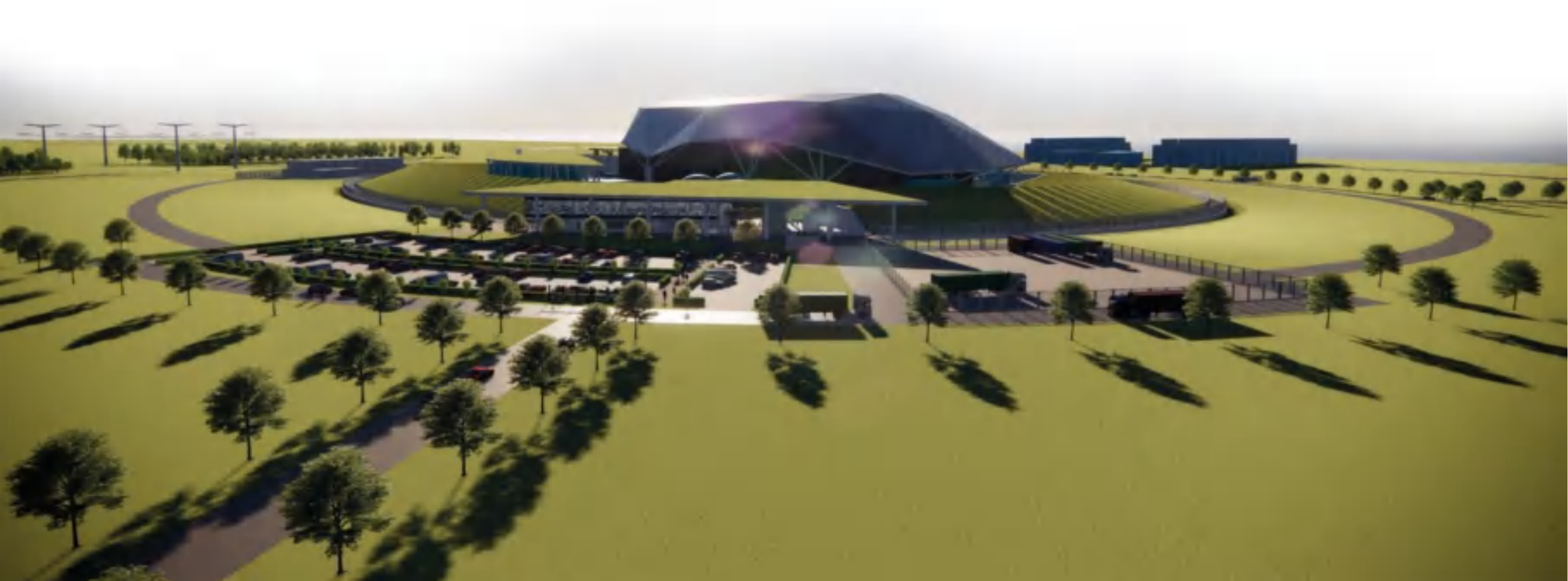
Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 8: Electrical Power



Record of Change

Date	Revision Number	Status	Reason for Change
March 2023	1	Issue	First issue of E3S Case
March 2024	2	Issue	Incorporates information at Reference Design 7, aligned to Design Reference Point 1, including: • Updated design descriptions of the electrical power systems covering architecture, layout, safety class, functional and non-functional requirements, and underlying design optioneering • Updated mapping of claims, arguments and evidence to sections within Chapter 8
May 2024	3	Issue	Updated to correct revision history status at Issue 2. Chapter changes include: • Update of Electromagnetic Compatibility section. • Additional detail within conclusions section for how arguments and evidence presented meet the generic E3S Case objective. Also minor template/editorial updates for overall E3S Case consistency.

Executive Summary

Chapter 8 of the generic Environment, Safety, Security, and Safeguards (E3S) Case presents the Electrical Power Systems of the Rolls-Royce Small Modular Reactor (RR SMR).

The chapter outlines the claims, arguments and evidence to underpin the high-level claim that the RR SMR Electrical Power Systems are conservatively designed and verified to deliver E3S functions through-life, in accordance with the E3S design principles, to reduce risks to as low as reasonably practicable (ALARP), apply best available techniques (BAT) and ensure secure by design and safeguards by design.

The systems covered include the Grid Transmission System [A], Electrical Power system [B], Generator Transmission Main Connection [MS], Earthing and Lightning Protection System [XF], and the Lighting Systems [XQ], as well as associated sub-systems.

For each system, the safety functions to be delivered by each SSC are presented, with the assignment of safety categorised functional requirements to achieve them. Non-functional system requirements derived from the E3S design principles discussed. The design definition presented for each system is developed based on relevant good practice (RGP) and operating experience (OPEX), with design to codes and standards according to the safety classification, and down-selection of options in accordance with criteria to ensure risks are reduced to ALARP, apply BAT, and are secure by design and safeguards by design. This provides confidence that claims can be met when the full suite of arguments and evidence is developed.

Version 2 of the generic E3S Case is developed in support of the reference design 7 (RD7) design, corresponding to design reference point 1 (DRP 1) for the generic design assessment (GDA). Further arguments and evidence are to be developed to underpin the top-level claim, including development of a complete set of E3S requirements and their associated verification and validation activities, and continued design development.

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8.0 Introduction

8.0.1 Introduction to Chapter

Chapter 8 of the Rolls-Royce Small Modular Reactor (RR SMR) generic Environment, Safety, Security and Safeguards (E3S) Case presents the overarching summary and entry point to the design and E3S information for the electrical power systems of the RR SMR.

8.0.2 Scope and Maturity

The list of structures, systems, and components (SSCs) that are included in the scope of this chapter is provided in section, Appendix B (section 8.9).

Version 2 of the generic E3S Case is based on reference design 7 (RD7), corresponding to design reference point 1 (DRP 1) for the generic design assessment (GDA). At RD7/DRP1, the safety functions to be delivered by each SSC are presented, with the assignment of safety categorised functional requirements to achieve them. No functional requirements for environment, security and safeguards are placed onto SSCs within the Electrical Power Systems at RD7/DRP1. The design definition presented is based on the design maturity of each respective SSC at RD7/DRP1. Verification and validation activities for SSCs within this chapter are still to be established.

8.0.3 Claims, Arguments and Evidence Route Map

The overall approach to claims, arguments, evidence (CAE) and the set of fundamental E3S claims to achieve the E3S fundamental objective are described in E3S Case Version 2, Tier 1, Chapter 1: Introduction [1]. The associated chapter level claim for E3S Case Version 2, Tier 1, Chapter 8: Electrical Power Systems is:

Claim 8: Electrical Power Systems are conservatively designed and verified to deliver E3S functions through-life, in accordance with the E3S design principles, to reduce risks to ALARP, apply BAT and in line with secure by design and safeguards by design.

A decomposition of this claim into sub-claims and mapping to the relevant Tier 2 and Tier 3 information containing the detailed arguments and evidence, is presented in the E3S Case Route Map [2]. Given the evolving nature of the E3S Case alongside the maturing design, the underpinning arguments and evidence may still be developed in future design stages; the trajectory of this information, where possible, is also illustrated in the route map.

A proportionate summary of the arguments and evidence from lower tier information, available at the current design stage, is presented within this chapter. A mapping of the claims to the corresponding sections that summarise the arguments and/or evidence is provided in Appendix A (section 8.8).

8.0.4 Applicable Regulations, Codes and Standards

The electrical power systems summarised in this chapter are designed in accordance with their safety classification. At the current design relevant key codes and standards have been outlined in Table 8.0-1. These codes and standards below do not represent the full list of codes and standards that will be used to support and guide the design of the electrical power systems. The full breakdown of the codes and standards referred to and how they will be referenced within the DOORS is located within Electrical Power Systems Codes and Standards [3]. The selection of appropriate codes and standards is being refined and developed as the design progresses.

Table 8.0-1: Electrical Power Systems Codes and Standards

Title of the Code/Standard/Legislation	**Code/Standard Reference**
Rotating electrical machines	International Electrotechnical Commission (IEC) 60034
Power transformers	IEC 60076
High-voltage switchgear and control gear	IEC 62271
Low-voltage switchgear and control gear	IEC 60947
Semiconductor converters	IEC 60146-1-1: 2009
Instrumentation systems important to safety – Electrical penetration assemblies in containment structures	IEC 60772:2018
Uninterruptible Power Systems (UPS)	IEC 62040
Protection against lightning	IEC 62305
Requirements for electrical installations. Institution of Engineering and Technology (IET) Wiring Regulations (UK)	British Standard (BS) 7671
Safety of machinery - General principles for design – Risk assessment and risk reduction	International Organization for Standardization (ISO) 12100
Safety of machinery - Safety-related parts of control systems	ISO 13849
Safety of machinery. Electrical equipment of machines	European Norm adopted as a British Standard (EN) 60204
Electromagnetic compatibility (EMC)	IEC 61000
Nuclear power plants - Electrical systems - General requirements	IEC 63046
Nuclear power plants - Electrical power systems - Electrical power systems analysis	IEC 62855
Nuclear power plants - Instrumentation and control systems important to safety - Requirements for electrical supplies	IEC 61225
Nuclear facilities - Electrical equipment important to safety - Qualification	IEC/IEEE 60780-323
Recommended Practices for Seismic Qualification of Electrical Equipment of the Safety System for Nuclear Generating Stations	IEC 60980
Nuclear power plants - Instrumentation and control systems important to safety – Separation	IEC 60709

The following relevant United Kingdom (UK) statutory regulations are also identified for the Electrical Systems:

- Electrical Safety, Quality and Continuity Regulations 2002 (as amended)
- The Building Regulations 2000 (as amended) for England and Wales
- The Electricity at Work Regulations 1989 (as amended)
- The Supply of Machinery (Safety) Regulations 1992 (as amended)
- The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002
- The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996
- Construction (Design and Management) Regulations 2015.

Each system will substantiate its selection of codes and standards that it will use to support the design. It is intended that this substantiation will exist inside the system design description (SDD) or an equivalent document for each system and this will allow the system to tailor its ALARP justification to the situation it will be deployed within.

8.1 Description of the Electrical Power Systems

8.1.1 Electrical Power Systems Overview

The electrical power systems for RR SMR include the Grid Transmission System [A], Electrical Power System [B], Generator Transmission Main Connection [MS], Earthing and Lightning Protection System [XF] and Lighting Systems [XQ].

The key functions of the electrical power systems [A, B, MS, XF, XQ] are:

- To transmit electrical power from the Main Generator to the Grid Connection Point
- To supply electrical power of appropriate quality and reliability to site loads.

The electrical power systems names are contained in the Product Breakdown Structure (PBS) module in IBM DOORS, which is based on the Reference Designation System for Power Plants (RDS-PP®) coding. The electrical power system names are listed in Table 8.1-1.

The electrical power systems chapter does not describe the Reactor Trip Breakers [JRA40/JQA40] as these are included in the E3S Case Version 2, Tier 1, Chapter 7: Instrumentation and Control [4].

The electrical power systems chapter also does not describe the details of Variable Frequency Drives (VFD) as these are considered within the PBS to be part of the relevant process plant system. For example, the Reactor Coolant Pumps (RCPs) are part of the Reactor Coolant Pump System [JEB] rather than the electrical power system that supplies power to the VFDs. Design details for VFDs are therefore captured in those relevant system and component design definitions (rather than as part of the electrical power system definitions), with the same approach taken for E3S Case documentation.

Table 8.1-1: Electrical Power System Codes and Names

System Code	System Name
A	Grid transmission system
AC_	400 kV Grid Transmission Connection System
B	Electrical power system
BB_	High Voltage Main AC Supply System
BC_	High Voltage Main AC Standby Supply System
BD_	High Voltage Essential AC Standby Supply System
BF_	Low Voltage Main AC Supply System for Process Equipment
BG_	Low Voltage Main AC Supply System for Non-Process Equipment
BK_	Low Voltage Essential AC Standby Supply System
BL_	Low Voltage Essential AC Alternate Supply System
BM_	Low Voltage Uninterruptible AC Supply System
BP_	Low Voltage Uninterruptible direct current (DC) Supply System
BQ_	Low Voltage Uninterruptible DC Supply System for Safety Services
MS_	Generator Transmission Main Connection
XF	Earthing and Lightning Protection System
XFA	Earthing/Grounding System
XFB	Equipotential Bonding System
XFC	External Lightning Protection
XFD	Internal Lightning Protection
XQ	Lighting Systems

The following naming conventions apply:

- The underscore_ represents any letter for a level 4 RDS-PP® system code in the Electrical Power Systems
- Main: Supplied only by the Grid or Main Generator
- Essential: Interruptible supplies with generator backup, e.g. Diesel Generator
- Uninterruptible: No-break supplies supported by batteries
- Process Equipment: Loads that directly support the plant power generation process. A loss of process loads leads to unplanned generation power reduction
- Non-Process Equipment: Loads that indirectly support the plant power generation process, which do not cause unplanned generation power reduction on loss of the load.

The simplified electrical power system architecture for one division of the RR SMR electrical power system is shown in Figure 8.1-1. This focuses on the power sources and systems supplying Reactor Island loads and does not show the arrangement of the electrical power systems for the other Islands.

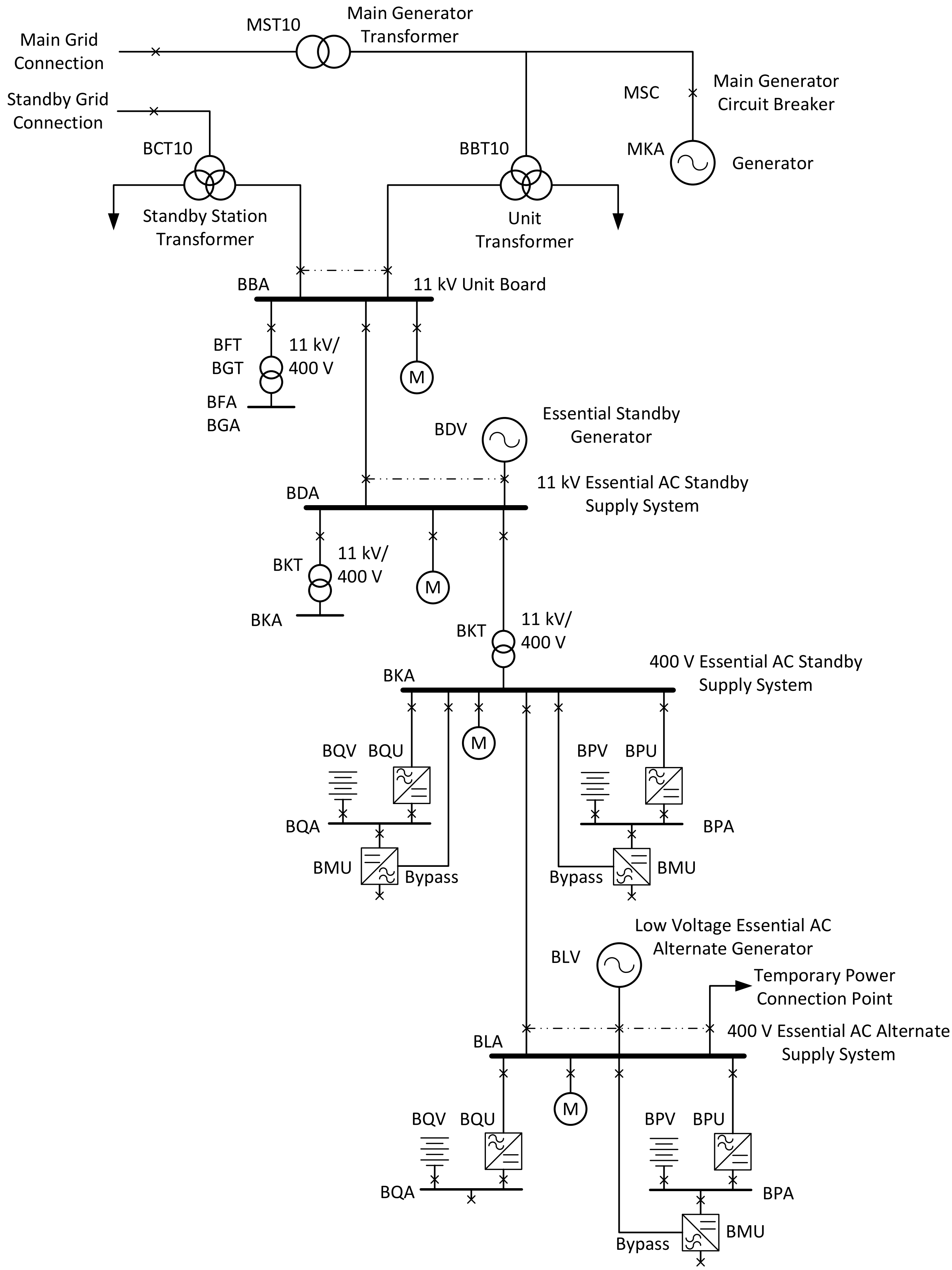

Figure 8.1-1: Electrical System Overview Diagram

The Generator [MKA] is connected to the Main Grid Connection via the Main Generator Circuit Breaker [MSC] and the Main Generator Transformer [MST]. Power station loads are supplied from the Unit Transformer [BBT10] or from the Standby Station Transformer [BCT10]. The Unit and Standby Transformers each have dual secondaries to provide a measure of electrical separation between downstream divisions. The architecture of the Onsite Power Supply system follows the principles established in IEC 63046 and SSG-34, where several levels of Defence in Depth are recommended [5].

Table 8.1-2: IAEA Electrical Levels of Defence in Depth

Level of DiD	Applied to plant electrical power systems
1	Comprehensive design bases, robust and reliable grid, robust and reliable on-site power systems.
2	Robust and reliable fault clearing system and coordination of protection, power supply transfer capability, house load operation possibilities.
3	Robust and reliable safety power systems, robust and reliable on-site standby AC power supplies.
4	Robust and reliable alternate AC power supply (AAC).
5	Mobile power supply connection point.

The first level of Defence in Depth covers the Main Grid Connection [AC_].

The Generator [MKA], Standby Grid Connection [AC_], High Voltage Main AC Supply System [BB_] and the High Voltage Main AC Standby Supply System [BC_] are the second level of Defence in Depth. The Generator [MKA] is capable of House Load operation to continue supplying the Unit loads should the Main Grid Connection [AC_] fail. The 11 kV Unit Boards [BBA] are normally supplied from the Unit Transformer [BBT10] and automatically switch over to the Standby Station Transformer [BCT10] should the normal supply fail. A number of Low Voltage Main AC Supply Systems for Process Equipment switchboards [BF_] and Low Voltage Main AC Supply System for Non-Process Equipment [BG_] switchboards are supplied from the 11 kV Unit Boards [BBA]. In general, the power station loads required to generate power are assigned to the 11 kV Unit Boards [BBA].

The High Voltage Essential AC Standby Supply System [BD_] is normally fed from the High Voltage Main AC Supply System [BB_] and has two 11 kV Essential Standby Generators [BDV] that can supply the 11 kV Essential AC Standby Supply System [BDA] should the normal supply fail. A number of 400 V Essential AC Standby Supply System [BK_] switchboards are supplied from the 11 kV Essential AC Standby Supply System [BDA], which in turn feed a number of Battery Charger [BQU, BPU], Battery [BQV, BPV] and Inverter [BMU] systems. In addition, two Low Voltage Essential AC Standby Generation System [BKV] supply Turbine Island and Balance of Plant loads independently of the 11 kV Essential Standby Generators [BDV]. This equipment forms the third level of Defence in Depth, and generally power station loads required to prevent and mitigate against nuclear accidents are assigned to these switchboards.

A fourth level of Defence in Depth is provided should the AC power from the 400 V Essential AC Standby Supply System [BK_] fail. Two Low Voltage Essential AC Alternate Generators [BLV] and associated 400 V Essential AC Alternate Supply System [BLA] switchboards normally supplied from the 400 V Essential AC Standby Supply System [BK_] are provided, which in turn supply a number of Battery Charger [BQU, BPU], Battery [BQV, BPV] and Inverter [BMU] systems. Generally, the power station loads performing backup functions to prevent and mitigate against nuclear accidents are assigned to these switchboards. The power station loads required for Severe Accident Management [JRQ20] are also assigned to this level of Defence in Depth.

A Temporary Power Connection Point allows mobile power modules to be connected to the 400 V Essential AC Alternate Supply System [BLA] as a fifth level of Defence in Depth.

The Single Line Diagrams [6] [7] [8] [9] [10] show the number of divisions at each level of Defence in Depth, which aligns with the divisions of Process and Control and Instrumentation (C&I) equipment. At Defence in Depth level two, there are three AC electrical divisions [BBA01, BBA02 and BBA03] to align with the three Reactor Coolant Pumps [JEB]. At Defence in Depth level three, there are two AC electrical divisions [BDA21 and BDA22] to align with the process systems, while there are three DC and Uninterruptible AC divisions [BQA21, BQA22 and BQA23] to align with the Reactor Protection System [JRA], and another two DC and Uninterruptible AC divisions [BPA21 and BPA22] to align with the Post-Accident Management System [JRQ10]. At Defence in Depth level four, there are two AC electrical divisions to align with the process systems, while there are four DC divisions [BQA24, BQA25, BQA26 and BQA27] to align with the Diverse Protection System [JQA], and another two DC and Uninterruptible AC divisions [BPA27 and BPA28] to align with the Severe Accident Management System [JRQ20].

The power station electrical loads are managed in the SMR project requirements management tool IBM DOORS. The Load Schedule [11] contains relevant load characteristics, including safety classification, operating modes, autonomy time, power demand and the type of load. The Load Schedule [11] is used to allocate loads to the appropriate part of the Electrical Power System architecture, based on the load characteristics and applicable level of Defence in Depth.

8.1.2 Electrical Power Systems Layout

The electrical power systems are located site-wide and a detailed overview of design assumptions, methodology and calculations used to update the electrical layout can be found in the Electrical Systems Layout Plan Report [12]. An overview of the location of the electrical systems across the site can be found in the General Arrangement Site Plan – Berm Site [13]. A marked up version of this highlighting the electrical systems is shown in Figure 8.1-2.

