads continuously for at least 72-hours with a minimum final discharge voltage sufficient to support the associated loads. Aligns with requirements for SECY-94-084.

Each of the Emergency Power System UPSs can supply 100% of the divisional load.

The Emergency Power System UPS outputs provide a single-phase nominal AC voltage of 230 VAC, 50 Hz.

The Emergency Power System battery banks are designed to supply DC power at 250 VDC nominal.

Emergency Power System Backup Uninterruptible Power Supply

The Emergency Power System has two UPSs per division provide a single-phase 230 VAC output. Two UPSs are provided primarily for the I&C DCIS system to provide redundant divisional power feeds. Loss of any individual divisional UPS still allows the DCIS of that division to function. Therefore, reliability is enhanced with the redundant UPS that powers each division of the DCIS. In addition, all emergency power UPSs have both AC and DC source inputs (the AC input is rectified internal to the UPS to match the DC input), allowing the battery testing without losing the divisional outputs (albeit the 72-hour mission time is unavailable from the battery in test during that time). While each divisional electrical system uses two redundant UPSs, they share a single RVT for bypass power. Although the RVT is normally de-energised, a Manual Transfer Switch (MTS) is included to allow the RVT alignment to one of two redundant sources from the Standby Power System. Since the RVT is normally de-energised, it must be manually placed into service. Use of an MTS in the UPS output circuit provides a means of isolating the UPS output from the loads when the RVT is placed in service. In this configuration, maintenance or testing of a single UPS can be done online without disturbing UPS loads. The AC power supplied through the UPS bypass RVT is powered from the SDG backed buses.

The power panels ultimately feed the individual loads. Where required, the UPSs are protected at the individual load level with current limiting fuses such that the resulting fault currents are within the transient rated current capability of the inverter. Individual faults have no effect on other loads on the same power panel. All DCIS components are redundantly powered from the Emergency Power System divisional UPSs. Loads with the ability to accept only a single supply are supplied by a single feed in line with an automatic transfer switch with input separately derived from the two UPSs. Therefore, failure of one divisional UPS has no adverse effect on plant operations or safety.

While each Emergency Power System divisional electrical system uses two redundant UPSs, the RVT is de-energised in the normal system lineup and must be manually placed into service. This means automatic swap over to the UPS bypass AC source is not provided, as required by IAEA SSG-34 (Reference 8-9). The reason for operating without automatic swap over to the bypass power is to mitigate the Forsmark event (USNRC ML102070360 (Reference 8-12)).

8.5.34 Instrumentation and Control

The BWRX-300 electrical systems are to be monitored and controlled by DCIS equipment (of the I&C systems) of a corresponding safety classification. Generally, the DCIS control systems are expected to operate and monitor the plant transformers and feeder breakers, including load breakers for pumps, adjustable speed drives, or other plant equipment.

MV breakers are controlled by protective relays established by the designer to protect the electrical system components. For example, the condensate pump motor breaker includes protective relays that monitor overcurrent, balanced phases, undervoltage, underfrequency, and ground and phase faults. The protective relay trips the breaker, and a trip command has precedence over a close command. The plant DCIS can command a breaker to open or close, but a DCIS close command can be overridden by the protective relay. Either a DCIS trip or protective relay trip command opens the breaker.

The protective relays are interfaced to the plant DCIS and can provide multiple signals to the attached plant controller. Potential signals include:

- Phase voltage
- Phase current
- Power factor
- Power
- Apparent power
- Reactive power
- Total running time
- Total off time
- Number of starts

Note: These signals are provided “automatically” by the protective relays and no further instrumentation is needed.

Although modern microprocessor based protective relays are considerably more flexible, cost effective, and accurate than older analogue designs (that cannot provide equivalent protection), the relays represent a separate DCIS network. The relays are considered critical digital assets and require appropriate cyber security monitoring and physical access protection.

For components and equipment in the plant electrical systems that are monitored by the DCIS, status inputs and alarm indications are provided to the plant DCIS.

Refer to PSR Ch. 7 (Reference 8-50) for a detailed discussion of the BWRX-300 I&C System design and operation.

8.5.35 Monitoring, Inspection, Testing and Maintenance

The design of the Emergency Power System is designed to accommodate required surveillance testing in accordance with the requirements of IEC 60671 (Reference 8-57) and complies with RG 1.118. Emergency Power System DC power sources are provided to support passive core cooling and containment Safety Category 1 functions and are compliant with the requirements of GDC 18.

Analysis and testing of the monitoring system are performed through inspections, tests, analyses, and acceptance criteria to determine set points to verify proper functionality.

Required electrical system testing is governed by the plant technical specification and industry standards. The electrical systems are designed to allow required testing with minimal disturbance to the balance of the system. Specific steps and alignments necessary for testing are controlled by plant procedures.

Emergency Power System Safety Class 1 Battery Capacity Testing

Maintenance, testing, and replacement activities for the Emergency Power System batteries are based on recommended practices in IEC 62485-1 (Reference 8-58), and IEC 62040-5-3 (Reference 8-54), and IEC 60671 (Reference 8-57).

Each Emergency Power System division has its own battery and two redundant UPSs. The two UPSs in each division are primarily for the DCIS system to provide redundant divisional power feeds. Loss of any individual divisional UPS still allows the DCIS of that division to function. Therefore, reliability is enhanced with the redundant UPSs that provide power to each division of the DCIS. In addition, all UPSs normally operate directly from AC power, allowing battery testing without losing the divisional outputs (albeit the 72-hour coping time is unavailable from the battery in test during that time).

The plant electrical system battery banks are designed to permit replacement of individual cells.

The design of the plant electrical systems accommodates online testing and inspection to the extent practical. Condition monitoring equipment is included where appropriate. For the Emergency Power System, the UPSs are in pairs per division, and testing can be done online without losing the complete divisional UPS output.

The Emergency Power System batteries require periodic testing under load to verify capacity. During battery testing, the associated DCIS loads remain powered because the UPSs have AC power available.

Depending on the type, a battery may periodically need a maintenance equalizing charge that raises battery voltage to levels that can cause stress on battery loads. With the redundant battery charger design configuration, one charger can supply the equalizing charge to the battery and be isolated from the DC loads while the other charger carries the DC loads at normal voltages. All DC loads are designed to withstand the equalization voltage.

Required electrical system testing is governed by the plant technical specification and industry standards. The batteries are designed to allow required testing with minimal disturbance to the balance of the system.

Emergency Power System Safety Class 1 Inverter Capacity Testing

Each Emergency Power System UPS has its own distribution panel to provide redundancy in the division. The power panels ultimately feed the individual dependant loads. Where required, the UPSs are protected at the individual load level with current limiting fuses such that the resulting fault currents are within the transient rated current capability of the inverter. Individual faults have no effect on other loads on the same power panel. All emergency power dependant DCIS components are redundantly powered from the Emergency Power System divisional UPSs. Loads with the ability to accept only a single supply are supplied by a single feed in line with an automatic transfer switch with input separately derived from the two UPS. Therefore, failure of one divisional UPS has no adverse effect on plant operations or safety.

Required electrical system testing is governed by the plant technical specification and industry standards. The inverters are designed to allow testing with minimal disturbance to the balance of the system.

Emergency Power System Safety Class 1 Charger Capacity Testing

There are two battery chargers per division. Each battery charger has the capacity to power all loads for the division while also charging the battery. The redundant battery chargers and bus configuration are arranged to provide operational flexibility to the system.

Required electrical system testing is governed by the plant technical specification and industry standards. The battery chargers are designed to allow testing with minimal disturbance to the balance of the system.

Emergency Power System Safety Class 1 Auxiliary Equipment Capacity Testing

Required electrical system testing is governed by the plant technical specification and industry standards. The Emergency Power System auxiliary equipment is designed to allow testing with minimal disturbance to the balance of the system.

Non-Safety Class 1 Electrical System Capacity Testing

Testing is conducted in accordance with plant procedures for:

- The Standby Power System SDGs and DC subsystems
- The Preferred Power System DC subsystems

Inspection of Electrical and Control Equipment, Panels, Racks, Cables, and Raceways

Normally the cabling and raceways are designed to not require any inspections once they have passed installation and commissioning testing. However, cabling and raceways are inspected based on operations surveillance programs, maintenance, and testing programs during normal operations and outages as appropriate.

Cabling and raceways testing is based on preventive and predictive maintenance programs. Site testing requirements are also used for post installation testing and inspection.

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 equipment and wiring of different divisions, and between safety categories and non-safety categorized equipment and wiring. The identification method is colour-coding. Markers within a division have the same color.

8.5.36 Radiological Aspects

The electrical system is expected and designed to function as specified by its safety category. The safety category function of the electrical SSC must be accomplished for safety for a facility or activity to prevent or to mitigate radiological consequences of normal operation, AOOs and accident conditions.

8.5.37 Performance and Safety Evaluation

The DC subsystems are designed to perform their associated function without operator interaction. Upon loss of AC power, the systems automatically transition to being supplied by the associated battery.

The three DC subsystems are:

- The Preferred Power System DC subsystem
- The Standby Power System DC subsystem
- The Emergency Power System DC subsystem

These DC subsystems supply loads of equivalent safety category or a lower safety category. Input AC power for such systems is derived from AC sources as identified in the figures included in this chapter. The systems also include interface with the DCIS of equivalent safety category for control and monitoring.

The onsite DC power subsystems are expected to perform their design functions in normal and abnormal conditions. Electrical power is supplied to the I&C systems. Refer to PSR Ch. 7 (Reference 8-50) for a further discussion.

