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Pre-Construction Safety Report

Chapter 9

Electric Power

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9.1 List of Abbreviations and Acronyms

AAD	Startup and Shutdown Feedwater System [SSFS]
AC	Alternating Current
ALARP	As Low As Reasonably Practicable
APA	Motor Driven Feedwater Pump System [MFPS]
ASG	Emergency Feedwater System [EFWS]
AT	Auxiliary Transformer
ATE	Condensate Polishing System [CPS]
BAX	Access Building
BDA	Emergency Diesel Generator Building A
BDB	Emergency Diesel Generator Building B
BDC	Emergency Diesel Generator Building C
BDU	SBO Diesel Generator Building for Train A
BDV	SBO Diesel Generator Building for Train B
BNX	Nuclear Auxiliary Building
BOP	Balance of Plant
BS	British Standard
BSA	Safeguard Building A
BSB	Safeguard Building B
BSC	Safeguard Building C
CCF	Common Cause Failure
CEX	Condensate Extraction System [CES]
CI	Conventional Island
CRF	Circulating Water System [CWS]
DBC	Design Basis Condition
DC	Direct Current
DCL	Main Control Room Air Conditioning System [MCRACS]
DCS	Digital Control System

DEC	Design Extension Condition
DEL	Safety Chilled Water System [SCWS]
DER	Operational Chilled Water System [OCWS]
DFL	Smoke Control System [SCS]
DG	Diesel Generator
DiD	Defence in Depth
DSA	Deterministic Safety Analysis
DSM	Turbine Hall Emergency Lighting System [THELS]
DSS	Safeguard Building Emergency Lighting System [SBELS]
DVD	Diesel Building Ventilation System [DBVS]
DVF	Conventional Island Electrical Building Ventilation System [CIEBVS]
DVL	Electrical Division of Safeguard Building Ventilation System [EDSBVS])
DWL	Safeguard Building Controlled Area Ventilation System [SBCAVS]
DWN	Nuclear Auxiliary Building Ventilation System [NABVS]
DXE	Extra Cooling Water and NI Firefighting Building Ventilation System [ECW&FFB VS]
EBA	Containment Sweeping and Blowndown Ventilation System [CSBVS]
ECS	Extra Cooling System [ECS]
EDE	Annulus Ventilation System [AVS]
EDG	Emergency Diesel Generator
EHR	Containment Heat Removal System [CHRS]
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMIT	Examination, Maintenance, Inspection and Testing
EOMM	Equipment Operation and Maintenance Manuals
EUF	Containment Filtration and Exhaust System [CFES]

EUH	Containment Combustible Gas Control System [CCGCS]
EVR	Containment Cooling and Ventilation System [CCVS]
FCG3	Fangchenggang Nuclear Power Plant Unit 3
GCB	Generator Circuit Breaker
GEX	Power Transmission System [PTS]
GGR	Turbine Lubrication, Jacking and Turning System [TLJTS]
GHE	Generator Seal Oil System [GSOS]
GIC	Geomagnetic Induced Current
GPA	Generator and Power Transmission Protection System [GPTPS]
GSY	Grid Synchronization and Connection System [GSCS]
HFE	Human Factors Engineering
HMI	Human Machine Interface
HPR1000 (FCG3)	Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3
HVAC	Heating, Ventilation and Air Conditioning
I&C	Instrumentation and Control
IAEA	International Atomic Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IPB	Isolated Phase Busbar
JAC	Fire-fighting Water Production System [FWPS]
JDT	Fire Alarm System [FAS]
JPI	Nuclear Island Fire Protection System [NIFPS]
KCP	Non-safety Process Control Cabinet System [NPCCS]
KCS	Safety Process Control Cabinet System [SPCCS]
KDA	Severe Accident I&C System [SA I&C]
KKO	Energy Measuring and Metering and Substation I&C System [EMSS]
KRT	Plant Radiation Monitoring System [PRMS]

LAA	NI 220V DC Power Supply and Distribution System (2h) [DCPS (NI-220V-2h)]
LAB	NI 220V DC Power Supply and Distribution System (2h) [DCPS (NI-220V-2h)]
LAC	NI 220V DC Power Supply and Distribution System (2h) [DCPS (NI-220V-2h)]
LAD	NI 220V DC Power Supply and Distribution System (2h) [DCPS (NI-220V-2h)]
LAM	CI 220V DC Power Supply and Distribution System (2h) [DCPS (CI-220V-2h)]
LAN	CI 220V DC Power Supply and Distribution System (2h) [DCPS (CI-220V-2h)]
LAP	NI 220V DC Power Supply and Distribution System (12h) [DCPS (NI-220V-12h)]
LAQ	NI 220V DC Power Supply and Distribution System (12h) [DCPS (NI-220V-12h)]
LAR	CI 220V DC Power Supply and Distribution System [DCPS (CI-220V)]
LGA	CI 10kV Normal Power Distribution System [NPDS (CI-10kV)]
LGB	CI 10kV Normal Power Distribution System [NPDS (CI-10kV)]
LGC	CI 10kV Normal Power Distribution System [NPDS (CI-10kV)]
LGD	CI 10kV Normal Power Distribution System [NPDS (CI-10kV)]
LGE	CI 10kV Normal Power Distribution System [NPDS (CI-10kV)]
LGF	CI 10kV Normal Power Distribution System [NPDS (CI-10kV)]
LGG	CI 10kV Normal Power Distribution System [NPDS (CI-10kV)]
LGH	CI 10kV Normal Power Distribution System [NPDS (CI-10kV)]
LGM	NI 10kV Normal Power Distribution System [NPDS (NI-10kV)]
LGN	NI 10kV Normal Power Distribution System [NPDS (NI-10kV)]
LGO	NI 10kV Normal Power Distribution System [NPDS (NI-10kV)]

LGP	NI 10kV Normal Power Distribution System [NPDS (NI-10kV)]
LGQ	NI 10kV Normal Power Distribution System [NPDS (NI-10kV)]
LHA	NI 10kV Emergency Power Distribution System [EPDS (NI-10kV)]
LHB	NI 10kV Emergency Power Distribution System [EPDS (NI-10kV)]
LHC	NI 10kV Emergency Power Distribution System [EPDS (NI-10kV)]
LHM	NI 10kV SBO Power Distribution System [SBOPDS (NI-10kV)]
LHN	NI 10kV SBO Power Distribution System [SBOPDS (NI-10kV)]
LHP	NI 10kV Emergency Power Supply System [EPSS (NI-10kV)]
LHQ	NI 10kV Emergency Power Supply System [EPSS (NI-10kV)]
LHR	NI 10kV Emergency Power Supply System [EPSS (NI-10kV)]
LHSI	Low Head Safety Injection
LHU	NI 10kV SBO Power Supply System [SBOPSS (NI-10kV)]
LHV	NI 10kV SBO Power Supply System [SBOPSS (NI-10kV)]
LKA	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LKB	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LKC	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LKD	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LKE	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LKF	NI 380V Normal Power Distribution System [NPDS (NI-380V)]

LKG	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LKH	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LKI	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LKJ	CI 380V Normal Power Distribution System [NPDS (CI-380V)]
LKK	CI 380V Normal Power Distribution System [NPDS (CI-380V)]
LKL	CI 380V Normal Power Distribution System [NPDS (CI-380V)]
LKM	CI 380V Normal Power Distribution System [NPDS (CI-380V)]
LKN	CI 380V Normal Power Distribution System [NPDS (CI-380V)]
LKO	CI 380V Normal Power Distribution System [NPDS (CI-380V)]
LKR	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LKU	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LKV	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LKW	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LLA	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LLB	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LLC	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LLD	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LLE	NI 380V Normal Power Distribution System [NPDS (NI-380V)]
LLF	NI 380V Normal Power Distribution System [NPDS (NI-380V)]

LLG	NI 380V SBO Power Distribution System [SBOPDS (NI-380V)]
LLH	NI 380V Emergency Power Distribution System [EPDS (NI-380V)]
LLI	NI 380V Emergency Power Distribution System [EPDS (NI-380V)]
LLJ	NI 380V Emergency Power Distribution System [EPDS (NI-380V)]
LLM	NI 380V SBO Power Distribution System [SBOPDS (NI-380V)]
LLN	NI 380V SBO Power Distribution System [SBOPDS (NI-380V)]
LOA	NI 380V AC Regulated Power System [ACRPS (NI-380V)]
LOB	NI 380V AC Regulated Power System [ACRPS (NI-380V)]
LOC	NI 380V AC Regulated Power System [ACRPS (NI-380V)]
LOCA	Loss of Coolant Accident
LOD	NI 380V AC Regulated Power System [ACRPS (NI-380V)]
LOE	NI 380V AC Regulated Power System [ACRPS (NI-380V)]
LOF	NI 380V AC Regulated Power System [ACRPS (NI-380V)]
LOOP	Loss of Offsite Power
LVA	NI 380V AC Uninterruptible Power System (2h) [UPS (NI-380V-2h)]
LVB	NI 380V AC Uninterruptible Power System (2h) [UPS (NI-380V-2h)]
LVC	NI 380V AC Uninterruptible Power System (2h) [UPS (NI-380V-2h)]
LVD	NI 380V AC Uninterruptible Power System (2h) [UPS (NI-380V-2h)]
LVM	CI 380V AC Uninterruptible Power System (2h) [UPS (CI-380V-2h)]
LVN	CI 380V AC Uninterruptible Power System (2h) [UPS (CI-380V-2h)]

LVP	NI 380V AC Uninterruptible Power System (12h) [UPS (NI-380V-12h)]
LVQ	NI 380V AC Uninterruptible Power System (12h) [UPS (NI-380V-12h)]
MCR	Main Control Room
MHSI	Medium Head Safety Injection
NC	Non-Classified
NI	Nuclear Island
NPP	Nuclear Power Plant
PCSR	Pre-Construction Safety Report
PIE	Postulated Initiating Event
PMC	Fuel Handling and Storage System [FHSS]
PS	Protection System
PSA	Probabilistic Safety Assessment
PSAS	Plant Standard Automation System
PTR	Fuel Pool Cooling and Treatment System [FPCTS]
RBS	Emergency Boration System [EBS]
RCD	Reactor Completely Discharge
RCP	Reactor Coolant System [RCS]
RCV	Chemical and Volume Control System [CVCS]
REA	Reactor Boron and Water Makeup System [RBWMS]
REN	Nuclear Sampling System [NSS]
RGP	Relevant Good Practice
RIS	Safety Injection System [SIS]
RPE	Nuclear Island Vent and Drain System [VDS]
RPN	Nuclear Instrumentation System [NIS]
RRI	Component Cooling Water System [CCWS]
SAS[1]	Safety Automation System
SBO	Station Black Out

SEC	Essential Service Water System [ESWS]
SFC	Single Failure Criterion
SRI	Conventional Island Closed Cooling Water System [CICCWS]
SSCs	Structures, Systems and Components
ST	Standby Transformer
TEG	Gaseous Waste Treatment System [GWTS]
TEP	Coolant Storage and Treatment System [CSTS]
UK HPR1000	UK version of the Hua-long Pressurised Reactor
UPS	Uninterruptible Power Supply
UT	Unit Transformer

System codes (XXX) and system abbreviations (YYY) are provided for completeness in the format (XXX [YYY]), e.g. Nuclear Island (NI) 220V Direct Current (DC) Power Supply and Distribution System (2h) (LAA [DCPS (NI-220V-2h)]).

9.2 Introduction

The main objective of this chapter is to present the design information of the electrical power system in the UK version of the Hua-long Pressurised Reactor (UK HPR1000) Nuclear Power Plant (NPP). This chapter belongs to the electrical engineering area of the Pre-Construction Safety Report (PCSR). Design information of the electrical power system and its component is addressed in this chapter to demonstrate that the system design meets the performance requirements.

9.2.1 Chapter Route Map

The ***Fundamental Objective*** of UK HPR1000 is that: *The Generic UK HPR1000 could be constructed, operated, and decommissioned in the UK on a site bounded by the generic site envelope in a way that is safe, secure and that protects people and the environment.*

To underpin this objective**,** five high level claims and a number of level 2 claims are developed and presented in Chapter 1. This chapter supports ***Claim 3.3*** derived from high level ***Claim 3*** through ***Claim 3.3.5***.

Claim 3*: The design and intended construction and operation of the UK HPR1000 will protect the workers and the public by providing multiple levels of defence to fulfil the fundamental safety functions, reducing the nuclear safety risks to a level that is as low as reasonably practicable.*

Claim 3.3*: The design of the processes and systems has been substantiated and the* *safety aspects of operation and management have been substantiated.*

Claim 3.3.5: *The design of the electrical power systems have been substantiated.*

To support ***Claim 3.3.5***, this chapter developed five Sub-claims and a number of relevant arguments and evidences. The sub-claims and arguments are listed below, how this chapter supports the sub-claims and arguments is presented in Appendix 9A and the list of evidence and relationship between arguments and evidence are presented in the *Basis of Safety Case on Electrical Power System*, Reference [1].

a) **Sub-claim 1**: The safety functional requirements (Design Basis) have been derived for the system:

   1) ***Argument 1.1****: The electrical power system safety function has been derived from the safety analysis: the electrical power system supports Structures, Systems and Components (SSCs) in performing the fundamental safety function of reactivity control by providing the required power supplies;*

   2) ***Argument 1.2****: The electrical power system safety function has been derived from the safety analysis: the electrical power system supports SSCs in performing the fundamental safety function of heat removal by providing the required power supplies;*

   3) ***Argument 1.3****: The electrical power system safety function has been derived from the safety analysis: the electrical power system supports SSCs in performing the fundamental safety function of confinement by providing the required power supplies;*

b) ***Sub-claim 2****: The system design satisfies the safety functional requirements:*

   1) ***Argument 2.1****: The electrical power system features are identified according to the safety function;*

      − *Categorisation and Classification: The Categorisation and Classification of the electrical power system is consistent with the general Categorisation and Classification approach of the UK HPR1000 NPP;*

      − *Defence in Depth (DiD): The DiD approach in the electrical power system is consistent with the overall DiD levels of the UK HPR1000 NPP;*

      − *Redundancy and Single Failure Criterion: The redundancy approach in the electrical power system is consistent with the overall redundancy and Single Failure Criterion requirement of the UK HPR1000 NPP;*

      − *Independence: The independence approach in the electrical power system is consistent with the overall independence principle of the UK*

HPR1000 NPP;

- *Common Cause Failure (CCF): The electrical power system offers resilience to CCF;*
- *Hazards: The electrical power system is robust with respect to the internal and external hazards;*
- *Qualification: The equipment of* the *electrical power system is qualified for its service conditions;*
- *Human factor: The design of the electrical power system meets the overall human factor requirement of the UK HPR1000 NPP.*

2) ***Argument 2.2****: The electrical power system features are identified according to the electrical design requirements;*