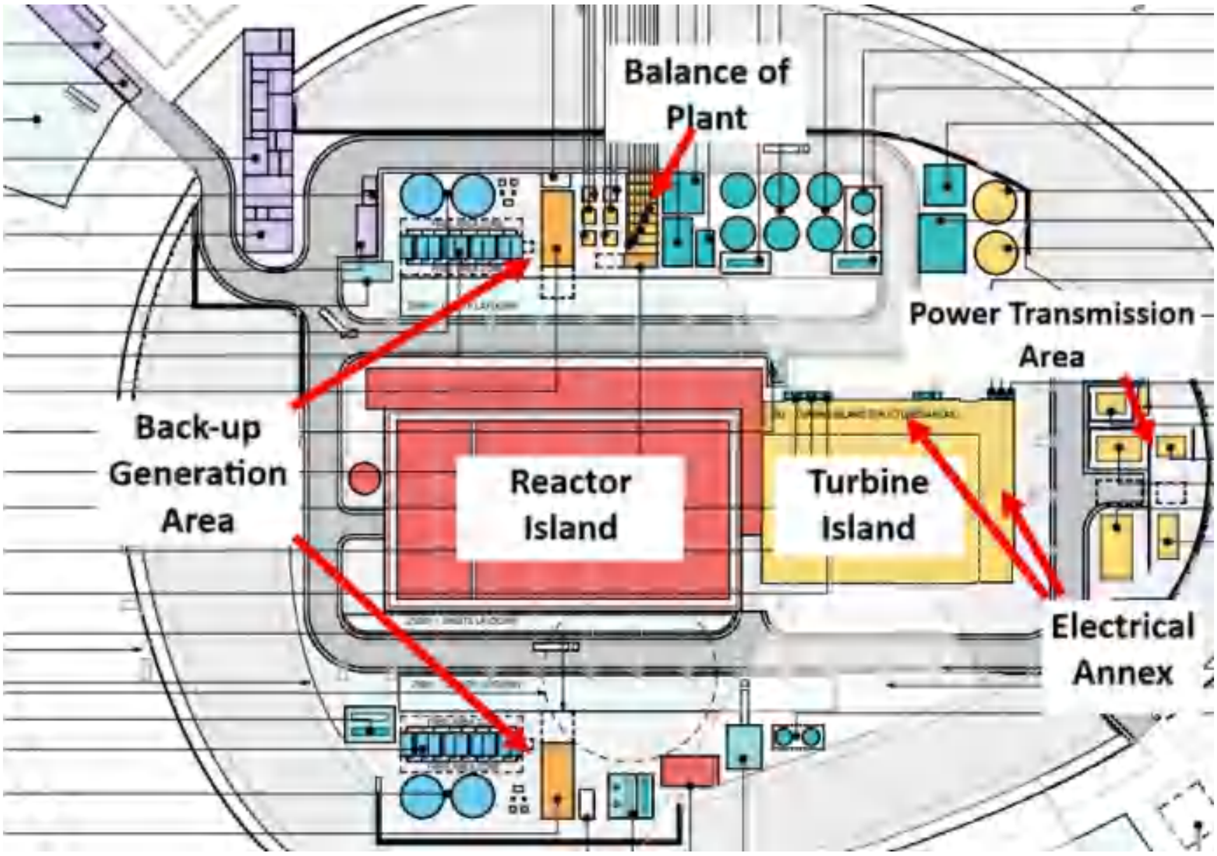

Figure 8.1-2: Marked-Up General Arrangement Site Plan – Inside the Berm

The RD7/DRP1 layout for inside Reactor Island is discussed in detail within the Reactor Island EC&I Systems Layout Summary Report [14]. That report describes the electrical power systems within Reactor Island being separated into five clusters as shown in Figure 8.1-3. Located in cluster 1 and 2 are all the High Voltage Essential AC Standby Supply System [BD_], Low Voltage Essential AC Standby Supply System [BK_] and Low Voltage Essential AC Alternate Supply System [BL_] allocated to reactor island. Cluster 5 contains the Low Voltage Main AC Supply System for Process Equipment [BF_] and Low Voltage Main AC Supply System for Non-Process Equipment [BG_] for Reactor Island loads. The Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_], Low Voltage Uninterruptible AC Supply System [BM_] and Low Voltage Uninterruptible DC Supply System [BP_] for Reactor Island are distributed throughout Clusters 1 to 4 segregated by electrical division.

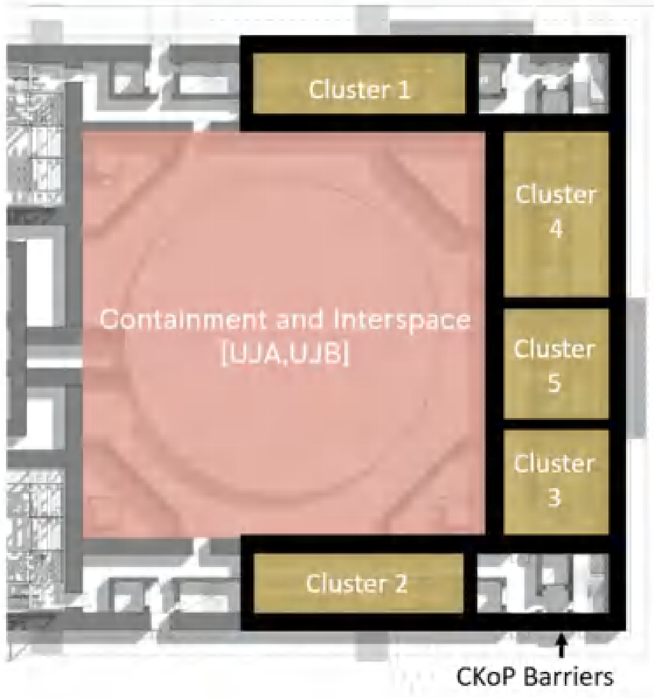

Figure 8.1-3: Reactor Island Electrical Layout Clusters

The RD7/DRP1 layout for inside the electrical annexes can be found in the Turbine Island General Arrangement Plans [15], [16] and [17]. These general arrangement plans show the distribution of the electrical systems within the electrical annexes.

8.2 General Principles and Design Approach

8.2.1 Design Rules

At RD7/DRP1, the Electrical Design Rules [18] have been derived from 'IEC 63046 Nuclear power plants – Electrical Power System – General Requirements' and are aligned to the RR SMR E3S Principles [19]. These design rules have been captured in the RR SMR Dynamic Object-Oriented Requirements System (DOORS) as Transverse Requirements. The DOORS Transverse Requirements module also contains requirements from sources like the Generic Site Envelope report [20], which inform the Electrical Power System design.

The Electrical Design Rules [18] facilitate:

- The consistent application of best practices and industry OPEX
- The demonstration of standards and legislative compliance
- The flow of design requirements to electrical and other systems
- The traceability and substantiation of design requirements.

8.2.2 Electrical Protection Philosophy

The purpose of the SMR Electrical Protection Philosophy and Smart Devices [21] is to provide a framework for the protection of electrical power systems, equipment and users of that equipment with regards to electrical faults. It also covers the approach to the use of smart devices for electrical protection purposes.

The RD7/DRP1 version of this document gives a high level overview of the Rolls-Royce SMR Limited approach to electrical protection and captures the key design requirements from applicable standards and relevant good practice. As the design develops, detailed protection architecture as well as co-ordination and settings will be produced as part of this philosophy.

The philosophy covers all electrical equipment within the Generator System [MK], Generator Transmission Main Connection System [MS], Grid Transmission System [A] and the Electrical Power System [B].

The electrical protection requirements are captured in the DOORS transverse requirements (TR) module where they will flow to the applicable systems and components via the system/component requirements modules.

8.2.3 Cable Routing Philosophy

The cable routing philosophy [22] provides a high-level framework for the management of cables and cable containment throughout a Rolls-Royce SMR site. The requirements that have been developed and will continue to be developed within DOORS as the project progresses.

The cable routing requirements developed within the philosophy are intended to apply to all cable systems, both electrical and C&I. Further development of requirements specific to C&I cables has been noted as further work within the philosophy. The detailed requirements are held within the DOORS transverse requirements module and will be flowed to the applicable systems via the system/component requirements modules. These requirements have been developed in accordance with applicable standards and relevant good practice. The full list of the codes and standards utilised in the creation of this philosophy are available within the cable routing philosophy.

The cable routing philosophy details:

- Separation requirements
- Cable routing requirements
- Duct bank requirements
- Conduit requirements
- Cable raceway requirements
- Requirements for the identification of cables and raceways
- Requirements for routing across the aseismic bearing
- Modularisation requirements
- Hazardous area requirements.

The detailed specification of individual cables and their sizing is not intended to fall within the scope of the philosophy document and will be covered in the system/component requirement modules.

8.2.4 Earthing and Lightning Protection Philosophy

The Earthing and Lightning Protection Philosophy is covered in section 8.5.1 in this document.

8.2.5 Electrical Codes and Standards

The Electrical Codes and Standards is covered in section 8.0.4 in this document.

8.3 Offsite Power Systems

8.3.1 Grid Transmission System & Generator Transmission Main Connection

8.3.1.1 System and Equipment Functions

The primary function of the Grid Transmission System [A] and its associated child 400 kV Grid Transmission Connection System [AC_] is to import and export power between the RR SMR and an external grid/electricity transmission system.

Although the details of the grid connection are site-specific, the generic design of the 400 kV Grid Transmission Connection System [AC_] comprises two off-site power connections: a main connection for the import/export of power and a standby connection for redundancy. The standby connection is for import only. It is not possible to export Generator System [MK] power via that connection. The RR SMR has been designed with a passive fault protection philosophy (using natural phenomena such as gravity and natural circulation) for key safety measures that minimise its dependence on off-site power for safety. Two independent off-site connections are not therefore required by the design to meet safety objectives, but are included in the generic design as a preferred interface maximising plant availability and offering Defence in Depth. A site-specific analysis will be done to confirm that the grid meets the generic design minimum requirements.

The main and standby connections are 400 kV connections and interfaces with the Generator Transmission Main Connection [MS_] and the Standby Transformer [BCT], respectively. This is shown on the Key Single Line Diagram [6].

Another child system forming part of Grid Transmission System [A] is the Low Voltage Grid Transmission Connection System [AN].

The primary function of the Low Voltage Grid Transmission Connection System [AN] is to provide LV power to equipment associated with the grid connection which intends to provide power for equipment with functions such as: control, monitoring, protection, and metering. It is anticipated that the majority of the [AN] system will be located in the Transmission System Operator's (TSO) substation and be dedicated to the RR SMR's connecting generator bays.

Due to the relatively small volume and complexity of the [AN] system, the child system [AN] PBS code will no longer be utilised post-RD7/DRP1 and instead its functional requirements and the scope of that system are to be combined with the [AC_] system. This change will be reflected in any future revisions of the E3S Case and SDDs relating to the [AC_] system.

The 400 kV Grid Transmission Connection System [AC_] and the Generator Transmission Main Connection [MS_] are currently in development, the safety requirements and architecture will be reported in a future revision of the E3S Case as evidence is developed in line with the CAE Route Map [2].

8.3.1.2 Design Bases

8.3.1.2.1 Functional Requirements

The 400 kV Grid Transmission Connection System [AC_] contains sub-systems and components which facilitate delivery of high level safety functions (HLSFs). The deterministic safety analysis presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [23], provides a systematic evaluation of the credible Postulated Initiating Events (PIEs). HLSFs are identified in the Fault Schedule [24] and assigned to each PIE to deliver the four Fundamental Safety Functions (FSFs): Control of Reactivity (CoR), Control of Fuel Temperature (CoFT), Confinement of Radioactive Material (CoRM), and Control of Radiation Exposure (CoRE).

The 400 kV Grid Transmission Connection System [AC_] imports and exports electrical power to the electricity transmission system. This is the electrical power source used in mode 3 to 6b to supply all electrical consumers on-site. The 400 kV Grid Transmission Connection System [AC_] contains sub-systems and components which facilitate the safety functional requirements associated with all Category C safety measures which aren't claimed during a Loss of Off-site Power fault.

Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS modules, including the rationale for their selection. The linked flow of requirements from the fault schedule through the safety measures to the electrical requirements modules is still in development.

8.3.1.2.2 Non-Functional System Requirements

Non-functional system requirements are specified for the 400 kV Grid Transmission Connection System [AC_] based on the E3S Principles [19] as outlined in Section 8.2. The requirements specified at RD7/DRP1 are listed in the DOORS transverse requirements module, including the rationale for their application. The process to flow these requirements efficiently to each applicable electrical power system requirements module in DOORS is still in development at RD7/DRP1.

A full set of non-functional system requirements from all identified sources are in development; these will be allocated to each applicable SSC.

8.3.1.2.3 E3S Categorisation and Classification

The highest category of the 400 kV Grid Transmission Connection System [AC_] functions fulfilling HLSF is Category C. In accordance with the SMR E3S Categorisation and Classification Method [25] this Electrical Power System is a Safety Class 3 system as it is providing power to systems/components that require power to deliver Category C duty functions

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic classifications for these systems are being developed in line with the Seismic Performance Classification Method [26] and the E3S Principles [19].

8.3.1.3 Description

The 400 kV Grid Transmission Connection System [AC_] comprises equipment at the operator's switchyards for both Main and Standby Grid Connections. The equipment consists of 400 kV isolators, disconnectors, grid circuit breaker, earth switches, HV and LV cabling and busbars, to provide the offsite connections to the transmission system.

Other ancillary equipment forming part of system [AC_] includes low voltage instrument transformers, protection and control equipment, UPS systems and metering and monitoring equipment.

The 400 kV Grid Transmission Connection System [AC_] Standby Grid Connection has been rated such that no load shedding is required if a transfer is required from Main Connection to Standby Connection. Part of the rationale for that rating (as recorded in the ECI-12 decision record [27]) is that it gives the possibility to implement a fast bus transfer. The type of transfer to be used is to be determined.

A description of the 400 kV Grid Transmission Connection System [AC_] design attributes are presented in the table below:

Table 8.3-1: Key Performance and Design Parameters for the 400 kV Grid Transmission Connection System [AC_]

Parameter	Value	Units
Grid Connection voltage	400	kV
Number of Grid Connections	2 (one main and one standby)	
Rating of Main Connection	600	MVA
Rating of Standby Connection	70	MVA
Grid Transmission LV Equipment Voltage	TBD	V

8.3.1.4 Materials

The approach to material selection, including qualification and ageing management considerations is addressed within E3S Case Version 2, Tier 1, Chapter 23 – Structural Integrity [28].

Materials will be confirmed as the design develops. Materials selection, and the supporting input information and rationale will be presented in future revisions to this chapter.

8.3.1.5 Interfaces with Other Systems

The 400 kV Transmission Connection System [AC_] functional and physical interfaces with electrical systems are the Earthing and Lightning Protection System [XF], the Generator Transmission Main Connection [MS_] and the High Voltage Main Standby Supply System [BC_]. These are identified and managed within DOORS, including flow down of functional requirements.

The 400 kV Transmission Connection System [AC_] interfaces with the external Transmission System Operator (TSO) which includes control, protection, measurement and communication cabling interface for both Main off-site Grid Connection and Standby off site Transmission Connection.

The 400 kV Transmission Connection System [AC_] has an interface with the C&I system, this interface is under development.

The 400 kV Transmission Connection System [AC_] also interfaces indirectly with the HVAC systems and fire extinguishing systems to ensure the components are operating in a controlled environment.

The Fire Detection systems are described in Chapter 7 [4] and the Fire Suppression systems are described in Chapter 9A [29].

8.3.1.6 System and Equipment Operation

The overarching operating philosophy for the Power Station in all operating modes is covered in [30], with operating modes defined in the operating philosophy for the Reactor Island [31].

8.3.1.6.1 Operational Mode 1 and 2 – Normal Power and Low Power (Startup) Operations

In Operational Mode 1 and 2, the 400 kV Transmission Connection System [AC_] is in the following state: energised; exporting power to Grid (when Generator output exceeds the SMR house load) and importing from Grid (when generator output does not exceed the SMR house load).

The [AC_] system receives power from the transmission system operators' derived supplies to provide power supplies to Low Voltage equipment and UPS.

8.3.1.6.2 Operational Mode 3 to 6B – Standby, Shutdown and Refuelling Operational Modes

In Operational Mode 3 to 6B, the 400 kV Transmission Connection System [AC_] is in the following state: energised; importing power from Grid and is also receiving power from grid-derived supplies; providing power to LV equipment associated with the Grid Connection.

8.3.1.6.3 Faulted Operations

In a loss of offsite power there is no power to import, so the [AC_] system is de-energised but is ready to receive power from the Grid power when deemed appropriate.

8.3.1.7 Instrumentation and Control

The basic functions allocated to the C&I systems, including details of alarms, warnings and control logic are yet to be developed.

As noted in Section 8.3.1.1, the [AN] system code will no longer be utilised post-RD7/DRP1 so the C&I interfaces for the [AN] system are to be developed as part of the 400 kV Transmission Connection System [AC_] instead. These will be developed via liaison and agreement with the TSO.

8.3.1.8 Examination, Monitoring, Inspection and Testing

The maintenance tasks and procedures, specific to the 400 kV Transmission Connection System [AC_] environment and operating context are to be defined as part of the final concept design. The examination, monitoring, inspection, and testing requirements will be captured in the relevant through life activities (AC_-TLA) module in DOORS.

Maintenance activities considered will include:

- Safety derived tasks (In Service Inspection (ISI))
- Design derived tasks (Supplier provided)
- Reliability derived tasks (Reliability Centred Maintenance (RCM)/Preventative Maintenance)

- Industry best practice/OPEX (primary source: Electric Power Research Institute (EPRI) Preventative Maintenance Basis Database (PMBD))

- Civil Structure and Module derived tasks.

The above monitoring, inspection, testing and maintenance activities will be developed via liaison and agreement with the TSO.

8.3.1.9 Radiological Aspects

No radiation assessment has been carried out for the 400 kV Transmission Connection System [AC_] at RD7/DRP1. It is envisaged there are no radiological requirements for this system.

8.3.1.10 Performance and Safety Evaluation

An initial hazard identification (HAZID) [32] was carried out for the electrical systems. Additional hazard assessments are being planned.

Verification activities against all requirements identified in the 400 kV Transmission Connection System [AC_] Requirements modules are in development.

8.3.1.11 Installation and Commissioning

The overall strategy for the RR SMR commissioning programme is presented in E3S Case Version 2, Tier 1, Chapter 14: Plant Construction and Commissioning [33].

Installation requirements for the 400 kV Transmission Connection System [AC_] are to be detailed in the allocated requirements (-D) modules in DOORS.

The Installation and Commissioning (ICOM) Policy [34] section 2.4, provides a non-exhaustive list of examples of electrical checks to be carried out post-installation and prior to commissioning as also detailed in Section 6 of the SDD for the Electrical Systems [5].

A comprehensive commissioning plan will be developed during detailed design. Commissioning plans will be developed in line with the RR SMR ICOM policy [34].

Appendix F of the RR SMR ICOM Policy [34] references IAEA Safety Guide NS-G-2.9 to provide an illustrative and non-exhaustive list of commissioning tests for Electrical Systems. NS-G-2.9 was superseded by IAEA Specific Safety Guide SSG-28 (Commissioning for Nuclear Power Plants [35]). Examples of the tests listed in the updated document are given in Table 8.3-2.

Table 8.3-2: Example Grid Connection System [AC] Commissioning Tests from SSG-28

System Type as described in SSG-28	Relevant RR SMR System(s)	Example Commissioning Tests from SSG-28
Normal AC power distribution system	[AC], [MS], [BB], [BC], [BF], [BG]	Operation of protection devices, initiating devices, relay and logic devices, breakers, motor controllers, switchgear, transformers, transfer and trip devices, prohibiting and permissive interlocks, instrumentation and alarms, load shedding capabilities, redundancy and electrical independence, integrated system performance with simulated partial and full LOOP under worst case conditions, capability to transfer from on-site to off-site power sources.

Lower-level SDDs will describe, where appropriate, the design features included specifically for commissioning.

8.4 Onsite Power Systems

8.4.1 Normal Onsite Power Supply

8.4.1.1 High Voltage Main Supply System [BB_]

8.4.1.1.1 System and Equipment Functions

The primary function of the High Voltage Main AC Supply System [BB_] is to distribute HV power received from Generator Transmission Main Connection [MS_], via the Generator System [MK] or the 400 kV Grid Transmission Connection System [AC_]. The High Voltage Main AC Supply System [BB_] also receives and distributes HV power from the second Grid Connection via High Voltage Main AC Standby Supply System [BC_].

8.4.1.1.2 Design Bases

8.4.1.1.2.1 Functional Requirements

The High Voltage Main AC Supply System [BB_] distributes power to all process HV power consumers that support the delivery of CoRM, CoFT and CoR during all plant operating modes. The High Voltage Main AC Supply System [BB_] contains sub-systems and components which facilitate the safety functional requirements associated with Category C safety measures. Safety categorised functional requirements specified for the High Voltage Main AC Supply System [BB_] based on the HLSFs they support the delivery of, are allocated in the DOORS BB_ requirements modules. Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS modules, including the rationale for their selection. The linked flow of requirements from the fault schedule through the safety measures to the electrical requirements modules is still in development.

8.4.1.1.2.2 Non-Functional System Requirements

Non-functional system requirements are specified for the High Voltage Main AC Supply System [BB_] based on the E3S Principles as outlined in Section 8.2. The requirements specified at RD7/DRP1 are listed in the DOORS transverse requirements module, including the rationale for their application. The process to flow these requirements efficiently to each applicable electrical power system requirements module in DOORS is still in development at RD7/DRP1.

A full set of non-functional system requirements from all identified sources are in development, these will be allocated to each applicable SSC.

8.4.1.1.2.3 E3S Categorisation and Classification

The highest category of the High Voltage Main AC Supply System [BB_] functions fulfilling HLSF is Category C. In accordance with the SMR E3S Categorisation and Classification Method [25], High Voltage Main AC Supply System [BB_] is a Safety Class 3 system.

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic classifications for these systems are being developed in line with the Seismic Performance Classification Method [26] and the E3S Principles [19]. The SPC of Class 3 equipment is to be developed.

8.4.1.1.3 Description

A single Unit Transformer [BBT10], transforms power from the Generator System [MK] voltage to 11 kV for the three main Unit Boards [BBA]. Each of the [BBA] main Unit Boards receive a normal power supply from the Unit Transformer which then distributes HV power supplies across the site.

Each of the three main Unit Boards [BBA] also have an alternative/standby supply from the Standby Transformer [BCT10].