The BWRX-300 electrical systems are monitored and controlled by DCIS equipment of a corresponding safety classification. Generally, the DCIS control systems are expected to operate and monitor the plant transformers and feeder breakers, including load breakers for pumps, adjustable speed drives, or other plant equipment.

MV breakers are controlled by protective relays to protect the electrical system components. For example, the condensate pump motor breaker includes protective relays that monitor overcurrent, balanced phases, undervoltage, underfrequency, and ground and phase faults. The protective relay trips the breaker, and a trip command has precedence over a close command. The plant DCIS can command a breaker to open or close, but a DCIS close command can be overridden by the protective relay. Either a DCIS trip or protective relay trip command opens the breaker.

The protective relays are interfaced to the plant DCIS and can provide multiple signals to the attached plant controller.

Modern microprocessor based protective relays are addressed as digital assets.

For components and equipment in the plant electrical systems that are monitored by the DCIS, status inputs and alarm indications are provided to the plant DCIS.

Condition monitoring equipment is included where appropriate.

The design of the plant electrical systems accommodates online testing and inspection to the extent practical. Condition monitoring equipment is included where appropriate. For the Emergency Power System, the UPSs are in pairs per division, and testing can be done online without losing the complete divisional UPS output.

Required electrical system testing is governed by the plant technical specification and industry standards. The electrical systems are designed to allow required tests are performed with minimal disturbance to the balance of the system. Specific steps and alignments necessary for testing are controlled by plant procedures.

Maintenance can be done during outages. However, given the redundancy in the electrical system, most maintenance can also be done with the plant online.

While the expected service life of the plant battery is less than the 60-year service life of the plant, the battery is optimized to the greatest extent possible. Optimum environmental conditions (e.g., temperature and humidity), limiting the discharge occasions to periodic surveillance and preventative maintenance testing, and having constant condition monitoring for cell degradation contribute to this optimization.

Depending on the type, a battery may periodically need a maintenance equalizing charge that raises battery voltage to levels that can cause stress on battery loads. With the redundant battery charger design configuration, one charger can supply the equalizing charge to the battery and be isolated from the DC loads while the other charger carries the DC loads at normal voltages. It is noted that all DC loads are designed to withstand the equalization voltage.

The safety category function of the electrical SSCs must be accomplished to prevent or to mitigate radiological consequences of normal operation, AOO, and accident conditions.

8.6 Electrical Equipment, Cables, and Raceways

8.6.1 System and Equipment Functions

The cabling for the BWRX-300 provides electrical power to designated loads. Fiber cabling is used for signal transmissions. safety category loads are provided appropriate safety category power from the EDS. Electrical cables and raceways are passive equipment and do not perform and active functions.

8.6.2 Safety Design Bases

Equipment, cabling separation, and electrical isolation are based on IEC 60709, (Reference 8-45) as appropriate.

The cabling for the BWRX-300 provides electrical power to designated loads.

The cables and raceways are designed commensurate with the safety category functions being provided.

Containment aspects of Electrical Penetrations are covered in PSR Ch. 6 (Reference 8-48).

8.6.3 Hazard Protection

Where redundant Emergency Power System and Non - Emergency Power System raceway systems traverse each other, separation is maintained to comply with and IEC 60709 (Reference 8-45).

Where hazards to Emergency Power System raceways are identified, a predetermined minimum separation is maintained between the break and/or missile source and any other Emergency Power System raceways, or I&C SC1 raceway, or a barrier designed to withstand the effects of the hazard is placed to prevent damage to raceway of redundant systems, including missile protection and high-energy line break protection.

Where redundant circuits, devices, or equipment (different separation groups) are exposed to the same external hazard(s), predetermined spatial separation is provided. Where the spatial separation cannot be met; qualified barriers are installed.

Where component and circuit independence are required by general safety standards such as IAEA safety guides, IEC 61513 (Reference 8-49), IEC 61000-3, "Electromagnetic Compatibility (EMC) – Part 3: – All Parts," (Reference 8-53) and other project constraints, two ways of achieving this independence are physical separation and electrical isolation between the components and circuits that perform safety category functions.

It is noted that traditional separation and isolation are performed in part based on safety category function, but the BWRX-300 safety strategy is predicated on redundancy and diversity, which do not correlate to safety category function in every case. As such, electrical and I&C cable and component separation and isolation is based on function.

8.6.4 Description

The cabling for the BWRX-300 provides electrical power to designated loads. Fiber cabling is used for signal transmissions. Safety categorized loads are provided appropriate safety categorized power from the EDS. Electrical cables and raceways are passive equipment and do not perform and active functions.

The Cable Raceway System includes raceway and supports necessary to route cable in and between buildings and equipment using cable trays, conduits, duct banks, or tunnels. This system is also responsible for routing the cable in accordance with separation and other project design rules. The Cable Raceway System also includes the primary containment penetration assemblies. The cabling is owned by the connecting systems within the I&C and electrical systems.

The safety categorized cabling and raceways are designed to meet the following design requirements:

1. Equipment, cabling separation, and electrical isolation are IEC 60709 (Reference 8-45).
2. Fire protection and fire safe shutdown program requirements are supported by cable separation, fire barriers, limiting cable tray fill, 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. Cables within the power block comply with BS EN 61034 (Reference 8-46), and BS EN 60754-1 + A1 (Reference 8-47).

The Cable Raceway Systems are separated on the basis of function, division, and voltage class. The raceways are physically arranged top to bottom based on the function and the voltage class of the cables. Cables are routed in horizontal and vertical runs of steel trays or through steel conduits. Trays or conduits are supported at intervals by appropriately designed supports. The supports are attached to walls, floors, and ceilings of structures as required by the arrangement. The type of support and spacing is determined by allowable tray or conduit spans which are governed by rigidity and stress. Underground raceways have limited application for the BWRX-300. When underground raceways are required, they are appropriately sloped and drained to minimize the potential for cable submergence.

8.6.5 Control of Compliance with Separation Criteria During Design and Installation

The BWRX-300 equipment, cabling separation, and electrical isolation comply with IEC 60709 (Reference 8-45), and IAEA SSG-34 (Reference 8-9). Divisional separation requirements of individual pieces of hardware are shown in the system elementary diagrams. Identification of raceways and cables is compatible with the identification of the Emergency Power System equipment with which it interfaces. Location of the identification is such that points of change of circuit classification (at isolation devices) are readily apparent.

Cabling and raceways are passive components that provide power from electrical supplies to components and/or loads.

Electrical cables and raceways are permanently installed passive components to support operation of connected loads.

While electrical cables transmit I&C signals throughout the plant, there are I&C features specific to the electrical cabling and raceway systems.

The cables and raceways are designed to perform required functions during all plant modes and under all anticipated normal and abnormal conditions.

Installation of the cabling and raceways is per approved procedures and testing requirements to ensure they can perform their designed and intended functions.

8.6.6 Materials

Materials are associated with the safety category of the individual systems. Materials are evaluated and selected based on the environmental conditions to which the cables/raceways are exposed in conjunction with the safety category of the equipment being served. For the safety category of the equipment see PSR Ch. 3 (Reference 8-4).

8.6.7 Interfaces With Other Equipment or Systems

Cabling and raceways are passive components that provide power from electrical supplies to components and/or loads.

Electrical cables and raceways are permanently installed passive components to support operation of connected loads.

8.6.8 System and Equipment Operation

Cables function to facilitate power distribution, control, and communication.

Raceways are passive equipment and do not perform any active functions. These serve to support cables for power distribution, control, and communication.

Raceways are an assembly of units or sections and associated fittings, including racking, cable trays, trunking and conduits forming a system to securely fasten or support cables.

8.6.9 Instrumentation and Control

While electrical cables transmit I&C signals throughout the plant, there are no I&C features specific to the electrical cabling and raceway systems.

8.6.10 Monitoring, Inspection, Testing and Maintenance

Normally the cabling and raceways are designed to not require any inspections once they have passed installation and commissioning testing. However, cabling and raceways are inspected based on operations surveillance programs, maintenance and testing programs during normal operations and outages as appropriate.

Cabling and raceways testing is based on preventive and predictive maintenance programs. Site testing requirements will also be used for post installation testing and inspection.

8.6.11 Radiological Aspects

The cables and raceways are designed for their location to maintain their required function. The cables and raceways are qualified for the anticipated radiological environment expected during the lifetime of the plant.

8.6.12 Performance and Safety Evaluation

The cables and raceways are designed for their location to maintain their required function. The cables and raceways are qualified for the operating environment expected during the lifetime of the plant.

8.7 Grounding (Earthing), Lightning Protection and Electromagnetic Compatibility

8.7.1 System and Equipment Functions

The plant earthing system is classified as SCN. Earthing is important for both safety of plant personnel and electrical system protection, and it is required for the operability and performance of the BWRX-300 DCIS.

As with any earthing system, the overall function of the plant earthing networks is to protect personnel and equipment from induced voltages and currents by providing a low impedance path to the earth.

8.7.2 DC System Grounding

The plant DC systems consist of an ungrounded system with ground detection. This requirement is based the recommendations of IEC 62485 (Reference 8-58), IEC 60896-11 (Reference 8-59), and IET Technical Briefing (Reference 8-60), and on sound engineering practice for DC systems to prevent interruption of DC power when a single line-to-ground fault occurs.

8.7.3 I&C Grounding, Filtering, EMI mitigation EMC

For I&C equipment grounding in generating stations, adequate filtering is to be provided by the battery charger, UPS, and regulating transformers to ensure that propagation of EMI/Radio Frequency Interference (RFI) of the levels allowed by IEC 61000-3 (Reference 8-53), and does not adversely affect other plant.