- *Load allocation: The loads are allocated to the electrical power system according to the operating condition and continuity requirement of the power supply;*
- *Rating: The equipment of the electrical power systems has a sufficient margin in all identified operating modes in comparison with its nominal rating;*
- *Electrical Protection: The electrical protection scheme limits the effect of the failures;*
- *Design Analysis: The design of the electrical power system is analysed and verified by electrical power system studies.*

3) ***Argument 2.3****: The electrical power system features are identified according to the interface requirements and effects from / to interfacing systems.*

- *The electrical power system design takes into account the power grid connection requirements and the plant can be connected with the grid;*
- *The electrical power system is designed to be resilient to electrical disturbances originating in the off-site power grid and on-site power network.*

c) ***Sub-claim 3****: All reasonably practicable measures have been adopted to improve the design:*

1) ***Argument 3.1****: The design of the electrical power system meets applicable standards, based on Relevant Good Practice (RGP) and operating experience, suitable for the UK context;*

2) ***Argument 3.2****: The electrical power system is analysed in fault analysis and the result is acceptable;*

3) ***Argument 3.3**: Design improvements have been considered and adopted where reasonably practicable.*

d) ***Sub-claim 4**: The system performance will be validated by suitable commissioning and testing:*

1) ***Argument 4.1**: The electrical power system has been designed to take benefit from a suite of pre-construction tests, to provide assurance of the initial quality of the manufacturing;*

2) ***Argument 4.2**: The electrical power system has been designed to take benefit from a suite of commissioning tests, to provide assurance of the initial quality of the build.*

e) ***Sub-claim 5**: The effects of ageing of the system have been addressed in the design and suitable Examination, Maintenance, Inspection and Testing (EMIT) specified:*

1) ***Argument 5.1**: An initial EMIT strategy has been developed for the electrical power system, identifying components that are expected to be examined, maintained, inspected and tested;*

2) ***Argument 5.2**: The components that are not intended to be replaced have been shown to have an adequate design life.*

9.2.2 Chapter Structure

The structure of this chapter is as follows:

a) Sub-chapter 9.1 lists the abbreviations and acronyms mentioned in PCSR Chapter 9;

b) Sub-chapter 9.2 provides the brief introduction of PCSR Chapter 9. The sub-claims and arguments of electrical power system are presented in this sub-chapter, together with how the sub-chapters support the sub-claims and arguments;

c) Sub-chapter 9.3 provides the information on applicable codes and standards. The general process and principle on selection of codes and standards of electrical power system are briefly introduced and parts of the applicable codes and standards are listed;

d) Sub-chapter 9.4 provides the architecture of the electrical power system. This sub-chapter explains how the electrical power system architecture supports a UK context understanding of DiD in the UK HPR1000 design, how the functional requirements are derived from the safety analysis and how it supports adequate reliability through multiple divisions;

e) Sub-chapter 9.5, 9.6 and 9.7 are system sub-chapters, which provide the design information of the off-site electrical power system, on-site electrical power system and auxiliary electrical system. These system sub-chapters of this PCSR chapter follow a common structure, which covers the following areas:

1) Safety requirements

This part confirms whether the electrical power system supports the four safety functions, and identifies applicable design requirements from PCSR Chapter 4 based on an assumed safety category of the low level safety function applying to the system.

2) Design Basis

This part identifies key assumptions for the electrical power system, based on its expected contribution to the low level safety functions. It also identifies assumptions regarding the interfacing electrical power system sub-systems and supporting sub-systems that are required for this sub-system to function.

3) System description and operation

This section provides a description of the SSCs that make up the electrical power system, their location and operation in different plant states.

4) Design Substantiation

This section identifies the SSCs supported by the electrical power system, which type of low level safety functions they contribute to (reactivity control, heat removal, confinement, extra), and confirms that the category of supported functions is consistent with the electrical power system function category. Full traceability between the SSCs supported, their low level safety function and the electrical power system low level safety function are provided in the *Basis of Safety Case on Electrical Power System*, Reference [1].

f) Sub-chapter 9.8 provides a general introduction to the specific principles. These issues and principles derived from electrical power system sub-claims and arguments but not systematically covered in the system sub-chapters are discussed in this sub-chapter;

g) Sub-chapter 9.9 provides a brief introduction to the As Low As Reasonably Practicable (ALARP) assessment of the electrical power system;

h) Sub-chapter 9.10 provides the approach to commissioning of the electrical power system;

i) Sub-chapter 9.11 provides the ageing and EMIT considerations of the electrical power system;

j) Sub-chapter 9.12 describes concluding remarks of the electrical power system;

k) Sub-chapter 9.13 provides the list of references.

9.2.3 Interfaces with Other Chapters

The interfaces with other chapters are listed in the following table.

T-9.2-1 Interfaces between Chapter 9 and Other Chapters

PCSR Chapter	Interface
Chapter 1 Introduction	Chapter 1 provides the fundamental objective, Level 1 claims and Level 2 claims. Chapter 9 provides chapter claims and arguments to support Level 2 Claim 3.3 that is addressed in Chapter 1.
Chapter 2 General Plant Description	Chapter 9 is summarized in Chapter 2.
Chapter 3 Generic Site Characteristics	The generic site characteristic provided in Chapter 3 is applied in Chapter 9. Grid connection is summarised in Chapter 3 and detailed in Chapter 9.
Chapter 4 General Safety and Design Principles	Chapter 9 presents the design of the electrical power system which is based on the relevant safety and design principles provided in Chapter 4.
Chapter 6 Reactor Coolant System	Chapter 9 provides the design information relevant to the electrical power system. The electrical power system supports the function of the Reactor Coolant System (RCP [RCS]). The power supply requirement of the RCP [RCS] is described in the references of PCSR Chapter 6. General power supply information of the RCP [RCS] is described in PCSR Chapter 9 and its references.
Chapter 7 Safety Systems	Chapter 7 provides the design information relevant to the safety systems. The power supply requirements of safety systems are described in Chapter 7. General power supply information is described in Chapter 9.
Chapter 8 Instrumentation and Control	The electrical power system in Chapter 9 supports the function of Instrumentation and Control (I&C) system in Chapter 8. The I&C system in Chapter 8 supports the function of the electrical power system in Chapter 9. Chapter 8 also presents the definition and the justification approach of smart devices used in the safety classified I&C system, which are also applicable to those used in the safety classified electrical power system presented in Chapter 9.

PCSR Chapter	Interface
Chapter 10 Auxiliary Systems	The electrical power system in Chapter 9 supports the functions of the auxiliary systems in Chapter 10. Ventilation systems in Chapter 10 support the function of the electrical power system in Chapter 9. The diesel generator engine and the auxiliaries in Chapter 9 are detailed in Chapter 10. Electrical parts of diesel generators in Chapter 10 are detailed in Chapter 9.
Chapter 11 Steam and Power Conversion System	The electrical power system in Chapter 9 supports the function of the steam and power conversion system in Chapter 11.
Chapter 12 Design Basis Condition Analysis	The electrical power system in Chapter 9 is considered in the Design Basis Condition (DBC) fault analysis of Chapter 12. The fault analysis is one of the design inputs of the electrical power system.
Chapter 13 Design Extension Conditions and Severe Accident Analysis	The electrical power system in Chapter 9 is considered in the Design Extension Condition (DEC) fault analysis of Chapter 13. The fault analysis is one of the design inputs of the electrical power system.
Chapter 14 Probabilistic Safety Assessment	Chapter 9 provides design inputs for the Probabilistic Safety Assessment (PSA) and fault trees modeling in Chapter 14. The PSA is used to identify the vulnerabilities in system design to improve the system reliability.
Chapter 15 Human Factors	Chapter 15 provides the principles and methodology of human factor integration. Chapter 9 provides the specific design of electrical power system, which is taken into account for further estimate in human factor area.
Chapter 18 External Hazards	The external hazards defined in Chapter 18 are considered in electrical power system design in Chapter 9.
Chapter 19 Internal Hazards	The internal hazards defined in Chapter 19 are considered in electrical power system design in Chapter 9.
Chapter 20 MSQA and Safety	The organisational arrangements and quality

PCSR Chapter	Interface
Case Management	assurance arrangements set out in Chapter 20 are implemented in the design process and in the production of Chapter 9.
Chapter 23 Radioactive Waste Management	PCSR Chapter 9 provides the design information relevant to the electrical power system. The electrical power system supports the function of the radioactive waste management systems. General power supply information of radioactive waste management systems is described in PCSR Chapter 9 and its reference.
Chapter 25 Conventional Safety and Fire Safety	Conventional safety and fire safety in Chapter 25 is considered in electrical power system design in Chapter 9.
Chapter 30 Commissioning	Chapter 30 provides the arrangements and requirements for commissioning. This design information is considered in Chapter 9.
Chapter 31 Operational Management	Chapter 31 provides the requirements of EMIT and ageing degradation. Chapter 9 provides the electrical power system design substantiation relevant to EMIT and ageing degradation.
Chapter 32 Emergency Preparedness	Chapter 9 provides the design information of communication systems which is related to emergency response in Chapter 32.
Chapter 33 ALARP Evaluation	The ALARP approach presented in Chapter 33 has been applied in Chapter 9 to demonstrate that all reasonably practicable measures have been adopted to improve the design and the safety, which support the overall ALARP demonstration addressed in Chapter 33.

9.3 Applicable Codes and Standards

The codes and standards for electrical design are selected according to the principles and process that presented in the PCSR Sub-chapter 4.4.7.

For Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3 (HPR1000 (FCG3)) electrical design, Chinese codes and standards are applied as a priority, and international codes and standards are applied to supplement them. For the UK HPR1000 design, international codes and standards such as the International Atomic Energy Agency (IAEA) guidance and International Electrotechnical Commission (IEC) standards for electrical power system design are considered as RGP.

As some referenced Chinese guidance is developed from IAEA guidance and some Chinese standards are equivalent to IEC standards, the IAEA guidance and IEC standards are applied as a priority for the UK HPR1000 electrical design. However, some other international codes and standards are referenced additionally to supplement them, further justification is also provided.

The selected codes and standards are demonstrated as RGP and to be sufficient for UK HPR1000 electrical power system design and evaluation. The justification on codes and standards applied in UK HPR1000 electrical design is detailed in *Justification on Codes and Standards of Electrical Engineering*, Reference [2]. Parts of the major codes and standards applied in UK HPR1000 electrical design are listed in the following table.

T-9.3-1 Major Codes and Standards Applied in Electrical Design

No.	Code and Standard No.	Date Issued	Title	Remark
1	SSG-34	2016	Design of electrical power systems for nuclear power plants	---
2	SSG-39	2016	Design of instrumentation and control systems for nuclear power plants	Applied for communication systems.
3	IEC/IEEE 60780-323	2016	Nuclear facilities – electrical equipment to safety – qualification	---
4	IEC 60980	1989	Recommended practices for seismic qualification of electrical equipment of the safety system for nuclear generating station	---
5	RCC-E	2016	Design and construction rules for electrical and I&C systems and equipment	Qualification and separation requirements are applied.
6	BS (British Standard) IEC62855	2016	Nuclear power plants – electrical power systems – analysis	---
7	IEC/TR 61000-5-2	1997	Electromagnetic compatibility (EMC) – part 5: installation and mitigation guidelines – section 2: earthing and cabling	---
8	IEC 62271-1	2007	High-voltage switchgear and controlgear – part 1: common specifications	---

No.	Code and Standard No.	Date Issued	Title	Remark
9	IEC 60364-1	2005	Low-voltage electrical installations	---
10	IEC 60076-1	2011	Power transformers – part 1: general	---
11	IEC 60255-1	2009	Measuring relays and protection equipment – part 1:common requirements	---
12	IEC 60896-11	2002	Stationary lead-acid batteries- part 11: vented types – general requirements and methods of tests	---
13	IEC 60146-1-1	2009	Semiconductor convertors; general requirements and line commutated convertors; part 1-1: specifications of basic requirements	---
14	IEC 62305-1	2010	Protection against lightning -part 1: general principles	---
15	BS EN1838	1999	Lighting applications – emergency lighting	---
16	IEEE 387	1995	Diesel-generator units applied as standby power supplies for nuclear power generating stations	Qualification requirement is applied.

9.4 Architecture of Electrical Power System

The electrical power system that supplies power to systems important to safety is essential to the safety of nuclear power plants. The electrical power system includes both on-site and off-site electrical power systems, which work together to provide necessary power in all plant conditions so that the plant can be maintained in a safe state. Although the external grid does not belong to the nuclear power plant, it plays a significant role in providing DiD to faults and is important to the safety of the nuclear power plant, Reference [3]. For the on-site electrical power system, the Emergency Diesel Generators (EDGs) provide backup supplies to the essential loads for the Loss of Offsite Power (LOOP) condition and there are DiD provisions that include Station Black Out (SBO) Diesel Generators (DGs) to address SBO conditions and mobile DG for accident mitigation.

According to PCSR Sub-chapter 4.4.3.2, the UK HPR1000 plant states are subdivided into 4 categories of DBC (DBC-1, DBC-2, DBC-3 and DBC-4) and 2 categories of

DEC (DEC-A and DEC-B). The analysis of DBC is presented in Chapter 12, and that of DEC in Chapter 13. Failure of the electrical power system is considered in the fault analysis, and electrical power system safety functions are derived from the safety analysis. The three fundamental safety functions are decomposed to high level safety functions and down to low level safety functions, which are then delivered by SSCs. The fault schedule identifies the SSCs providing the main line of protection, and the second line where required for frequent faults. For faults beyond the design basis, and for severe accidents, the design identifies further SSCs which support the low level safety functions in these circumstances. Extra safety functions are also identified for provision of support to reactivity control, heat removal and confinement low level safety functions (for example cooling water to safety system pumps or HVAC controlling safety system temperatures) and for features to limit the effect of hazards. The electrical power systems support the performance of low level safety functions by providing electric power to the SSCs.

The electrical power system architecture is shown in Appendix 9B, which is a simplified diagram based on the *Plant Auxiliary Electrical System Wiring Diagram* and *NI DC and AC UPS System Single Line Diagram*, Reference [4] and [5].

The main safety system loads are indicated on the system architecture diagram. The diagram is divided into areas for division A, division B and division C, and each division is further divided into areas showing whether the safety system loads are classed as DBC loads or DEC loads. In some cases, the safety system loads perform safety function in both DBC and DEC, and this combined class of safety system loads is also indicated on the system architecture diagram.