The architecture of the three main Unit Boards is such that power to the whole site is divided to feed two divisions of redundant essential and non-essential loads.

These three main Unit Boards provide power to high power loads such as the Reactor Coolant Pumps [JEB], and also provide the normal source of power to all on-site loads via feeders to other switchboards and transformers across the site.

Another two 11 kV unit boards forming part of the [BBA] system provide HV power from each power supply division to the cooling water island facilities. The loads within the cooling water island comprise of power supplies to Main Cooling Water System (MCWS) and Auxiliary Cooling and Make-Up System (ACMS) cooling water pumps within the [PAC] system.

A description of the High Voltage Main AC Supply System [BB_] design attributes are presented in the Table below.

Table 8.4-1: Key Performance and Design Parameters for the High Voltage Main AC Supply System [BB_]

Parameter	Value	Units
Number of unit transformers	1	
Number of unit boards	5	
System voltage	11	kV
Unit Transformer [BBT] rating	70	MVA

8.4.1.1.4 Materials

The approach to material selection, including qualification and ageing management considerations is addressed within E3S Case Version 2, Tier 1, Chapter 23 – Structural Integrity [28].

Materials will be confirmed as the design develops. Materials selection, and the supporting input information and rationale will be presented in future revisions to this chapter.

8.4.1.1.5 Interfaces with Other Systems

The High Voltage Main AC Supply System [BB_] functional and physical interfaces with electrical systems are the Earthing and Lightning Protection System [XF], the Generator Transmission Main Connection [MS_], the Low Voltage Main AC Supply Systems for Process Equipment [BF_], the Low

Voltage Main AC Supply System for Non-Process Equipment [BG_], the High Voltage Essential AC Standby Supply System [BD_] and the High Voltage Main Standby Supply System [BC_]. These are identified and managed within DOORS, including flow down of functional requirements.

The High Voltage Main AC Supply System [BB_] interfaces with all process loads requiring HV power. These loads are captured within the Electrical Load Schedule [11].

The High Voltage Main AC Supply System [BB_] has an interface with the C&I system, this interface is under development.

The High Voltage Main AC Supply System [BB_] also interfaces indirectly with the HVAC systems and fire extinguishing systems to ensure the components are operating in a controlled environment. The Fire Detection systems are described in Chapter 7 [4] and the Fire Suppression systems are described in Chapter 9A [29].

8.4.1.1.6 System and Equipment Operation

The overarching operating philosophy for the Power Station in all operating modes is covered in [30], with operating modes defined in the operating philosophy for the Reactor Island [31].

8.4.1.1.6.1 Operational Mode 1 & 2 – Normal Power and Low Power (Startup) Operations

In these non-faulted operating modes the Unit Transformer and switchboards are energised and receiving power from Generator/Grid via [MS_]; providing power to site loads. The breakers to [BC_] standby system are open during these operational modes.

8.4.1.1.6.2 Operational Mode 3 to 6B – Standby, shutdown and refuelling Operational Modes

Unit Transformer and switchboards are energised and receiving power from Grid via [MS_] or [BC_] providing power to site loads.

8.4.1.1.6.3 Degraded Mode

If the Generator Transmission Main Connection [MS_] is unavailable, there would be a transfer of the Unit Board supplies from the Main Grid Connection (via Unit Transformer [BBT]) to the Standby Grid Connection (via Standby Transformer [BCT]).

8.4.1.1.6.4 Faulted Mode

In loss of offsite power from both Main Generator [MK], Main Grid Connection (via Unit Transformer [BBT]) and also the Standby Grid Connection (via Standby Transformer [BCT]), the [BB_] system is de-energised but is ready to receive power from the Grid power when deemed appropriate.

8.4.1.1.7 Instrumentation and Control

The basic functions allocated to the C&I systems and details of alarms, warnings and control logic are yet to be developed.

8.4.1.1.8 Examination, Monitoring, Inspection and Testing

The maintenance tasks and procedures, specific to the High Voltage Main Supply System [BB_] environment and operating context are to be defined as part of the final concept design. The examination, monitoring, inspection and testing requirements will be captured in the relevant through life activities (BB_-TLA) module in DOORS.

Maintenance activities considered will include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best practice/OPEX (EPRI PMBD)
- Civil Structure and Module derived tasks.

8.4.1.1.9 Radiological Aspects

No radiation assessment has been carried out for the High Voltage Main Supply System [BB_] at RD7/DRP1.

8.4.1.1.10 Performance and Safety Evaluation

An initial hazard identification (HAZID) [32] was carried out for the electrical systems. Additional hazard assessments are being planned.

Verification activities against all requirements identified in the High Voltage Main Supply System [BB_] Requirements modules are in development.

8.4.1.1.11 Installation and Commissioning

The overall strategy for the RR SMR commissioning programme is presented in E3S Case Version 2, Tier 1, Chapter 14: Plant Construction and Commissioning [33].

Installation requirements for the High Voltage Main Supply System [BB_] are to be detailed in the allocated requirements (-D) modules in DOORS.

The Installation and Commissioning (ICOM) Policy [34], section 2.4, provides a non-exhaustive list of examples of electrical checks to be carried out post-installation and prior to commissioning that include:

- Visual checks including checking of labels and tags for equipment, cables and trays
- Cable tray, panel and terminal box installation checks
- Component or equipment checks (pre energising), e.g. relays, contactors, circuit breakers, cells, rectifier and battery, motor, inverter (done during pre-Operational Commissioning tests)
- Wire to wire and post to post continuity checks
- Cable continuity and routing
- Earthing continuity checks to main earthing system

- Earthing of strips and shielding
- Shielding continuity
- Cable quality
- Electrical tests on HV / LV cables (after laying and before connection)
- Dielectric tests or insulation measurement for motors and cables
- Connections (crimping, connectors, cable lugs, end fittings, etc.)
- Wiring of inter-chassis links, controls, sensors, actuators, etc.

A comprehensive commissioning plan will be developed during detailed design. Commissioning plans will be developed in line with the RR SMR ICOM policy [34].

Appendix F of the ICOM Policy [34] references IAEA Safety Guide NS-G-2.9 to provide an illustrative and non-exhaustive list of commissioning tests for Electrical Systems. NS-G-2.9 was superseded by IAEA Specific Safety Guide SSG-28 (Commissioning for Nuclear Power Plants [35]) which gives the following list:

Table 8.4-2: Example High Voltage Main Supply System [BB_] Commissioning Tests from SSG-28

System Type as described in SSG-28	Relevant SMR System(s)	Example Commissioning Tests from SSG-28
Normal AC power distribution system	[AC], [MS], [BB], [BC], [BF], [BG]	Operation of protection devices, initiating devices, relay and logic devices, breakers, motor controllers, switchgear, transformers, transfer and trip devices, prohibiting and permissive interlocks, instrumentation and alarms, load shedding capabilities, redundancy and electrical independence, integrated system performance with simulated partial and full LOOP under worst case conditions, capability to transfer from on-site to off-site power sources.

8.4.1.2 High Voltage Main Standby Supply System [BC_]

8.4.1.2.1 System and Equipment Functions

The primary function of the High Voltage Main AC Standby Supply System [BC_] is to use Standby Grid power from the 400 kV Grid Transmission Connection System [AC_] to provide standby power to the Unit Boards [BBA].

8.4.1.2.2 Design Bases

8.4.1.2.2.1 Functional Requirements

The High Voltage Main AC Standby Supply System [BC_] transforms power to the High Voltage Main Supply System [BB_] which distributes this power to all process HV power consumers that support the delivery of CoRM, CoFT and CoR during all plant operating modes. The High Voltage Main AC Standby Supply System [BC_] contains sub-systems and components which facilitate the safety functional requirements associated with Category C safety measures. Safety categorised functional requirements specified for the High Voltage Main AC Standby Supply System [BC_] based on the HLSFs they support the delivery of, are allocated in the DOORS BC_ Requirements Modules. Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS modules, including the rationale for their selection. The linked flow of requirements from the fault schedule through the safety measures to the electrical requirements modules is still in development.

8.4.1.2.2.2 Non-Functional System Requirements

Non-functional system requirements are specified for the High Voltage Main AC Standby Supply System [BC_] based on the E3S Principles, as outlined in Section 8.2. The requirements specified at RD7/DRP1 are listed in the DOORS transverse requirements module, including the rationale for their application. The process to flow these requirements efficiently to each applicable electrical power system requirements module in DOORS is still in development at RD7/DRP1.

A full set of non-functional system requirements from all identified sources are in development, these will be allocated to each applicable SSC.

8.4.1.2.2.3 E3S Categorisation and Classification

The highest category of the High Voltage Main AC Standby Supply System [BC_] functions fulfilling HLSF is Category C. In accordance with the SMR E3S Categorisation and Classification Method [25], High Voltage Main AC Standby Supply System [BC_] is a Safety Class 3 system.

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic classifications for these systems are being developed in line with the Seismic Performance Classification Method [26] and the E3S Principles [19]. The SPC of Class 3 equipment is to be developed.

8.4.1.2.3 Description

The [BC_] System comprises of a single HV Main AC Standby Transformer [BCT10] located in the Power Transmission Area. This Standby Transformer shall transform power from the Grid Connection voltage to 11 kV for the three main Unit Boards [BBA]. Each of the Unit Boards [BBA] receives a standby power supply from the Unit Transformer [BCT10].

There are no switchboards in the [BC_] system.

The Standby Grid Connection and associated structures, systems and components (SSCs) [BC_], for example the Standby Transformer, have been rated such that no load shedding is required if a transfer is required from Main Connection to Standby Connection. Part of the rationale for that rating (as recorded in the ECI-12 decision record) [27] is that it gives the possibility to implement a fast bus transfer. The type of transfer to be used is to be determined.

A description of the High Voltage Main Standby Supply System [BC_] design attributes are presented in Table below:

Table 8.4-3: Key Performance and Design Parameters for the High Voltage Main Standby Supply System [BC_]

Parameter	Value	Units
Number of Standby Transformers	1	
System voltage	11	kV
Standby Transformer [BCT] rating	70	MVA

8.4.1.2.4 Materials

The approach to material selection, including qualification and ageing management considerations is addressed within E3S Case Version 2, Tier 1, Chapter 23 – Structural Integrity [28].

Materials will be confirmed as the design develops with vendor support. Materials selection, and the supporting input information and rationale will be presented in future revisions to this chapter.

8.4.1.2.5 Interfaces with Other Systems

The High Voltage Main Standby Supply System [BC_] functional and physical interfaces with electrical systems are the Earthing and Lightning Protection System [XF], the 400 kV Grid Transmission Connection System [AC_] and the High Voltage Main AC Supply System [BB_]. These are identified and managed within DOORS, including flow down of functional requirements.

The High Voltage Main Standby Supply System [BC_] has an interface with the C&I system, this interface is under development.

The High Voltage Main Standby Supply System [BC_] also interfaces indirectly with the HVAC systems and fire extinguishing systems to ensure the components are operating in a controlled environment. The Fire Detection systems are described in Chapter 7 [4] and the Fire Suppression systems are described in Chapter 9A [29].

8.4.1.2.6 System and Equipment Operation

The overarching operating philosophy for the Power Station in all operating modes is covered in [30], with operating modes defined in the operating philosophy for the Reactor Island [31].

8.4.1.2.6.1 Operational Mode 1 & 2 – Normal Power and Low Power (Startup) Operations

In these non-faulted operating modes, the Standby Transformer [BCT] is energised, but not under load.

The 11 kV Main AC Supply System [BBA] circuit breakers which connect to the [BC_] standby system are open during these operational modes.

8.4.1.2.6.2 Operational Mode 3 to 6B – Standby, shutdown and refuelling Operational Modes

The Standby Transformer [BCT] energised, not under load.

The 11 kV Main AC Supply System [BBA] circuit breakers which connect to the [BC_] standby system are open during these operational modes.

8.4.1.2.6.3 Degraded Mode

If the Generator Transmission Main Connection [MS_] is unavailable, there would be a transfer of the Unit Board supplies from the Main Grid Connection (via Unit Transformer [BBT]) to the Standby Grid Connection (via Standby Transformer [BCT]).

8.4.1.2.6.4 Faulted Mode

In a loss of offsite power from both Main Generator [MK], main grid connection (via Unit Transformer [BBT]) and the standby grid connection (via Standby Transformer [BCT]), the [BC_] system is de-energised but is ready to receive power from the Grid when deemed appropriate.

8.4.1.2.7 Instrumentation and Control

The basic functions allocated to the C&I systems and details of alarms, warnings and control logic are yet to be developed.

8.4.1.2.8 Examination, Monitoring, Inspection and Testing

The maintenance tasks and procedures, specific to the High Voltage Main Standby Supply System [BC_] environment and operating context are defined as part of the final concept design. The examination, monitoring, inspection and testing requirements will be captured in the relevant through life activities (BC_-TLA) module in DOORS.

Maintenance activities considered will include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best practice/OPEX (EPRI PMBD)
- Civil Structure and Module derived tasks.

8.4.1.2.9 Radiological Aspects

No radiation assessment has been carried out for the High Voltage Main Standby Supply System [BC_] at RD7/DRP1.

8.4.1.2.10 Performance and Safety Evaluation

An initial hazard identification (HAZID) [32] was carried out for the electrical systems. Additional hazard assessments are being planned.

Verification activities against all requirements identified in the High Voltage Main Standby Supply System [BC_] Requirements modules are in development.

8.4.1.2.11 Installation and Commissioning

The overall strategy for the RR SMR commissioning programme is presented in E3S Case Version 2, Tier 1, Chapter 14: Plant Construction and Commissioning [33].

Installation requirements for the High Voltage Main Standby Supply System [BC_] are to be detailed in the allocated requirements (-D) modules in DOORS.

The Installation and Commissioning (ICOM) Policy [34], section 2.4, provides a non-exhaustive list of examples of electrical checks to be carried out post-installation and prior to commissioning that include:

- Visual checks including checking of labels and tags for equipment, cables and trays
- Cable tray, panel and terminal box installation checks
- Component or equipment checks (pre energising), e.g. relays, contactors, circuit breakers, cells, rectifier and battery, motor, inverter (done during pre-Operational Commissioning tests)
- Wire to wire and post to post continuity checks
- Cable continuity and routing
- Earthing continuity checks to main earthing system
- Earthing of strips and shielding
- Shielding continuity
- Cable quality
- Electrical tests on HV / LV cables (after laying and before connection)
- Dielectric tests or insulation measurement for motors and cables
- Connections (crimping, connectors, cable lugs, end fittings, etc.)
- Wiring of inter-chassis links, controls, sensors, actuators, etc.

A comprehensive commissioning plan will be developed during detailed design. Commissioning plans will be developed in line with the RR SMR ICOM policy [34].

Appendix F of the ICOM Policy [34] references IAEA Safety Guide NS-G-2.9 to provide an illustrative and non-exhaustive list of commissioning tests for Electrical Systems. NS-G-2.9 was superseded by IAEA Specific Safety Guide SSG-28 (Commissioning for Nuclear Power Plants [35]) which gives the following list:

Table 8.4-4: Example High Voltage Main Supply System [BC_] Commissioning Tests from SSG-28

System Type as described in SSG-28	Relevant SMR System(s)	Example Commissioning Tests from SSG-28
Normal AC power distribution system	[AC], [MS], [BB], [BC], [BF], [BG]	Operation of protection devices, initiating devices, relay and logic devices, breakers, motor controllers, switchgear, transformers, transfer and trip devices, prohibiting and permissive interlocks, instrumentation and alarms, load shedding capabilities, redundancy and electrical independence, integrated system performance with simulated partial and full LOOP under worst case conditions, capability to transfer from on-site to off-site power sources.

A description of the design features for commissioning will be included where appropriate within the SDD for the High Voltage Main Standby Supply System [BC_].

8.4.1.3 Low Voltage Main Supply System for Process Equipment [BF_]

8.4.1.3.1 System and Equipment Functions

The primary function of the Low Voltage Main AC Supply Systems for Process Equipment [BF_] is to receive HV power from the High Voltage Main AC Supply System [BB_] and provide LV power to all site process LV loads that do not require an essential supply. The definition of process loads is covered in section 8.1.1.

The [BF_] system components are situated across the site in multiple locations as they are required to be near to the LV loads to minimise cable lengths and avoid excessive voltage drop.

8.4.1.3.2 Design Bases

8.4.1.3.2.1 Functional Requirements

The Low Voltage Main AC Supply Systems for Process Equipment [BF_] distributes power to all process LV power consumers that support the delivery of CoRM, CoFT and CoR during all plant operating modes. The Low Voltage Main AC Supply Systems for Process Equipment [BF_] contains sub-systems and components which facilitate the safety functional requirements associated with pumped Category C safety measures. Safety categorised functional requirements specified for the Low Voltage Main AC Supply Systems for Process Equipment [BF_] based on the HLSFs they support the delivery of, are allocated in the DOORS BF_ requirements modules. Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS modules, including the rationale for their selection. The linked flow of requirements from the fault schedule through the safety measures to the electrical requirements modules is still in development.

8.4.1.3.2.2 Non-Functional System Requirements

Non-functional system requirements are specified for the Low Voltage Main AC Supply Systems for Process Equipment [BF_] based on the E3S Principles as outlined in Section 8.2. The requirements specified at RD7/DRP1 are listed in the DOORS transverse requirements module, including the rationale for their application. The process to flow these requirements efficiently to each applicable electrical power system requirements module in DOORS is still in development at RD7/DRP1.

A full set of non-functional system requirements from all identified sources are in development, these will be allocated to each applicable SSC.

8.4.1.3.2.3 E3S Categorisation and Classification

The highest category of the Low Voltage Main AC Supply Systems for Process Equipment [BF_] functions fulfilling HLSF is Category C. In accordance with the SMR E3S Categorisation and Classification Method [25], Low Voltage Main AC Supply Systems for Process Equipment [BF_] is a Safety Class 3 system.

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic classifications for these systems are being developed in line with the Seismic Performance Classification Method [26] and the E3S Principles [19]. The SPC of Class 3 equipment is to be developed.

8.4.1.3.3 Description

The Low Voltage Main AC Supply Systems for Process Equipment [BF_] comprises the following sub-systems:

- 400 V Main AC Supply System for Process Equipment [BFA], which distributes electrical power to all process consumers requiring power at 400 V. The 400 V Main AC Supply System for Process Equipment [BFA] is distributed around site within two independent electrical divisions. The 400 V Main AC Supply System for Process Equipment [BFA] receives power from the Low voltage Main AC Auxiliary Power Transformer for Process Equipment [BFT] in all areas.

- Low voltage Main AC Auxiliary Power Transformer for Process Equipment [BFT], which transforms electrical power to the distribution voltage level from the received power voltage level. There is a transformer for every 400 V Main AC Supply System for Process Equipment [BFA] split across two independent electrical divisions. These transformers convert the power received from the High Voltage Main AC Supply System [BB_] to 400 V and supplies this power to the 400 V Main AC Supply System for Process Equipment [BFA].

The key performance and design parameters for the Low Voltage Main AC Supply Systems for Process Equipment [BF_] is shown in Table 8.4-5 and in the key electrical single line diagram [6].

Table 8.4-5: Key Performance and Design Parameters for the Low Voltage Main AC Supply Systems For Process Equipment [BF_]

Parameter	Value	Units
Number of Standby Transformers	14	
Number of Independent Divisions	2	
System voltage	400	V AC
Number of Switchboards	14	

8.4.1.3.4 Materials

The approach to material selection, including qualification and ageing management considerations is addressed within E3S Case Version 2, Tier 1, Chapter 23 – Structural Integrity [28].

Materials selection, and the supporting input information and rationale will be presented in future revisions to this chapter.

8.4.1.3.5 Interfaces with Other Systems

The Low Voltage Main AC Supply Systems for Process Equipment [BF_] functional and physical interfaces with electrical systems are the Earthing and Lightning Protection System [XF], Low Voltage Uninterruptible DC Supply System [BP_], the Low Voltage Essential AC Standby Supply Systems [BK_] and the High Voltage Main AC Supply System [BB_]. These are identified and managed within DOORS, including flow down of functional requirements.

The Low Voltage Main AC Supply Systems for Process Equipment [BF_] interfaces with all process loads requiring LV power. These loads are captured within the Electrical Load Schedule [11].

The Low Voltage Main AC Supply Systems for Process Equipment [BF_] has an interface with the C&I system, this interface is under development.

The Low Voltage Main AC Supply Systems for Process Equipment [BF_] also interfaces indirectly with the HVAC systems and fire extinguishing systems to ensure the components are operating in a controlled environment. The Fire Detection systems are described in Chapter 7 [4] and the Fire Suppression systems are described in Chapter 9A [29].

8.4.1.3.6 System and Equipment Operation

The overarching operating philosophy for the Power Station in all operating modes is covered in [30], with operating modes defined in the operating philosophy for the Reactor Island [31].

In all non-faulted operating modes the Low Voltage Main AC Supply Systems for Process Equipment [BF_] is in the following state: energised and receiving power from [BB_] while providing the normal ([BB_]-derived) source of power to the process loads.

In Faulted operation the Low Voltage Main AC Supply Systems for Process Equipment [BF_] provides support to all non-essential SSCs that use LV powered equipment to respond to plant faults. The Low Voltage Main AC Supply Systems for Process Equipment [BF_] response to all faults other than loss of electrics is to provide power to the necessary SSCs.

The key fault to the Low Voltage Main AC Supply Systems for Process Equipment [BF_] is a loss of electrics (LOE) fault.

LOE.1.0.01: LOOP (72 hours) – under this event (which is defined in [36] as including a failure of house load operation) Low Voltage Main AC Supply Systems for Process Equipment [BF_] is de-energised.

LOE.1.0.02: LOOP (168 hours) – under this event, Low Voltage Main AC Supply Systems for Process Equipment [BF_] is de-energised.

8.4.1.3.7 Instrumentation and Control

The basic functions allocated to the C&I systems and details of alarms, warnings and control logic is currently under development.

8.4.1.3.8 Examination, Monitoring, Inspection and Testing

The maintenance tasks and procedures, specific to the Low Voltage Main AC Supply Systems for Process Equipment [BF_] environment and operating context are defined as part of the final concept design. The examination, monitoring, inspection and testing requirements will be captured in the relevant through life activities (BF_-TLA) module in DOORS.