8.7.4 Safety Design Basis

The overall earthing system consists of a buried earthing grid and includes different types of earthing systems that all connect to a common plant earthing grid.

Building grounds (connections of the building foundations and external structures to the earthing grid) are provided. Equipment grounds (connection of equipment to the internal earthing system of the buildings) are provided for equipment protection. Instrument grounds (separate earthing connection to the earthing grid for analogue and digital instrumentation systems) are provided for instrumentation protection and operation. The lightning protection system provides protection for equipment against lightning induced surges.

8.7.5 Description

The electrical earthing system is comprised of the following earthing networks connected to a plant earthing grid:

1. An instrument and computer earthing network.
2. An equipment-earthing network for earthing electrical equipment (e.g., transformer, switchgear, motors, distribution panels, cables) and selected mechanical components (e.g., fuel tanks, chemical tanks).
3. Building grounds.
4. A lightning protection network for protection of all structures, transformers, and equipment.

The instrumentation earthing system is provided to include both the plant analogue (i.e., relays, solenoids) and digital instrumentation systems. The plant instrumentation is earthed through a separate insulated radial earthing system composed of busses and insulated cables. The instrumentation earthing system is connected to a discrete point of the station earthing grid at a dedicated instrumentation earthing rod by exothermic welding. The instrumentation earthing system is insulated from all other earthing and surge protection circuits up to the point of connection at the ground grid. It is recognized that there are numerous accepted earthing techniques, and that the actual installation of a ground system is made with reference to the recommendations of the I&C equipment manufacturers because the techniques used to solve one problem may result in the creation of a different problem, IEC 62305 (Reference 8-61). The equipment-earthing network is such that all major equipment, structures, and tanks are earthed with two diagonally opposite ground connections. The ground bus of all switchgear assemblies, motor control centres 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 earthing 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 earthing grid consisting of bare copper cables is provided to limit step and touch potentials to safe values under all fault conditions. The buried grid is connected to the ground mat at the switchyard and connected to systems within the buildings by a bare copper loop, which encircles each building.

The plant's main generator is earthed with a neutral earthing device to limit the magnitude of fault current due to a solid phase-to-ground fault. The impedance of the neutral earthing device limits the maximum phase-to-ground current under short-circuit conditions.

The onsite, MV AC distribution system is resistance earthed at the neutral point of the LV windings of the UAT and RAT. The neutral point of the generator windings of the standby onsite AC power supply is through neutral resistors, sized for continuous operation in the event of a ground fault.

The neutral point of the LV AC distribution systems is solidly Earthed to ensure proper coordination of ground fault protection. The DC systems are un-Earthed.

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 earthing electrodes. Lightning arresters are provided for each phase of all tie lines connecting the plant electrical systems to the switchyard and offsite lines. These arresters are connected to the high-voltage terminals of the main step-up transformers, UAT and RAT. Plant instrumentation located outdoors or connected to cabling running outdoors is provided with surge suppression devices to protect the equipment from lightning induced surges.

System Requirements for the plant earthing system contain the following:

1. The EDS plant earthing grid is classified as SCN.
2. The plant earthing grid meets the applicable requirements of IEC 62305 (Reference 8-61), and IEC 62855 (Reference 8-14) and BS EN 50522, "Earthing Of Power Installations Exceeding 1 kV," (Reference 8-63).
3. The electrical earthing protection system includes an instrument and computer earthing network that is separate from the standard equipment and system ground network.

Lightning and surge suppression meets the applicable requirements given in IEC 62305 (Reference 8-61), and IEC 62855 (Reference 8-14). Guidance is also provided for the earthing (Grounding) protection in BS EN 50522 (Reference 8-63). Lightning protection requirements are provided in IAEA SSG-34 (Reference 8-9).

8.7.6 Materials

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

8.7.7 Interfaces With Other Equipment or Systems

The plant earthing and lightening arresting system is designed to provide protection in the BWRX-300 plant. The earthing system interfaces with all site buildings and structures, all electrical and I&C equipment, and select mechanical equipment needing earthing protection (for example, tanks).

8.7.8 System and Equipment Operation

The plant earthing and lightening arresting system is designed to provide protection with all equipment and structures in the BWRX-300 plant. As such the system is designed to be passive and does not perform an active safety category function. The neutral point of the LV AC distribution systems is solidly earthed to ensure proper coordination of ground fault protection. The DC systems are un-Earthed.

8.7.9 Instrumentation and Control

Instrument grounds (earths) have separate grounding connections to the grounding grid for analog and digital instrumentation systems.

8.7.10 Monitoring, Inspection, Testing and Maintenance

Much of the earthing systems are underground and inaccessible once installed. Normally the earthing wiring is designed to not require any inspections once they have passed installation and commissioning testing.

Above ground inspections are conducted based on manufacturer recommendations and industry standard guidance.

There is no testing after installation/construction.

Maintenance of the earthing system is not anticipated after installation/construction.

8.7.11 Radiological Aspects

The earthing, lightening protection, and electromagnetic compatibility systems that are exposed to high radiation areas and are designed for the radiological conditions to which they may be exposed.

8.7.12 Performance and Safety Evaluation

The electrical earthing system is expected to perform its design functions in normal and abnormal conditions. These systems are completely passive and perform no active function.

8.8 Main Equipment Types

The main equipment types include Transformers, Breakers, Batteries, Rectifiers, Direct Current Switchgears and Inverters, Protection Devices, Switches and Distributors.

The design is not yet sufficiently mature to inform details of equipment types. An overview of main equipment follows:

The offsite power system: supplying the onsite power systems with reliable power from multiple power sources:

- Main generator via auxiliary transformers.
- Grid power supply via the standby transformer.

Generator breaker: between the generator output and main transformer, and the UAT. GSU step-up transformer, auxiliary transformer, standby transformer, and distribution system feeding unit auxiliaries, service auxiliaries, switchgear, batteries, rectifiers, inverters and/or uninterruptible power supplies, cables, and standby AC power sources.

DC power system. This supplies DC loads, without interruption, from batteries. The DC power system includes battery chargers that are connected to the AC power system of the EDSs.

Electric systems protective relaying, triply redundant for the main generator, main transformer, and unit transformers.

Other protective relaying: single failure proof to trip.

8.8.1 System and Equipment Functions

As the design is not yet sufficiently mature to inform details of equipment types, this section will be developed as the design matures.

8.8.2 Safety Design Basis

As the design is not yet sufficiently mature to inform details of equipment types, this section will be developed as the design matures.

8.8.3 Description

As the design is not yet sufficiently mature to inform details of equipment types, this section will be developed as the design matures.

8.8.4 Materials

As the design is not yet sufficiently mature to inform details of equipment types, this section will be developed as the design matures.

8.8.5 Interfaces With Other Equipment or Systems

As the design is not yet sufficiently mature to inform details of equipment types, this section will be developed as the design matures.

8.8.6 System and Equipment Operation

As the design is not yet sufficiently mature to inform details of equipment types, this section will be developed as the design matures.

8.8.7 Instrumentation and Control

As the design is not yet sufficiently mature to inform details of equipment types, this section will be developed as the design matures.

8.8.8 Monitoring, Inspection, Testing and Maintenance

As the design is not yet sufficiently mature to inform details of equipment types, this section will be developed as the design matures.

8.8.9 Radiological Aspects

As the design is not yet sufficiently mature to inform details of equipment types, this section will be developed as the design matures.

8.8.10 Performance and Safety Evaluation

As the design is not yet sufficiently mature to inform details of equipment types, this section will be developed as the design matures.