9.4.1 Defence in Depth

The application of DiD on the electrical power system design of the UK HRP1000 is based on the principle described in PCSR Sub-chapter 4.4.2 and 4.4.3. A comparison of the DiD levels between the IAEA, UK context terminologies and application of UK HPR1000 electrical power system is shown in Table T-9.4-1. The intended electrical power system approach to defence in depth for the UK HPR1000 is as follows:

a) Normal operation: The off-site grid or the main generator provide a power supply to the normal power distribution system. They also supply the emergency and SBO power distribution systems, keep the DC batteries charged and provide power to the loads which are powered from the emergency or SBO power distribution system during normal operation. Electrical protection systems, a standby grid connection and the ability to transfer to house load are provided to minimise the progression from abnormal operations to faults.

b) Design basis faults: The systems delivering the main line of protection are powered from the emergency power distribution systems, with power supply from the grid (if available), from the main generator (if available) or from the

EDGs. For frequent faults where a second line of protection is required, the systems delivering the second line are powered from the SBO power distribution systems, with power supply from the grid (if available), from the main generator (if available), from the EDG (if available) or from the SBO Diesel Generators. {

}

c) Beyond design basis faults and severe accidents: Where systems are provided to mitigate beyond design basis faults, these may be powered from either the emergency or SBO power distribution systems, depending on the detail of the fault. Connections are provided for mobile generator power supply to mitigate loss of grid and all on-site generation sources. Systems provided to mitigate severe accidents are powered by the 12h DC and AC UPS systems.

T-9.4-1 Electrical Power System DiD

IAEA Terminology DiD Levels		UK HPR 1000 Plant State	UK Context Terminology			
			Plant State	DiD Level (used in UK HPR1000)		Application on UK HPR1000 Electrical Power System
1	Prevention of abnormal operation and failures	DBC-1	Normal operation	Prevention of abnormal operation and failures by design	1	The off-site main connection and on-site main generator supply the normal Alternating Current (AC) power distribution system and its loads (Sub-chapter 9.5.2 and 9.6.1).
2	Control of abnormal operation and detection of failures	DBC-2		Prevention and control of abnormal operation and detection of failures	2	a) Electrical power system protection devices and coordination of protection (Sub-chapter 9.8.2); b) House load control (Sub-chapter 9.5.1); c) Off-site standby connection (Sub-chapter 9.5.3) and power supply transfer (Sub-chapter 9.5.4).
3a	Control of design basis accidents	DBC-3	Frequent faults	Control of faults within the design basis to protect against escalation to an accident	3	a) Emergency AC power distribution systems (Sub-chapter 9.6.2); b) EDGs (Sub-chapter 9.6.4); c) NI 2h DC and AC UPS systems (Sub-chapter 9.6.8).
		DBC-4	Infrequent faults			
3b	Control of design extension conditions to prevent core melt	DEC-A	Frequent fault + failure of 1st line of protection			a) SBO AC power distribution systems (Sub-chapter 9.6.3); b) SBO DGs (Sub-chapter 9.6.5). c) NI 2h DC and AC UPS systems for safety system and control power of electrical power systems; d) NI 12h DC and AC UPS systems (Sub-chapter 9.6.9) for alternative control power of electrical power systems.
			Beyond design basis conditions (including severe accident)	Control of severe plant conditions in which the design basis may be exceeded, including protecting against further fault escalation and mitigation of the consequences of severe accidents	4	For Beyond design basis conditions except for severe accidents, the power supplies in Level 3 are used if available; For severe accidents: a) NI 12h DC and AC UPS systems; b) Mobile DG (Sub-chapter 9.6.6).
4	Control of design extension conditions to mitigate the consequences of severe accidents	DEC-B				
5	Mitigation of radiological consequences of significant releases of radioactive materials	N/A	Off-site emergency	Mitigation of radiological consequences of significant releases of radioactive material	5	a) NI 12h DC and AC UPS systems ; b) Mobile DG.

9.4.2 Architecture of One Division

The architecture of one division (division A) is described first, and the relationships with the other divisions and architectural differences will be described later.

AC loads required to support power generation are supplied by the Conventional Island (CI) 10kV Normal Power Distribution System (LGA [NPDS (CI-10kV)]). The LGA [NPDS (CI-10kV)]) is connected to the main generator and the Unit Transformer (UT) via the Auxiliary Transformer (AT). Here, AC power is available from the main generator when it is operating or from the grid when the Generator Circuit Breaker (GCB) is open.

As the loss of off-site main power supply potentially affects many safety functions, the plant is designed with the ability to transfer from 100% power operation to house load operation. This plant transient occurs when grid instability or faults cause the 400kV breakers to trip, resulting in the loads being supplied by the main generator.

When the plant is shut down for maintenance, the AC power is not available from the main generator. The LGA [NPDS (CI-10kV)] switchboard can be de-energized.

Nevertheless, there are loads that require power during unit shutdown, which are supplied by the CI 10kV Normal Power Distribution System (LGB [NPDS (CI-10kV)]). The LGB [NPDS (CI-10kV)] can be powered by the main generator, the off-site main power supply or standby power supply. To minimise process disruptions, there is an automatic transfer of the power supply from the AT to the Standby Transformer (ST), and transfer from the ST to AT can only be triggered manually. The transfer from AT to ST does not occur if the house load operation is successful.

In the event of LOOP, which is defined as a DBC, AC power fails on the LGB [NPDS (CI-10kV)] switchboard, which means there is no AC power available from the main generator, the 400 kV network nor the ST. The EDG, which is defined as the NI 10kV Normal Power Distribution System (LHP [EPSS (NI-10kV)]) will start and connect to the NI 10kV Emergency Power Distribution System (LHA [EPDS (NI-10kV)]) switchboard automatically. As the DG has limited step load acceptance, loads of the LHA [EPDS (NI-10kV)] switchboard are reloaded in sequences designed to limit the voltage and frequency variations at each load step. The safety Digital Control System (DCS) provides control to the load shedding and reloading sequence. The reloading sequence depends on the design condition that has been detected.

In the event of SBO, which is defined as a DEC, the EDGs or the 10kV emergency power distribution switchboards are unavailable. Hence, SBO DGs, which start manually, are designed to cope with this accident. The SBO DG in Division A, which is defined as the NI 10kV SBO Power Supply System (LHU [SBOPSS (NI-10kV)]), starts and connects to the NI 10kV SBO Power Distribution System (LHM [SBOPDS (NI-10kV)]) switchboard manually. Several accident loads on the LHM [SBOPDS

(NI-10kV)] switchboard are also required for DBC; thus the LHM [SBOPDS (NI-10kV)] switchboard can also be supplied from the EDG via the LHA [EPDS (NI-10kV)] switchboard. A 10kV voltage level is applied in both the emergency power distribution switchboard and SBO power distribution switchboard under the following consideration:

a) Minimise the types of equipment to make procurement and maintenance easier;

b) Apply qualified and mature equipment to improve the reliability of the system and equipment.

It is recognised that applying the same voltage level may bring about risk regarding CCF, and this issue will be further analysed.

Finally, under the SBO coupled with SBO DGs failure condition, the 10kV mobile DG can be connected to the LHM [SBOPDS (NI-10kV)] switchboard, and the 380V mobile DG can be connected to the NI 380V SBO Power Distribution System (LLD [SBOPDS (NI-380V)]) switchboard.

The division A DC power sources are:

a) The 2h DC system: LAA [DCPS (NI-220V-2h);

b) The 12h DC system: NI 220V DC Power Supply and Distribution System (12h) (LAP [DCPS (NI-220V-12h)]).

The division A battery chargers are supplied by the EDG and the SBO DG.

Inverters generate AC UPS from the DC supplies of the battery charger or batteries. In the event of an inverter internal fault, a static switch transfers the AC UPS loads to a bypass supply.

9.4.3 Redundant Divisions

Three redundant safety divisions are provided. The electrical power systems in divisions A and B are identical.

The division C EDG is identical to those in divisions A and B. Division C has no SBO DG and 12h batteries. Division C has two sets of 2h batteries, one of which is for the fourth channel of the Protection System (PS). The two DC and AC UPS systems (including cabling) are separate from each other.

The electrical equipment from different trains or divisions is separated in independent buildings or rooms. Separation of the different DiD levels in the same train is not compulsive, but is consider if reasonable and practicable. The segregation could be carried out by the use of zones, barriers and distance.

9.4.4 Interconnection between Divisions

Electrical power systems incorporate interconnection between switchboards of different trains, and the interconnections are relevant to operating conditions:

a) During specific accident conditions, as some safety loads such as Safety Injection System (RIS [SIS]) valves need to be continually powered, interconnection of the power supply between different divisions is required and provided;

b) During the Reactor Completely Discharge (RCD) operating mode, some specific equipment (supporting maintenance) needs to have power restored to it, such as hoisting machines, lighting, heating, ventilation, air conditioning system and spent fuel pool cooling equipment.

There are dedicated sub-switchboards for these loads; incoming circuit breakers are applied in these sub-switchboards for each division and mechanical interlock is designed to ensure the correct sequence of operation and to avoid two safety trains being connected together. If one train of the power supplies fail due to an accident or maintenance shutdown, the power supply of the sub-switchboard is transferred to the other train manually.

9.4.5 Electrical Power System Single Line Diagram

The detail of electrical power system is presented in the electrical power system single line diagram, Appendix 9B.

9.5 Off-site Electrical Power System

9.5.1 General Description

The general technical requirements for the electrical design are presented in *Unified Technical Regulation for Electrical Design*, Reference [6].

The off-site electrical power system performs an essential role in terms of safety in supplying the on-site power systems with reliable power from multiple power sources: (i) main generator via ATs; and (ii) grid power supply via the ST or ATs. The off-site power system is part of the preferred power supply.

The UK HPR1000 unit is connected to the external grid through a main connection and a standby connection. The two off-site power sources are physically independent and are designed and located to minimise, to the extent which is practicable, the likelihood of their simultaneous failure.

For normal operation, the electrical power generated by the plant is transmitted to the external grid through the main connection. The main connection provides reliable power from the grid to the plant auxiliaries through two ATs during the start-up and normal shutdown phase.

The standby connection serves as a backup of the main connection. When the main connection is unavailable due to a fault and the house load operation is not successful, the automatic switchover between the main connection and standby connection will be triggered to ensure the continuous power supply to the unit for shut down.

The following main connection sub-chapter covers some on-site devices, such as the generator, GCB, UT and ATs. The standby connection sub-chapter also covers some on-site devices, such as the ST.

9.5.2 Main Connection

9.5.2.1 Safety Requirements

The main connection system is not required to directly perform the safety functions.

9.5.2.1.1 Fundamental Safety Functional Requirements

9.5.2.1.1.1 Control of Reactivity

The main connection system is not required to directly perform the reactivity control function.

9.5.2.1.1.2 Removal of Heat

The main connection system is not required to directly perform the heat removal function.

9.5.2.1.1.3 Confinement

The main connection system is not required to directly perform the radioactivity confinement function.

9.5.2.1.1.4 Extra Safety Functions

The main connection system is not required to perform extra safety functions.

9.5.2.1.2 Design Requirements

9.5.2.1.2.1 Safety Classification

According to the safety classification principles presented in Sub-chapter 4.4.5.1, as the main connection provides power to equipment which does not perform safety functions, its function is Non-Classified (NC). The design requirements presented in Sub-chapter 4.4.5.3 are not applicable.

9.5.2.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

   As the function categorisation of the main connection system is NC, it does not need to meet the requirements of the Single Failure Criterion (SFC) and redundancy.

b) Independence

   As a power level of the electrical power system DiD, the independence requirements presented in Sub-chapter 4.4.6.1.3 are applied to the main connection system.

c) Diversity

As the main connection system does not contribute to the main and diverse protection line, the requirements of diversity presented in Sub-chapter 4.4.6.1.4 are not applicable.

9.5.2.1.2.3 Design to Ensure Functionality

a) Equipment qualification

As the function categorisation of the main connection system is NC, it does not need to meet the requirements of equipment qualification.

b) Ageing and degradation

As the main connection system is required to remain available during its lifetime, the requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As the main connection system is required to remain available during its lifetime, the EMIT of the main connection system is applied according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.5.2.1.2.4 Hazard Protection

a) External hazards

Although the function categorisation of the main connection system is NC, the external hazard protection presented in Sub-chapter 18.6 is taken into consideration in terms of plant reliability and conventional safety if practicable.

b) Internal hazards

Although the function categorisation of the main connection system is NC, the internal hazard protection presented in Sub-chapter 19.6 is taken into consideration in terms of plant reliability and conventional safety if practicable.

9.5.2.2 Design Basis

9.5.2.2.1 General Assumption

9.5.2.2.1.1 Control of Reactivity

Not applicable. The main connection system is not required to directly perform the reactivity control functions.

9.5.2.2.1.2 Removal of Heat

Not applicable. The main connection system is not required to directly perform the residual heat removal functions.

9.5.2.2.1.3 Confinement

Not applicable. The main connection system is not required to directly perform the radioactivity confinement functions.

9.5.2.2.1.4 Extra Safety Functions

a) The main connection system does not directly supply power to the equipment that performs the three fundamental safety functions (control of reactivity, removal of heat and confinement);

b) The main connection system does not directly supply power to the equipment that contributes to main protection line and diverse protection line.

9.5.2.2.2 Design Assumption

The following key assumptions are applied for the design:

a) Assumption regarding grid code compliance

The UK HPR1000 complies with the UK grid code. If there are some gaps between the UK HPR1000 and the grid code, they will be identified, narrowed down, and reach an agreement with the grid.

b) Assumption regarding connection

There is an available connection scheme for the plant.

c) Assumption regarding ambient condition

The main connection can operate normally in the ambient condition.

9.5.2.3 System Description and Operation

9.5.2.3.1 System Description

9.5.2.3.1.1 General System Description

The main connection refers to the circuit from the main generator to the external grid (the grid is site-specific) via the GCB, UT and high voltage switchgear. AT branch circuits are connected to the downstream of the UT.

9.5.2.3.1.2 Description of Main Equipment

The equipment parameters in specifications are determined by electrical system studies.

a) Generator

The generator is compatible with the turbine capacity in different conditions. The final output power is determined according to the turbine capacity and specific environmental conditions such as the cooling water temperature.

Typical parameters are as follows:

1) Rated voltage: 24kV;

2) Rated power: 1187MW;

3) Rated power factor: { };

4) Direct-axis subtransient reactance: { }.

b) GCB

The GCB is gas insulated breaker with excellent performance and high reliability. The GCB is closed in plant normal operation. Through plant start-up, shutdown and maintenance phase, the GCB is open, which allows the unit auxiliaries to be fed back from the external main grid by the UT and ATs.

Typical parameters are as follows:

1) Rated voltage: { };

2) Rated short-circuit rupturing current:

   - Symmetrical open circuit component: { };

   - Asymmetrical open circuit component: { }.

c) Isolated phase busbar

The Isolated Phase Busbar (IPB) is used to connect the generator to the UT with high reliability. The single phase busbar is enclosed separately within metal covers to connect termination points.

Typical parameters are as follows:

1) Rated voltage: 28.8kV;

2) Rated current (main circuit): 38000A.

d) UT

The UT is designed according to the plant and grid requirements. The capacity of the UT will be sized according to the maximum continuous output of the generator and the deduction of auxiliary loads. Taking into consideration the equipment manufacturing and transportation, the UT adopts the single-phase transformer. To facilitate the maintenance and reduce the outage time caused by transformer failure, one or more spare single phase transformers can be set.