Maintenance activities considered will include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best practice/OPEX (EPRI PMBD)
- Civil Structure and Module derived tasks

8.4.1.3.9 Radiological Aspects

No radiation assessment has been carried out for the Low Voltage Main AC Supply Systems for Process Equipment [BF_] at RD7/DRP1.

8.4.1.3.10 Performance and Safety Evaluation

An initial hazard identification (HAZID) [32] was carried out for the electrical systems. Additional hazard assessments are being planned.

Verification activities against all requirements identified in the Low Voltage Main AC Supply Systems for Process Equipment [BF_] Requirements modules are in development.

8.4.1.3.11 Installation and Commissioning

The overall strategy for the RR SMR commissioning programme is presented in E3S Case Version 2, Tier 1, Chapter 14: Plant Construction and Commissioning [33].

Installation requirements for the Low Voltage Main AC Supply Systems for Process Equipment [BF_] are to be detailed in the allocated requirements (-D) modules in DOORS.

The Installation and Commissioning (ICOM) Policy [34], section 2.4, provides a non-exhaustive list of examples of electrical checks to be carried out post-installation and prior to commissioning that include:

- Visual checks including checking of labels and tags for equipment, cables and trays
- Cable tray, panel and terminal box installation checks

- Component or equipment checks (pre energising), e.g. relays, contactors, circuit breakers, cells, rectifier and battery, motor, inverter (done during pre-Operational Commissioning tests)
- Wire to wire and post to post continuity checks
- Cable continuity and routing
- Earthing continuity checks to main earthing system
- Earthing of strips and shielding
- Shielding continuity
- Cable quality
- Electrical tests on HV / LV cables (after laying and before connection)
- Dielectric tests or insulation measurement for motors and cables
- Connections (crimping, connectors, cable lugs, end fittings, etc.)
- Wiring of inter-chassis links, controls, sensors, actuators, etc.

A comprehensive commissioning plan will be developed during detailed design. Commissioning plans will be developed in line with the RR SMR ICOM policy [34].

Appendix F of the ICOM Policy [34] references IAEA Safety Guide NS-G-2.9 to provide an illustrative and non-exhaustive list of commissioning tests for Electrical Systems. NS-G-2.9 was superseded by IAEA Specific Safety Guide SSG-28 (Commissioning for Nuclear Power Plants [35]) which gives the following list:

Table 8.4-6: Example Low Voltage Main AC Supply Systems for Process Equipment [BF_] Commissioning Tests from SSG-28

System Type as described in SSG-28	Relevant SMR System(s)	Example Commissioning Tests from SSG-28
Normal AC power distribution system	[AC], [MS], [BB], [BC], [BF], [BG]	Operation of protection devices, initiating devices, relay and logic devices, breakers, motor controllers, switchgear, transformers, transfer and trip devices, prohibiting and permissive interlocks, instrumentation and alarms, load shedding capabilities, redundancy and electrical independence, integrated system performance with simulated partial and full LOOP under worst case conditions, capability to transfer from on-site to off-site power sources.

8.4.1.4 Low Voltage Main AC Supply System for Non-Process Equipment [BG_]

8.4.1.4.1 System and Equipment Functions

The primary function of the Low Voltage Main AC Supply System for Non-Process Equipment [BG_] is to receive HV power from the High Voltage Main AC Supply System [BB_] and provide LV power to all site non-process LV loads that do not require an essential supply. The definition of non-process loads is covered in section 8.1.1.

The [BG] system components are situated across the site in multiple locations as they are required to be near to the LV loads to minimise cable lengths and to avoid excessive volt drop.

8.4.1.4.2 Design Bases

8.4.1.4.2.1 Functional Requirements

The Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] distributes power to all non-process LV power consumers that support the delivery of CoRM, CoFT and CoR during all plant operating modes. The Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] contains sub-systems and components which facilitate the safety functional requirements associated with pumped Category C safety measures. Safety categorised functional requirements specified for the Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] based on the HLSFs they support the delivery of, are allocated in the DOORS BG_ requirements modules. Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS modules, including the rationale for their selection.

The linked flow of requirements from the fault schedule through the safety measures to the electrical requirements modules is still in development.

8.4.1.4.2.2 Non-Functional System Requirements

Non-functional system requirements are specified for the Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] based on the E3S Principles [19] as outlined in Section 8.2. The requirements specified at RD7/DRP1 are listed in the DOORS transverse requirements module, including the rationale for their application. The process to flow these requirements efficiently to each applicable electrical power system requirements module in DOORS is still in development at RD7/DRP1.

A full set of non-functional system requirements from all identified sources are in development, these will be allocated to each applicable SSC.

8.4.1.4.2.3 E3S Categorisation and Classification

The highest category of the Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] functions fulfilling HLSF is Category C. In accordance with the SMR E3S Categorisation and Classification Method [25], Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] is a Safety Class 3 system.

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic classifications for these systems are being developed in line with the Seismic Performance Classification Method [26] and the E3S Principles [19]. The SPC of Class 3 equipment is to be developed.

8.4.1.4.3 Description

The Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] comprises the following sub-systems:

- 400 V Main AC Supply System for Non-Process Equipment [BGA], which distributes electrical power to all non-process consumers requiring power at 400 V. The 400 V Main AC Supply System for Non-Process Equipment [BGA] is distributed around site within two independent electrical divisions. The 400 V Main AC Supply System for Non-Process Equipment [BGA] receives power from the Low voltage Main AC Auxiliary Power Transformer for Non-Process Equipment [BGT] in all areas.

- Low voltage Main AC Auxiliary Power Transformer for Non-Process Equipment [BGT]. There is a transformer for every 400 V Main AC Supply System for Non-Process Equipment [BGA], this splits across two independent electrical divisions. These transformers convert the power received from the High Voltage Main AC Supply System [BB_] to 400 V and supplies this power to the 400 V Main AC Supply System for Non-Process Equipment [BGA].

The key performance and design parameters for the Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] is shown in Table 8.4-7 and in the key electrical single line diagram [6].

Table 8.4-7: Key Performance and Design Parameters for the Low Voltage Main AC Supply Systems For Non-Process Equipment [BG_]

Parameter	Value	Units
Number of Standby Transformers	10	
Number of Independent Divisions	2	
System voltage	400	V AC
Number of Switchboards	10	

8.4.1.4.4 Materials

The approach to material selection, including qualification and ageing management considerations is addressed within E3S Case Version 2, Tier 1, Chapter 23 – Structural Integrity [28].

Materials will be confirmed as the design develops with vendor support. Materials selection, and the supporting input information and rationale will be presented in future revisions to this chapter.

8.4.1.4.5 Interfaces with Other Systems

The Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] functional and physical interfaces with electrical systems are the Earthing and Lightning Protection System [XF], Low Voltage Uninterruptible DC Supply System [BP_] and the High Voltage Main AC Supply System [BB_]. These are identified and managed within DOORS, including flow down of functional requirements.

The Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] interfaces with all non-process loads requiring LV power. These loads are captured within the Electrical Load Schedule [11].

The Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] has an interface with the C&I system, this interface is under development.

The Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] also interfaces with indirectly with the HVAC systems and fire extinguishing systems to ensure the components are operating in a controlled environment. The Fire Detection systems are described in Chapter 7 [4] and the Fire Suppression systems are described in Chapter 9A [29].

8.4.1.4.6 System and Equipment Operation

The overarching operating philosophy for the Power Station in all operating modes is covered in [30], with operating modes defined in the operating philosophy for the Reactor Island [31].

In all non-faulted operating modes the Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] is in the following state; energised and receiving power from [BB_] while providing the normal ([BB_]-derived) source of power to the non-process loads.

In Faulted operation the Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] provides support to all SSCs that use electrically powered equipment to respond to plant faults. The Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] response to the majority of plant faults is therefore typically to provide power to the necessary SSCs, regardless of the fault.

The key fault to the Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] is a loss of electrics (LOE) fault.

LOE.1.0.01: LOOP (72 hours) – under this event (which is defined in [36] as including a failure of house load operation) Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] is de-energised.

LOE.1.0.02: LOOP (168 hours) – under this event, Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] is de-energised.

8.4.1.4.7 Instrumentation and Control

The basic functions allocated to the C&I systems and details of alarms, warnings and control logic is currently under development.

8.4.1.4.8 Examination, Monitoring, Inspection and Testing

The maintenance tasks and procedures, specific to the Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] environment and operating context are defined as part of the final concept design. The examination, monitoring, inspection and testing requirements will be captured in the relevant through life activities (BG_-TLA) module in DOORS.

Maintenance activities considered will include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)

- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best practice/OPEX (EPRI PMBD)
- Civil Structure and Module derived tasks.

8.4.1.4.9 Radiological Aspects

No radiation assessment has been carried out for the Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] at RD7/DRP1.

8.4.1.4.10 Performance and Safety Evaluation

An initial hazard identification (HAZID) [32] was carried out for the electrical systems. Additional hazard assessments are being planned.

Verification activities against all requirements identified in the Low Voltage Main AC Supply Systems for Non-Process Equipment [BG_] Requirements modules are in development.

8.4.1.4.11 Installation and Commissioning

See 8.4.1.3.11 for the installation and commissioning details for the Normal AC power distribution system.

8.4.2 Standby AC Power Supply

8.4.2.1 High Voltage Essential AC Standby Supply System [BD_]

8.4.2.1.1 System and Equipment Functions

The primary function of the High Voltage Essential AC Standby Supply Systems [BD_] is to provide essential standby power to HV loads. Essential Standby is defined as backed-up by the standby AC generation sources. 'Standby' terminology aligns with IAEA SSG-34 Section 7.35-7.82 [37].

When the grid or Main Generator [MK] supplies are available, the [BD_] system receives HV power from the Unit Boards [BBA]. Each of the two redundant divisions of the [BD_] system receives two feeds from the High Voltage Main AC Supply System [BBA].

The High Voltage Essential AC Standby Supply System [BD_] includes two on-site HV Standby AC Power Sources [BDV], used to provide power when the Grid and Main Generator [MK] is unavailable. The HV Standby AC Power Source [BDV] is automatically started when the C&I systems detect a loss of power from the normal power supplies. These on-site power sources are independent from other on-site power sources [BLV] and [BKV].

The High Voltage Essential AC Standby Supply System [BD_] is located in the Reactor Island and Backup Generation Areas with the two redundant divisions located to the north and the south of the Reactor Island structures.

8.4.2.1.2 Design Bases

8.4.2.1.2.1 Functional Requirements

The High Voltage Essential AC Standby Supply System [BD_] distributes power to all HV essential standby power consumers that support the delivery of CoRM, CoFT and CoR during all plant operating modes. The High Voltage Essential AC Standby Supply System [BD_] contains sub-systems and components which facilitate the safety functional requirements associated with pumped Category B safety measures. Safety categorised functional requirements specified for the High Voltage Essential AC Standby Supply System [BD_] based on the HLSFs they support the delivery of, are allocated in the DOORS BD_ requirements modules. Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS modules, including the rationale for their selection. The linked flow of requirements from the fault schedule through the safety measures to the electrical requirements modules is still in development.

8.4.2.1.2.2 Non-Functional System Requirements

Non-functional system requirements are specified for the High Voltage Essential AC Standby Supply System [BD_] based on the E3S Principles [19] as outlined in Section 8.2. The requirements specified at RD7/DRP1 are listed in the DOORS transverse requirements module, including the rationale for their application. The process to flow these requirements efficiently to each applicable electrical power system requirements module in DOORS is still in development at RD7/DRP1.

A full set of non-functional system requirements from all identified sources are in development, these will be allocated to each applicable SSC.

8.4.2.1.2.3 E3S Categorisation and Classification

The highest category of the High Voltage Essential AC Standby Supply System [BD_] functions fulfilling HLSF is Category B. In accordance with the SMR E3S Categorisation and Classification Method [25], High Voltage Essential AC Standby Supply System [BD_] is a Safety Class 2 system.

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic classifications for these systems are being developed in line with the Seismic Performance Classification Method [26] and the E3S Principles [19]**,** which specify that the Class 1 and Class 2 SSCs are to be Seismic Performance Class 1 (SPC1), capable of remaining fully functional during and after a Design Basis Earthquake. The SPC of Class 3 equipment is to be developed.

8.4.2.1.3 Description

The High Voltage Essential AC Standby Supply System [BD_] comprises the following sub-systems:

- 11 kV Essential AC Standby Supply System [BDA], which distributes electrical power to all essential standby consumers requiring power at 11 kV. The 11 kV Essential AC Standby Supply System [BDA] consists of four switchboards divided into two divisions that receives two power connections from the High Voltage Main AC Supply System [BB_] and one from the High Voltage Essential AC Standby Generation System [BDV]. There are no HV interconnections between the two divisions of the 11 kV Essential AC Standby Supply System [BDA]. More details of the 11 kV Essential AC Standby Supply System [BDA] are shown in the Reactor Island Essential – Single Line Diagram [7].

- High Voltage Essential AC Standby Generation System [BDV], which generates electrical power for distribution when the received power is unavailable. The High Voltage Essential AC Standby Generation System [BDV] consists of two diesel generators located north and south of the reactor island building connected to each side of the High Voltage Essential AC Standby Supply System [BD_] divisions. The High Voltage Essential AC Standby Generation System [BDV] automatically starts up when the RR SMR plant detects a Loss of Offsite Power and has the capability to provide continuous full power for 72 hours.

Table 8.4-8: Key Performance and Design Parameters for the High Voltage Essential AC Standby Supply System [BD_]

Parameter	Value	Units
Number of redundant divisions	2	
HV system voltage	11	kV
HV Standby AC Power Source [BDV] rating	TBD (previously estimated at 3 MW, but work is required to confirm the rating reduction from the decision, made as part of ECI-16 [38], to transfer the Class 3 loads from this system to [BKV], leaving only the Class 2 loads)	MW at 0.8 pf lagging
On-site HV Standby AC power source autonomy time	72	Hours

Further description of the High Voltage Essential AC Standby Supply System [BD_] and associated sub-systems is provided in System Design Description for the Electrical Systems [A, B, MS, XF, XQ] [5].

8.4.2.1.4 Materials

The approach to material selection, including qualification and ageing management considerations is addressed within E3S Case Version 2, Tier 1, Chapter 23 – Structural Integrity [28].

Materials will be confirmed as the design develops with vendor support. Materials selection, and the supporting input information and rationale will be presented in future revisions to this chapter.

8.4.2.1.5 Interfaces with Other Systems

The High Voltage Essential AC Standby Supply System [BD_] functional and physical interfaces with electrical systems are the Earthing and Lightning Protection System [XF], the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_], the Low Voltage Essential AC Standby Supply Systems [BK_] and the High Voltage Main AC Supply System [BB_]. These are identified and managed within DOORS, including flow down of functional requirements.

The High Voltage Essential AC Standby Supply System [BD_] interfaces with all essential standby loads requiring HV power. These loads are captured within the Electrical Load Schedule [11].

The High Voltage Essential AC Standby Supply System [BD_] has an interface with the C&I system, this interface is under development.

The High Voltage Essential AC Standby Supply System [BD_] also interfaces indirectly with the HVAC and fire extinguishing systems to ensure the components are operating in a controlled environment. The Fire Detection systems are described in Chapter 7 [4] and the Fire Suppression systems are described in Chapter 9A [29].

8.4.2.1.6 System and Equipment Operation

The overarching operating philosophy for the Power Station in all operating modes is covered in [30], with operating modes defined in the operating philosophy for the Reactor Island [31].

In all non-faulted operating modes, the High Voltage Essential AC Standby Supply System [BD_] is in the following state; energised and receiving power from [BB_] while providing the normal ([BB_]-derived) source of power to the essential loads with the gensets [BDV] available but not started/running.

In Faulted operation the High Voltage Essential AC Standby Supply System [BD_] provides support to all SSCs that use electrically powered equipment to respond to plant faults. The High Voltage Essential AC Standby Supply System [BD_] response to the majority of plant faults is therefore typically to provide power to the necessary SSCs, regardless of the fault.

The key fault to the High Voltage Essential AC Standby Supply System [BD_] is a loss of electrics (LOE) fault.

LOE.1.0.01: LOOP (72 hours) – under this event (which is defined in [36] as including a failure of house load operation), the Electrical Systems provide power from on-site energy stores to support all necessary plant responses, defined in the Fault Schedule [24]. For example: in Modes 1 & 2, if scram fails, the second protective high level safety function for Control of Reactivity (Alternative Shutdown Function) is powered by Standby AC supplies from the High Voltage Essential AC Standby Supply System [BD_]. The Standby AC supplies also provide power for Passive Decay Heat Removal (using the High Pressure Injection System (HPIS) pumps) and Low Temperature Decay Heat Removal (via the Cold Shutdown Cooling System). UPS (from batteries) provide power for the required C&I and actuation, during the start-up of the Standby AC generators, and if the Standby AC supplies are unavailable e.g. to support Emergency Core Cooling and Containment Isolation Category A safety measures.

LOE.1.0.02: LOOP (168 hours) – under this event, the Electrical Systems response is as described for the shorter duration loss of electrics fault, but in this case Standby AC power reserves would be exhausted after approximately 72 hours (assuming no prioritisation of electrical loading / fuel reserves). The responses post 72-hours in the Fault Schedule [24] are listed with 'TBD' but with the following actions expected: re-filling fuel tanks to continue to provide Standby AC power, and the use of the Alternate AC supplies to provide motive power for transfer of water to top-up the Local Ultimate Heat Sink tanks.

8.4.2.1.7 Instrumentation and Control

The basic functions allocated to the C&I systems and details of alarms, warnings and control logic is currently under development.

8.4.2.1.8 Examination, Monitoring, Inspection and Testing

The maintenance tasks and procedures, specific to the High Voltage Essential AC Standby Supply System [BD_] environment and operating context are to be defined as part of the final concept design. The examination, monitoring, inspection and testing requirements will be captured in the relevant through life activities (BD_-TLA) module in DOORS.

Maintenance activities considered will include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best practice/OPEX (primary source: EPRI PMBD)
- Civil Structure and Module derived tasks

8.4.2.1.9 Radiological Aspects

No radiation assessment has been carried out for the High Voltage Essential AC Standby Supply System [BD_] at RD7/DRP1.

8.4.2.1.10 Performance and Safety Evaluation

An initial hazard identification (HAZID) [32] was carried out for the electrical systems. Additional hazard assessments are being planned.

Verification activities against all requirements identified in the High Voltage Essential AC Standby Supply System [BD_] Requirements modules are in development.

8.4.2.1.11 Installation and Commissioning

This section describes the installation and commissioning strategy for all essential systems regardless of class/duty.

The overall strategy for the RR SMR commissioning programme is presented in E3S Case Version 2, Tier 1, Chapter 14: Plant Construction and Commissioning [33].

Installation requirements for the High Voltage Essential AC Standby Supply System [BD_], the Low Voltage Essential AC Standby Supply Systems [BK_] and the Low Voltage Essential AC Alternate Supply System [BL_] are to be detailed in the allocated requirements (-D) modules in DOORS.

The Installation and Commissioning (ICOM) Policy [34], section 2.4, provides a non-exhaustive list of examples of electrical checks to be carried out post-installation and prior to commissioning that include:

- Visual checks including checking of labels and tags for equipment, cables and trays
- Cable tray, panel and terminal box installation checks
- Component or equipment checks (pre energising), e.g. relays, contactors, circuit breakers, cells, rectifier and battery, motor, inverter (done during pre-Operational Commissioning tests)
- Wire to wire and post to post continuity checks
- Cable continuity and routing

- Earthing continuity checks to main earthing system
- Earthing of strips and shielding
- Shielding continuity
- Cable quality
- Electrical tests on HV / LV cables (after laying and before connection)
- Dielectric tests or insulation measurement for motors and cables
- Connections (crimping, connectors, cable lugs, end fittings, etc.)
- Wiring of inter-chassis links, controls, sensors, actuators, etc.

A comprehensive commissioning plan will be developed during detailed design. Commissioning plans will be developed in line with the RR SMR ICOM policy [34].

Appendix F of the ICOM Policy [34] references IAEA Safety Guide NS-G-2.9 to provide an illustrative and non-exhaustive list of commissioning tests for Electrical Systems. NS-G-2.9 was superseded by IAEA Specific Safety Guide SSG-28 (Commissioning for Nuclear Power Plants [35]) which gives the following list for essential electrical systems:

Table 8.4-9: Example Essential Electrical System Commissioning Tests from SSG-28

System Type as described in SSG-28	Relevant SMR System(s)	Example Commissioning Tests from SSG-28
Emergency AC power distribution system	[BD], [BK], [BL] [XQ] for example relating to lighting adequacy. [BM] for example relating to motor-generator sets.	Operation of protection devices, relaying and logic devices, breakers, motor controllers, switchgear, transformers, transfer and trip devices, prohibiting and permissive interlocks, instrumentation and alarms, load shedding capabilities, capability of emergency and vital loads to start in the proper sequence and to operate under simulated accident conditions with both the normal (preferred) AC power sources and/or the emergency (standby) power source in accordance with design requirements for voltage and frequency; Duration tests of diesel generators or equivalent machines, capability to start and operate with maximum and minimum design voltage available; To the extent practicable, testing of emergency or vital loads conducted for a sufficient period of time to provide assurance that equilibrium conditions are attained; Verification of system redundancy and electrical independence; Testing of loads supplied from the system such as motor generator sets with flywheels designed to provide non-interruptible power to vital plant loads, to demonstrate proper operation; Load tests for vital busbars using normal and emergency sources of power supplies to the busbar; Operation of indicating and alarm devices used to monitor the availability of the emergency power system in the control room; Adequacy of the plant’s emergency lighting system.
Emergency or standby AC power supplies	[BD], [BK], [BL]	Redundancy, electrical independence, and proper voltage and frequency regulation under transient, steady state and emergency conditions; Performance of auxiliary systems such as those used for starting, cooling, heating, ventilating, lubricating and fuelling, duration of test to ensure that equilibrium conditions are attained; Logic, correctness of set points for trip devices and proper operation of initiating devices, prohibiting and permissive interlocks, redundancy and electrical independence.

8.4.2.2 Low Voltage Essential AC Standby Supply System [BK_]

8.4.2.2.1 System and Equipment Functions

The primary function of the Low Voltage Essential AC Standby Supply Systems [BK_] is to provide essential standby power to LV loads. Essential Standby is defined as backed-up by the standby AC generation sources. 'Standby' terminology aligns with IAEA SSG-34 Section 7.35-7.82 [37].