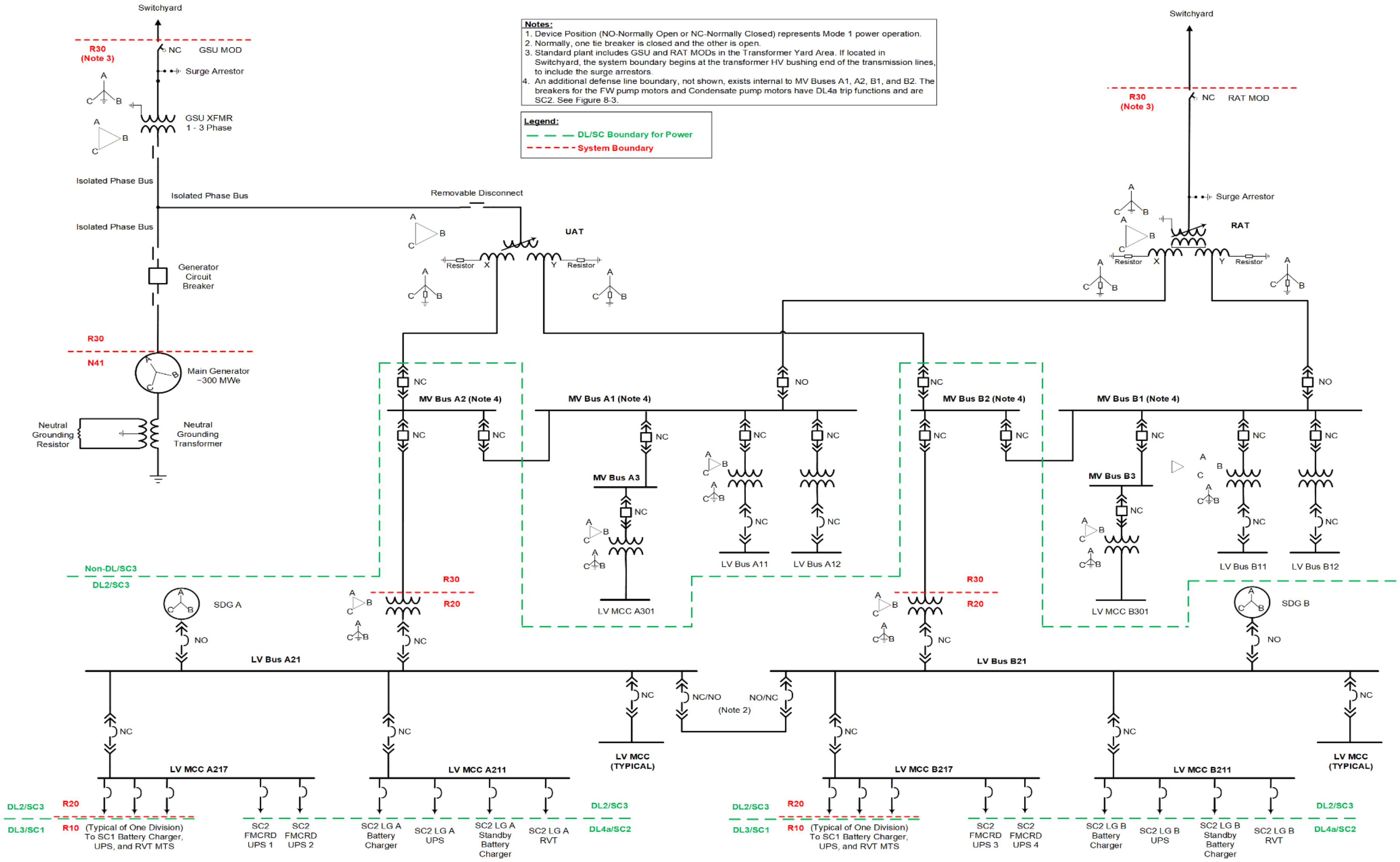


Figure 8-1: Main Electrical One-Line Diagram

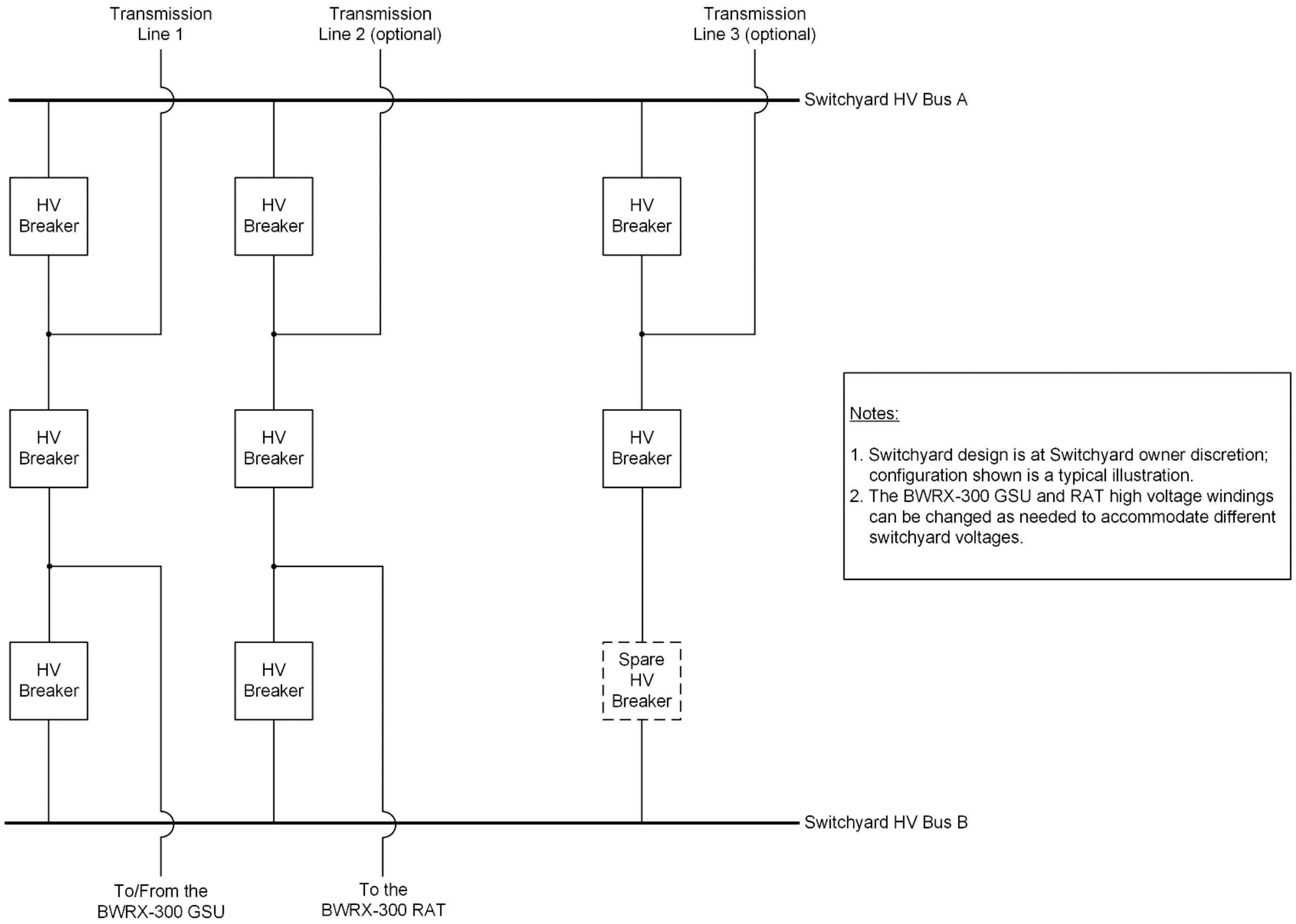


Figure 8-2: Typical BWRX-300 Switchyard Interface

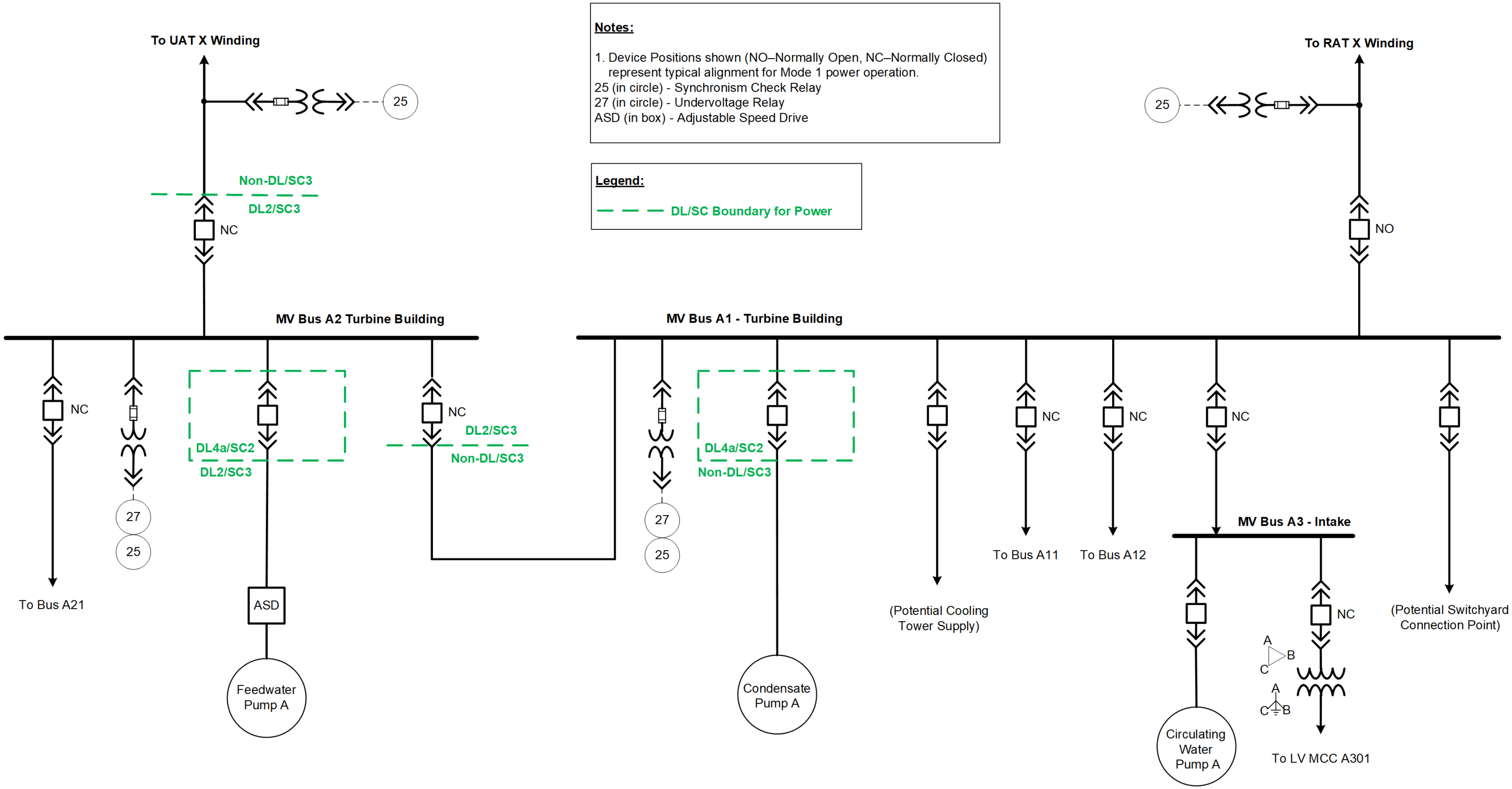


Figure 8-3: Preferred Power Medium Voltage Bus A Train