Typical parameters are as follows:

1) Rated capacity: 3×450 MVA;

2) Rated voltage: 420±2×2.5%/24kV;

3) Short-circuit impedance: 20%;

4) Coupling group No.: YN, d11.

e) AT

Two ATs, which are split winding, oil-filled, three phase transformers, are set for each unit. One or more spare ATs can be set. To meet the requirement of the voltage deviation in each auxiliary bus, an on-load tap changer is adopted for the AT.

Typical parameters are as follows:

1) Rated capacity: 88/44-44 MVA;

2) Rated voltage: 24±8×1.25%/10.5kV;

3) Short-circuit impedance: $Ud_{I-II}=Ud_{I-III}=18\%$;

4) Coupling group No.: YN, d1-d1.

f) Transmission line

For normal operation, the electric power generated by the plant is transmitted to the external grid through the transmission line, which is used to connect the plant UT to the substation of the grid. The type of transmission line, such as overhead transmission line, extra high voltage cable, and gas insulated transmission line, will be finalized and chosen by the licensee for the specific site.

Typical parameters are as follows:

1) Rated voltage: 440kV;

2) Rated current: 2500A.

9.5.2.3.1.3 Description of Main Layout

The generator, GCB, and part of the IPB are located in the turbine building.

The UT, ATs, and part of the IPB are arranged in specific transformer areas. The transformer platform is adjacent to the CI turbine building. The layout scheme ensures that the layout of the high voltage outgoing line is convenient and the low voltage incoming line is as short as possible. Each transformer is set with fire-barriers to prevent fire spreading.

There is sufficient reserved space for installation and inspection in the layout scheme, which also allows for the convenience of operation and maintenance.

9.5.2.3.1.4 Description of System Interfaces

The main interfaces for the main connection system are:

a) The interface with the grid: The NPP operating organisation and the transmission system operator determine and establish requirements for equipment interfaces and communication interfaces;

b) The interface with the plant auxiliary electrical system: the main connection system energises the plant auxiliary electrical system via ATs.

9.5.2.3.1.5 Control and Monitoring

The main connection is provided with control and monitoring devices, which are intended to control, monitor and protect the system. The main connection can be put into or out of service by the DCS. If there is a fault in the system, the monitoring and protection scheme can detect and deal with it. Furthermore, it can disconnect the plant from the grid if necessary.

9.5.2.3.2 System Operation

9.5.2.3.2.1 Normal Conditions

a) Normal conditions

The normal conditions include the conditions during plant power operation, start up and normal shutdown. During plant power operation, the power generated by the main generator is transmitted to the external main grid through the UT. Meanwhile, the unit auxiliaries are powered by the main generator as well. The main connection is also in service during plant start-up and normal shutdown.

Furthermore, if the GCB is open, the unit auxiliaries can be fed back from the external grid by the UT and ATs.

b) Transient conditions

If there is a fault with the off-site main power supply and meanwhile the generator is available during normal conditions, the plant will transfer to the house load condition, in which the generator supplies power to the plant auxiliary equipment.

9.5.2.3.2.2 Accident Conditions

a) DBC-2/3/4 condition

The main connection system could be out of service during DBC-2/3/4 condition.

b) DEC condition

The main connection system could be out of service during DEC condition.

If the off-site main power or the main generator is available during plant accident conditions, either one can supply power to the emergency power distribution system, which can support SSCs to cope with the accident conditions. It is, if available, a preferred choice of power supply during plant accident conditions.

9.5.2.4 Design Substantiation

9.5.2.4.1 Compliance with Fundamental Safety Functional Requirements

9.5.2.4.1.1 Control of Reactivity

Not applicable.

9.5.2.4.1.2 Removal of Heat

Not applicable.

9.5.2.4.1.3 Confinement

Not applicable.

9.5.2.4.1.4 Extra Safety Functions

Not applicable.

9.5.2.4.2 Compliance with Design Requirements

9.5.2.4.2.1 Compliance with Safety Classification

According to classification principles in Sub-chapter 4.4.5.2, the safety classification of the main connection system is NC.

9.5.2.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

   The SFC and redundancy are not applicable for the main connection system.

b) Independence

   As different power levels of the electrical power system DiD, the off-site main power and the off-site standby power are designed and located to minimise, to the extent which is practicable, the likelihood of their simultaneous failure.

c) Diversity

   Diversity is not applicable for the main connection system.

9.5.2.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

   The qualification category of the main connection system is NC.

b) Ageing and degradation

Ageing and degradation is considered in the equipment lifespan design of the main connection system. Appropriate margins are provided in the design to take due account of relevant mechanisms of ageing and degradation, to ensure the capability of items to perform their necessary functions throughout their design life.

c) Examination, maintenance, inspection and testing

In general, the equipment of the main connection system is examined, maintained, inspected and tested in accordance with the requirements from the maintenance strategy of the plant, equipment technical specification, Equipment Operation and Maintenance Manual (EOMM), operational experience, etc.

9.5.2.4.2.4 Compliance with Hazard Protection

a) External Hazards

1) Earthquake

The main connection system could be out of service after safety shutdown earthquake.

2) Electromagnetic interference and space weather

The main connection system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, cable shielding and cabling.

Strong solar storms causing geomagnetic disturbances are capable of disrupting power grid operation through electromagnetic interaction. Specifically, the disturbances can induce quasi-DC currents in transformer neutral windings which saturate the iron cores and lead to increased excitation current and reactive power demand. The geomagnetic induced current can create excessive harmonics in the transformers and in the bulk transmission network. The plant will take this current into account and provide some feasible counter measures.

3) Meteorological (extreme wind, extreme temperature, extreme hail, sleet, snow and icing, lightning)

Extreme weather is considered for the outdoor parts of the main connection system. The design of that equipment takes due account of extreme wind, extreme temperature and lightning. For example, lightning rods are designed for the lightning protection of the transformers in transformer areas.

4) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards are usually addressed through the structure design.

b) Internal hazards

1) Internal fire

The risk of internal fire is reduced by the adoption of fire-resistance materials and the cable penetrations are fire proof where necessary. There are fire-barriers in transformer areas for reducing fire spreading. Electrical protection will cut off any fault section as soon as possible to reduce the risk of fire.

2) Internal flooding

Drainage design is considered for internal flooding such as due to fire-extinguishing water of transformers, which protects the system from flooding.

3) Electromagnetic interference

The main connection system is protected against Electromagnetic Interference (EMI) by EMC qualification and the application of an earthing network, cable shielding and cabling.

4) Toxic and corrosive materials and gases

Typically, the generator circuit breaker in the UK HPR 1000, with more than a 25.2kV rated voltage, adopts sulphur hexafluoride (SF6) insulated switchgear. Gas leakage related measures of the breaker are considered in the design.

5) Other internal hazards

Other internal hazards such as high energy pipe failures, dropped load, internal explosion and internal missiles are not applicable for the main connection.

9.5.3 Standby Connection

9.5.3.1 Safety Requirements

9.5.3.1.1 Fundamental Safety Functional Requirements

9.5.3.1.1.1 Control of Reactivity

The standby connection system is not required to directly perform the reactivity control function.

9.5.3.1.1.2 Removal of Heat

The standby connection system is not required to directly perform the residual heat removal function.

9.5.3.1.1.3 Confinement

The standby connection system does not perform the radioactivity confinement function.

9.5.3.1.1.4 Extra Safety Functions

The standby connection system is not required to perform extra safety function.

9.5.3.1.2 Design Requirements

9.5.3.1.2.1 Safety Classification

According to the safety classification principles presented in Sub-chapter 4.4.5.1, as the standby connection provides power to equipment which does not perform safety function, its function categorisation is NC. The design requirements presented in Sub-chapter 4.4.5.3 are not applicable.

9.5.3.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

As the safety function categorisation of the standby connection system is NC, it does not need to meet the requirements of SFC and redundancy.

b) Independence

As a power level of the electrical power system DiD, the independence requirements presented in Sub-chapter 4.4.6.1.3 are applied in the standby connection system.

c) Diversity

As the standby connection system does not contribute to the main and diverse protection line, the requirements of diversity presented in Sub-chapter 4.4.6.1.4 are not applicable.

9.5.3.1.2.3 Design to Ensure Functionality

a) Equipment qualification

As the function categorisation of the standby connection system is NC, it does not need to meet the requirements of equipment qualification.

b) Ageing and degradation

As the standby connection system is required to remain available during its lifetime, the requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As the standby connection system is required to remain available during its lifetime, the EMIT of the standby connection system is applied according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.5.3.1.2.4 Hazard Protection

a) External hazards

Although the function categorisation of the standby connection system is NC, the external hazard protection presented in Sub-chapter 18.6 is taken into consideration in terms of plant reliability and conventional safety if practicable.

b) Internal hazards

Although the function categorisation of the standby connection system is NC, the internal hazard protection presented in Sub-chapter 19.6 is taken into consideration in terms of plant reliability and conventional safety if practicable.

9.5.3.2 Design Basis

9.5.3.2.1 General Assumption

9.5.3.2.1.1 Control of Reactivity

Not applicable. The standby connection system is not required to directly perform the reactivity control function.

9.5.3.2.1.2 Removal of Heat

Not applicable. The standby connection system is not required to directly perform the residual heat removal function.

9.5.3.2.1.3 Confinement

Not applicable. The standby connection system is not required to directly perform the radioactivity confinement function.

9.5.3.2.1.4 Extra Safety Functions

a) The standby connection system does not directly supply power to the equipment that performs the three fundamental safety functions (control of reactivity, removal of heat and confinement);

b) The standby connection system does not directly supply power to the equipment that contributes to the main protection line and diverse protection line.

9.5.3.2.2 Design Assumption

The following key assumption is applied for the design:

a) Assumption regarding connection

There is sufficient off-site backup power supply and another available connection scheme for the plant.

b) Assumption regarding ambient condition

The standby connection system can operate normally in the ambient condition.

9.5.3.3 System Description and Operation

9.5.3.3.1 System Description

9.5.3.3.1.1 General System Description

The standby connection serves as a backup power supply to the main connection. Therefore, it has as much independence as possible from the main connection in its transmission route and upstream power source, which to some extent is determined by the local grid. When the main connection is unavailable due to a fault condition and the house load operation is not successful, the automatic switchover between the main connection and standby connection is executed to ensure the continuous power supply for the unit to shut down.

9.5.3.3.1.2 Description of Main Equipment

There are several standby connection schemes for the plant, which will be finalised by the licensee. Therefore, the equipment described here only includes the ST and transmission line. The equipment parameters in the specification are determined by electrical system studies.

a) ST

One ST, a split winding, oil-filled, three phase transformer, is set for each unit. To meet the requirements of the voltage deviation in each auxiliary bus, an on-load voltage regulator is adopted for the ST. The voltage regulation range will be determined by the bus voltage selection and relevant check-up calculation for the specific site. The ST is sized according to the load balance calculation to cope with relevant conditions.

Typical parameters are as follows:

1) Rated capacity: 88/44-44 MVA;

2) Short-circuit impedance: { };

3) Coupling group No.: { }.

b) Transmission line

The transmission line is used to connect ST to the substation of the grid. The type of transmission line, such as overhead transmission line, high voltage cable, and gas insulated transmission line, will be finalized and chosen by licensee for specific site. The capacity of the transmission line will be compatible with ST's capacity.

9.5.3.3.1.3 Description of Main Layout

The ST is arranged at the specific transformer area. The transformer platform is adjacent to the UT and ATs platform. The transformer is set with fire-barriers to prevent fire spreading.

There is enough reserved space for installation and inspection in the layout scheme, which also allows for the convenience of operation and maintenance.

9.5.3.3.1.4 Description of System Interfaces

There are some system interfaces for the standby connection system, such as:

a) The interface between the standby connection system and the grid: the transmission line of the standby connection system is connected to the grid, through which the plant can get power from the grid;

b) The interface with the plant auxiliary electrical system: the standby connection system energises the plant auxiliary electrical system via the ST.

9.5.3.3.1.5 Control and Monitoring

The standby connection is provided with control and monitoring devices, which are intended to control, monitor and protect the system. The standby connection can be put into or out of service by DCS in particular scenarios. If there is a fault in the system, the monitoring and protection device can detect and deal with it.

9.5.3.3.2 System Operation

9.5.3.3.2.1 Plant Normal Conditions

During plant normal and transient conditions, the standby connection system is in backup condition. When the main connection is unavailable due to a fault condition and the house load operation is not successful, the automatic switchover between the main connection and standby connection is executed to ensure the continuous power supply for the unit to shut down.

9.5.3.3.2.2 Plant Accident Conditions

a) DBC-2/3/4 condition

The standby connection system could be out of service during DBC-2/3/4 condition.

b) DEC condition

The standby connection system could be out of service during DEC conditions.

If both of the off-site main power and the main generator are unavailable during plant accident conditions, the off-site standby power can ensure the plant shut down. It is, if available, a preferred choice of power supply during plant accident conditions.

9.5.3.4 Design Substantiation

9.5.3.4.1 Compliance with Fundamental Safety Functional Requirements

9.5.3.4.1.1 Reactivity Control

Not applicable.

9.5.3.4.1.2 Heat Removal

Not applicable.

9.5.3.4.1.3 Confinement

Not applicable.

9.5.3.4.1.4 Extra Safety Functions

Not applicable.

9.5.3.4.2 Compliance with Design Requirements

9.5.3.4.2.1 Compliance with Safety Classification

According to classification principles in Sub-chapter 4.4.5.2, the safety classification of the standby connection system is NC.

9.5.3.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

The SFC and redundancy are not applicable for the standby connection system.

b) Independence

As different power levels of the electrical power system DiD, the off-site main power and the off-site standby power are designed and located to minimise, to the extent which is practicable, the likelihood of their simultaneous failure.

c) Diversity

Diversity is not applicable for the standby connection system.

9.5.3.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

The qualification category of the standby connection system is NC.

b) Ageing and degradation

Ageing and degradation is considered in the equipment lifespan design of the standby connection system. Appropriate margins are provided in the design to take due account of relevant mechanisms of ageing and degradation, to ensure the capability of items to perform their necessary functions throughout their design life.

c) Examination, maintenance, inspection and testing

In general, the equipment of the standby connection system is examined, maintained, inspected and tested in accordance with the requirements from the maintenance strategy of the plant, equipment technical specification, EOMM, operation experience, etc.

9.5.3.4.2.4 Compliance with Hazard Protection

a) External hazards

1) Earthquake

The standby connection system could be out of service after safety shutdown earthquake.

2) Electromagnetic interference and space weather

The standby connection system is protected against EMI by EMC qualification and the application of an earthing network, cable shielding and cabling.

The geomagnetic induced current for the standby connection will be considered together with the main connection.

3) Meteorological (extreme wind, extreme temperature, extreme hail, sleet, snow and icing and lightning)

Extreme weather is considered for the outdoor parts of the standby connection system. The design of those equipment takes due account of extreme wind, extreme temperature and lightning. For example, lightning rods are designed for the lightning protection of the transformers in the transformer areas.

4) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards are usually addressed through the structure design.

b) Internal hazards

1) Internal fire

The risk of internal fires is reduced by the selection of fire-resistance materials and the cable penetrations are fire proof where necessary. There are fire-barriers in transformer areas for reducing fire spreading. Electrical protection will cut off the fault section as soon as possible to reduce the risk of fire.

2) Internal flooding

Drainage design is considered for internal flooding, such as fire-extinguishing water of transformers, which protects the system from flooding.

3) Electromagnetic interference

The standby connection system is protected against EMI by EMC qualification and the application of an earthing network, cable shielding and cabling.

4) Other internal hazards

Other internal hazards such as high energy pipe failures, dropped load, internal explosion and internal missiles are not applicable for the standby connection.

9.5.4 AT/ST Transfer

When there is a voltage loss of the main connection, the automatic power transfer from the main connection to the standby connection is executed, this means power supply of the normal AC power distribution system is transferred from the AT to ST. Power transfer from the AT to ST can also be triggered manually. During and after this AT/ST transfer, normal AC power distribution system which supplied the loads required for power generating, such as the LGA [NPDS (CI-10kV)] , will be tripped and out of service. The normal AC power distribution system which supplied the loads requiring power during unit shutdown, such as the LGB [NPDS (CI-10kV)], will be powered by the AT. Electrical interlocks between breakers are applied to prevent the AT and ST incoming circuits being connected in parallel which could result in adverse voltage or current conditions on the LGB [NPDS (CI-10kV)] bus.

{

}

9.5.5 Grid Connection Compliance Analysis

Analysis will be performed on a regular basis to ensure that the NPP has adequate electrical power (at the correct voltage and frequency) from the grid and to assess the reliability of the grid connections. The connection compliance of the UK HPR1000 will also be assessed to permit the plant to connect with the UK grid.

The non-site-specific requirements in the UK grid code will be identified and grid code compliance will be performed for the UK HPR1000 in GDA.

9.6 On-site Electrical Power System

9.6.1 Normal AC Power Distribution System

9.6.1.1 Safety Requirements

9.6.1.1.1 Fundamental Safety Functional Requirements

9.6.1.1.1.1 Control of Reactivity

The normal AC power distribution system is not required to directly perform reactivity control function.

9.6.1.1.1.2 Removal of Heat

The normal AC power distribution system is not required to directly perform heat removal function.

9.6.1.1.1.3 Confinement

The normal AC power distribution system is not required to directly perform radioactive material confinement function.

9.6.1.1.1.4 Extra Safety Functions

The normal AC power distribution system is not required to perform extra safety functions except for tripping the reactor coolant pump.

9.6.1.1.2 Design Requirements

9.6.1.1.2.1 Safety Classification

According to the safety classification principles presented in Sub-chapter 4.4.5.1, as the normal AC power distribution system provides power to equipment which performs NC safety functions, its function categorisation (except tripping the reactor coolant pump) is NC. Design requirements presented in Sub-chapter 4.4.5.3 are not applicable.

As the categorisation of tripping the reactor coolant pump is FC1, the tripping function of the electrical circuit breakers for the reactor coolant pump is FC1. Design requirements presented in Sub-chapter 4.4.5.3 are applied to the design of electrical circuit breakers for the reactor coolant pump.

9.6.1.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

As the function categorisation of the normal AC power distribution system (except tripping the reactor coolant pump) is NC, it does not need to meet the requirements of SFC and redundancy.

As the categorisation of the breaker tripping function for the reactor coolant pump is FC1, the design principle of the SFC and redundancy presented in Sub-chapter 4.4.6.1.2 is required to be applied.

b) Independence

As the function categorisation of the normal AC power distribution system (except tripping the reactor coolant pump) is NC, it does not need to meet the requirements of independence.

As categorisation of the breaker tripping function for the reactor coolant pump is FC1, the design principle of independence presented in Sub-chapter 4.4.6.1.3 is required to be applied.

c) Diversity

As the normal AC power distribution system does not contribute to the main and diverse protection line, requirements of diversity presented in Sub-chapter 4.4.6.1.4 is not applicable.

9.6.1.1.2.3 Design to Ensure Functionality

a) Equipment qualification

As the function categorisation of the normal AC power distribution system (except tripping the reactor coolant pump) is NC, it does not need to meet the requirements of equipment qualification.

As the categorisation of the breaker tripping function for the reactor coolant pump is FC1, the design principle of equipment qualification presented in Sub-chapter 4.4.6.2.1 is required to be applied to the reactor coolant pump trip breaker.

b) Ageing and degradation

As the normal AC power distribution system is required to remain available during its lifetime, the requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As normal AC power distribution system is required to remain available during the service life, EMIT of the normal AC power distribution systems is applied according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.6.1.1.2.4 Hazard Protection

a) External hazards

As categorisation of the breaker tripping function for the reactor coolant pump is FC1, the normal AC power distribution system is protected against external hazards in accordance with the principle presented in Sub-chapter 18.6.

Although the function categorisation of the normal AC power distribution system (except tripping the reactor coolant pump) is NC, external hazard protection is taken into consideration in terms of plant reliability and conventional safety if practicable.

b) Internal hazards

As the categorisation of the breaker tripping function for reactor coolant pump is FC1, the normal AC power distribution system is protected against internal hazards in accordance with the principle presented in Sub-chapter 19.6.

Although the function categorisation of the normal AC power distribution system (except tripping the reactor coolant pump) is NC, internal hazard protection is taken into consideration in terms of plant reliability and conventional safety if practicable.

9.6.1.2 Design Basis

9.6.1.2.1 General Assumption

9.6.1.2.1.1 Control of Reactivity

Not applicable. The normal AC power distribution system is not required to directly perform reactivity control function.

9.6.1.2.1.2 Removal of Heat

Not applicable. The normal AC power distribution system is not required to directly perform heat removal function.

9.6.1.2.1.3 Confinement

Not applicable. The normal AC power distribution system is not required to directly perform radioactive material confinement function.

9.6.1.2.1.4 Extra Safety Functions

a) The normal AC power distribution system does not directly supply power to the equipment that performs the three fundamental safety functions (control of reactivity, removal of heat and confinement);

b) The normal AC power distribution system directly supplies power to the equipment whose function (operation during power supply) categorisation is NC;

c) The normal AC power distribution system does not directly supply power to the equipment that contributes to the main protection line and diverse protection line;

d) The breaker tripping function for the reactor coolant pump is implemented when the breaker is open.

9.6.1.2.2 Design Assumption

The following key assumptions are applied for the design:

a) Assumption regarding power supply

The main connection is available during power operation. The main generator is available during house load condition. The standby connection is available after the AT/ST transfer.

b) Assumption regarding control power supply

The control power supply is available during normal operation and reactor coolant pump trip.

c) Assumption regarding qualification

As the function categorisation of the normal AC power distribution system (except tripping the reactor coolant pump) is NC, the assumption regarding qualification is not applicable.

The qualified breaker for the reactor coolant pump can perform its function under service conditions.

d) Assumption regarding ambient condition

The Heating, Ventilation and Air Conditioning (HVAC) system can ensure the ambient conditions of the normal AC power distribution system during normal operation.

The HVAC system can ensure the ambient conditions of the reactor coolant breaker during normal and accident conditions.

9.6.1.3 System Description and Operation

9.6.1.3.1 System Description

9.6.1.3.1.1 General System Description

The normal AC power distribution system consists of:

a) The CI 10kV normal power distribution systems:

1) Division A: LGA/LGB [NPDS (CI-10kV)];

2) Division B: CI 10kV Normal Power Distribution System (LGC/LGD [NPDS (CI-10kV)]);

3) Division C: CI 10kV Normal Power Distribution System (LGE/LGF [NPDS (CI-10kV)]);

4) Fourth division: CI 10kV Normal Power Distribution System (LGG/LGH [NPDS (CI-10kV)]).

b) The NI 10kV normal power distribution systems:

1) Division A: NI 10kV Normal Power Distribution System (LGM/LGP [NPDS (NI-10kV)]);

2) Division B: NI 10kV Normal Power Distribution System (LGN/LGQ [NPDS (NI-10kV)]);

3) Division C: NI 10kV Normal Power Distribution System (LGO [NPDS (NI-10kV)]).

c) The CI 380V normal power distribution systems:

1) Division A: CI 380V Normal Power Distribution System (LKJ/LKK [NPDS (CI-380V)]);

2) Division B: CI 380V Normal Power Distribution System (LKL/LKM [NPDS (CI-380V)]);

3) Division C: CI 380V Normal Power Distribution System (LKN/LKO [NPDS (CI-380V)]);

4) Fourth division: Balance of Plant (BOP) 380V Normal Power Distribution System (LKP/LKS [NPDS (BOP-380V)]).

d) The NI 380V normal power distribution systems:

1) Division A: NI 380V Normal Power Distribution System (LKA/LKD/LKU/LKE/LKI [NPDS (NI-380V)]);

2) Division B: NI 380V Normal Power Distribution System

(LKB/LKG/LKV/LKF/LKR [NPDS (NI-380V)]);

3) Division C: NI 380V Normal Power Distribution System (LKC/LKH/LKW [NPDS (NI-380V)]).

For the CI 10kV normal power distribution system, there are four divisions. Division A, B and C of the CI 10kV normal power distribution system supply power to the equipment belonging to the same process circuit in the CI turbine generator building, and circulating water pump (BOP scope). The fourth division of the CI 10kV normal power distribution system is designed for the load balance of the AT, and it supplies power to the start-up feedwater pump (CI scope), circulating pump station dry-type transformer and other BOP loads.

The LGA/LGD/LGE/LGG [NPDS (CI-10kV)] are connected with the AT and the LGB/LGC/LGF/LGH [NPDS (CI-10kV)] are connected with the ST. In division A, LGA/LGB [NPDS (CI-10kV)] are connected by cables through breakers, so do the other divisions.

The CI 10kV normal distribution system could get power:

a) From the AT in the normal operation, normal start-up and normal shutdown condition;

b) From the main generator during the house load condition;

c) From the ST after the AT/ST transfer in case of a loss of the main connection and main generator.

For the NI 10kV normal distribution system, there are three independent divisions. Division A, B and C of the NI 10kV normal distribution system supply power to the equipment belonging to the same division in the NI building.

The NI 10kV normal distribution system could get the required power from the CI 10kV normal distribution system. The LGM [NPDS (NI-10kV)] is connected to the LGB [NPDS (CI-10kV)], the LGP [NPDS (NI-10kV)] to the LGB [NPDS (CI-10kV)], the LGN [NPDS (NI-10kV)] to the LGC [NPDS (CI-10kV)], the LGQ [NPDS (CI-10kV)] to the LGH [NPDS (CI-10kV)], and the LGO [NPDS (NI-10kV)] to the LGF [NPDS (CI-10kV)]. The LGM/LGN/LGO [NPDS (NI-10kV)] supplies power to the reactor coolant pump and NI 380V normal power distribution system of the safeguard building. The LGP/LGQ [NPDS (NI-10kV)] supplies power to the Operational Chilled Water System (DER [OCWS]) chilled water set, Coolant Storage and Treatment System (TEP [CSTS]) compressor and NI 380V normal distribution system of the Nuclear Auxiliary Building (BNX).

The CI 380V normal power distribution system is powered from the upstream CI 10kV normal power distribution system. The LKJ [NPDS (CI-380V)] which is powered from the LGA [NPDS (CI-10kV)], the LKK [NPDS (CI-380V)] from the

LGB [NPDS (CI-10kV)], the LKL [NPDS (CI-380V)] from the LGC [NPDS (CI-10kV)], the LKM [NPDS (CI-380V)] from the LGD [NPDS (CI-10kV)], the LKN [NPDS (CI-380V)] from the LGF, the LKO [NPDS (CI-380V)] from the LGE [NPDS (CI-10kV)], the LKP [NPDS (BOP-380V)] from the LGH [NPDS (CI-10kV)] and the LKS [NPDS (BOP-380V)] from the LGG [NPDS (CI-10kV)].

The NI 380V normal power distribution system is powered from the upstream NI 10kV normal distribution system. The LKA/LKB/LKC [NPDS (NI-380V)] of the safeguard building powered from the LGM/LGN/LGO [NPDS (NI-10kV)] respectively is used to supply power to the loads of the NI buildings. The main switchboard system LKE/LKF [NPDS (NI-380V)] of the BNX powered from the LGP/LGQ [NPDS (NI-10kV)] respectively is used to supply power to the load for the BNX and Access Building (BAX).

Sub-switchboard system LKD/LKG/LKH [NPDS (NI-380V)] supplies power to the loads of the NI buildings which could have power restored to them during RCD mode by the interconnection. Sub-switchboard system LKI/LKR [NPDS (NI-380V)] supplies power to the loads for the BNX and BAX which could have power restored to them during RCD mode by the interconnection. Sub-switchboard system LKU/LKV/LKW [NPDS (NI-380V)] supplies power to the loads for the diesel generator building which includes the auxiliary equipment of the DGs.

The 10kV AC power distribution system supplies power to the 10kV motors and 10/0.4kV dry-type transformer. The 380V AC power distribution system supplies power to the 380V motors, electrical valves, electrical heaters and other 380V equipment.

The 10kV normal AC power distribution system is an ungrounded system. The earthing type of 380V normal AC power distribution system is TN-S.

Electrical connection information of the normal AC power distribution system is presented in the *Plant Auxiliary Electrical System Wiring Diagram*, Reference [4].

9.6.1.3.1.2 Description of Main Equipment

a) 10kV AC switchboard

The 10kV AC switchboard is a pre-fabricated metal-clad three-phase alternating current electrical switchboard with draw-out connection devices.

The rated voltage of the 10kV AC switchboard is 12kV and the rated frequency is 50Hz. The 10kV circuit breaker is used in the switchboard and its rated current is 1250A or 3150A. The rated short-time withstand current is 50kA (3s) and the rated peak withstand current is 150kA.

The draw-out connection device of the 10kV AC switchboard adopts a truck unit. The switchboard adopts single bus connection. The typical 10kV AC switchboard includes the following compartments:

1) Busbar compartment;

2) Cable connection compartment;

3) Low voltage compartment;

4) Truck compartment (10kV circuit breaker, or Potential Transformer (PT)).

b) 380V AC switchboard

The 380V AC switchboard is an indoor type metal frame cabinet with withdrawable drawers. The rated voltage of the switchboard is 380V, and its insulation voltage of the main circuit is 1kV. The rated frequency is 50Hz.

The rated current of the CI 380V AC switchboard is 2000A. The rated short-time withstand current is 35kA (1s) and the rated peak withstand current is 90kA.

The rated current of the NI 380V AC switchboard is 4000A (main switchboard connected to the transformer) or 2000A (sub-switchboard). The rated short-time withstand current is 65kA (1s) and the rated peak withstand current is 143kA.