The Reactor Island switchboards in the Low Voltage Essential AC Standby Supply System [BK_] receive HV power from the [BD_] system to the transformers, in [BKT], that in turn supply LV power to LV switchboards, in [BKA]. The switchboards of the [BK_] system that are outside Reactor Island receive LV power from the Low Voltage Main AC Supply Systems for Process Equipment [BF_].

Outside of reactor island, the Low Voltage Essential AC Standby Supply Systems [BK_] includes on-site LV Standby AC Power Sources [BKV], used to provide power when the normal supply from the Low Voltage Main AC Supply System for Process Equipment [BF_] is not available. These on-site power sources are independent from other on-site power sources [BDV] and [BLV].

The Low Voltage Essential AC Standby Supply System [BK_] is a site-wide system and in each location the two divisions are physically separated from each other.

8.4.2.2.2 Design Bases

8.4.2.2.2.1 Functional Requirements

The Low Voltage Essential AC Standby Supply System [BK_] distributes power to all LV essential standby power consumers that support the delivery of CoRM, CoFT and CoR during all plant operating modes. The Low Voltage Essential AC Standby Supply System [BK_] contains sub-systems and components which facilitate the safety functional requirements associated with pumped Category B safety measures. Safety categorised functional requirements specified for the Low Voltage Essential AC Standby Supply System [BK_] based on the HLSFs they support the delivery of, are allocated in the DOORS BK_ requirements modules. Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS modules, including the rationale for their selection. The linked flow of requirements from the fault schedule through the safety measures to the electrical requirements modules is still in development.

8.4.2.2.2.2 Non-Functional System Requirements

Non-functional system requirements are specified for the Low Voltage Essential AC Standby Supply System [BK_] based on the E3S Principles [19] as outlined in Section 8.2. The requirements specified at RD7/DRP1 are listed in the DOORS transverse requirements module, including the rationale for their application. The process to flow these requirements efficiently to each applicable electrical power system requirements module in DOORS is still in development at RD7/DRP1.

A full set of non-functional system requirements from all identified sources are in development, these will be allocated to each applicable SSC.

8.4.2.2.2.3 E3S Categorisation and Classification

The highest category of the Low Voltage Essential AC Standby Supply System [BK_] functions fulfilling HLSF is Category B. In accordance with the SMR E3S Categorisation and Classification Method [25], Low Voltage Essential AC Standby Supply System [BK_] is a Safety Class 2 system.

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic classifications for these systems are being developed in line with the Seismic Performance Classification Method [26] and the E3S Principles [19], which specify that the Class 1 and Class 2 SSCs are to be Seismic Performance Class 1 (SPC1), capable of remaining fully functional during and after a Design Basis Earthquake.

8.4.2.2.3 Description

The Low Voltage Essential AC Standby Supply System [BK_] comprises the following sub-systems:

- 400 V Essential AC Standby Supply System [BKA], which distributes electrical power to all essential standby consumers requiring power at 400 V. The 400 V Essential AC Standby Supply System [BKA] is distributed around site within two independent electrical divisions. The 400 V Essential AC Standby Supply System [BKA] receives power from the Low voltage Essential Power Transformer System [BKT] within reactor island and the back-up generation area and receives power from the Low Voltage Main Supply System for Process Equipment [BF_] in all other areas. The 400 V Essential AC Standby Supply System [BKA] also receives power from the Low Voltage Essential AC Standby Generation System [BKV] when power is not available on the Low Voltage Main Supply System for Process Equipment [BF_].

- Low voltage Essential Power Transformer System [BKT], which transforms electrical power to the distribution voltage level from the received power voltage level. There are four transformers within the Low voltage Essential Power Transformer System [BKT] split into two independent electrical divisions. These transformers convert the power received from the High Voltage Essential AC Standby Supply System [BD_] to 400 V and supplies this power to the 400 V Essential AC Standby Supply System [BKA] within the reactor island and the back-up generation area.

- Low Voltage Essential AC Standby Generation System [BKV], which generates electrical power for distribution when the received power is unavailable. The Low Voltage Essential AC Standby Generation System [BKV] consists of two generators one located in the electrical annex and one located in the balance of plant area that provide power to the 400 V Essential AC Standby Supply System [BKA] when Low Voltage Main Supply System for Process Equipment [BF_] is unavailable. A decision was made on the interruptible essential architecture to determine the optimal number and location of back-up power sources [38]. The outcome of this decision was the addition of the Low Voltage Essential AC Standby Generation System [BKV] which supplies power for the class 3 loads physically located in the same areas as the generators.

Table 8.4-10: Key Performance and Design Parameters for the Low Voltage Essential AC Standby Supply System [BK_]

Parameter	Value	Units
Number of redundant divisions	2	
LV system voltage	400	V AC
LV Standby AC Power Source [BKV] rating	TBD (approximately 1 MW)	MW at 0.8 pf lagging
On-site LV Standby AC power source autonomy time	72	Hours

Further description of the Low Voltage Essential AC Standby Supply System [BK_] and associated sub-systems is provided in System Design Description for the Electrical Systems [A, B, MS, XF, XQ] [5].

8.4.2.2.4 Materials

The approach to material selection, including qualification and ageing management considerations is addressed within E3S Case Version 2, Tier 1, Chapter 23 – Structural Integrity [28].

Materials will be confirmed as the design develops with vendor support. Materials selection, and the supporting input information and rationale will be presented in future revisions to this chapter.

8.4.2.2.5 Interfaces with Other Systems

The Low Voltage Essential AC Standby Supply System [BK_] functional and physical interfaces with electrical systems are the Earthing and Lightning Protection System [XF], the High Voltage Essential AC Standby Supply Systems [BD_], Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_], the Low Voltage Uninterruptible DC Supply System [BP_], the Low Voltage Uninterruptible AC Supply System [BM_] and the Low Voltage Main AC Supply Systems for Process Equipment [BF_]. These are identified and managed within DOORS, including flow down of functional requirements.

The Low Voltage Essential AC Standby Supply System [BK_] interfaces with all essential standby loads requiring LV power. These loads are captured within the Electrical Load Schedule [11].

The Low Voltage Essential AC Standby Supply System [BK_] has an interface with the C&I system, this interface is under development.

The Low Voltage Essential AC Standby Supply System [BK_] also interfaces indirectly with the HVAC systems and fire extinguishing systems to ensure the components are operating in a controlled environment. The Fire Detection systems are described in Chapter 7 [4] and the Fire Suppression systems are described in Chapter 9A [29].

8.4.2.2.6 System and Equipment Operation

The overarching operating philosophy for the Power Station in all operating modes is covered in [30], with operating modes defined in the operating philosophy for the Reactor Island [31].

In all non-faulted operating modes, the Low Voltage Essential AC Standby Supply System [BK_] is in the following state; energised and receiving power from [BD_] or [BF_] while providing the normal ([BB_]-derived) source of power to the essential loads with the gensets [BKV] available but not started/running.

In Faulted operation the High Voltage Essential AC Standby Supply System [BK_] provides support to all SSCs that use LV electrically powered equipment to respond to plant faults. The Low Voltage Essential AC Standby Supply System [BK_] response to the majority of plant faults is therefore typically to provide power to the necessary SSCs, regardless of the fault.

The key fault to the Low Voltage Essential AC Standby Supply System [BK_] is a loss of electrics (LOE) fault.

LOE.1.0.01: LOOP (72 hours) – under this event (which is defined in [36] as including a failure of house load operation), the Electrical Systems provide power from on-site energy stores to support all necessary plant responses, defined in the Fault Schedule [24]**.** For example: in Modes 1 & 2, if scram fails, the second protective high level safety function for Control of Reactivity (Alternative Shutdown Function) is powered by Standby AC supplies from the High Voltage Essential AC Standby Supply System [BD_]. The Standby AC supplies also provide power for Passive Decay Heat Removal (using the High Pressure Injection System (HPIS) pumps) and Low Temperature Decay Heat Removal (via the Cold Shutdown Cooling System). UPS (from batteries) provide power for the required C&I and actuation, during the start-up of the Standby AC generators, and if the Standby AC supplies are unavailable e.g. to support Emergency Core Cooling and Containment Isolation Category A safety measures.

LOE.1.0.02: LOOP (168 hours) – under this event, the Electrical Systems response is as described for the shorter duration loss of electrics fault, but in this case Standby AC power reserves would be exhausted after approximately 72 hours (assuming no prioritisation of electrical loading / fuel reserves). The responses post 72-hours in the Fault Schedule [24] are listed with 'TBD' but with the following actions expected: re-filling fuel tanks to continue to provide Standby AC power, and the use of the Alternate AC supplies to provide motive power for transfer of water to top-up the Local Ultimate Heat Sink tanks.

8.4.2.2.7 Instrumentation and Control

The basic functions allocated to the C&I systems and details of alarms, warnings and control logic is currently under development.

8.4.2.2.8 Examination, Monitoring, Inspection and Testing

The maintenance tasks and procedures, specific to the Low Voltage Essential AC Standby Supply System [BK_] environment and operating context are to be defined as part of the final concept design. The examination, monitoring, inspection and testing requirements will be captured in the relevant through life activities (BK_-TLA) module in DOORS.

Maintenance activities considered will include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)

- Industry best practice/OPEX (primary source: EPRI PMBD)
- Civil Structure and Module derived tasks.

8.4.2.2.9 Radiological Aspects

No radiation assessment has been carried out for the Low Voltage Essential AC Standby Supply System [BK_] at RD7/DRP1.

8.4.2.2.10 Performance and Safety Evaluation

An initial hazard identification (HAZID) was carried out for the electrical systems, reported in [32]. Additional hazard assessments are being planned.

Verification activities against all requirements identified in the Low Voltage Essential AC Standby Supply System [BK_] Requirements modules are in development.

8.4.2.2.11 Installation and Commissioning

See 8.4.2.1.11 for the installation and commissioning details for the essential AC power supply systems.

8.4.3 Alternate AC Power Supply

8.4.3.1 Low Voltage Essential AC Alternate Supply System [BL_]

8.4.3.1.1 System and Equipment Functions

The primary function of the Low Voltage Essential AC Alternate Supply System [BL_] is to provide LV power to the Essential Alternate loads. Essential Alternate is defined as systems that are backed-up by the alternate AC generation sources. ‘Alternate’ terminology aligns with IAEA SSG-34 Section 8 [37].

During normal operation of the plant the Low Voltage Essential AC Alternate Supply System [BL_] receives LV power from the Low Voltage Essential AC Standby Supply System [BK_].

Although the overall plant response to Station Blackout is being developed, the Low Voltage Essential AC Alternate Supply System [BL_] includes provision for two permanent on-site LV Alternate AC Power Sources, in [BLV], used to provide power when the Low Voltage Essential AC Standby Supply System [BK_] is not available.

In addition, the Low Voltage Essential AC Alternate Supply System [BL_] also includes two connection points for LV Mobile Power Sources [BLV] to provide an additional means of power supply when the Low Voltage Essential AC Standby Supply System [BK_] and the permanent LV Power Sources [BLV] are not available.

The Alternate AC Power Sources, in [BLV], is manually started by the operator when required.

8.4.3.1.2 Design Bases

8.4.3.1.2.1 Functional Requirements

The Low Voltage Essential AC Alternate Supply System [BL_] distributes power to all LV essential alternate power consumers that support the delivery of CoRM, CoFT and CoR during all plant operating modes. The Low Voltage Essential AC Alternate Supply System [BL_] contains sub-systems and components which facilitate the safety functional requirements associated with pumped Category C safety measures. Safety categorised functional requirements specified for the Low Voltage Essential AC Alternate Supply System [BL_] based on the HLSFs they support the delivery of, are allocated in the DOORS BL_ requirements modules. Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS modules, including the rationale for their selection. The linked flow of requirements from the fault schedule through the safety measures to the electrical requirements modules is still in development.

8.4.3.1.2.2 Non-Functional System Requirements

Non-functional system requirements are specified for the Low Voltage Essential AC Alternate Supply System [BL_] based on the E3S Principles [19] as outlined in Section 8.2. The requirements specified at RD7/DRP1 are listed in the DOORS transverse requirements module, including the rationale for their application. The process to flow these requirements efficiently to each applicable electrical power system requirements module in DOORS is still in development at RD7/DRP1.

A full set of non-functional system requirements from all identified sources are in development, these will be allocated to each applicable SSC.

8.4.3.1.2.3 E3S Categorisation and Classification

The highest category of the Low Voltage Essential AC Alternate Generation System [BLV] functions fulfilling HLSF is Category C. In accordance with the SMR E3S Categorisation and Classification Method [25], Low Voltage Essential AC Alternate Generation System [BLV] is a Safety Class 3 system.

The highest category of the 400 V Essential AC Alternate Supply System [BLA] functions fulfilling HLSF is Category B. In accordance with the SMR E3S Categorisation and Classification Method [25], 400 V Essential AC Alternate Supply System [BLA] is a Safety Class 2 system. Initially the 400 V Essential AC Alternate Supply System [BLA] was specified as a Class 3 system as the loads it powers directly are providing Category C functions but as it provides Category B power from the Low Voltage Essential AC Standby Supply Systems [BK_] to the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] it has been re-classified as Safety Class 2.

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic classifications for these systems are being developed in line with the Seismic Performance Classification Method [26] and the E3S Principles [19], which specify that the Class 1 and Class 2 SSCs are to be Seismic Performance Class 1 (SPC1), capable of remaining fully functional during and after a Design Basis Earthquake. The SPC of Class 3 equipment is to be developed.

8.4.3.1.3 Description

The Low Voltage Essential AC Alternate Supply System [BL_] comprises the following sub-systems:

- 400 V Essential AC Alternate Supply System [BLA], which distributes electrical power to all consumers requiring power at 400 V. The 400 V Essential AC Alternate Supply System [BLA] consists of two electrically independent distribution systems located in reactor island. The 400 V Essential AC Alternate Supply System [BLA] receives power from the Low Voltage Essential AC Standby Supply System [BK_] or from the Low Voltage Essential AC Alternate Generation System [BLV] when Low Voltage Essential AC Standby Supply System [BK_] is unavailable.

- Low Voltage Essential AC Alternate Generation System [BLV], which generates electrical power for distribution when the received power is unavailable. The Low Voltage Essential AC Alternate Generation System [BLV] consists of two independent generators that supply power to 400 V Essential AC Alternate Supply System [BLA] when the Low Voltage Essential AC Standby Supply System [BK_] is unavailable. It also includes two temporary connection points that allows a mobile generation source to be temporarily connected to the 400 V Essential AC Alternate Supply System [BLA] when required.

Table 8.4-11: Key Performance and Design Parameters for the Low Voltage Essential AC Alternate Supply System [BL_]

Parameter	Value	Units
Number of redundant divisions	2	
System voltage	400	V AC
LV Alternate AC Power Source [BLV] rating	TBD	kVA
On-site Alternate AC power source autonomy time	TBD	Hours

8.4.3.1.4 Materials

The approach to material selection, including qualification and ageing management considerations is addressed within E3S Case Version 2, Tier 1, Chapter 23 – Structural Integrity [28].

Materials will be confirmed as the design develops with vendor support. Materials selection, and the supporting input information and rationale will be presented in future revisions to this chapter.

8.4.3.1.5 Interfaces with Other Systems

The Low Voltage Essential AC Alternate Supply System [BL_] functional and physical interfaces with electrical systems are the Earthing and Lightning Protection System [XF], the Low Voltage Uninterruptible AC Supply Systems [BM_], the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_], the Low Voltage Uninterruptible DC Supply System [BP_] and the Low Voltage Essential AC Standby Supply Systems [BK_]. These are identified and managed within DOORS, including flow down of functional requirements.

The Low Voltage Essential AC Alternate Supply System [BL_] interfaces with all essential standby loads requiring LV power. These loads are captured within the Electrical Load Schedule [11].

The Low Voltage Essential AC Alternate Supply System [BL_] has an interface with the C&I system, this interface is under development.

The Low Voltage Essential AC Alternate Supply System [BL_] also interfaces indirectly with the HVAC systems and fire extinguishing systems to ensure the components are operating in a controlled environment. The Fire Detection systems are described in Chapter 7 [4] and the Fire Suppression systems are described in Chapter 9A [29].

8.4.3.1.6 System and Equipment Operation

The overarching operating philosophy for the Power Station in all operating modes is covered in [30], with operating modes defined in the operating philosophy for the Reactor Island [31].

In all non-faulted operating modes, the Low Voltage Essential AC Alternate Supply System [BL_] is in the following state; energised and receiving power from [BK_] while providing the normal ([BB_]-derived) source of power to the essential alternate loads with the gensets [BLV] available but not started/running.

In Faulted operation the Low Voltage Essential AC Alternate Supply System [BL_] provides support to all SSCs that use LV electrically powered equipment to respond to plant faults. The Low Voltage Essential AC Alternate Supply System [BL_] response to the majority of plant faults is therefore typically to provide power to the necessary SSCs, regardless of the fault.

Station Black-Out (SBO) faults are not listed explicitly as PIEs in the Definition of PIEs [36]**,** as they are considered in that report to be defined as “a LOOP with a loss of a safety function” with “support for [SBO faults] given by the defence in depth (DiD) shown in the Fault Schedule.”

In the event of an SBO, UPS provide power for the required C&I and actuation. Provision has been made in the design for two Alternate AC power sources via the Low Voltage Essential AC Alternate Supply System [BL_], if required. There are also provisions for temporary connection of mobile power sources.

8.4.3.1.7 Instrumentation and Control

The basic functions allocated to the C&I systems and details of alarms, warnings and control logic is currently under development.

8.4.3.1.8 Examination, Monitoring, Inspection and Testing

The maintenance tasks and procedures, specific to the Low Voltage Essential AC Alternate Supply System [BL_] environment and operating context are to be defined as part of the final concept design. The examination, monitoring, inspection and testing requirements will be captured in the relevant through life activities (BL_-TLA) module in DOORS.

Maintenance activities considered will include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best practice/OPEX (primary source: EPRI PMBD)
- Civil Structure and Module derived tasks

8.4.3.1.9 Radiological Aspects

No radiation assessment has been carried out for the Low Voltage Essential AC Alternate Supply System [BL_] at RD7/DRP1.

8.4.3.1.10 Performance and Safety Evaluation

An initial Hazard Identification (HAZID) [32] was carried out for the electrical systems, reported in Reference. Additional hazard assessments are being planned.

Verification activities against all requirements identified in the Low Voltage Essential AC Alternate Supply System [BL_] Requirements modules are in development.

8.4.3.1.11 Installation and Commissioning

See 8.4.2.1.11 for the installation and commissioning details for the essential AC power supply systems.

8.4.4 Uninterruptible Power Supply

8.4.4.1 Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_]

8.4.4.1.1 System and Equipment Functions

The primary functions of the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] are to:

- Rectify incoming AC power to DC power
- Store Chemical energy in the form of batteries
- Generate DC power from batteries
- Distribute uninterruptible (battery backed) DC power to Class 1 and Class 2 loads

The major components in this system are the battery charger/rectifier, in [BQU], the batteries, in [BQV], and the switchboard, in [BQA].

During normal operation of the plant the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] is supplied from the Low Voltage Essential AC Standby Supply System [BK_] for Class 2 applications or the Low Voltage Essential AC Alternate Supply System [BL_] for Class 1 applications.

If the AC supply to the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] is lost the loads continue to receive battery backed power, without the need for operator intervention.

The Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] is primarily located in reactor island, providing power to the Reactor Protection System (RPS) [JRA] and the Diverse Protection System (DPS) [JQA]. [BQ_] is also used to supply uninterruptible power to the switching supplies of Class 2 switchboards [BK_] and [BD_]. The [BQ_] sub-systems that provide power to the RPS are independent from and diverse to the [BQ_] sub-systems that provide power to the DPS.

8.4.4.1.2 Design Bases

8.4.4.1.2.1 Functional Requirements

The Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] distributes power to all LV uninterruptible power consumers that support the delivery of CoFT, CoR and CoRM during all plant operating modes. The Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] contains sub-systems and components which facilitate the safety function requirements associated with valve-actuated Category A and B safety measures. Safety categorised functional requirements specified for the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] based on the HLSFs they support the delivery of, are allocated in the DOORS BQ_ Requirements Modules. Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS modules, including the rationale for their selection. The linked flow of requirements from the fault schedule through the safety measures to the electrical requirements modules is still in development.

8.4.4.1.2.2 Non-Functional System Requirements

Non-functional system requirements are specified for the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] based on the E3S Principles [19] as outlined in Section 8.2. The requirements specified at RD7/DRP1 are listed in the DOORS transverse requirements module, including the rationale for their application. The process to flow these requirements efficiently to each applicable electrical power system requirements module in DOORS is still in development at RD7/DRP1.

A full set of non-functional system requirements from all identified sources are in development, these will be allocated to each applicable SSC.

8.4.4.1.2.3 E3S Categorisation and Classification

The highest category of the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] functions fulfilling HLSF is Category A. In accordance with the SMR E3S Categorisation and Classification Method [25], Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] is a Safety Class 1 system.

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic classifications for these systems are being developed in line with the Seismic Performance Classification Method [26] and the E3S Principles [19], which specify that the Class 1 and Class 2 SSCs are to be Seismic Performance Class 1 (SPC1), capable of remaining fully functional during and after a Design Basis Earthquake.

8.4.4.1.3 Description

The Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] comprises the following sub-systems:

- Low Voltage Uninterruptible DC Converter System for Safety Services [BQU], which receives 400 V AC power, rectifies it to 220 V DC and charges the batteries.
- Low Voltage Uninterruptible DC Battery System for Safety Services [BQV], which stores chemical energy and distributes electrical energy when main AC is unavailable.
- 220 V Low Voltage Uninterruptible DC Supply System for Safety Services [BQA], which distributes electrical power to all consumers requiring uninterruptible power at 220 V DC.

The [BQ_] system uses a 'dual parallel redundant' architecture, whereby the batteries are split into two strings, with each string consisting of one charger and one battery bank and capable of meeting the full demand/rating, but for at least half of the autonomy time. In normal operation, both strings would be available, such that the full autonomy time can be met. This configuration allows for failure or test of individual battery banks with only a loss in autonomy time, rather than a complete loss of one redundant division. This configuration was the result of an optioneering study into architecture and is available to view in ECI-5 Uninterruptible Power Supply Architecture decision record [39].

The Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] system provides power to the Reactor Protection System (RPS) [JRA] and the Diverse Protection System (DPS) [JQA].

The RPS consists of three divisions, each with their own independent, dual parallel uninterruptible power supplies. These power supplies have 24 hours of autonomy time in total, and 12 hours per string. The RPS power supplies also provide power to the Low Voltage Uninterruptible AC Supply System [BM_], which in turn provides power to the RPS HVAC [KL] and, for example, safety measures such as the Category B actuators for PDHR (CoFT), and ASF (CoR).

The DPS has four divisions, each with their own independent dual parallel uninterruptible power supplies. These power supplies have 24 hours of autonomy time in total, and 12 hours per string. The DPS power supplies also provide power to the DPS HVAC [KL] and the Category A actuators for ECC (CoFT) and Containment Isolation (CoRM) safety measures.

As the RPS (DiD 3a) and DPS (DiD 3b) are of different defence in depth levels the power supplies must be diverse from one another. In addition to this the power supplies of one division cannot be cross-connected to another division (this applies to both systems).

Table 8.4-12:Key Performance and Design Parameters for the Uninterruptible DC Supply System [BQ_]

Parameter	**Value**	**Units**
Number of redundant divisions	3 (for sub-systems serving RPS) and 4 (for sub-systems serving DPS)	
System input voltage	400	V AC
System output voltage	220	V DC
Architecture	50 % Dual Parallel Redundant Batteries 100 % Dual Parallel Redundant Chargers	
Autonomy time	24 (2 x 12 hours) (RPS) 24 (2 x 12 hours) (DPS)	Hours
Battery Technology	Valve Regulated Lead Acid* (VRLA) – with diversity between RPS and DPS	

* The choice of Valve Regulated Lead Acid was the result of an optioneering study into battery technology and is available to view in ECI-17 Battery Technology decision record [40].

Further description of the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] and associated sub systems is provided in System Design Description for the Electrical Systems [A, B, MS, XF, XQ].

8.4.4.1.4 Materials

The approach to material selection, including qualification and ageing management considerations is addressed within E3S Case Version 2, Tier 1, Chapter 23 – Structural Integrity [28].

Materials will be confirmed as the design develops with vendor support. Materials selection, and the supporting input information and rationale will be presented in future revisions to this chapter.

8.4.4.1.5 Interfaces with Other Systems

The Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] functional and physical with electrical systems are the Earthing and Lightning Protection System [XF], the Low Voltage Uninterruptible AC Supply System [BM], the High Voltage Essential AC Standby Supply System [BD_], the Low Voltage Essential AC Standby Supply System [BK_] and the Low Voltage Essential AC Alternate Supply System [BL_]. These are identified and managed within DOORS, including flow down of functional requirements.

The Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] interfaces with all uninterruptible loads requiring LV DC power. These loads are captured within the Electrical Load Schedule [11].

The Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] has an interface with the C&I system, this interface is under development.

The Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] also interfaces indirectly with the HVAC systems and fire extinguishing systems to ensure the components are operating in a controlled environment. The Fire Detection systems are described in Chapter 7 [4] and the Fire Suppression systems are described in Chapter 9A [29].

8.4.4.1.6 System and Equipment Operation

The overarching operating philosophy for the Power Station in all operating modes is covered in [30], with operating modes defined in the operating philosophy for the Reactor Island [31].

In all non-faulted operating modes the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] is in the following state; energised and receiving power from [BK_] (Class 2 applications) or [BL_] (Class 1 applications) while providing the normal ([BB_]-derived) source of power to the uninterruptible loads with the batteries [BQV] available and charging, but not providing power to the loads

In faulted operation, the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] provides support to all SSCs that use electrically powered equipment to respond to plant faults. The Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] response to all major plant faults is therefore typically to provide power to the necessary SSCs, regardless of the fault.

The key fault to the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] is a loss of electrics (LOE) fault.

LOE.1.0.01: LOOP (72 hours) – under this event (which is defined in [36] as including a failure of house load operation), the Electrical Systems provide power from on-site energy stores to support all necessary plant responses, defined in the Fault Schedule [24]. In the case of the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_], this involves providing power to the Reactor Protection C&I, HVAC and Category A actuators, of which are a part of the Containment Isolation, Emergency Core Cooling functions. Initially during this fault the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] provides power using the batteries until the standby AC generators are able to accept load.

LOE.1.0.02: LOOP (168 hours) – under this event, the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] response is as described for the shorter duration loss of electrics fault, but in this case the Standby AC would maintain battery charge for approximately 72 hours until the fuel is fully exhausted. At this point the standby AC system can rely on mobile on-site sources to refill the fuel tanks. If this is unavailable then the batteries would supply the loads for a further 24 hours for protection systems or 72 hours for accident management systems. The responses post 72-hours in the Fault Schedule [24] are listed with 'TBD' but with the following actions expected: re-filling fuel tanks to continue to provide Standby AC power, and the use of the Alternate AC supplies to provide motive power for transfer of water to top-up the Local Ultimate Heat Sink tanks.

SBO: LOOP (Loss of grid) with Loss of first level of DiD (Standby AC) – under this event the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] would immediately (without operator intervention) discharge batteries to provide power to the SSCs that require support during an SBO condition. If this event happens in Modes 1 and 2, the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] would support Auto SCRAM (CoR) though C&I as well as ECC (CoFT) through valve actuation and C&I.

8.4.4.1.7 Instrumentation and Control

The basic functions allocated to the C&I systems and details of alarms, warnings and control logic is currently under development.

8.4.4.1.8 Examination, Monitoring, Inspection and Testing

The maintenance tasks and procedures, specific to the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] environment and operating context are to be defined as part of the final concept design. The examination, monitoring, inspection and testing requirements will be captured in the relevant through life activities (BQ_-TLA) module in DOORS.

Maintenance activities considered will include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best practice/OPEX (primary source: EPRI PMBD)
- Civil Structure and Module derived tasks.

8.4.4.1.9 Radiological Aspects

No radiation assessment has been carried out for the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] at RD7/DRP1.

8.4.4.1.10 Performance and Safety Evaluation

An initial hazard identification (HAZID) [32] was carried out for the electrical systems. Additional hazard assessments are being planned.

Verification activities against all requirements identified in the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] Requirements modules are in development.

8.4.4.1.11 Installation and Commissioning

The overall strategy for the RR SMR commissioning programme is presented in E3S Case Version 2, Tier 1, Chapter 14: Plant Construction and Commissioning [33].

Installation requirements for the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_] are to be detailed in the allocated requirements (-D) modules in DOORS.

The Installation and Commissioning (ICOM) Policy [34], section 2.4, provides a non-exhaustive list of examples of electrical checks to be carried out post-installation and prior to commissioning that include:

- Visual checks including checking of labels and tags for equipment, cables and trays
- Cable tray, panel and terminal box installation checks
- Component or equipment checks (pre energising), e.g. relays, contactors, circuit breakers, cells, rectifier and battery, motor, inverter (done during pre-Operational Commissioning tests)
- Wire to wire and post to post continuity checks
- Cable continuity and routing
- Earthing continuity checks to main earthing system
- Earthing of strips and shielding
- Shielding continuity
- Cable quality
- Electrical tests on LV cables (after laying and before connection)
- Dielectric tests or insulation measurement for motors and cables
- Connections (crimping, connectors, cable lugs, end fittings, etc.)
- Wiring of inter-chassis links, controls, sensors, actuators, etc.

A comprehensive commissioning plan will be developed during detailed design. Commissioning plans will be developed in line with the RR SMR ICOM policy [34].

Table 8.4-13:Example Low Voltage UPS [BB_] Commissioning Tests from SSG-28

System Type as described in SSG-28	Relevant SMR System(s)	Example Commissioning Tests from SSG-28
DC system	[BP], [BQ]	Calibration and trip settings of protective devices, including relaying devices, operation of breakers, prohibiting and permissive interlocks; Capability of battery chargers, transfer devices, inverters, instrumentation and alarms used to monitor system availability, including undervoltage alarms and ground detection instrumentation; Redundancy, electrical independence and actual total system loads, a discharge test of each battery bank at full load and for the design duration of load, adequacy of emergency lighting

8.4.4.2 Low Voltage Uninterruptible DC Supply System [BP_]

8.4.4.2.1 System and Equipment Functions

The primary function of the Low Voltage Uninterruptible DC Supply System [BP_] is to provide uninterruptible (battery backed) DC power to Class 3 and unclassified loads.

The major components in this system are the Battery Charger/Rectifier [BPU], the Batteries [BPV], and the switchboard, in [BPA].

During normal operation of the plant, the Low Voltage Uninterruptible DC Supply System [BP_] receives power from either the Low Voltage Essential AC Standby Supply System [BK_], the Low Voltage Essential AC Alternate Supply System [BL_], the Low Voltage Main AC Supply Systems for Process Equipment [BF_] or the Low Voltage Main AC Supply System for Non-Process Equipment [BG_], depending on the sub-system of [BP_].

If the AC supply to the Low Voltage Uninterruptible DC Supply System [BP_] is lost the loads continue to receive battery backed power, without the need for operator intervention.

The Low Voltage Uninterruptible DC Supply System [BP_] sub-systems are located across the SMR for the purposes of providing DC uninterruptible power to various equipment of differing safety classes. There is a [BP_] system in Reactor Island which provides 72 hours of autonomy time for the Class 3 Accident Management System (AMS) [JRQ].

8.4.4.2.2 Design Bases

8.4.4.2.2.1 Functional Requirements

The Low Voltage Uninterruptible DC Supply System [BP_] distributes power to all LV essential power consumers that support the delivery of CoFT, CoR and CoRM during all plant operating modes. The Low Voltage Uninterruptible DC Supply System [BP_] contains sub-systems and components which facilitate the duty / preventative function requirements associated with C&I Category C duty / preventative measures. Duty / preventative categorised functional requirements specified for the Low Voltage Uninterruptible DC Supply System [BP_] based on the HLSFs they support the delivery of, are allocated in the DOORS BP_ requirements modules. Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS modules, including the rationale for their selection. The linked flow of requirements from the fault schedule through the safety measures to the electrical requirements modules is still in development.

8.4.4.2.2.2 Non-Functional System Requirements

Non-functional system requirements are specified for the Low Voltage Uninterruptible DC Supply System [BP_] based on the E3S Principles [19] as outlined in Section 8.2. The requirements specified at RD7/DRP1 are listed in the DOORS transverse requirements module, including the rationale for their application. The process to flow these requirements efficiently to each applicable electrical power system requirements module in DOORS is still in development at RD7/DRP1.

A full set of non-functional system requirements from all identified sources are in development, these will be allocated to each applicable SSC.

8.4.4.2.2.3 E3S Categorisation and Classification

The highest category of the Low Voltage Uninterruptible DC Supply System for Safety Services [BP_] functions fulfilling HLSF is Category C. In accordance with the SMR E3S Categorisation and Classification Method [25], Low Voltage Uninterruptible DC Supply System for Safety Services [BP_] is a Safety Class 3 system.

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic classifications for these systems are being developed in line with the Seismic Performance Classification Method [26] and the E3S Principles [19], which specify that the Class 1 and Class 2 SSCs are to be Seismic Performance Class 1 (SPC1), capable of remaining fully functional during and after a Design Basis Earthquake. The SPC of Class 3 equipment is to be developed.

8.4.4.2.3 Description

The Low Voltage Uninterruptible DC Supply System [BP_] comprises the following sub-systems:

- Low Voltage Uninterruptible DC Converter System for Safety Services [BPU], which receives 400 V AC power, rectifies it to 220 V DC and charges the batteries.

- Low Voltage Uninterruptible DC Battery System for Safety Services [BPV], which stores chemical energy and distributes electrical energy when main AC is unavailable.

- 220 V Low Voltage Uninterruptible DC Supply System for Safety Services [BPA], which distributes electrical power to all consumers requiring uninterruptible power at 220 V DC.

The [BP_] system uses a dual parallel redundant architecture, as described in section 8.4.4.1.3 for [BQ_].

The Low Voltage Uninterruptible DC Supply System [BP_] provides power to the following systems:

- Reactor Island

- Post Accident Management System (PAMS) [JRQ10]*

- Severe Accident Management System (SAMS) [JRQ20]*
- Reactor Plant Control System (RPCS) [JSA]*.

* Battery and battery charging elements is provided by the Low Voltage Uninterruptible DC Supply System [BP_], with the inverter and load distribution being provided by the Low Voltage Uninterruptible AC Supply System [BM_].

PAMS (DiD 3) consists of two divisions, each with their own independent, dual parallel uninterruptible power supplies. These power supplies have 72 hours of autonomy time in total, and 36 hours per battery string. The battery and battery charging elements is provided by the Low Voltage Uninterruptible DC Supply System [BP_], with the inverter and load distribution being provided by the Low Voltage Uninterruptible AC Supply System [BM_].

SAMS (DiD 4) consists of two divisions, each with their own independent, dual parallel uninterruptible power supplies. These power supplies have 72 hours of autonomy time in total, and 36 hours per battery string. The battery and battery charging elements is provided by the Low Voltage Uninterruptible DC Supply System [BP_], with the inverter and load distribution being provided by the Low Voltage Uninterruptible AC Supply System [BM_].

The RPCS (DiD 1 and DiD 2) consists of a single division which is fed from a single dual parallel uninterruptible power supply. This power supply has 2 hours of autonomy time in total, and 1 hour per string. The battery and battery charging elements is provided by the Low Voltage Uninterruptible DC Supply System [BP_], with the inverter and load distribution being provided by the Low Voltage Uninterruptible AC Supply System [BM_].

The supply architecture for the remaining loads within Turbine Island, Balance of Plant and other areas is yet to be determined.

Table 8.4-14: Key Performance and Design Parameters for the Uninterruptible DC Supply System [BP_]

Parameter	Value	Units
Number of redundant divisions	Up to 2, depending on the sub-system	
System input voltage	400	V AC
System output voltage	220	V DC
Architecture	50 % Dual Parallel Redundant Batteries (AMS) & 100 % Dual Parallel Redundant Chargers and Standard assumption: 50 % Dual Parallel Redundant batteries & 100 % Dual Parallel Redundant Chargers for others (TBD based on application)	
Autonomy time	Various, dependent on system being supplied: 2 (2 x 1 hour) (turbine island uninterruptible supplies e.g. to DC lubricating oil pump for steam turbine [MA] / main generator [MK]) 2 (2 x 1 hour) (standard assumption for other systems) 72 (2 x 36 hours) (AMS)	Hours
Battery Technology	TBD (Valve Regulated Lead Acid (VRLA) proposed in ECI-17 [40], Reference, but dependent on application)	

8.4.4.2.4 Materials

The approach to material selection, including qualification and ageing management considerations is addressed within E3S Case Version 2, Tier 1, Chapter 23 – Structural Integrity [28].

Materials will be confirmed as the design develops with vendor support. Materials selection, and the supporting input information and rationale will be presented in future revisions to this chapter.

8.4.4.2.5 Interfaces with Other Systems

The Low Voltage Uninterruptible DC Supply System [BP_] functional and physical interfaces with electrical systems are the Earthing and Lightning Protection System [XF], the Low Voltage Essential AC Standby Supply System [BK_], the Low Voltage Essential AC Alternate Supply System [BL_], the Low Voltage Main AC Supply System for Process Equipment [BF_], the Low Voltage Uninterruptible AC Supply System [BM_] and the Low Voltage Main AC Supply System for Non-Process Equipment [BG_]. These are identified and managed within DOORS, including flow down of functional requirements.

The Low Voltage Uninterruptible DC Supply System [BP_] interfaces with all uninterruptible loads requiring LV DC power. These loads are captured within the Electrical Load Schedule [11].

The Low Voltage Uninterruptible DC Supply System [BP_] has an interface with the C&I system, this interface is under development.

The Low Voltage Uninterruptible DC Supply System [BP_] also interfaces indirectly with the HVAC systems and fire extinguishing systems to ensure the components are operating in a controlled environment. The Fire Detection systems are described in Chapter 7 [4] and the Fire Suppression systems are described in Chapter 9A [29].

8.4.4.2.6 System and Equipment Operation

The overarching operating philosophy for the Power Station in all operating modes is covered in [30], with operating modes defined in the operating philosophy for the Reactor Island [31].

In all non-faulted operating modes the Low Voltage Uninterruptible DC Supply System [BP_] is in the following state; energised and receiving power from [BK_], [BL_] [BF_] or [BG_] while providing the normal ([BB_]-derived) source of power to the essential loads with the batteries [BPV] available and charging, but not providing power to the loads.

In faulted operation, the Low Voltage Uninterruptible DC Supply System [BP_] provides support to all SSCs that use electrically powered equipment to duty and preventive plant states. The Low Voltage Uninterruptible DC Supply System [BP_] response to these measures is therefore typically to provide power to the necessary SSCs, regardless of the fault.

The key fault to the Low Voltage Uninterruptible DC Supply System [BP_] is a loss of electrics (LOE) fault.

LOE.1.0.01: LOOP (72 hours) – under this event (which is defined in [36] as including a failure of house load operation), the Electrical Systems provide power from on-site energy stores to support all necessary plant responses, defined in the Fault Schedule [24]. In the case of the Low Voltage Uninterruptible DC Supply System [BP_] this involves providing power to the Reactor Control System and Reactor Limitation and Preventative Protection System C&I which provide duty and preventative measures for CoR, CoFT and CoRM.

LOE.1.0.02: LOOP (168 hours) – under this event, the Low Voltage Uninterruptible DC Supply System [BP_] response is as described for the shorter duration loss of electrics fault, but in this case the Standby AC would maintain battery charge for approximately 72 hours until the fuel is fully exhausted. At this point the standby AC system can rely on mobile on-site sources to refill the fuel tanks. If this is unavailable then the batteries would continue to supply the loads, with the autonomy varying depending on each load. The responses post 72-hours in the Fault Schedule [24] are listed with 'TBD' but with the following actions expected: re-filling fuel tanks to continue to provide Standby AC power, and the use of the Alternate AC supplies to provide motive power for transfer of water to top-up the Local Ultimate Heat Sink tanks.

8.4.4.2.7 Instrumentation and Control

The basic functions allocated to the C&I systems and details of alarms, warnings and control logic is currently under development.

8.4.4.2.8 Examination, Monitoring, Inspection and Testing

The maintenance tasks and procedures, specific to the Low Voltage Uninterruptible DC Supply System [BP_] environment and operating context are to be defined as part of the final concept design. The examination, monitoring, inspection and testing requirements will be captured in the relevant through life activities (BP_-TLA) module in DOORS.

Maintenance activities considered will include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best practice/OPEX (primary source: EPRI PMBD)
- Civil Structure and Module derived tasks

8.4.4.2.9 Radiological Aspects

No radiation assessment has been carried out for the Low Voltage Uninterruptible DC Supply System [BP_] at RD7/DRP1.

8.4.4.2.10 Performance and Safety Evaluation

An initial hazard identification (HAZID) [32] was carried out for the electrical systems. Additional hazard assessments are being planned.

Verification activities against all requirements identified in the Low Voltage Uninterruptible DC Supply System [BP_] Requirements modules are in development.

8.4.4.2.11 Installation and Commissioning

The overall strategy for the RR SMR commissioning programme is presented in E3S Case Version 2, Tier 1, Chapter 14: Plant Construction and Commissioning [33].

Installation requirements for the Low Voltage Uninterruptible DC Supply System [BP_] are to be detailed in the allocated requirements (-D) modules in DOORS.

The Installation and Commissioning (ICOM) Policy [34], section 2.4, provides a non-exhaustive list of examples of electrical checks to be carried out post-installation and prior to commissioning that include:

- Visual checks including checking of labels and tags for equipment, cables and trays
- Cable tray, panel and terminal box installation checks
- Component or equipment checks (pre energising), e.g. relays, contactors, circuit breakers, cells, rectifier and battery, motor, inverter (done during pre-Operational Commissioning tests)
- Wire to wire and post to post continuity checks
- Cable continuity and routing
- Earthing continuity checks to main earthing system

- Earthing of strips and shielding
- Shielding continuity
- Cable quality
- Electrical tests on LV cables (after laying and before connection)
- Dielectric tests or insulation measurement for motors and cables
- Connections (crimping, connectors, cable lugs, end fittings, etc.)
- Wiring of inter-chassis links, controls, sensors, actuators, etc.

A comprehensive commissioning plan will be developed during detailed design. Commissioning plans will be developed in line with the RR SMR ICOM policy [34].

Table 8.4-15: Example Low Voltage UPS [BP_] Commissioning Tests from SSG-28

System Type as described in SSG-28	Relevant SMR System(s)	Example Commissioning Tests from SSG-28
DC system	[BP], [BQ]	Calibration and trip settings of protective devices, including relaying devices, operation of breakers, prohibiting and permissive interlocks; Capability of battery chargers, transfer devices, inverters, instrumentation and alarms used to monitor system availability, including undervoltage alarms and ground detection instrumentation; Redundancy, electrical independence and actual total system loads, a discharge test of each battery bank at full load and for the design duration of load, adequacy of emergency lighting

8.4.4.3 Low Voltage Uninterruptible AC Supply System [BM_]

8.4.4.3.1 System and Equipment Functions

The primary function of the Low Voltage Uninterruptible AC Supply System [BM_] is to provide uninterruptible (battery backed) AC power to Class 2, 3 and unclassified loads.

The major components in this system are the inverter/ isolation transformer, in [BMU], and switchboard [BMA].

Although the [BM_] system mostly comprises a set of inverters and associated equipment, it also includes [BMU77/78], the motor-generator sets for the power supplies to the rod control system which provide resilience to brief power supply interruptions, minimising the risk of an unintended reactor trip (dropped rod(s) or scram).

Low Voltage Uninterruptible AC Supply System [BM_] works in conjunction with the Low Voltage Uninterruptible DC Supply System [BP_] or the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_], taking the DC output from one of those systems as the input to the inverter.

If the main AC supply to [BP_] or [BQ_] is lost, the Low Voltage Uninterruptible AC Supply Systems [BM] loads continue to receive battery backed AC power, without the need for operator intervention.

If the main DC supply from [BP_] or [BQ_] is lost, the Low Voltage Uninterruptible AC Supply Systems [BM_] switches from inverter supply to mains AC (provided the main AC is still healthy) via a bypass supply and isolation transformer (also uses the code [BMU]). The main AC supply shall be the same switchboard that distributes power to the DC system charger, either [BK_], [BL_], [BF_] or [BG_].