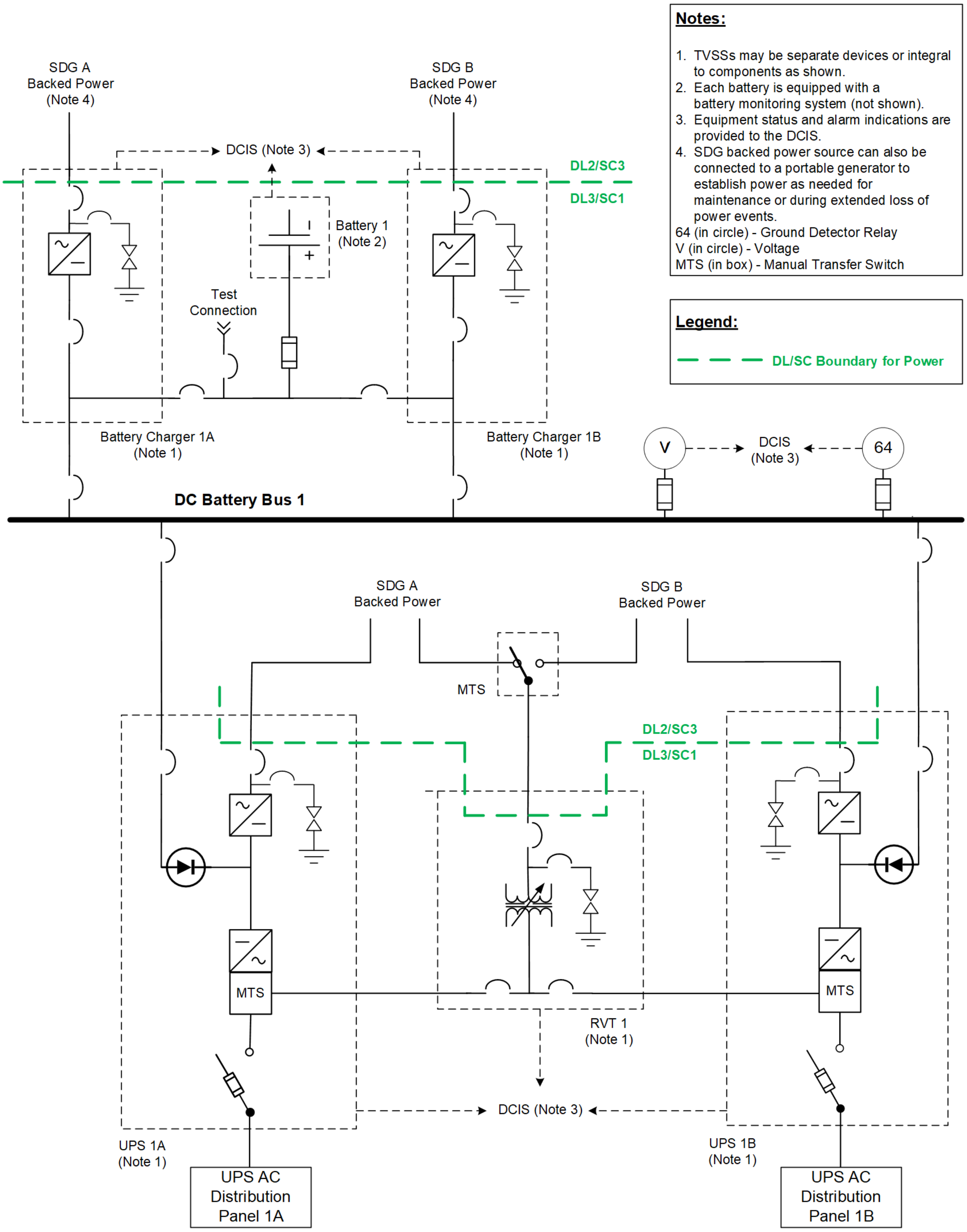


Figure 8-4: Emergency Power System

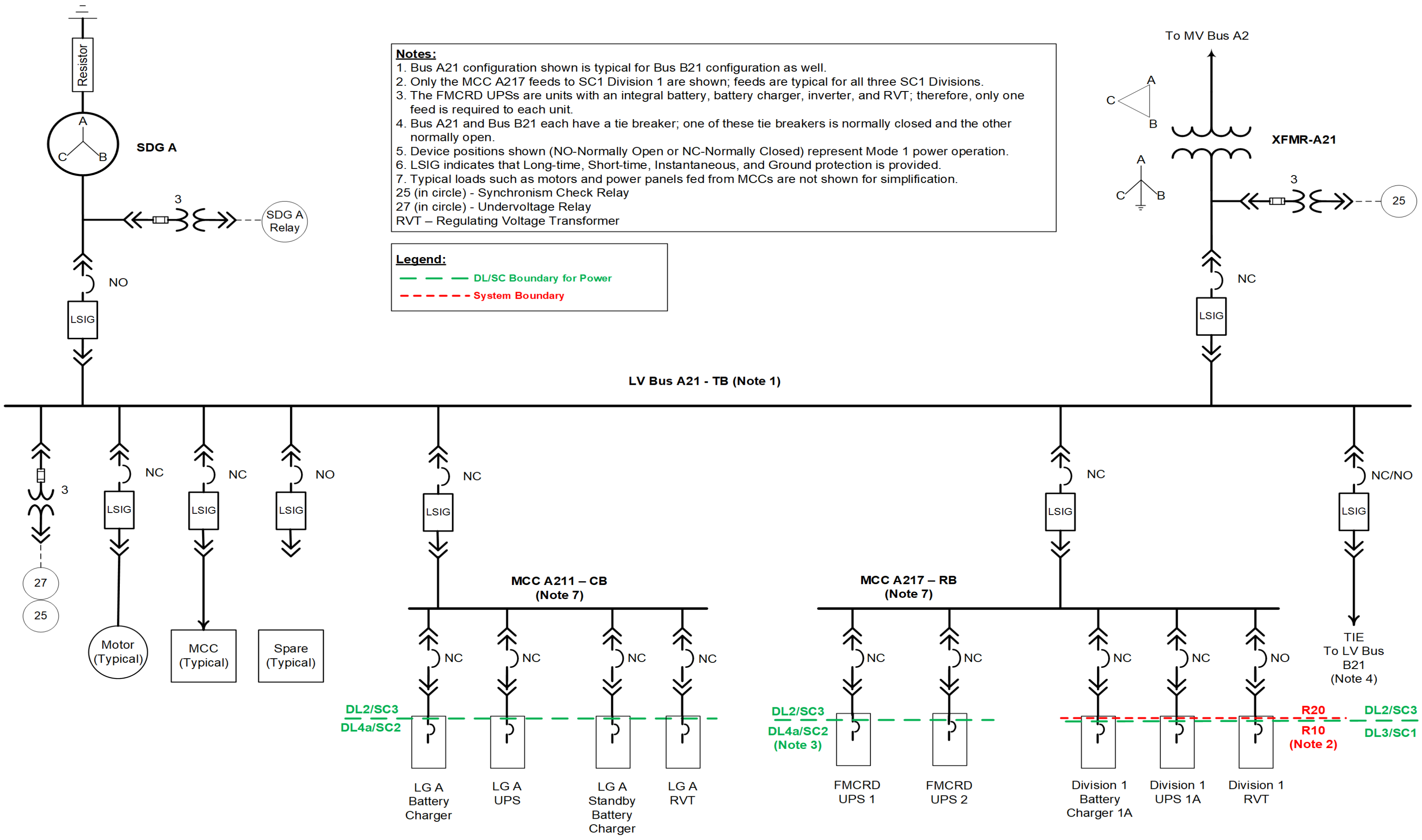


Figure 8-5: Standby Power System Low Voltage Distribution Train A

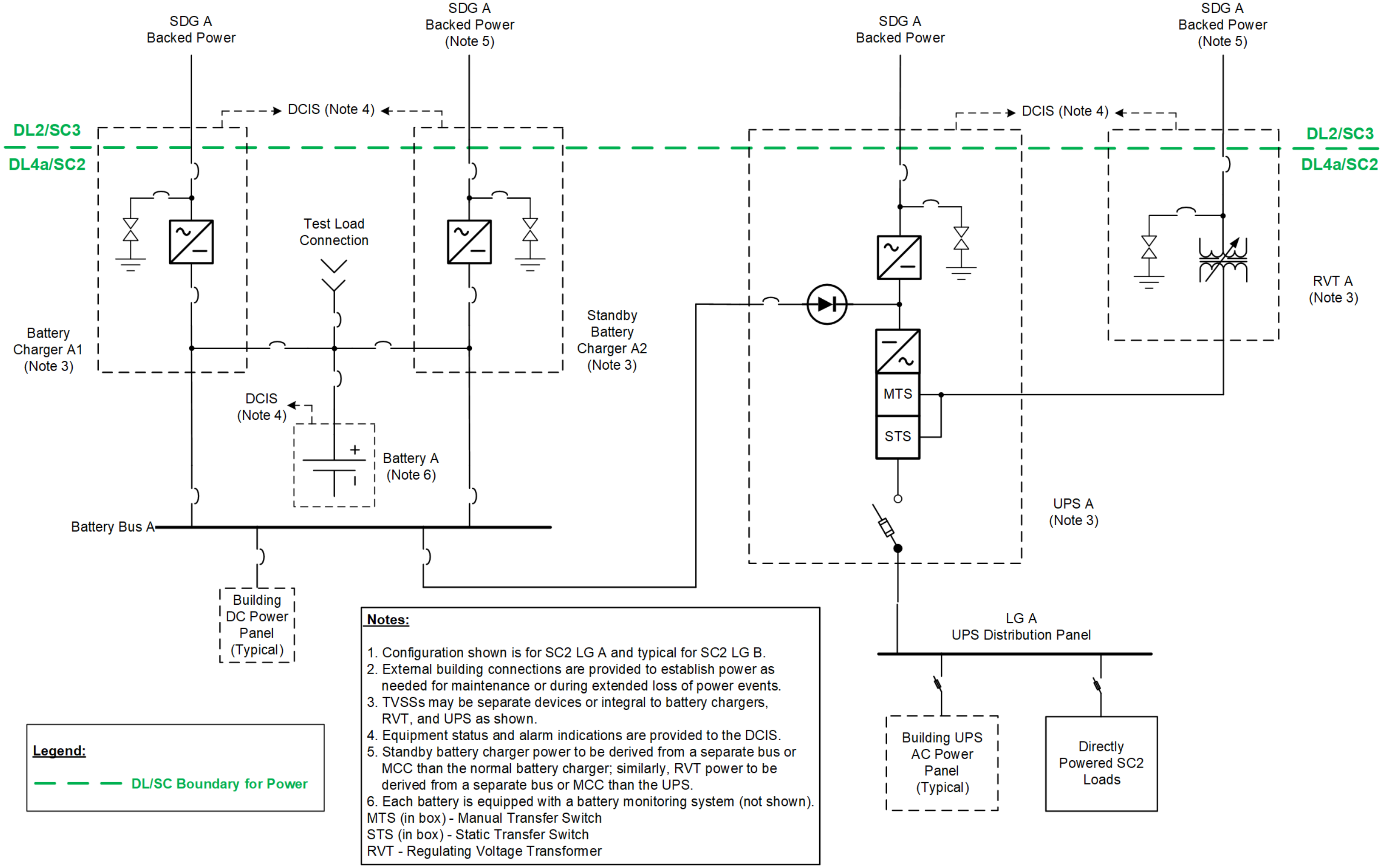


Figure 8-6: Standby Power System – 250 VDC System