The typical 380V AC switchboard includes the following compartments:

1) Busbar compartment;

2) Cable connection and current transformer compartment;

3) Withdrawable or movable parts compartment;

4) Bus voltage monitoring compartment for the incoming feeder.

The withdrawable drawer could be used at four positions: service position, test position, disconnected position and withdrawn position.

c) 10/0.4kV dry-type transformer

The 10/0.4kV transformer is an air natural circulation cooling dry-type transformer with a metal protective shell. The connection with the 380V AC switchboard is via copper busbar connection. The neutral point of the transformer is directly earthed.

The capacity of the transformer is 1250kVA for the CI system and 2500kVA for the NI system. The connection symbol of the transformer is Dyn11. The range of off-line tap changer is ±2×2.5% on the high-voltage side. The maximum voltage of the high-voltage winding is 12kV; the maximum voltage of the low-voltage winding is 1.1kV.

9.6.1.3.1.3 Description of Main Layout

a) 10kV AC switchboard

The CI 10kV normal power distribution switchboards are located in the level +0.00m of the CI electrical building.

The LGM/LGN/LGO [NPDS (NI-10kV)] are located in the level of +8.70m of the Safeguard Building (BSA/BSB/BSC). The NI 10kV normal power distribution switchboards LGP/LGQ [NPDS (NI-10kV)] are located in the level of +11.25m of BNX.

b) 380V AC switchboard

The CI 380V normal power distribution switchboards and dry-type transformers are located in the level of +20.40m of turbine generator building.

The LKA/LKB/LKC/LKD/LKG/LKH [NPDS (NI-380V)] are located in the level of +8.70m of the BSA/BSB/BSC. The NI 380V normal power distribution switchboards LKE/LKF/LKI/LKR [NPDS (NI-380V)] are located in the level of +11.25m of the BNX. The NI 380V normal power distribution switchboards LKU/LKV/LKW [NPDS (NI-380V)] are located in the level of +0.00m of the Emergency Diesel Generator Building (BDA/BDB/BDC) or SBO Diesel Generator Building (BDU/BDV).

c) 10/0.4kV dry-type transformer

The CI 10/0.4kV dry-type transformers are located in the level of +20.40m of the turbine generator building.

The NI 10/0.4kV dry-type transformers of the LKA/LKB/LKC [NPDS (NI-380V)] are located in the level of +8.70m of the BSA/BSB/BSC. The NI 10/0.4kV dry-type transformers of the LKE/LKF [NPDS (NI-380V)] are located in the level of +11.25m of the BNX.

Detailed information about the equipment layout of normal AC power distribution system is presented in the Reference [7].

9.6.1.3.1.4 Description of System Interfaces

a) CI normal power distribution systems

1) Support system

The support systems of the CI normal power distribution system include the HVAC system, I&C system and control power system:

- CI HVAC system;
- Plant Standard Automation System (PSAS)
- CI 380V AC uninterruptible power system (2h)
- CI 220V DC Power Supply and Distribution System (2h)

2) Customer system

The customer system of the CI normal power distribution system mainly includes:

- Motor Driven Feedwater Pump System (APA [MFPS])
- Condensate Extraction System (CEX [CES])
- Conventional Island Closed Cooling Water System (SRI [CICCWS])
- Circulating Water System (CRF [CWS])
- Condensate Polishing System (ATE [CPS])
- Startup and Shutdown Feedwater System (AAD [SSFS])
- CI 380V normal power distribution system
- CI 380V AC uninterruptible power system (2h)
- CI 220V DC power supply and distribution system (2h)

b) NI normal power distribution systems

1) Support system

The support systems of the NI normal power distribution system include the HVAC system, I&C system and control power system:

- Electrical Division of Safeguard Building Ventilation System (DVL [EDSBVS])
- Nuclear Auxiliary Building Ventilation System (DWN [NABVS])
- Diesel Building Ventilation System (DVD [DBVS])
- PSAS
- NI 380V AC uninterruptible power system
- NI 220V DC power supply and distribution system

2) Customer system

The customer system interface of the NI normal power distribution system mainly includes:

- RCP [RCS]
- TEP [CSTS]
- DER [OCWS]
- Nuclear Island Vent and Drain System (RPE [VDS])

- Fuel Handling and Storage System (PMC [FHSS])
- Smoke Control System (DFL [SCS])
- NI 380V normal power distribution system
- NI 380V AC uninterruptible power system
- NI 220V DC power supply and distribution system

9.6.1.3.1.5 Control and Monitoring

Each normal AC power distribution system is provided with control and monitoring devices, which are intended to control, monitor and protect the system. Start-up and operation of the normal AC power distribution system are controlled manually except for the AT/ST transfer is automatic. The manual control can be realised in the Main Control Room (MCR) through the DCS or locally in the switchboards. Important information of the system can be sent to the MCR for monitoring of the availability of the system. Electrical protection isolates the faults of the system.

9.6.1.3.2 System Operation

9.6.1.3.2.1 Plant Normal Conditions

a) Normal operation conditions

The normal operation conditions of the system include power operation, plant start-up and normal shutdown.

During normal operation conditions, the CI normal power distribution system is supplied by the main generator through the AT. The NI normal power distribution system is supplied by the main generator through the AT and CI 10kV normal power distribution system.

The normal power distribution system is in service during power operation, plant start-up and normal shutdown.

b) Transient operation conditions

The transient operation conditions of the system include feedback from the off-site main power supply, house load and the transfer from the AT to ST.

The normal AC power distribution system is still in service during feedback from the off-site main power supply condition and house load condition.

The LGA/LGD/LGE/LGG [NPDS (CI-10kV)] are out of service after the transfer from AT to ST. The CI 10kV normal power distribution system LGB/LGC/LGF/LGH [NPDS (CI-10kV)] and the LGM/LGN/LGO/LGP/LGQ [NPDS (NI-10kV)] are still in service.

9.6.1.3.2.2 Plant Accident Conditions

a) DBC-2/3/4 condition

The normal power distribution system could be out of service during DBC-2/3/4 conditions.

b) DEC condition

Normal power distribution system could be out of service during DEC conditions. It is, if available, the preferred choice of power supply during plant accident condition.

9.6.1.4 Design Substantiation

9.6.1.4.1 Compliance with Fundamental Safety Functional Requirements

9.6.1.4.1.1 Control of Reactivity

Not applicable.

9.6.1.4.1.2 Removal of Heat

Not applicable.

9.6.1.4.1.3 Confinement

Not applicable.

9.6.1.4.1.4 Extra Safety Functions

The LGM/LGN/LGO [NPDS (NI-10kV)] supply power to the reactor coolant pump through the 10kV circuit breaker. As the reactor coolant pump is required to be automatically tripped under accident conditions to prevent primary loop over-cooling to ensure reactivity control, the disconnection of the 10kV circuit breaker performs the extra function by tripping the breaker to stop the reactor coolant pump.

9.6.1.4.2 Compliance with Design Requirements

9.6.1.4.2.1 Compliance with Safety Classification

The function categorisation of the 10kV circuit breaker tripping function for the reactor coolant pump is FC1, while for rest of the normal AC power distribution system it is NC.

According to classification principles in Sub-chapter 4.4.5.2, the safety classification of the 10kV circuit breaker for the reactor coolant pump is F-SC1 and the safety classification of other equipment or components in the normal AC power distribution system is NC.

Detailed information of safety classification for the normal power distribution system is in the following table.

T-9.6-1 Categorisation and Classification of the Normal Power Distribution System

System	Categorisation	Classification
10kV circuit breakers for the reactor coolant pump in LGM/LGN/LGO [NPDS (NI-10kV)]	FC1	F-SC1
LGA/LGB/LGC/LGD/LGE/LGF/LGG/LGH [NPDS (CI-10kV)]	NC	NC
LGM/LGN/LGO/LGP/LGQ [NPDS (NI-10kV)] (except 10kV circuit breaker for reactor coolant pump)	NC	NC
LKJ/LKK/LKL/LKM/LKN/LKO [NPDS (CI-380V)] LKP/LKS [NPDS (BOP-380V)]	NC	NC
LKA/LKD/LKU/LKE/LKI/LKB/LKG/LKV/LKF/LKR /LKC/LKH/LKW [NPDS (NI-380V)]	NC	NC

9.6.1.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

The SFC and redundancy are not applicable for the normal AC distribution system except for the 10kV circuit breakers for the reactor coolant pump.

Two breakers for the reactor coolant pump are designed in each division and they are redundant for the tripping function. The 10kV circuit breaker for the reactor coolant pump is capable of performing its tripping task in the presence of a single failure.

b) Independence

Independence is not applicable for the normal AC distribution system except for 10kV circuit breakers for the reactor coolant pump in the LGM/LGN/LGO [NPDS (NI-10kV)].

Different divisions of the CI normal power distribution system are not independent from each other and they are located in the same room. Division A, B and C of the NI normal power distribution system are independent and located in the BSA/BNX/BDA, BSB/BNX/BDB and BSC/BDC. For division A and division B of the normal power distribution system in the BNX, they are located independently in different rooms and different fire compartments. Meanwhile, the two breakers for the reactor coolant pump in each division are located in different rooms.

c) Diversity

Not applicable.

9.6.1.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

The qualification category of the 10kV circuit breaker for the reactor coolant pump is K3. The qualification category of other equipment and components is NC. Qualification categories for electrical equipment are defined according to RCC-E 2016 V.2120. Qualification K3 covers equipment located outside the containment building that shall be able to perform its function under environmental conditions corresponding to normal operation conditions and seismic conditions.

b) Ageing and degradation

The ageing of the equipment for the normal power distribution system is considered in EMIT. It is managed in the following aspects:

1) Thermal ageing and ageing caused by operation (including mechanical and electrical) is addressed by type tests, such as the mechanical operation ageing tests (e.g. draw-push circle and close-open circle) and environmental thermal ageing tests (e.g. dry heat and damp heat cyclic) for switchboards;

2) The switchboards are equipped with on-line inspection, such as insulation monitoring;

3) The layout of equipment facilitates EMIT, repair and replacement, such as the distance between two face to face switchboards is defined for equipment layout design;

4) The replacement period of the equipment is defined according to its individual lifetime and the plant design life, such as the lifetime of a component which is intended to be used for 30 years is replaced at the middle of the plant design life.

c) Examination, maintenance, inspection and testing

The normal AC power distribution system and equipment are designed to permit periodic examination, maintenance, inspection and testing. The examination includes visual checks and mechanical checks of the switchboard and checking of the earthing switch and the insulator lamps. The maintenance of the switchboard includes the replacement of circuit breakers or fuses, and adjustment of the protection relay and transformer tap changer. The inspection of the switchboard and transformer includes the insulation of the circuit and the indicator lamps. For periodic testing, the switchover from the AT to the ST is done in RCD mode to demonstrate the availability of the system and equipment.

9.6.1.4.2.4 Compliance with Hazard Protection

a) External hazards

1) Earthquake

The normal AC power distribution system could be out of service after safety shutdown earthquake.

Only the 10kV circuit breakers for the reactor coolant pump are designed to open reliably in case of an earthquake. The switchboards for the reactor coolant pump are seismically qualified and could perform the disconnection function during or after an earthquake.

2) Electromagnetic interference and space weather

The normal AC power distribution system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards and meteorological hazards are usually addressed through the structure design or HVAC design of buildings.

b) Internal hazards

1) Internal fire

For CI normal power distribution, the risk of internal fires is reduced by the selection of fire-resistance materials and cable penetrations are fire proof where necessary.

For the NI normal power distribution system, the three division of electrical equipment are in three independent fire compartments. The internal fire in one fire compartment could not cause the equipment located in the other fire compartment to fail. Electrical protection will cut off the fault section as soon as possible to reduce the risk of fire.

2) Electromagnetic interference

The normal AC power distribution system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other internal hazards

Other internal hazards such as high energy pipe failures, dropped load, internal explosion and internal missiles are usually addressed through the system layout, protection degree of equipment or the structure design of buildings.

9.6.2 Emergency AC Power Distribution System

9.6.2.1 Safety Requirements

9.6.2.1.1 Fundamental Safety Functional Requirements

9.6.2.1.1.1 Control of Reactivity

The emergency AC power distribution system is not required to directly perform the reactivity control function.

9.6.2.1.1.2 Removal of Heat

The emergency AC power distribution system is not required to directly perform the heat removal function.

9.6.2.1.1.3 Confinement

The emergency AC power distribution system is not required to directly perform the radioactive material confinement function.

9.6.2.1.1.4 Extra Safety Functions

As the emergency AC power distribution system is required to supply power to the equipment contributing to the three fundamental safety functions, it performs extra safety functions.

9.6.2.1.2 Design Requirements

9.6.2.1.2.1 Safety Classification

According to the safety classification principles presented in Sub-chapter 4.4.5.1, as the emergency AC power distribution system provides power to equipment which performs FC1 or FC2 safety functions, its function categorisation is FC1. Design requirements presented in Sub-chapter 4.4.5.3 are applied to the design of the emergency AC power distribution system.

9.6.2.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

As the safety function categorisation of the emergency AC power distribution system is FC1, the design principle of the SFC and redundancy presented in Sub-chapter 4.4.6.1.2 is required to be applied.

b) Independence

As the safety function categorisation of the emergency AC power distribution system is FC1, the design principle of independence presented in Sub-chapter 4.4.6.1.3 is required to be applied.

c) Diversity

As the emergency AC power distribution system supplies power to the equipment that contributes to the main protection line, the diversity principle presented in Sub-chapter 4.4.6.1.4 is required to be applied.

9.6.2.1.2.3 Design to Ensure Functionality

a) Equipment qualification

As the safety function categorisation of the emergency AC power distribution system is FC1, equipment of the emergency AC power distribution system is required to be qualified according to the principles presented in Sub-chapter 4.4.6.2.1.

b) Ageing and degradation

As the emergency AC power distribution system is required to remain available during its lifetime, requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As the emergency AC power distribution system is required to remain available during its lifetime, EMIT of the emergency AC power distribution system is applied according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.6.2.1.2.4 Hazard Protection

a) External hazards

As the safety function categorisation of the emergency AC power distribution system is FC1, the emergency AC power distribution system is protected against external hazards in accordance with the principle presented in Sub-chapter 18.6.

b) Internal hazards

As the safety function categorisation of the emergency AC power distribution system is FC1, the emergency AC power distribution system is protected against internal hazards in accordance with the principle presented in Sub-chapter 19.6.

9.6.2.2 Design Basis

9.6.2.2.1 General Assumption

9.6.2.2.1.1 Control of Reactivity

Not applicable. The emergency AC power distribution system is not required to directly perform reactivity control function.

9.6.2.2.1.2 Removal of Heat

Not applicable. The emergency AC power distribution system is not required to directly perform heat removal function.

9.6.2.2.1.3 Confinement

Not applicable. The emergency AC power distribution system is not required to directly perform radioactive material confinement function.