Low Voltage Uninterruptible AC Supply Systems [BM_] are located across the SMR for the purposes of providing AC uninterruptible power to various equipment of differing safety classes. There is a Class 2 [BM_] system in Reactor Island which provides uninterruptible AC power to the actuators associated with the Reactor Protection Systems (RPS [JRA]), a Class 3 [BM_] system in the Reactor Island for PAMS/SAMS [JRQ] as well as a Class 3 [BM_] system located in the Turbine Island.

8.4.4.3.2 Design Bases

8.4.4.3.2.1 Functional Requirements

The Low Voltage Uninterruptible AC Supply System [BM_] distributes power to all LV essential power consumers that support the delivery of CoFT, CoR and CoRM during all plant operating modes. The Low Voltage Uninterruptible AC Supply System [BM_] contains sub-systems and components which facilitate the safety function requirements associated with valve-actuated Category B safety measures. Safety categorised functional requirements specified for the Low Voltage Uninterruptible AC Supply System [BM_] based on the HLSFs they support the delivery of, are allocated in the DOORS BM_ requirements modules. Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS modules, including the rationale for their selection. The linked flow of requirements from the fault schedule through the safety measures to the electrical requirements modules is still in development.

8.4.4.3.2.2 Non-Functional System Requirements

Non-functional system requirements are specified for The Low Voltage Uninterruptible AC Supply System [BM_] based on the E3S Principles [19] as outlined in Section 8.2. The requirements specified at RD7/DRP1 are listed in the DOORS transverse requirements module, including the rationale for their application. The process to flow these requirements efficiently to each applicable electrical power system requirements module in DOORS is still in development at RD7/DRP1.

A full set of non-functional system requirements from all identified sources are in development, these will be allocated to each applicable SSC.

8.4.4.3.2.3 E3S Categorisation and Classification

The highest category of the Low Voltage Uninterruptible AC Supply System [BM] functions fulfilling HLSF is Category B. In accordance with the SMR E3S Categorisation and Classification Method [25], Low Voltage Uninterruptible AC Supply System [BM] is a Safety Class 2 system.

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic classifications for these systems are being developed in line with the Seismic Performance Classification Method [26] and the E3S Principles [19], which specify that the Class 1 and Class 2 SSCs are to be Seismic Performance Class 1 (SPC1), capable of remaining fully functional during and after a Design Basis Earthquake. The SPC of Class 3 equipment is to be developed.

8.4.4.3.3 Description

The Low Voltage Uninterruptible AC Supply Systems [BM_] comprises the following sub-systems:

- Low Voltage Uninterruptible AC Converter system [BMU], which receives 220 V DC power and inverts it to 230 V AC.
- 230 V Uninterruptible AC Supply System 1, which distributes electrical power to all consumers requiring uninterruptible power at 230 V AC [BMA].

The Low Voltage Uninterruptible AC Supply Systems [BM_] provides power to the following systems:

- Reactor Island
- Reactor Protection System (RPS) [JRA]
- Post Accident Management System (PAMS) [JRQ10]
- Severe Accident Management System (SAMS) [JRQ20]
- Reactor Plant Control System (RPCS) [JSA]

The RPS consists of three divisions, each with their own independent, dual parallel uninterruptible power supplies. These power supplies have 24 hours of autonomy time in total, and 12 hours per battery string. The RPS power supplies also provide power to the Low Voltage Uninterruptible AC Supply System [BM_], which in turn provides power to the RPS HVAC [KL] and Category B actuators for ASF (CoR). The [BM_] also contains a bypass supply to the [BKA] switchboard should the DC supply from [BQA] fail.

PAMS (DiD 3) consists of two divisions, each with their own independent, dual parallel uninterruptible power supplies. These power supplies have 72 hours of autonomy time in total, and 36 hours per battery string. The battery and battery charging elements is provided by the Low Voltage Uninterruptible DC Supply System [BP_], with the inverter and load distribution being provided by the Low Voltage Uninterruptible AC Supply System [BM_]. The [BM_] also contains a bypass supply to the [BKA] switchboard should the DC supply from [BQA] fail.

SAMS (DiD 4) consists of two divisions, each with their own independent, dual parallel uninterruptible power supplies. These power supplies have 72 hours of autonomy time in total, and 36 hours per battery string. The battery and battery charging elements is provided by the Low Voltage Uninterruptible DC Supply System [BP_], with the inverter and load distribution being provided by the Low Voltage Uninterruptible AC Supply System [BM_]. The [BM_] also contains a bypass supply to the [BLA] switchboard should the DC supply from [BQA] fail.

The RPCS (DiD 1 and DiD 2) consists of a single division which is fed from a single dual parallel uninterruptible power supply. This power supply has 2 hours of autonomy time in total, and 1 hour per battery string. The battery and battery charging elements is provided by the Low Voltage Uninterruptible DC Supply System [BP_], with the inverter and load distribution being provided by the Low Voltage Uninterruptible AC Supply System [BM_]. The [BM_] also contains a bypass supply to the [BFA] switchboard should the DC supply from [BQA] fail.

Table 8.4-16: Key Performance and Design Parameters for the Uninterruptible DC Supply System [BM_]

Parameter	Value	Units
Number of redundant divisions	Up to 3, depending on the sub-system	
System input voltage (AC)	400	V AC
System input voltage (DC)	220	V DC
System output voltage	230	V AC
Autonomy time	See [BP_] and [BQ_]	Hours

8.4.4.3.4 Materials

The approach to material selection, including qualification and ageing management considerations is addressed within E3S Case Version 2, Tier 1, Chapter 23 – Structural Integrity [28].

Materials will be confirmed as the design develops with vendor support. Materials selection, and the supporting input information and rationale will be presented in future revisions to this chapter.

8.4.4.3.5 Interfaces with Other Systems

The Low Voltage Uninterruptible AC Supply Systems [BM_] functional and physical interfaces with electrical systems are the Earthing and Lightning Protection System [XF], the Low Voltage Essential AC Standby Supply Systems [BK_], the Low Voltage Essential AC Alternate Supply System [BL_], the Low Voltage Uninterruptible DC Supply System [BP_] and the Low Voltage Uninterruptible DC Supply System for Safety Services [BQ_]. These are identified and managed within DOORS, including flow down of functional requirements.

The Low Voltage Uninterruptible AC Supply Systems [BM_] interfaces with all uninterruptible loads requiring LV AC power. These loads are captured within the Electrical Load Schedule [11].

The Low Voltage Uninterruptible AC Supply Systems [BM_] have an interface with the C&I system, this interface is under development.

The Low Voltage Uninterruptible AC Supply Systems [BM_] also interfaces indirectly with the HVAC systems and fire extinguishing systems to ensure the components are operating in a controlled environment. The Fire Detection systems are described in Chapter 7 [4] and the Fire Suppression systems are described in Chapter 9A [29].

8.4.4.3.6 System and Equipment Operation

The overarching operating philosophy for the Power Station in all operating modes is covered in [30], with operating modes defined in the operating philosophy for the Reactor Island [31].

In all non-faulted operating modes the Low Voltage Uninterruptible AC Supply Systems [BM_] is in the following state; energised and receiving power from [BQ_] (Class 1 or 2 applications) or [BP_]

(Class 3 or non-classified applications) while providing the normal ([BB_]-derived) source of power to the essential loads.

In faulted operation, the Low Voltage Uninterruptible AC Supply Systems [BM_] provides support to all SSCs that use electrically powered equipment to respond to plant faults. The Low Voltage Uninterruptible AC Supply Systems [BM_] response to certain major plant faults is therefore typically to provide power to the necessary SSCs, regardless of the fault.

The key fault to the Low Voltage Uninterruptible AC Supply Systems [BM_] is a loss of electrics (LOE) fault.

LOE.1.0.01: LOOP (72 hours) – under this event (which is defined in [36] as including a failure of house load operation), the Electrical Systems provide power from on-site energy stores to support all necessary plant responses, defined in the Fault Schedule [24]. In the case of the Low Voltage Uninterruptible AC Supply Systems [BM_], this provides power to the Reactor Protection C&I, HVAC and Category B actuators which are part of the Alternative Shutdown Function (ASF) CoR safety function.

LOE.1.0.02: LOOP (168 hours) – under this event, the Low Voltage Uninterruptible AC Supply Systems [BM_] response is as described for the shorter duration loss of electrics fault, but in this case the Standby AC would maintain battery charge of the [BQ_] and [BP_] systems (both of which supply power to [BM_] for approximately 72 hours until the fuel is fully exhausted. At this point the standby AC system can rely on mobile on-site sources to refill the fuel tanks. If this is unavailable then the batteries would supply the loads for a further 24 hours for protection systems or 72 hours for management systems. The responses post 72-hours in the Fault Schedule [24] are listed with 'TBD' but with the following actions expected: re-filling fuel tanks to continue to provide Standby AC power, and the use of the Alternate AC supplies to provide motive power for transfer of water to top-up the Local Ultimate Heat Sink tanks.

SBO: LOOP (Loss of grid) with Loss of first level of DiD (Standby AC) – under this event the Low Voltage Uninterruptible AC Supply Systems [BM_] would continue to provide power to the SSCs that require support during an SBO condition via the [BQ_] and [BP_] system batteries discharging. If this event happens in Modes 1 and 2, the Low Voltage Uninterruptible AC Supply Systems [BM_] shall support, if required, Alternative Shutdown Function (CoR) through valve actuation.

8.4.4.3.7 Instrumentation and Control

The basic functions allocated to the C&I systems and details of alarms, warnings and control logic is currently under development.

8.4.4.3.8 Examination, Monitoring, Inspection and Testing

The maintenance tasks and procedures, specific to the Low Voltage Uninterruptible AC Supply Systems [BM_] environment and operating context are to be defined as part of the final concept design. The examination, monitoring, inspection and testing requirements will be captured in the relevant through life activities (BM_-TLA) module in DOORS.

Maintenance activities considered will include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)

- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best practice/OPEX (primary source: EPRI PMBD)
- Civil Structure and Module derived tasks.

8.4.4.3.9 Radiological Aspects

No radiation assessment has been carried out for the Low Voltage Uninterruptible AC Supply Systems [BM_] at RD7/DRP1.

8.4.4.3.10 Performance and Safety Evaluation

An initial hazard identification (HAZID) [32] was carried out for the electrical systems. Additional hazard assessments are being planned.

Verification activities against all requirements identified in the Low Voltage Uninterruptible AC Supply Systems [BM_] Requirements modules are in development.

8.4.4.3.11 Installation and Commissioning

The overall strategy for the RR SMR commissioning programme is presented in E3S Case Version 2, Tier 1, Chapter 14: Plant Construction and Commissioning [33].

Installation requirements for the Low Voltage Uninterruptible AC Supply System [BM_] are to be detailed in the allocated requirements (-D) modules in DOORS.

The Installation and Commissioning (ICOM) Policy [34], section 2.4, provides a non-exhaustive list of examples of electrical checks to be carried out post-installation and prior to commissioning that include:

- Visual checks including checking of labels and tags for equipment, cables and trays
- Cable tray, panel and terminal box installation checks
- Component or equipment checks (pre energising), e.g. relays, contactors, circuit breakers, cells, rectifier and battery, motor, inverter (done during pre-Operational Commissioning tests),
- Wire to wire and post to post continuity checks
- Cable continuity and routing
- Earthing continuity checks to main earthing system
- Earthing of strips and shielding
- Shielding continuity
- Cable quality
- Electrical tests on LV cables (after laying and before connection)

- Dielectric tests or insulation measurement for motors and cables
- Connections (crimping, connectors, cable lugs, end fittings, etc.)
- Wiring of inter-chassis links, controls, sensors, actuators, etc.

A comprehensive commissioning plan will be developed during detailed design. Commissioning plans will be developed in line with the RR SMR ICOM policy [34].

Table 8.4-17:Example Low Voltage UPS [BM_] Commissioning Tests from SSG-28

System Type as described in SSG-28	**Relevant SMR System(s)**	**Example Commissioning Tests from SSG-28**
Vital busbar and associated AC power supplies	[BM]	Load tests that use all and minimum sources of power supplies to busbars.
Emergency AC power distribution system	[BD], [BK], [BL] [XQ] for example relating to lighting adequacy [BM] for example relating to motor-generator sets	Operation of protection devices, relaying and logic devices, breakers, motor controllers, switchgear, transformers, transfer and trip devices, prohibiting and permissive interlocks, instrumentation and alarms, load shedding capabilities, capability of emergency and vital loads to start in the proper sequence and to operate under simulated accident conditions with both the normal (preferred) AC power sources and/or the emergency (standby) power source in accordance with design requirements for voltage and frequency; Duration tests of diesel generators or equivalent machines, capability to start and operate with maximum and minimum design voltage available; To the extent practicable, testing of emergency or vital loads conducted for a sufficient period of time to provide assurance that equilibrium conditions are attained; Verification of system redundancy and electrical independence; Testing of loads supplied from the system such as motor generator sets with flywheels designed to provide non-interruptible power to vital plant loads, to demonstrate proper operation; Load tests for vital busbars using normal and emergency sources of power supplies to the busbar; Operation of indicating and alarm devices used to monitor the availability of the emergency power system in the control room; Adequacy of the plant's emergency lighting system.

8.5 Earthing, Lightning Protection and Electromagnetic Compatibility

8.5.1 Earthing and Lightning Protection System

8.5.1.1.1 System and Equipment Functions

The primary function of the Earthing and Lightning Protection System [XF] is to protect people and equipment from the effects of lightning strikes and electrical faults in the electrical system that may cause electrical shock, fire or explosion.

8.5.1.1.1.1 Earthing Systems

The Earthing System design shall comprise of a global earthing system which covers all electrical, control, instrumentation and mechanical systems across the site in accordance with the regulations and standards and safety rules identified from hazard assessments.

The Earthing System is still in development. The Earthing System will be designed in accordance with nuclear standard IEC 63046 and also BS 7430, BS EN 50522 and IEC 61000-5-2. For further details and scope for earthing systems requirements refer to SMR Earthing and Lightning Protection Philosophy document [41].

The earthing system design shall also include requirements for nuclear safety hazards identified via hazard identification reviews. For the preliminary hazard identification, see Electrical Power System Hazard Identification report [32].

8.5.1.1.1.2 Earth Mats

The Earth Mats will be designed as a low resistance path for fault currents and ensuring the safe operation of the power station and safety of personnel working within and around the power station.

it is envisaged that Earth Mats/grids will be provided and installed buried within the earth located beneath the concrete foundations for the following main areas of the RR SMR Power Plant site as a minimum, subject to design recommendations from Earthing and Lightning Protection System calculation studies:

- Single combined Earth Mat located beneath the foundations of Electrical annex buildings, Turbine Island Building and Reactor Island Building. These areas comprise a combination of High Voltage and Low Voltage Electrical and Mechanical equipment.

- Earth Mat located beneath foundation of the Grid connection yard.

- Earth Mat located beneath the foundation for the Cooling Water Island Substation building, which will comprise a combination of High and Low Voltage equipment.

- Earth Mat beneath transformer pens and associated Substations located within the Entrance Area comprising of 11 kV/400 V Step down transformers.

- Separate Earth Mats located under each foundation of the Electrical buildings (comprising of High and Low Voltage substations and Electrical equipment) and associated Transformers pens within the Balance of Plant (BoP) areas located around the perimeter of the main power plant.

8.5.1.1.1.3 Lightning Protection Systems

The Lightning Protection System is still in development.

The Lightning Protection systems will be designed in accordance with BS EN 62305-1 to 4 and shall include requirements to address nuclear safety hazards due to lightning. For the preliminary hazard identification study, see the Electrical Power System Hazard Identification report [32].

The design for the Lightning Protection Systems will be based on the following:

- The design recommendations of lightning risk assessments. Lightning protection risk assessments will be performed on buildings structures and equipment infrastructure across the RR SMR site in accordance with BS EN 62305-2:2012.

- Lightning strike design parameters and assumptions identified in the RR SMR GB Generic Site Envelope [20] and in the DOORS transverse requirements module.

- Site specific soil resistivity values.

For further details and scope for earthing systems requirements refer to SMR Earthing & Lightning Protection Philosophy document [41].

8.5.1.1.2 Design Basis

8.5.1.1.2.1 Functional Requirements

The Earthing and Lightning Protection System [XF] contains sub-systems and components which are also associated with the facilities that deliver the High Level Safety Functions (HLSFs). The deterministic safety analysis presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [23], provides a systematic evaluation of the credible Postulated Initiating Events (PIEs). HLSFs are identified in the Fault Schedule [24] and assigned to each PIE to deliver the four Fundamental Safety Functions (FSFs): Control of Reactivity (CoR), Control of Fuel Temperature (CoFT), Confinement of Radioactive Material (CoRM), and Control of Radiation Exposure (CoRE).

8.5.1.1.2.2 Non-Functional System Requirements

Non-functional system requirements are captured in the DOORS transverse requirements module as outlined in Section 8.2. The process to flow these requirements efficiently to each applicable electrical power system requirements module in DOORS is still in development at RD7/DRP1.

8.5.1.1.2.3 E3S Categorisation and Classification

The Safety Classification of Earthing and Lightning Protection System [XF] will be determined based on the area and equipment the system is protecting, in accordance with the SMR E3S Categorisation and Classification Method [25].

In some instances, the lightning protection system will be a potential common cause of failure associated with Class 1 or Class 2 equipment and hence will also be rated as Class 1 for those areas. The classification is presently under assessment.

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic classifications for this system are yet to be developed in line with the Seismic Performance Classification Method [26] and the E3S Principles [19], which specify that the Class 1 and Class 2 SSCs are to be Seismic Performance Class 1 (SPC1), capable of remaining fully functional during and after a Design Basis Earthquake. The SPC of Class 3 equipment is to be developed.

8.5.1.1.3 Description

The Earthing and Lightning Protection System [XF] will comprise four sub-systems, which will span the SMR site:

- Earthing/Grounding System [XFA]
- Equipotential Bonding System [XFB]
- External Lightning Protection [XFC]
- Internal Lightning Protection [XFD].

The earthing system design will provide a global earthing system, which will cover all electrical systems across the site. Earth Mats/grids will be installed for the Reactor Island Building, Turbine Island Building, associated Electrical Annex building, Power Transmission area and grid connection yard.

Earth Mats/grids for other areas will be provided for the high voltage substation and transformer pens.

The earthing system design will be based on software model case design with assumed parameters of earth resistivity values, which will based on proposed SMR site locations.

The SMR Earthing & Lightning Protection Philosophy document [41] sets out the basis of the design parameters and assumptions made for the earthing and lightning protection design. That document also outlines the philosophy and requirements stipulated from standards and guidance documents.

Table 8.5-1: Key Performance and Design Parameters for the Earthing & Lightning Protection System [XF]

Parameter	Value	Units
Lightning Strike peak bounding current (see Generic Site Envelope, Reference [20])	300	kA
Thunderstorm days (Reference [20])	15	Days/year
Mean Flash Frequency (of Lightning Strikes) (Reference [20])	1.4	Flashes/km^2/year
Soil Resistivity	TBD (Dependent on proposed location of SMR site)	Ωm

8.5.1.1.4 Materials

The materials selection for the Earthing, Equipotential Bonding and Lightning Protection Systems will be recommended as part of the lightning protection assessments and Earthing design calculations studies to be carried out for each RR SMR site.

Where reasonably practicable in the design, the materials used for the lightning protection systems will be selected to achieve protection against lightning strikes taking into consideration the lightning strike parameter values set out in SMR Earthing and Lightning Protection Philosophy document [41] and associated design assumptions.

Similarly, the materials used for earthing and equipotential bonding will be selected, where reasonably practicable considering worst case earth resistivity values (to be determined).

The approach to material selection, including qualification and ageing management considerations is addressed within E3S Case Version 2, Tier 1, Chapter 23 – Structural Integrity [28]. Materials will be confirmed as the design develops with vendor support. Materials selection, and the supporting input information and rationale will be presented in future revisions to this chapter.

8.5.1.1.5 Interfaces with Other Systems

The Earthing and Lightning protection system shall encompass scope which interfaces with the following areas.

- Interface with all electrical systems.
- All Instrumentation & Control Systems.
- The earthing design will interface with mechanical to ensure bonding and earthing of extraneous conductive parts and metallic structures across the site.
- Interface with Process Systems to ensure earthing and bonding of pipework.
- Interface with architectural, civils and structural design disciplines to ensure appropriate earthing and bonding of equipment is achieved in accordance with standards. This will include for earthing and bonding of metallic SSCs and incorporation of Earth Mat and Lightning protection design elements within the structural, civils design.

The Earthing and Lightning Protection System [XF] interfaces will be identified and managed within DOORS, including its flow down of functional requirements.

8.5.1.1.6 System and Equipment Operation

The Earthing and Lightning Protection System [XF] is a static system and will not be subject to operational modes. There are connections to the Earthing and Lightning Protection System [XF] that change state: HV switchgear earth switches and diesel generator neutral points. However, the active equipment is not allocated to the Earthing and Lightning Protection System [XF].

8.5.1.1.7 Instrumentation and Control

An earthing network shall be installed around the RR SMR plant site which serves to maintain both electrical safety and the functionality of the instrumentation and control systems.

It is envisaged this earthing network shall comprise of hierarchy of instrument Earth bars and ring main earth cabling situated around the plant site to provide multiple earth paths to cater for connection of instrumentation and control systems.

There is no requirement for a separate and independent clean earthing system as this would introduce a hazard in the equipotential bonding of systems and equipment across the site. The earthing of instrumentation and control systems shall either be single point or multiple point earthing which shall be determined based on the specific design adopted for the site.

The earthing and bonding network of instrumentation and control systems shall be adopted in accordance with the relevant earthing standards and requirements for low voltage systems in accordance with IAEA Safety Standard Series No. SSG-34 and associated IEC standards.

A multitude of parallel earth paths shall be provided which will be effective in keeping electrical noise low and it shall be coordinated with the overall design provisions for electromagnetic compatibility.

Any earth monitoring or status signals that may be required for systems on site are yet to be identified and developed.

The flow down of non-functional requirements from C&I to Earthing and Lightning Protection System [XF] will be done through interfaces which will be identified and managed within DOORS.