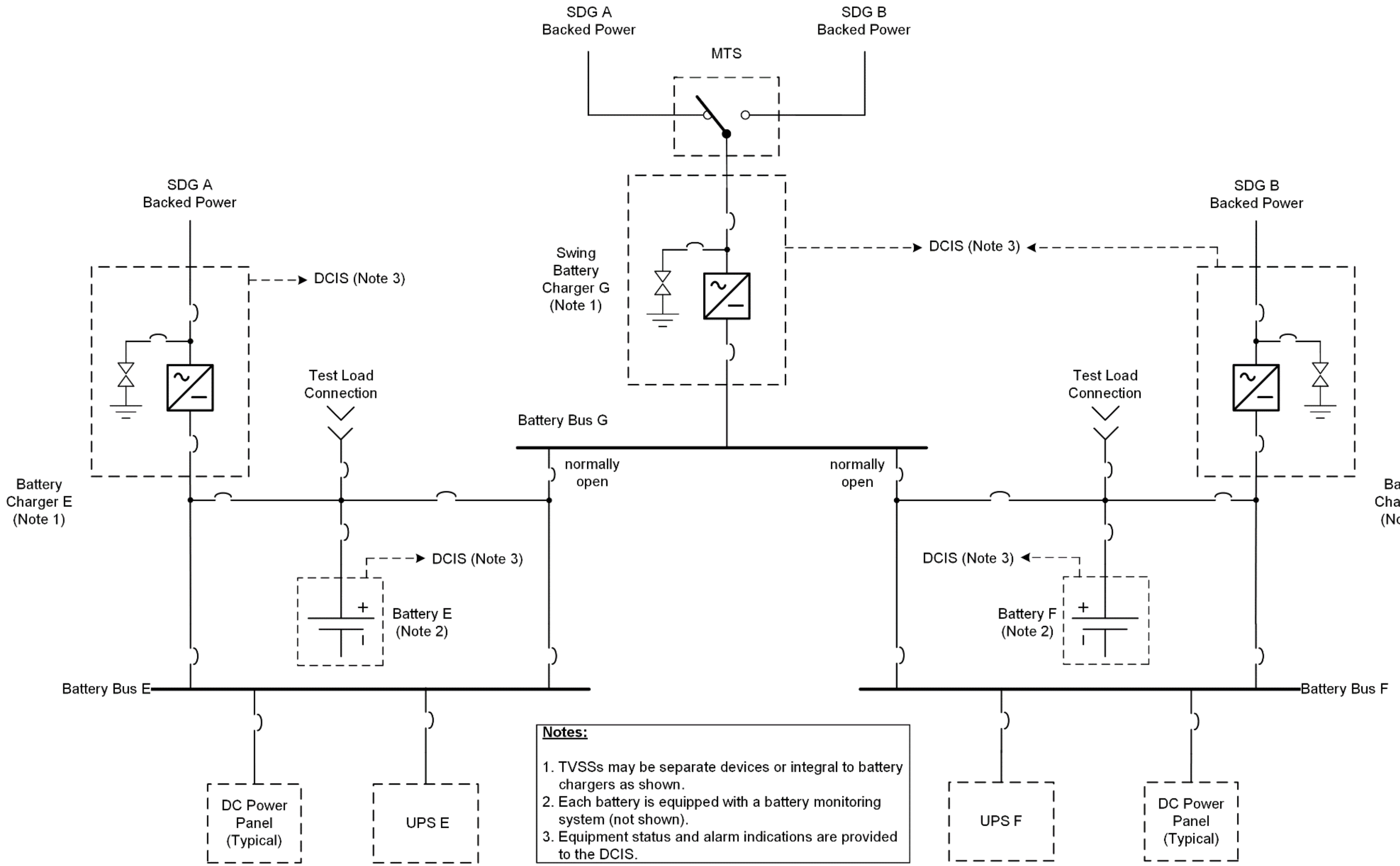
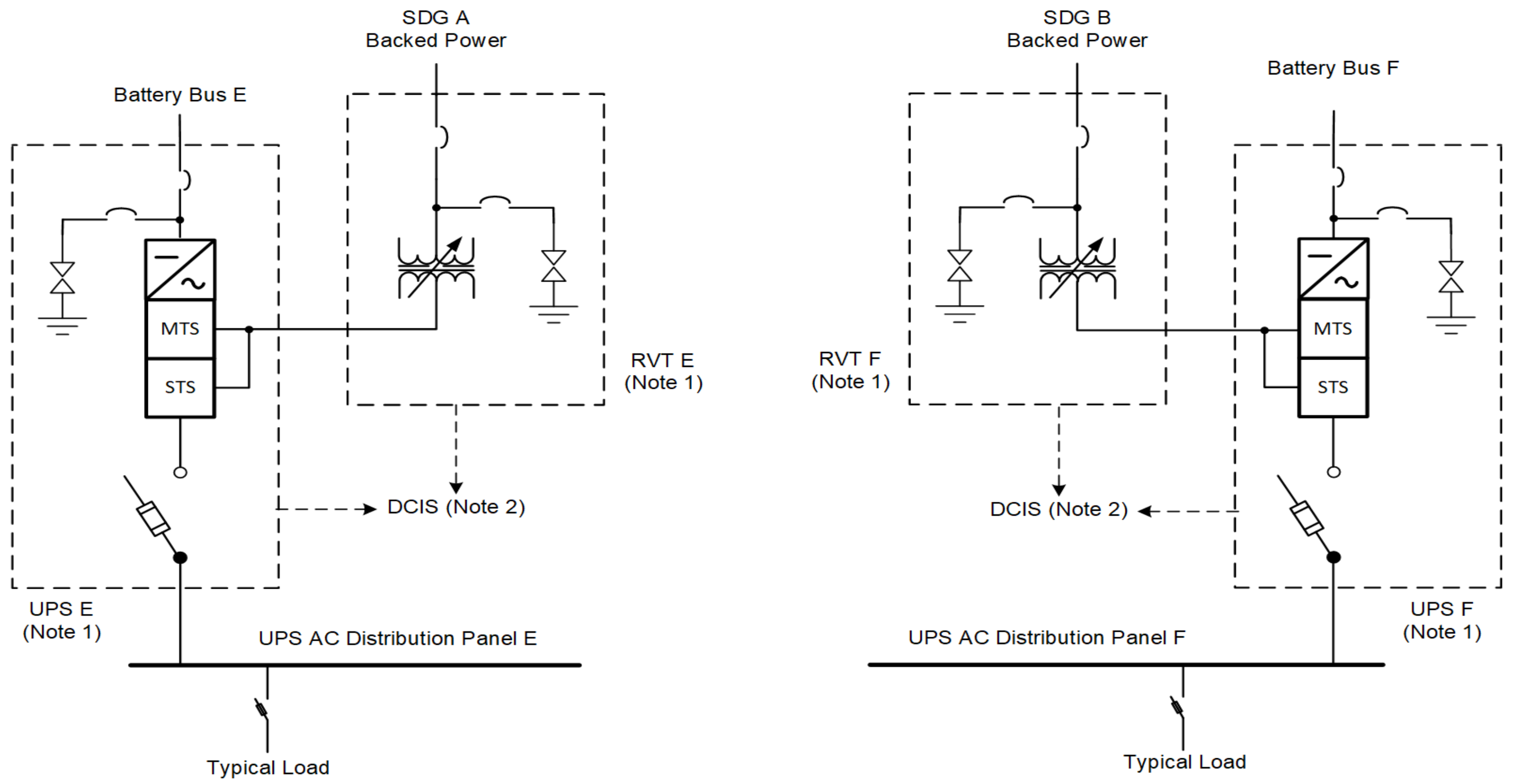


Figure 8-7: Preferred Power 250 VDC System Part One



Notes:

1. TVSSs may be separate devices or integral to RVTs as shown.
2. Equipment status and alarm indications are provided to the DCIS.