9.6.2.2.1.4 Extra Safety Functions

a) The emergency AC power distribution system supplies power to equipment that performs the three fundamental safety functions (control of reactivity, removal of heat and confinement);

b) The function categorisation of performing the three fundamental safety functions for equipment supplied by the emergency AC power distribution system is FC1 or FC2;

c) The emergency AC power distribution system supplies power to the equipment that contributes to the main protection line;

d) The extra safety function of the emergency AC power distribution system is implemented after it supplies power (within normal variation of the frequency and voltage) to the customer loads.

9.6.2.2.2 Design Assumption

The following key assumptions are applied for the design:

a) Assumption regarding power supply

   The corresponding EDG is available during the LOOP condition.

b) Assumption regarding control power supply

   The control power supply of the emergency AC power distribution system is available during normal and accident conditions.

c) Assumption regarding qualification

   The qualified equipment of the emergency AC power distribution system can perform its function during normal and accident conditions.

d) Assumption regarding ambient condition

   The HVAC system can ensure the ambient condition of the emergency AC power distribution system during normal and accident conditions.

9.6.2.3 System Description and Operation

9.6.2.3.1 System Description

9.6.2.3.1.1 General System Description

The emergency AC power distribution system is divided into three trains and refers to:

a) NI 10kV emergency power distribution system

1) LHA [EPDS (NI-10kV)] for train A;

2) LHB [EPDS (NI-10kV)] for train B;

3) LHC [EPDS (NI-10kV)] for train C.

b) NI 380V emergency power distribution system

1) NI 380V Emergency Power Distribution System (LLE/LLF/LLK/LLU [EPDS (NI-380V)]) for train A;

2) NI 380V Emergency Power Distribution System (LLH/LLI/LLS/LLV [EPDS (NI-380V)]) for train B;

3) NI 380V Emergency Power Distribution System (LLC/LLJ/LLT [EPDS (NI-380V)]) for train C.

The LHA/LHB/LHC [EPDS (NI-10kV)] are normally powered by the LGB/LGC/LGF [NPDS (CI-10kV)] and can be powered by the NI 10kV Emergency Power Supply System (LHP/LHQ/LHR [EPSS (NI-10kV)]) when the CI 10kV Power Distribution System LGB/LGC/LGF [NPDS (CI-10kV)] are unavailable.

The LLE/LLH/LLC [EPDS (NI-380V)] are powered by the upstream LHA/LHB/LHC [EPDS (NI-10kV)]. The LLF/LLK/LLU [EPDS (NI-380V)] are powered by the LLE [EPDS (NI-380V)], the LLI/LLS/LLV [EPDS (NI-380V)] are powered by the LLH [EPDS (NI-380V)], the LLJ/LLT [EPDS (NI-380V)] are powered by the LLC [EPDS (NI-380V)]. The LLF/LLI/LLJ [EPDS (NI-380V)] supply power to the loads which could have power restored to them during RCD mode by the interconnection. The LLU/LLV [EPDS (NI-380V)] supply power to the equipment of the BNX. The LLK/LLS/LLT [EPDS (NI-380V)] supply power to the equipment of the BDA/BDB/BDC.

The NI 10kV emergency power distribution system supplies power to the charging pump, Medium Head Safety Injection (MHSI) pump, component cooling water pump, essential service water pump, operational chilled water set and 10/0.4kV dry-type transformer LLE/LLH/LLC [EPDS (NI-380V)]. The NI 380V emergency power distribution system mainly supplies power to the equipment that are in service during DBC-2/3/4 condition, such as such as the 380V motors whose rated power is smaller than 200kW, electrical valves, electrical heaters and regulated transformers.

The NI 10kV emergency power distribution system is an ungrounded system. The earthing type of the NI 380V emergency power distribution system is TN-S.

Electrical connection information of the emergency AC power distribution system is presented in *Plant Auxiliary Electrical System Wiring Diagram*, Reference [4].

9.6.2.3.1.2 Description of Main Equipment

a) 10kV AC switchboard

The 10kV AC switchboard is a pre-fabricated metal-clad three-phase alternating current electrical switchboard with a draw-out connection device. The rated voltage of the 10kV AC switchboard is 12kV and the rated frequency is 50Hz.

The 10kV circuit breaker is used in the switchboard and its rated current is 1250A. The rated short-time withstand current is 50kA (3s) and the rated peak withstand current is 150kA.

The draw-out connection device of the 10kV AC switchboard adopts a truck unit. The switchboard adopts the single bus connection. The typical 10kV AC switchboard includes the following compartments:

1) Busbar compartment;

2) Cable connection compartment;

3) Low voltage compartment;

4) Truck compartment (10kV circuit breaker, or Potential Transformer (PT)).

b) 380V AC switchboard

The 380V AC switchboard is an indoor type metal frame three-phase cabinet with withdrawable drawers. The rated voltage of the switchboard is 380V, and its insulation voltage of the main circuit is 1kV. The rated frequency is 50Hz.

The rated current of the 380V AC switchboard is 4000A (main switchboard connected to the transformer) or 2000A (sub-switchboard). The permissible rated short-term current is 65kA with a duration time of 1s and the permissible rated peak current is 143kA.

The typical 380V AC switchboard includes the following compartments:

1) Busbar compartments;

2) Cable connection and current transformer compartment;

3) Withdrawable or movable parts compartment;

4) Bus voltage monitoring compartment for the incoming feeder.

The withdrawable drawer could be used at four positions: service position, test position, disconnected position and removed position.

c) 10/0.4kV dry-type transformer

The NI 10/0.4kV transformer is an air natural circulation cooling dry-type three – phase dual-winding transformer with a metal protective shell. The connection with the 380V AC switchboard is via a copper busbar connection. The neutral point of the transformer is directly earthed.

The capacity of the transformer is 2500kVA. The short-circuit impedance of the transformer is 8%. The connection symbol of the transformer is Dyn11. The range of the off-line tap changer is $\pm 2 \times 2.5\%$ on the high-voltage side. The maximum voltage of the high-voltage winding is 12kV; The maximum voltage of the low-voltage winding is 1.1kV.

9.6.2.3.1.3 Description of Main Layout

a) 10kV AC switchboard

The 10kV emergency AC switchboards LHA/LHB/LHC [EPDS (NI-10kV)] are installed in the level of +8.70m of the BSA, BSB and BSC. The equipment of the 10kV AC switchboards in the different trains is physically separated from each other.

b) 380V AC switchboard

The 380V emergency AC switchboards LLE/LLH/LLC/LLF/LLI/LLJ [EPDS (NI-380V)] are located in the level of +8.70m of the BSA/BSB/BSC. The 380V emergency AC switchboards LLU/LLV [EPDS (NI-380V)] are located in the level of +11.25m of BNX. The 380V emergency AC switchboards LLK/LLS/LLT are located in the level of +0.00m of the BDA/BDB/BDC.

The 380V AC switchboards are installed in the same room of the 10kV AC switchboards belonging to the same train. The equipment of the 380V AC switchboards in the different trains is physically separate from each other.

c) 10/0.4kV dry-type transformer

The 10/0.4kV dry-type transformer is generally located together with the 380V AC switchboard belonging to the same system. The transformers of the LLE/LLH/LLC [EPDS (NI-380V)] are located in the level of +8.70m of the BSA/BSB/BSC.

Detailed information about the equipment layout of the emergency AC power distribution system is presented in the Reference [7].

9.6.2.3.1.4 Description of System Interface

a) NI 10kV emergency power distribution systems

1) Support system

The support systems of the NI 10kV emergency power distribution system include the HVAC system, I&C system and control power system:

- DVL [EDSBVS]
- Protection System (PS)
- Safety Automation System (SAS[1])
- NI 380V AC Uninterruptible Power System (LVA/LVB/LVC [UPS (NI-380V-2h)])
- NI 220V DC Power Supply and Distribution System (LAA/LAB/LAC [DCPS (NI-220V-2h)])

2) Customer system

The customer system of the 10kV emergency power distribution system mainly includes:

- Chemical and Volume Control System (RCV [CVCS])
- RIS [SIS]
- Component Cooling Water System (RRI [CCWS])
- Essential Service Water System (SEC [ESWS])
- DER [OCWS]
- LLE/LLH/LLC [EPDS (NI-380V)]

b) NI 380V emergency power distribution system

1) Support system

The support systems of the emergency AC power distribution system include the HVAC system, I&C system and control power system:

- DVL [EDSBVS])
- PS
- SAS[1]
- LVA/LVB/LVC [UPS (NI-380V-2h)]
- LAA/LAB/LAC [DCPS (NI-220V-2h)]

2) Customer system

The customer system interface of the 380V emergency power distribution system mainly includes:

- RCV [CVCS]
- RIS [SIS]
- RRI [CCWS]
- SEC [ESWS]
- DER [OCWS]
- Emergency Boration System (RBS [EBS])
- Safeguard Building Controlled Area Ventilation System (DWL [SBCAVS])
- Gaseous Waste Treatment System (TEG [GWTS])
- Nuclear Sampling System (REN [NSS])
- Containment Cooling and Ventilation System (EVR [CCVS])
- Nuclear Island Fire Protection System (JPI [NIFPS])
- Fire-fighting Water Production System (JAC [FWPS])
- LHP/LHQ/LHR [EPSS (NI-10kV)]
- NI 380V AC Regulated Power System (LOA/LOB/LOC [ACRPS (NI-380V)])

9.6.2.3.1.5 Control and Monitoring

Each emergency AC supply system is provided with control and monitoring devices, which are intended to control, monitor and protect the system. Start up and operational controls of the emergency AC supply system are realised through the DCS automatically in a priority order. The manual control can be realised in the MCR through the DCS or locally in the switchboards. Important information of the system can be sent to the MCR for monitoring of the availability of the system. Electrical protection isolates the faults of the system.

9.6.2.3.2 System Operation

9.6.2.3.2.1 Plant Normal Conditions

a) Normal operation conditions

During normal operation conditions, the emergency AC power distribution system is in service and is powered from the CI 10kV normal AC power distribution.

b) Transient operation conditions

During transient operation conditions, the emergency AC power distribution system is in service and is powered from the CI 10kV normal AC power distribution.

9.6.2.3.2.2 Plant Accident Conditions

a) DBC-2/3/4 conditions

The emergency AC power distribution system is in service and is powered from the EDGs in case of LOOP. If the voltage of the LHA/LHB/LHC [EPDS (NI-10kV)] is lower than 0.8Un for 0.9s, the EDGs will be started. After the EDG is started successfully, when both the system undervoltage signal and the EDG start signal are received, the normal incoming circuit breaker of the system is opened automatically, the EDG incoming circuit breaker is closed automatically with a delay of 1.5s and then the emergency power distribution bus is repowered by the EDG.

In other DBC-2/3/4 conditions when the CI 10kV normal power distribution system is available, the emergency AC power distribution system is still powered from the CI 10kV normal power distribution system.

b) DEC conditions

The emergency AC power distribution system is out of service when LOOP combined with the failure of all EDGs. In other DEC conditions when the emergency AC power distribution system is available, the emergency AC power distribution system could supply power to the equipment required in the DEC conditions.

9.6.2.4 Design Substantiation

9.6.2.4.1 Compliance with Fundamental Safety Functional Requirement

9.6.2.4.1.1 Control of Reactivity

Not applicable.

9.6.2.4.1.2 Removal of Heat

Not applicable.

9.6.2.4.1.3 Confinement

Not applicable.

9.6.2.4.1.4 Extra Safety Functions

The emergency AC power distribution systems support the performance of safety functions by providing the necessary power supplies:

a) The emergency AC power distribution system provides electrical power to safety systems, such as the RIS [SIS] and RBS [EBS], which perform the reactivity control safety function;

b) The emergency AC power distribution system provides electrical power to safety systems, such as the RRI [CCWS] and SEC [ESWS], which perform the heat removal safety function;

c) The emergency AC power distribution system provides electrical power to safety systems, such as the REN [NSS] and RCV [CVCS], which perform the radioactive materials confinement safety function.

9.6.2.4.2 Compliance with Design Requirements

9.6.2.4.2.1 Compliance with Safety Classification

As the function categorisation of the emergency AC power distribution system is FC1, according to classification principles in Sub-chapter 4.4.5.2, the safety classification of the emergency AC power distribution system equipment is F-SC1.

Detailed information of safety classification for the emergency power distribution system is in the following table.

T-9.6-2 Categorisation and Classification of Emergency Power Distribution System

System	Categorisation	Classification
LHA/LHB/LHC [EPDS (NI-10kV)]	FC1	F-SC1
LLE/LLF/LLK/LLU/LLH/LLI/LLS/LLV/LLC /LLJ/LLT [EPDS (NI-380V)]	FC1	F-SC1

9.6.2.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

The emergency AC power distribution system consists of three redundant trains and meets the requirements of the SFC. The system and equipment are identical in each train.

The emergency AC power distribution system is capable of performing its tasks in the presence of single failure. Failure of a system or equipment in one train does not affect the system or equipment in other trains.

T-9.6-3 SFC and Redundancy of Emergency Power Distribution System

Train	10kV	380V			
A	LHA [EPDS (NI-10kV)]	LLE [EPDS (NI-380V)]	LLF [EPDS (NI-380V)]	LLK [EPDS (NI-380V)]	LLU [EPDS (NI-380V)]
B	LHB [EPDS (NI-10kV)]	LLH [EPDS (NI-380V)]	LLI [EPDS (NI-380V)]	LLS [EPDS (NI-380V)]	LLV [EPDS (NI-380V)]
C	LHC [EPDS (NI-10kV)]	LLC [EPDS (NI-380V)]	LLJ [EPDS (NI-380V)]	LLT [EPDS (NI-380V)]	*

*: Emergency AC power distribution system in BNX is not designed for train C.

b) Independence

Independence is accomplished in the design of the emergency power distribution system by using electrical and physical separation. They are independent from each other in terms of system, equipment and layout.

T-9.6-4 Independence of the Emergency Power Distribution System

Train	BS*	BD*	BNX
A	BSA (LHA [EPDS (NI-10kV)], LLE/LLF [EPDS (NI-380V)])	BDA (LLK [EPDS (NI-380V)])	Room of train A (LLU [EPDS (NI-380V)])
B	BSB (LHB [EPDS (NI-10kV)], LLH/LLI [EPDS (NI-380V)])	BDB (LLS [EPDS (NI-380V)])	Room of train B (LLV [EPDS (NI-380V)])
C	BSC (LHC [EPDS (NI-10kV)], LLC/LLJ [EPDS (NI-380V)])	BDC (LLT [EPDS (NI-380V)])	*

*: The emergency AC power distribution system in the BNX is not designed for train C.

c) Diversity

The emergency AC power distribution system between the three trains is identical and without diversity. It is recognised that diversity is required between the main protection line and diverse protection line. The emergency AC power distribution system, however, is identical to the SBO AC power distribution system for the current design which is based on the Fangchenggang Nuclear Power Plant Unit 3 (FCG3). Further work will be done to deal with the gap.