8.5.1.1.8 Examination, Monitoring, Inspection and Testing

The maintenance tasks and procedures, specific to the Earthing and Lightning Protection System [XF] environment and operating context are to be defined as part of the final concept design. The examination, monitoring, inspection and testing requirements will be captured in the relevant through life activities (XF_-TLA) module in DOORS.

Maintenance activities considered will include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best practice/OPEX (primary source: EPRI PMBD)
- Civil Structure and Module derived tasks.

8.5.1.1.9 Radiological Aspects

No radiation assessment has been carried out for the Earthing and Lightning Protection System [XF] at RD7/DRP1.

8.5.1.1.10 Performance and Safety Evaluation

An initial hazard identification (HAZID) [32] was carried out for the electrical systems. Additional hazard assessments are being planned.

Verification activities against all requirements identified in the Earthing and Lightning Protection System [XF] Requirements modules are in development.

8.5.1.1.11 Installation and Commissioning

The overall strategy for the RR SMR commissioning programme is presented in E3S Case Version 2, Tier 1, Chapter 14: Plant Construction and Commissioning [33].

Installation requirements for the Earthing and Lightning Protection System [XF] are to be detailed in the allocated requirements (-D) modules in DOORS.

The Installation, Commissioning, Operation and Maintenance (ICOM) Policy (Reference [34]), section 2.4, provides a non-exhaustive list of examples of electrical checks to be carried out post-installation and prior to commissioning that also include:

- Visual checks including checking of labels and tags for earthing and lightning protection equipment
- Earthing continuity checks to main earthing system
- Earthing of strips and shielding
- Shielding continuity.

Lower-level SDDs will describe, where appropriate, the design features included specifically for commissioning.

8.5.2 Electromagnetic Compatibility

The RR SMR will include electrical and electronic equipment that could be susceptible to electromagnetic interference (EMI) and that may produce electromagnetic interference, for example thyristors and VFDs. EMI risks from external sources include Lightning, Space Weather and Industry.

Hazard reviews will be carried out by EC&I (Electrical, Control & Instrumentation) system and internal hazards system teams during detail design to identify EMI risks and associated mitigations. Credible combinations of EMI risks will be considered.

Electromagnetic Compatibility (EMC) will be ensured through:

- Selection of Electrical and Electronic equipment with suitable EMC characteristics, including diversity and EMC functional safety requirements as necessary.
- Provision of Faraday Cages in buildings as needed.
- State of the Art application of EMI mitigation measures, including separation, screening, filtering, suppression, galvanic isolation, earthing and bonding. For example, standard BS IEC 61000-5-2:1997 provides guidelines for earthing and cabling requirements of installations to ensure Electromagnetic compatibility among Electrical and Electronic apparatus and systems.
- Provision of Lightning protection systems and surge suppression, based on risk assessments in accordance with IEC 62305.

- Exclusion of unwanted sources of EMI (mobile telephones, CB radio, etc.) as required.
- Measures to ensure continued EMC through life.

The overall approach to ensuring electromagnetic compatibility is still in development.

8.5.2.1 EMI from Lightning Strike

Requirements around protection against EMI due to lightning strikes are yet to be developed. It is envisaged that the design of the lightning protection system will incorporate means to mitigate EMI emissions to site equipment from direct lightning strikes with peak current levels identified within SMR Earthing & Lightning Protection Philosophy document [41].

The Reactor Island and Turbine Island buildings will be covered by an architectural dome structure which can act as a Faraday cage providing protection against lightning strikes. Other areas not covered by the Dome Structure will be provided with appropriate air terminal networks and down conductors.

Other mitigation solutions due to direct or distant lightning strikes such as use of surge protection, signal isolation and transformer impulse ratings will be determined as part of design development.

8.5.2.2 Space Weather EMI

The overall approach to ensuring protection against space weather is still under development.

As part of further research and detail design, requirements are to be developed as reasonably practicable for protection measures to be incorporated to mitigate potential hazards from space weather anomalies. The potential hazards identified are as follows:

8.5.2.2.1 Geomagnetically Induced Currents

Large geomagnetically induced currents (GICs) can lead to Generator and Standby Transformer damage, Grid voltage instability and harmonics triggering protective relays. These effects can all result in a Loss of Off-site Power (LOOP), or if not successfully mitigated through the design of the on-site electrical power system and its electrical protection systems, the potential for failure of on-site power systems or components. This hazard is caused by solar flares and Coronal Mass Ejections (CMEs).

GICs induce Quasi-DC currents in the AC power network at Grid level during a period of Solar Magnetic storms. The National Grid coordinate the response to this hazard.

As part of on-going design development, liaison with the TSO will be carried out to discuss relevant measures and mitigations that will need to be incorporated. This interface will be done through the 400 kV Grid Transmission Connection System [AC_].

Hazard reviews will be conducted to determine any substantial risks due to GICs. The required mitigations shall be reviewed and incorporated within the electrical design to reduce or mitigate the effects of GICs. Methods of possible mitigations are as follows:

- Monitoring of Grid transformer neutrals for GICs and provision of alarms to allow appropriate operator actions, including unit power reduction, or in extreme cases, disconnection of the unit from the Grid.

- Selection of power transformers in accordance with specification parameters and performance characteristics defined within IEEE Standard C57.163-2015. The susceptibility classification of transformers will be determined as part of evaluation and hazard reviews.
- Using current limiting capacitance in transformer neutrals to block low frequencies.
- Use of Neutral Blocking/bypass devices to prevent flow of quasi-Direct currents due to GIC.

8.5.2.2.2 Solar Energy Particles and Solar Radio Bursts

The severity and probability from solar energy particles (SEPs) and solar radio bursts (SRBs) hazards will be dependent on the location of the site.

Possible methods of mitigation are:

- Avoiding the use of equipment that is susceptible (e.g. depends on radio communication bands that are affected).
- Shielding of EC&I equipment, to achieve pre-defined Functional EMC requirements.

Work on these hazards is ongoing to understand the level of impact and the design features required to mitigate the hazards.

8.5.2.3 Industrial EMI

Industrial sources of EMI are yet to be assessed, potential industrial EMI may originate from sources such as the following:

- Local and portable transmitters (radar stations, mobiles, malicious, plant equipment, etc.)
- Conducted EMI (switching impulses, harmonics, etc.)
- Coupled EMI (from large current flows)
- ESD (Electrostatic discharge)
- Magnetic fields.

8.6 Conclusions

8.6.1 ALARP, BAT, Secure by Design, Safeguards by Design

The design of all SSCs presented in this chapter are developed in accordance with the Engineering Management Plan for Rolls-Royce SMR. [42] This includes alignment to relevant good practice (RGP) and operating experience (OPEX), design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant criteria that ensure risks are reduced to ALARP, apply BAT, and are secure by design and safeguards by design, as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [43]. This provides confidence that claims can be met when the full suite of arguments and evidence is developed.

The overall demonstration of ALARP, BAT, secure by design and safeguards by design at RD7/DRP1 is presented in E3S Case Chapters 24 [44], 27 [45], 32 [46] and 33 [47] respectively.

8.6.2 Assumptions and Commitments on Future Dutyholder / Licensee / Permit Holder

None identified at this revision.

8.6.3 Conclusions and Forward Look

The generic E3S Case at Version 2 is 'to provide confidence that the RR SMR design will be capable of delivering the E3S fundamental objective as it developed from a concept design into a detailed design' [1]. This confidence is built through development and underpinning of top-level claims across each chapter of the E3S Case, through supporting arguments and evidence. The top-level claim for chapter 8 is "Electrical Power Systems are conservatively designed and verified to deliver E3S functions through-life, in accordance with the E3S design principles, to reduce risks to ALARP, apply BAT and in line with secure by design and safeguards by design".

The arguments and evidence presented to meet the generic E3S Case objective at Version 2 include:

- The Electrical Power Systems SSC design at RD7/DRP1 is developed and evaluated in accordance with the E3S design principles [19] through the integrated E3S and engineering processes, including design optioneering using RGP, to drive risk reduction to ALARP, and to demonstrate BAT, secure by design and safeguards by design. However, no functional requirements for environment, security and safeguards are placed onto SSCs within the Electrical Power Systems at RD7/DRP1.

- The Electrical Power Systems architecture has been developed with appropriate Defence in Depth to provide suitably reliable and robust electrical power to known electrical load groups. The precise linking of each electrical load to an Electrical Power System division is pending the flow of Safety Requirements.

- The Layout of the Electrical Power Systems includes separation provisions intended to achieve divisional independence. The plant Layout activities are being developed to finalise separation of major divisional cable routes.

- The Electrical Power Systems design basis includes applicable Codes and Standards, Design Rules and Philosophies, which encapsulate over-arching non-functional system requirements derived from the E3S design principles [19], relevant good practice (RGP) and operating experience (OPEX).

- At Electrical Power System level, system functions are defined, along with functional and non-functional requirements. SSCs are categorised in accordance with the E3S categorisation and classification methodology [25]. System lifecycle activities are described (ICOM, Operation, EMIT).

- Design decisions are documented, to record the down-selection of options in accordance with criteria to ensure risks are reduced to ALARP.

Further arguments and evidence to underpin the claim will be developed in line with the E3S Case Route Map [2] and reported in future revisions of the generic E3S Case, which will further build confidence that the RR SMR can deliver its fundamental E3S objective. This broadly includes:

- Develop a complete set of E3S requirements for the Electrical Power Systems, subsystems and components, including any environment, security and safeguards requirements

- Develop associated verification and validation activities for E3S requirements

- Design of the Generator Transmission Main Connection [MS_] and Lighting Systems [XQ], and further detailed design development of all Electrical Power SSCs

- Conduct relevant safety, reliability, and human factors assessments of the design

- Continue the development of the installations, commissioning, maintenance and decommissioning philosophies of the Electrical Power Systems

- Continue the development of the layout of Electrical Power SSCs within the RR SMR plant including full development of the modularisation in line with build certainty guidelines

- Develop the manual/mechanical handling and maintenance procedures for all equipment within the Electrical Power Systems

- Flow of transverse requirements into Electrical Power Systems Requirements modules in DOORS

- Develop the basic functions allocated to the C&I systems and details of alarms, warnings and control logic

- Conduct further Hazard Assessments for the Electrical Power Systems.

8.7 References

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[2] RR SMR Report, SMR0002155/003, “E3S Case CAE Route Map,” November 2023.

[3] RR SMR Report, SMR0006160/002, “Electrical Power System Codes and Standards,” January 2023.

[4] RR SMR Report, SMR0003929/003, “Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 7: Instrumentation and Control,” May 2024.

[5] RR SMR Report, SMR0006019/001, “System Design Description for the Electrical Systems [A, B, MS, XF, XQ],” July 2023.

[6] RR SMR Report, SMR0001400/003, “Key Single Line Diagram: Electrical Power System,” December 2023.

[7] RR SMR Report, SMR0006329/002, “Essential Reactor Island - Single Line Diagram,” December 2023.

[8] RR SMR Report, SMR0006330/002, “Essential Turbine Island - Single Line Diagram,” December 2023.

[9] RR SMR Report, SMR0006331/001, “Essential Balance Of Plant - Single Line Diagram,” June 2023.

[10] RR SMR Report, SMR0006332/001, “Essential All Other Areas - Single Line Diagram,” June 2023.

[11] RR SMR Report, SMR0000975/003, “Overall Electrical Load Schedule,” Nov 2023.

[12] RR SMR Report, SMR0006684/002, “Electrical Systems Layout Plan Report,” August 2023.

[13] RR SMR Report, SMR0001287/003, “General Arrangement Site Plan – Berm Site,” November 2023.

[14] RR SMR Report, SMR0008140/001, “Reactor Island EC&I Systems Layout Summary Report,” January 2024.

[15] RR SMR Report, SMR0007514/001, “TURBINE ISLAND - LEVEL 00 GENERAL ARRANGEMENT FLOOR PLAN,” August 2023.

[16] RR SMR Report, SMR0007515/001, “TURBINE ISLAND - LEVEL 02 GENERAL ARRANGEMENT FLOOR PLAN,” August 2023.

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[19] RR SMR Report, SMR0001603/001, “Environment, Safety, Security and Safeguarding Design Principles,” August 2022.

[20] RR SMR Report, SMR0001535/002, “RR SMR GB Generic Site Envelope,” June 2023.

[21] RR SMR Report, SMR0005438/002, “SMR Electrical Protection Philosophy and Smart Devices,” July 2023.

[22] RR SMR Report, SMR0006313/001, “Cable Routing Philosophy,” July 2023.

[23] RR SMR Report, SMR0003977/003, “Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 15: Safety Analysis,” May 2024.

[24] RR SMR Report, SMR0004444/003, “RR SMR Fault Schedule,” January 2024.

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[26] RR SMR Report, SMR0001391/002, "Rolls-Royce Small Modular Reactor Seismic Performance Classification Method," Oct 2022.

[27] RR SMR Report, SMR0003587/001, "[ECI-12] – AC System Offsite Power Connection – Decision Record," Jan 2023.

[28] RR SMR Report, SMR0004363/003, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 23: Structural Integrity," May 2024.

[29] RR SMR Report, SMR0003863/003, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 9A: Auxiliary Systems," May 2024.

[30] RR SMR Report, SMR0005213/001, "Power Station Operating Philosophy," July 2023.

[31] RR SMR Report, SMR0006900/001, "Reactor Island Operating Philosophy," July 2023.

[32] RR SMR Report, EDNS01000540444/001, "Electrical Power System Hazard Identification," March 2017.

[33] RR SMR Report, SMR0004289/003, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 14: Plant Construction and Commissioning," May 2024.

[34] RR SMR Report, EDNS01000488614/001, "Small Modular Reactor – Installation and Commissioning Policy," September 2016.

[35] International Atomic Energy Agency, "Commissioning for Nuclear Power Plants, Specific Safety Guide No. SSG-28," 2014.

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[41] RR SMR Report, SMR0006241/001, "SMR Earthing & Lightning Protection Philosophy," July 2023.

[42] RR SMR Report, SMR0000520/003, "Engineering Management Plan for Rolls-Royce SMR," October 2022.

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[44] RR SMR Report, SMR0004487/003, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 24: ALARP Summary," May 2024.

[45] RR SMR Report, SMR0008113/001, "Environment, Safety, Security and Safeguards Case Chapter 27: Demonstration of Best Available Techniques," February 2024.

[46] RR SMR Report, SMR0004682/001, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 32: Generic Security Report," May 2024.

[47] RR SMR Report, SMR0004293/003, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 33: Safeguards," May 2024.

8.8 Appendix A: Claims, Arguments, Evidence

Table 8.8-1 provides a mapping of the claims to the corresponding sections of the chapter that summarise the arguments and/or evidence. The full decomposition of claims and link to underpinning Tier 2 and Tier 3 information containing the detailed arguments and evidence is presented in the E3S Case Route Map [2]. The route map includes the trajectory of Tier 2 and Tier 3 information as the generic E3S Case develops, which will be incorporated into Tier 1 chapters as it becomes available and in line with generic E3S Case issues described in [1].

Table 8.8-1: Mapping of Claims to Chapter Sections

Claim	Section of Chapter 8 containing Arguments / Evidence summary
Electrical Power Systems non-functional system requirements are complete	8.3.1.2.2 8.4.1.1.2.2 8.4.1.2.2.2 8.4.1.3.2.2 8.4.1.4.2.2 8.4.2.1.2.2 8.4.2.2.2.2 8.4.3.1.2.2 8.4.4.1.2.2 8.4.4.2.2.2 8.4.4.3.2.2
Electrical Power Systems non-functional system requirements are correctly assigned	8.3.1.2.2 8.4.1.1.2.2 8.4.1.2.2.2 8.4.1.3.2.2 8.4.1.4.2.2 8.4.2.1.2.2 8.4.2.2.2.2 8.4.3.1.2.2 8.4.4.1.2.2 8.4.4.2.2.2 8.4.4.3.2.2
Electrical Power Systems codes and standards are correctly assigned	8.0.4
Safety requirements for the Electrical Power Systems are complete	8.3.1.2.1 8.4.1.1.2.1 8.4.1.2.2.1 8.4.1.3.2.1 8.4.1.4.2.1

Claim	Section of Chapter 8 containing Arguments / Evidence summary
	8.4.2.1.2.1 8.4.2.2.2.1 8.4.3.1.2.1 8.4.4.1.2.1 8.4.4.2.2.1 8.4.4.3.2.1
Environmental functional requirements for the Electrical Power Systems are complete	None at this revision
Security functional requirements for the Electrical Power Systems are complete	None at this revision
Safeguards functional requirements for the Electrical Power Systems are complete	None at this revision
The Electrical Power Systems are classified correctly	8.3.1.2.3 8.4.1.1.2.3 8.4.1.2.2.3 8.4.1.3.2.3 8.4.1.4.2.3 8.4.2.1.2.3 8.4.2.2.2.3 8.4.3.1.2.3 8.4.4.1.2.3 8.4.4.2.2.3 8.4.4.3.2.3 8.5.1.1.2.3
The Electrical Power Systems design achieves its E3S functional requirements	8.3.1.3 8.4.1.1.3 8.4.1.2.3 8.4.1.3.3 8.4.1.4.3 8.4.2.1.3 8.4.2.2.3 8.4.3.1.3 8.4.4.1.3 8.4.4.2.3 8.4.4.3.3
The Electrical Power Systems design achieves its E3S non-functional system requirements	8.3.1.3 8.4.1.1.3 8.4.1.2.3

Claim	Section of Chapter 8 containing Arguments / Evidence summary
	8.4.1.3.3 8.4.1.4.3 8.4.2.1.3 8.4.2.2.3 8.4.3.1.3 8.4.4.1.3 8.4.4.2.3 8.4.4.3.3
The layout design facilitates the Electrical Power Systems achieving its E3S requirements	8.1.2
The Electrical Power Systems design definition is verified to meet its requirements	Not covered in this revision
The implemented Electrical Power Systems system is validated to meet its E3S functions	Not covered in this revision
Verification of the Electrical Power Systems system is preserved through its operational life	Not covered in this revision

8.9 Appendix B: SSCs in Scope of Chapter 8

Table 8.9-1 lists those SSCs that are within the scope of Chapter 8, and the section of the chapter they are addressed.

Table 8.9-1: SSCs in Scope of Chapter 8

RDS-PP®	SSC	Section in Chapter 8
A	Grid transmission system	8.3.1
AC_	400 kV Grid Transmission Connection System	
B	Electrical power system	8.1
BB_	High Voltage Main AC Supply System	8.4.1.1
BC_	High Voltage Main AC Standby Supply System	8.4.1.2
BD_	High Voltage Essential AC Standby Supply System	8.4.2.1
BF_	Low Voltage Main AC Supply System for Process Equipment	8.4.1.3
BG_	Low Voltage Main AC Supply System for Non-Process Equipment	8.4.1.4
BK_	Low Voltage Essential AC Standby Supply System	8.4.2.2
BL_	Low Voltage Essential AC Alternate Supply System	8.4.3.1
BM_	Low Voltage Uninterruptible AC Supply System	8.4.4.3
BP_	Low Voltage Uninterruptible direct current (DC) Supply System	8.4.4.2
BQ_	Low Voltage Uninterruptible DC Supply System for Safety Services	8.4.4.1
MS_	Generator Transmission Main Connection	Not covered in this revision.
XF	Earthing and Lightning Protection System	8.5
XFA	Earthing/Grounding System	
XFB	Equipotential Bonding System	
XFC	External Lightning Protection	
XFD	Internal Lightning Protection	
XQ	Lighting Systems	Not covered in this revision.

8.10 Abbreviations

AC	Alternating Current
ACMS	Auxiliary Cooling and Make-Up System
AFNOR	Association Française de Normalisation
ALARP	As Low As Reasonably Practicable
AMS	Accident Management System
ASF	Alternative Shutdown Function
BAT	Best Available Techniques
BoP	Balance of Plant
BS	British Standard
CAE	Claim, Argument, Evidence
C&I	Control and Instrumentation
CoFT	Control of Fuel Temperature
CoR	Control of Reactivity
CoRE	Control of Radiation Exposure
CoRM	Confinement of Radioactive Material
DBC	Design Basis Condition
DC	Direct Current
DEC	Design Extension Condition
DiD	Defence in Depth
DOORS	Dynamic Object-Oriented Requirements System
DPS	Diverse Protection System
DRP	Design Reference Point
DSEAR	The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002
E3S	Environmental, Safety, Security and Safeguards
EC&I	Electric, Control and Instrumentation
ECC	Emergency Core Cooling
EDG	Emergency Diesel Generator
EMC	Electromagnetic Compatibility

EMI	Electromagnetic Interference
EMIT	Examination, Maintenance, Inspection and Testing
EMP	Electromagnetic Pulse
EN	European Norm adopted as a British Standard
EPRI	Electric Power Research Institute
ESD	Electrostatic Discharge
FSF	Fundamental Safety Function
GDA	Generic Design Assessment
HAZID	Hazard Identification
HLSF	High Level Safety Function
HPIS	High-Pressure Injection System
HV	High Voltage
HVAC	Heating, Ventilation and Cooling
IAEA	International Atomic Energy Agency
IBM	International Business Machines Corporation
ICOM	Installation and Commissioning
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IET	The Institution of Engineering and Technology
ISI	In Service Inspection
ISO	International Organization for Standardization
LOE	Loss of Electrics
LOOP	Loss of Offsite Power
LPS	Lightning Protection System
LV	Low Voltage
MCWS	Main Cooling Water System
OPEX	Operating Experience

PAMS	Post Accident Management System
PBS	Product Breakdown Structure
PCD	Preliminary Concept Definition
PDHR	Passive Decay Heat Removal
PIE	Postulated Initiating Events
PMDB	Preventive Maintenance Basis Database
PWR	Pressurised Water Reactor
RCM	Reliability Centred Maintenance
RD	Reference Design
RDS-PP®	Reference Designation System for Power Plants
RGP	Relevant Good Practice
RPCS	Reactor Plant Control System
RPS	Reactor Protection System
RR SMR	Rolls-Royce Small Modular Reactor
SAMS	Severe Accident Management System
SBO	Station Blackout
SDD	System Design Description
SLD	Single Line Diagram
SMR	Small Modular Reactor
SPC	Seismic Performance Class
SSC	System, Structure, Component
TBD	To be developed
TSO	Transmission System Operator
UK	United Kingdom
UPS	Uninterruptible Power Supply
VFD	Variable Frequency Drive
VRLA	Valve Regulated Lead Acid