MTS (in box) – Manual Transfer Switch
STS (in box) – Static Transfer Switch
RVT – Regulating Voltage Transformer

Figure 8-8: Preferred Power 250 VDC System Part Two

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APPENDIX A CLAIMS, ARGUMENTS AND EVIDENCE

Claims, Arguments and Evidence

The ONR "Safety Assessment Principles (SAPs)," (Reference 8-64) identify ONR's expectation that a safety case should clearly set out the trail from safety claims, through arguments to evidence. The Claims, Arguments and Evidence (CAE) approach can be explained as follows:

1. Claims (assertions) are statements that indicate why a facility is safe.

Arguments (reasoning) explain the approaches to satisfying the claims.

Evidence (facts) supports and forms the basis (justification) of the arguments.

The GDA CAE structure is defined within NEDC-34140P, "BWRX-300 UK GDA Safety Case Development Strategy (SCDS)," (Reference 8-65) and is a logical breakdown of an overall claim that:

> *"The BWRX-300 is capable of being constructed, operated and decommissioned in accordance with the standards of environmental, safety, security and safeguard protection required in the UK."*

This overall claim is broken down into Level 1 claims relating to environment, safety, security, and safeguards, which are then broken down again into Level 2 area related sub-claims and then finally into Level 3 (chapter level) sub-claims.

The Level 3 sub-claims that this chapter demonstrates compliance against are identified within NEDC-34140P (Reference 8-65) and are as follows:

> *2.1.2: The design of the system/structure has been substantiated to achieve the safety functions in all relevant operating modes.*
>
> *2.1.3: The system/structure design has been undertaken in accordance with relevant design codes and standards (RGP) and design safety principles and taking account of Operating Experience to support reducing risks ALARP.*
>
> *2.1.4: System/structure performance will be validated by suitable testing throughout manufacturing,* construction, *and commissioning.*
>
> *2.1.5: Ageing and degradation mechanisms will be identified and assessed in the design. Suitable examination, inspection,* maintenance, *and testing will be specified to maintain systems/structures fit-for-purpose through-life.*
>
> *2.1.6: The BWRX will be designed so that it can be decommissioned safely, using current available technologies, and with minimal impact on the environment and people.*
>
> *2.4.1: Relevant Good Practice (RGP) has been taken into account across all disciplines.*
>
> *2.4.2: Operational Experience (OPEX) and Learning from Experience (LfE) has been taken into account across all disciplines.*
>
> *2.4.3: Optioneering (all reasonably practicable measures have been implemented to reduce risk).*

In order to facilitate compliance demonstration against the above Level 3 sub-claims, this PSR chapter has derived a suite of arguments that comprehensively explain how their applicable Level 3 sub-claims are met (see Table A-1 below).

It is not the intention to generate a comprehensive suite of evidence to support the derived arguments, as this is beyond the scope of GDA Step 2. However, where evidence sources are available, examples are provided.

Risk Reduction As Low As Reasonably Practicable

It is important to note that nuclear safety risks cannot be demonstrated to have been reduced ALARP within the scope of a 2-Step GDA. It is considered that the most that can be realistically achieved is to provide a reasoned justification that the BWRX-300 SMR design aspects will effectively contribute to the development of a future ALARP statement. In this respect, this chapter contributes to the overall future ALARP case by demonstrating that:

- The chapter-specific arguments derived may be supported by existing and future planned evidence sources covering the following topics: RGP has demonstrably been followed. OPEX has been taken into account within the design processes. All reasonably practicable options to reduce risk have been incorporated within the design. It supports its applicable level 3 sub-claims, defined within NEDC-34140P (Reference 8-65). Consideration of the probabilistic safety aspects of the ALARP argument are out of the scope of this chapter.

In terms of the Electrical Power system design reducing risks the BWRX-300 design follows international RGP by reducing the reliance on electrical power to support safety category functions. Commonly, plant design relies on AC power sources, including diesel generators, to mitigate DBAs. The BWRX-300 instead relies on battery backed DC power with a coping period of 72 hours for all DBAs which are automatically initiated on loss of power. This feature significantly reduces the importance of grid connection and grid stability for anything other than power production. The reliance of the design on natural rather than forced circulation means that a Loss of Offsite Power does not result in a loss of circulation. RGP has also been followed by ensuring that the electrical system meets the requirements of the IAEA and the National Energy System Operator Grid Code.

Table A-1: Claims, Arguments, Evidence Route Map

L3 No.	Level 3 Chapter Claim	Chapter 8 Arguments	Sub-sections and/or Reports that Evidence the Arguments
2.1: The functions of systems and structures have been derived and substantiated taking into account RGP and OPEX, and processes are in place to maintain these through-life. (Engineering Analysis)			
2.1.2	The design of the system/structure has been substantiated to achieve the safety category functions in all relevant operating modes.	Safety functions associated with the relevant SSC have been substantiated during normal operating conditions (including design codes and standards compliance).	006N5200 (Reference 8-26). Also see the "Performance and Safety Evaluation" subsections of this chapter.
		A record of safe BWR plant operation and continuous improvement demonstrates a well-founded design.	NEDC-34137P, "BWRX-300 Design Evolution," (Reference 8-66).
		Safety functions associated with the relevant SSC have been substantiated during hazard and fault conditions.	Safety functions will be identified in PSR Chapters 3 & 15 (References 8-4 and 8-32). The means of substantiation will be included in post-GDA developments of PSR Ch. 8.
		Any shortfalls in safety category function substantiation have been identified and assessed to identify any reasonably practicable means to reduce risk.	This argument is out of the scope of a 2-Step GDA and will be addressed during a site-specific stage (when evidence is developed).
2.1.3	The system/structure design has been undertaken in accordance with relevant design codes and standards (RGP) and design safety principles and taking account of Operating	Design evolutions to SSCs have been considered taking into account relevant BWR OPEX, and any reasonably practicable changes to reduce risk have been implemented.	NEDC-34137P (Reference 8-66).
		The SSCs have been designed in accordance with relevant codes and standards (RGP)	006N3441, "BWRX-300 Applicable Codes, Standards, and Regulations List," (Reference 8-67).

L3 No.	Level 3 Chapter Claim	Chapter 8 Arguments	Sub-sections and/or Reports that Evidence the Arguments
	Experience to support reducing risks ALARP.		NEDC-34139P, "BWRX-300 UK GDA Step 1 Codes and Standards Report," (Reference 8-68). 006N5200 (Reference 8-26).
		The SSCs have been designed in accordance with an appropriate suite of design safety principles.	The GEH Safety and Design Principles are documented in the BWRX-300 Safety Strategy, supplemented by the BWRX-300 General Description. These principles are also be presented within PSR Ch. 3 (Reference 8-4): • 006N5064, "BWRX-300 Safety Strategy," (Reference 8-69). • 005N9751, "BWRX-300 General Description," (Reference 8-70). Section 8.3: Electrical Power systems general principles and design approach.
2.1.4	System/structure performance will be validated by suitable testing throughout manufacturing, construction, and commissioning.	SSC pre-commissioning tests (e.g., NDT) validate the relevant performance requirements.	This is considered to be beyond the scope of a 2-Step GDA to define.
		SSC commissioning tests (e.g., system level pressure and leak tests) validate the relevant performance requirements.	This is considered to be beyond the scope of a 2-Step GDA to define.
		SSCs are manufactured, constructed, and commissioned in accordance with QA arrangements appropriate to their safety classification	DBR-0066822, "BWRX-300 System Functional Requirements (A11)," (Reference 8-71) describes how safety categorisation and SSC classification are linked to quality group (QA arrangement) definition. 006N8706, "BWRX-300 Construction Strategy Report," (Reference 8-72) describes the high-level construction quality assurance and quality control arrangements and responsibilities.
2.1.5	Ageing and degradation mechanisms will be identified and assessed in the design. Suitable examination, inspection, maintenance, and testing	SSC ageing and degradation mechanisms will be identified during SSC design. These will be assessed to determine how they could potentially lead to SSC failure.	This is considered to be out of the scope of a 2-Step GDA, where the design maturing is at a concept stage. However, early project examples of such considerations are included within the following report: • NEDC-34137P (Reference 8-66).

L3 No.	Level 3 Chapter Claim	Chapter 8 Arguments	Sub-sections and/or Reports that Evidence the Arguments
	will be specified to maintain systems/structures fit-for-purpose through-life.	Appropriate Examination, Maintenance, Inspection, and Testing (EMIT) arrangements will be specified taking into account SSC ageing and degradation mechanisms.	This is considered to be out of the scope of a 2-Step GDA, where the design maturing is at a concept stage. However, early project examples of such considerations are included within the following report: • 006N6279, "BWRX-300 In Service Inspection Requirements," (Reference 8-73).
		The SSCs that cannot be replaced have been shown to have adequate life.	This is considered to be out of the scope of a 2-Step GDA, where the design maturing is at a concept stage.
		Ageing and degradation OPEX will be considered as part of the design stage component/materials selection process in order to mitigate SSC failure risk.	This is considered to be out of the scope of a 2-Step GDA, where the design maturing is at a concept stage. However, early project examples of such considerations are included within the following report: • NEDC-34137P (Reference 8-66).
2.1.6	The BWRX will be designed so that it can be decommissioned safely, using current available technologies, and with minimal impact on the environment and people.	SSC decommissioning is considered at the design stage to ensure that safe decommissioning may take place.	OPEX demonstrates that decommissioning of reactor facilities is facilitated if the following are considered during the design phase: • Materials are selected to minimise the quantities of radioactive waste and assisting decontamination. • Plant layout is designed to facilitate access for decommissioning or dismantling activities. • Future potential requirements for storage of radioactive waste. See PSR Ch. 21 (Reference 8-74).
		SSCs are designed in order to minimise impacts on people and the environment during decommissioning.	See PSR Ch. 21 (Reference 8-74).

L3 No.	Level 3 Chapter Claim	Chapter 8 Arguments	Sub-sections and/or Reports that Evidence the Arguments
2.4 Safety risks have been reduced as low as reasonably practicable			
2.4.1	Relevant Good Practice (RGP) has been taken into account across all disciplines.	Relevant SSC codes and standards (RGP) are identified.	006N3441 (Reference 8-67). NEDC-34139P (Reference 8-68).
		SSCs have been designed in accordance with relevant codes and standards (RGP).	006N3441 (Reference 8-67). NEDC-34139P (Reference 8-68). The descriptions included within this chapter identify how the SSCs have been designed in accordance with relevant codes and standards.
		Any shortfalls in codes and standards compliance are identified and assessed to reduce risks ALARP.	Out of the scope of this PSR chapter.
2.4.2	Operational Experience (OPEX) and Learning from Experience (LfE) has been taken into account across all disciplines.	Design improvements to SSCs have been identified considering relevant OPEX and LfE.	NEDC-34137P (Reference 8-66).
		Any reasonably practicable design changes to reduce risk have been implemented.	NEDC-34137P (Reference 8-66).
2.4.3	Optioneering (all reasonably practicable measures have been implemented to reduce risk).	Design optioneering has been performed in accordance with an approved process.	006N3139, "BWRX-300 Design Plan," (Reference 8-75).
		Design optioneering has considered all reasonably practicable measures.	006N3139 (Reference 8-75). NEDC-34137P (Reference 8-66).
		Any reasonably practicable design changes to reduce risk have been implemented.	NEDC-34137P (Reference 8-66).

APPENDIX B FORWARD ACTIONS

The FAP is not required to capture the ‘normal business’ of Safety, Security, Safeguards and Environmental case development as the design progresses from concept to design for construction and commissioning. FAP items can arise from several sources:

- Assumptions and commitments made in the GDA submissions that will require future verification/implementation, for example, by the future constructor and/or plant operator.
- A gap in the underpinning of the GDA submissions currently under development.
- A potential gap in a future phase of submissions if additional work is not performed or
- A gap identified by the regulators and communicated to the Requesting Party (RP) through a Regulatory Query or Regulatory Observation.

Within this chapter there is a single FAP item identified that is intended to be resolved within GDA Step 2, which is as follows:

- A high-level review of UK Grid Code requirements compliance will be performed during GDA to provide confidence that there are no design ‘blockers’ that would prevent design deployment into the UK.

It is proposed to perform a more detailed UK Grid Code compliance assessment during a future site-specific phase.

Alignment of Codes and Standards

Within this chapter there is a single FAP item identified that is intended to be resolved during a post-GDA phase, which is as follows:

- The Electrical system design requires alignment with standards for UK applications, particularly for low voltage systems and for earthing / grounding requirements. It is recommended that the design of electrical installations is reviewed against relevant UK accepted standards, such as BS 7671 (Reference 8-22).

Alignment of Codes and Standards: The inclusion of IEC standards at present is provisional. The appropriate IEC standards corresponding to IEEE standards will be assessed and updated During GDA Step 2, following receipt of 006N5200 (Reference 8-26).

Presently, within this document, the IEC standards identified as relating to PSR IEEE standards may appear under more than one reference number, as one IEEE standard may relate to more than one IEC and vice-versa, which is to be resolved after GDA Step 2. Within this document IAEA standards have been identified as relating to PSR references to PDC, GDC, CFR, RG and BTP of USNRC, Standard Review Plan Documents/Criteria/Requirements, codes, standards, and guides. These are to be assessed for their relevance as international best practice and applicability for UK / EU equivalence, or adopting as RGP, which is to be resolved after GDA Step 2. The Non-IEC and Non-IAEA codes and standards cited in 006N5115 (Reference 8-2) are to be aligned to relevant IAEA and IEC standards after GDA Step 2. IEC Standards related to the BWRX-300 are identified in 006N5200 (Reference 8-26), which are to be checked and assimilated into later revisions of this document during GDA Step 2.

APPENDIX C INTERFACES

Interfaces with Other Disciplines

The design is to be developed through interface and cooperation between disciplines, and stakeholders, including designers, constructors, operators, and maintainers, in accordance with PSR Ch. 17 (Reference 8-76), and NEDC-34150P, "BWRX-300 UK GDA Project Implementation Plan," (Reference 8-77). The foreseen points of interface at this stage are:

Mechanical, Process, Plant, Nuclear, I&C, security, fire, building services, electrical auxiliary power.

This includes:

- The electrical load schedule.
- Electrical power availability and quality.
- Heating, Ventilation, and Air Conditioning (HVAC) requirements, and equivalent safety classification of electrical power supplies.

The load schedule will be developed with other design disciplines. This document is essential to developing the electrical design.

This includes power and duty cycle requirements for electrical drives and valve actuators.

Auxiliary Generators (diesel, or other), and related subsystems.

RAM Requirements, operational and Safety Case requirements.

Electrical

Other electrical Basis of Design for building electrical systems and external services including load schedule and electrical protection coordination.

Safety Case/Assurance

The PSR safety justification has been developed in accordance with GEH's suite of safety methodologies, which are identified within PSR Ch. 15 (Reference 8-32). It is intended to develop a Safety Case Manual specification during GDA, which summarises these.

I&C Systems and Equipment

- Smart devices, and qualifying commercial control equipment, software, and programable devices.
- Final circuits to I&C systems and equipment.
- Reactor core, reactor coolant system and nuclear fuel management.
- Reactor pressure vessel, nuclear boiler system and auxiliaries.
- Core cooling systems (emergency).
- Mechanical handling (nuclear and conventional).
- Station auxiliary systems.
- Turbine, condensate, and feedwater systems.
- External hazards.
- Internal hazards.
- Maintenance.
- Radiation protection.

- Commissioning.
- Security functional requirements.

Civil, Structural, Architectural

At this stage, the areas for interface are identified to be as below:

- Integrated design models.
- Structural design models and layouts, including identification of radiological and contamination zones, and hazardous areas (combustible atmospheres).
- Integration with structures & services systems.
- Separation and segregation of routes.
- EMI & EMC, considering space weather.
- Cathodic protection.
- Project architect: Layouts, colour schemes, and protective finishes.
- Foundations, mountings, seismic conditions, restraint, and anti-vibration requirements,
- Seismic study to inform fixing and mounting of equipment and components.
- earthing, and lightning protection, structural interfaces including EMI mitigation metal reinforced concrete.
- Penetrations and transits for electrical services.
- Pollution prevention & control: bunding, interceptors, catchment, and drainage.

Facility Layout

- Layout for access and maintenance.
- Electrical system transport/routes.
- Coordination of the layout, including access/maintenance/security.
- Equipment locations.
- Plant space provision.
- Setting out of equipment.
- Coordination of buried services, including draw-pits and ducts.
- Access to electrical systems and fixtures for maintenance, (e.g., re-lamping.)
- Cable management system.
- Cable routes.

Other

- Requirements for en-cast fixing points.
- Policy on “post drilled” fixings.
- Requirements for EMIT and through life stewardship.
- Operations Interfaces.

The design is developed through collaboration with operational stakeholders. At this stage they are identified as:

- For functional area requirements.
- Plant operations.
- Maintenance function.
- Work management function.
- Radiation protection function.
- Outage plan function.
- Training function.
- Industrial safety function.
- Emergency response function.
- Commissioning function.
- Transport plan function.
- Human factors/human performance function.
- Decommissioning function.
- Plant engineering function.
- Fire detection and protection.
- Security.

Other Systems and Services

These will be identified and managed through the project governance processes in accordance with NEDC-34150P (Reference 8-77) for:

- I&C systems.
- Information Technology (IT) & software security.
- Physical security.
- Domestic water system.
- Fire inspection requirements.
- Fire protection requirements and system, including generator, transformers, switchgear, and standby generator fuel.
- I&C basis of design, and other fire protection references.
- Automatic fire alarm system.
- Smoke exhaust equipment.
- Radiation control system.
- Environmental chemistry control.
- Structures and services systems.
- Plant layout and ergonomics.

The design of the electrical system is coordinated with the facility layout and other engineering/architectural specifications with regards to the following:

- Coordination of the layout, including access/maintenance/security.
- Equipment locations.
- Plant space provision.
- Setting out of equipment.
- Coordination of buried services, including draw-pits and ducts.
- Access to electrical systems and fixtures for maintenance, (e.g., re-lamping.)
- Cable management system.
- Cable routes.
- Aesthetic requirements.

APPENDIX D BWRX-300 SYSTEM CODES AND SAFETY CLASS