9.6.2.4.2.3 Compliance with Ensuring Functionality

a) Equipment qualification

The equipment of the emergency AC power distribution system is qualified according to its normal conditions and accident conditions. The seismic category of the equipment is SSE1 and it could perform its function during and after earthquakes.

The qualification category is K3 for the 10kV AC switchboard, 380V switchboard and 10/0.4kV dry-type transformer according to RCC-E 2016. Qualification categories for electrical equipment are defined according to RCC-E 2016 V.2120. Qualification K3 covers equipment located outside the containment building that shall be able to perform its function under environmental conditions corresponding to normal operation condition and seismic conditions.

b) Ageing and degradation

The ageing and degradation of the equipment for the emergency power distribution system is considered in qualification and EMIT. It is managed in the following aspects:

1) Equipment of the emergency AC power distribution system is qualified according to its service condition, such as seismic testing;

2) Material ageing properties are considered in accelerated ageing test, such as the activation energy value for transformer insulation materials is considered in the transformer accelerated ageing test;

3) Thermal ageing and ageing caused by operation (including mechanical and electrical) is addressed by type tests, such as mechanical operation ageing tests (e.g. draw-push circle and close-open circle) and environmental thermal ageing tests (e.g. dry heat and damp heat cyclic) for switchboards;

4) The switchboards are equipped with on-line inspection, such as insulation monitoring;

5) The layout of equipment facilitates EMIT, repair and replacement, such as the distance between two face to face switchboards is defined for the equipment layout design;

6) The replacement period of the equipment is defined according to its individual lifetime and the plant design life, such as the design life of the dry-type transformer which is intended to be used through the whole plant design life is 60 years.

c) Examination, maintenance, inspection and testing

The emergency AC power distribution system and equipment are designed to permit periodic examination, maintenance, inspection and testing. The examination includes visual checks and mechanical checks of the switchboard, and checking of the earthing switch and insulator lamps. The maintenance of switchboards includes the replacement of circuit breakers or fuses, and adjustment of the protection relay and transformer tap changer. The inspection of the switchboard and transformer includes the insulation of the circuit and the indicator lamps. For periodic testing, switchover from the CI 10kV normal power distribution system to the EDGs is done in RCD mode to demonstrate the availability of the system and equipment.

9.6.2.4.2.4 Compliance with Hazard Protection

a) External hazards

1) Earthquake

The emergency AC power distribution system could be in service during and after a safety shutdown earthquake. The switchboards and transformers for the system are seismically qualified and could perform their function during or after an earthquake.

2) Electromagnetic interference and space weather

The emergency AC power distribution system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards and meteorological hazards are usually addressed through the structure design or HVAC design of buildings.

b) Internal hazards

1) Internal fire

For emergency AC power distribution, the risk of internal fires is reduced by the selection of fire-resistance materials and cable penetrations are fire proof where necessary.

The three divisions of electrical equipment are in three independent fire compartments. The internal fire in one fire compartment could not cause the equipment located in the other fire compartment to fail. Electrical protection will cut off the fault section as soon as possible to reduce the risk of fire.

2) Electromagnetic interference

The emergency AC power distribution system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other internal hazards

Other internal hazards such as high energy pipe failures, dropped load, internal explosion and internal missiles are usually addressed through the system layout, protection degree of equipment or structure design of buildings.

9.6.3 SBO AC Power Distribution System

9.6.3.1 Safety Requirements

9.6.3.1.1 Fundamental Safety Functional Requirements

9.6.3.1.1.1 Control of Reactivity

The SBO AC power distribution system is not required to directly perform the reactivity control functions.

9.6.3.1.1.2 Removal of Heat

The SBO AC power distribution system is not required to directly perform the heat removal function.

9.6.3.1.1.3 Confinement

The SBO AC power distribution system is not required to directly perform the radioactive material confinement function.

9.6.3.1.1.4 Extra Safety Functions

As the SBO AC power distribution system is required to supply power to the equipment that contributes to the three fundamental safety functions, it performs extra safety functions.

9.6.3.1.2 Design Requirements

9.6.3.1.2.1 Safety Classification

According to the safety classification principles presented in Sub-chapter 4.4.5.1, as the SBO AC power distribution system provides power to equipment which perform FC3 safety functions, as some of this equipment may be required to perform FC1 or FC2 functions in other conditions, the function categorisation of the SBO AC power distribution system is FC1. Design requirements presented in Sub-chapter 4.4.5.3 are applied to the design of the SBO AC power distribution system.

9.6.3.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

As the safety function categorisation of the SBO AC power distribution system is FC1, the design principle of the SFC and redundancy presented in Sub-chapter 4.4.6.1.2 is required to be applied.

b) Independence

As the safety function categorisation of the SBO AC power distribution system is FC1, the design principle of independence presented in Sub-chapter 4.4.6.1.3 is required to be applied.

c) Diversity

As the SBO AC power distribution system supplies power to the equipment that contributes to the diverse protection line, the diversity principle presented in Sub-chapter 4.4.6.1.4 is required to be applied.

9.6.3.1.2.3 Design to Ensure Functionality

a) Equipment qualification

As the safety function categorisation of the SBO AC power distribution system is FC1, equipment of the SBO AC power distribution system is required to be qualified according to the principles presented in Sub-chapter 4.4.6.2.1.

b) Ageing and degradation

As the SBO AC power distribution system is required to remain available during its lifetime, requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As the SBO AC power distribution system is required to remain available during its lifetime, EMIT of the SBO AC power distribution system is applied according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.6.3.1.2.4 Hazard Protection

a) External hazards

As the safety function categorisation of the SBO AC power distribution system is FC1, the SBO AC power distribution system is protected against external hazards in accordance with the principle presented in Sub-chapter 18.6.

b) Internal hazards

As the safety function categorisation of the SBO AC power distribution system is FC1, the SBO AC power distribution system is protected against internal hazards in accordance with the principle presented in Sub-chapter 19.6.

9.6.3.2 Design Basis

9.6.3.2.1 General Assumption

9.6.3.2.1.1 Control of Reactivity

Not applicable. The SBO AC power distribution system is not required to directly perform the reactivity control function.

9.6.3.2.1.2 Removal of Heat

Not applicable. The SBO AC power distribution system is not required to directly perform the heat removal function.

9.6.3.2.1.3 Confinement

Not applicable. The SBO AC power distribution system is not required to directly perform the radioactive material confinement function.

9.6.3.2.1.4 Extra Safety Functions

a) The SBO AC power distribution system supplies power to equipment that performs the three fundamental safety functions (control of reactivity, removal of heat and confinement);

b) The function categorisation of performing three fundamental safety functions for the equipment supplied by the SBO AC power distribution system is FC3, some of these equipment may perform FC1 or FC2 functions in other conditions;

c) The SBO AC power distribution system supplies power to the equipment that contributes to the diverse protection line;

d) The extra safety functions of the SBO AC power distribution system are implemented after it supplies power (within normal variation of the frequency and voltage) to the customer loads.

e) The equipment of the customer systems can operate normally during normal and expected abnormal range of the frequency and voltage.

9.6.3.2.2 Design Assumption

The following key assumptions are applied for the design:

a) Assumption regarding power supplies

   The SBO DG is available during SBO condition.

b) Assumption regarding control power supplies

   The control power supply of the SBO AC power distribution system is available during normal operation and accident conditions.

c) Assumption regarding qualification

The qualified equipment of the SBO AC power distribution system can perform its function during normal and accident conditions.

d) Assumption regarding ambient condition

The HVAC system can ensure the ambient conditions of the SBO AC power distribution system during normal and accident conditions.

9.6.3.3 System Description and Operation

9.6.3.3.1 System Description

9.6.3.3.1.1 General System Description

The SBO AC power distribution systems consist of:

a) LHM/LHN [SBOPDS (NI-10kV)];

b) NI 380V SBO Power Distribution System: LLA/LLB/LLD/LLG/LLM/LLN [SBOPDS (NI-380V)]

The SBO AC power distribution system is divided into two trains: the LHM [SBOPDS (NI-10kV)] and the LLA/LLD [SBOPDS (NI-380V)] belong to train A; the LHN [SBOPDS (NI-10kV)] and the LLB/LLG [SBOPDS (NI-380V)] belong to train B.

The LHM/LHN [SBOPDS (NI-10kV)] are powered by the LHA/LHB [EPDS (NI-10kV)].

The LLA/LLB [SBOPDS (NI-380V)] are powered by the upstream LHM/LHN [SBOPDS (NI-10kV)]. The LLD/LLM [SBOPDS (NI-380V)] are powered by the LLA [SBOPDS (NI-380V)]; the LLG/LLN [SBOPDS (NI-380V)] are powered by the LLB [SBOPDS (NI-380V)], and each of these systems consists of a group of 380V AC sub-switchboards. The LLD/LLG [SBOPDS (NI-380V)] supply power to the loads which could be repowered during the RCD mode by the interconnection. The LLM/LLN [SBOPDS (NI-380V)] supply power to the equipment of the BDU and BDV.

The NI 10kV SBO power distribution system supplies power to the Low Head Safety Injection (LHSI) pump, containment heat removal pump, emergency feedwater pump, safety chilled water unit and 10/0.4kV dry-type transformer of the LLA/LLB [SBOPDS (NI-380V)]. The NI 380V SBO Power Distribution System [SBOPDS (NI-380V)] mainly supplies power to the equipment that are in service during DEC conditions or both the DEC and DBC-2/3/4 conditions, such as the 380V motors whose rated power is smaller than 200kW, electrical valves, electrical heaters and DC chargers.

The NI 10kV SBO power distribution system is an ungrounded system. The earthing type of the NI 380V SBO power distribution system is TN-S.

Electrical connection information of the SBO AC power distribution system is presented in *Plant Auxiliary Electrical System Wiring Diagram*, Reference [4].

9.6.3.3.1.2 Description of Main Equipment

a) 10kV AC switchboard

The SBO AC switchboard is constituted of a group of circuits, which includes a circuit breaker located in the metal compartment. The connection device adopts a withdrawable truck unit. The switchboard adopts a single bus.

The functional unit includes one or more of the following compartments, such as the busbar compartment, cable connection compartment, low voltage compartment and truck compartment.

The rated voltage of the 10kV AC switchboard is 12kV and the rated frequency is 50Hz. The 10kV breaker in the 10kV switchboard is a vacuum type. There is no use of fuse-contactor in the 10kV switchboard. The rated current of the 10kV breaker is 1250A. The rated short-time withstand current is 50kA (3s) and the rated peak withstand current is 150kA.

b) 380V AC switchboard

The 380V switchboard is an indoor type metal frame cabinet with withdrawable drawers. The 380V AC switchboard consists of the power supply circuit, a group of busbars, auxiliary busbar, grounding circuit and the fixing and adjusting devices.

The power supply circuit includes the busbar compartments, cable connection and current transformer compartment, withdrawable or movable parts compartment, bus voltage monitoring compartment when necessary and the withdrawable control and protection device is installed on the switchboard.

The withdrawable drawer could be used at four positions: service position, test position, disconnected position and removed position.

c) 10/0.4kV dry-type transformer

The 10/0.4kV transformer is an air natural circulation cooling dry-type transformer with a metal protective shell. The connection with the 380V AC switchboard is via a copper busbar connection. The neutral point of the transformer is directly earthed.

The capacity of the transformer is 2500kVA. The connection symbol of the transformer is Dyn11. The off-load tap changers on the high-voltage side are ±2×2.5% and could be changed under the no-load condition. The maximum voltage of the high-voltage winding is 12kV. The maximum voltage of the low-voltage winding is 1.1kV.

9.6.3.3.1.3 Description of Main Layout

a) 10kV AC switchboard

The 10kV SBO AC switchboards are installed in different buildings that are physically separated. The LHM [SBOPDS (NI-10kV)] for train A is located in the level of +8.70m of the BSA. The LHN [SBOPDS (NI-10kV)] for train B is located in the level of +8.70m of the BSB.

b) 380V AC switchboard

The 380V SBO AC switchboards are installed in different buildings that are physically separate. 380V SBO power distribution switchboards for train A are located in the level of +8.70m of the BSA, such as the main switchboard LLA [SBOPDS (NI-380V)] and the sub-switchboard LLD [SBOPDS (NI-380V). The 380V SBO power distribution switchboards for train B are located in the level of +8.70m of the BSB, such as the main switchboard LLB [SBOPDS (NI-380V)] and sub-switchboard LLG [SBOPDS (NI-380V).

c) 10/0.4kV dry-type transformer

The 10/0.4kV dry-type transformers of the SBO power distribution system are generally located together with the main switchboard of the same system. The 10/0.4kV dry-type transformers of the LLA/LLB [SBOPDS (NI-380V)] are located in the level of +8.70m of the BSA/BSB.

Detailed information about the equipment layout of the SBO AC power distribution system is presented in the Reference [7].

9.6.3.3.1.4 Description of System Interfaces

a) NI 10kV SBO power distribution system

1) Support system

The support systems of the NI 10kV SBO power distribution system include the HVAC system, I&C system and control power systems:

- DVL [EDSBVS]
- PS
- SAS[1]
- Diverse Actuation System [KDS(DAS)]
- LVA/LVB [UPS (NI-380V-2h)]

- LAP/LAQ [DCPS (NI-220V-12h)]

2) Customer system

The customer system of the 10kV SBO power distribution system mainly includes:

- RIS [SIS]
- Emergency Feedwater System (ASG [EFWS])
- Containment Heat Removal System (EHR [CHRS])
- Safety Chilled Water System (DEL [SCWS])
- LLA/LLB [SBOPDS (NI-380V)])

b) 380V SBO power distribution systems

1) Support system

The support systems of the 380V SBO power distribution system include the NI HVAC system, I&C system and control power system:

- DVL [EDSBVS]
- PS
- SAS[1]
- KDS [DAS]
- LVA/LVB/LVC [UPS (NI-380V-2h)]
- LAP/LAQ [DCPS (NI-220V-12h)]

2) Customer system

The customer system interface of the NI normal power distribution system mainly includes:

- RIS [SIS]
- ASG [EFWS]
- EHR [CHRS]
- DEL [SCWS])
- Fuel Pool Cooling and Treatment System (PTR [FPCTS])
- Extra Cooling System (ECS [ECS])
- Containment Filtration and Exhaust System (EUF [CFES])

- Main Control Room Air Conditioning System (DCL [MCRACS])
- DVL [EDSBVS]
- DWL [SBCAVS]
- Containment Sweeping and Blowndown Ventilation System (EBA [CSBVS])
- Extra Cooling Water and NI Firefighting Building Ventilation System (DXE [ECW&FFB VS])
- EVR [CCVS]
- LAA/LAB [DCPS (NI-220V-2h)]
- LAP/LAQ [DCPS (NI-220V-12h)]

9.6.3.3.1.5 Control and Monitoring

Each SBO AC power distribution system is provided with control and monitoring devices, which are intended to control, monitor and protect the system. Start-up and operation of the SBO AC power distribution system could be controlled through the DCS or locally in the switchboards by manual operation. Important information of the system can be sent to the MCR for monitoring of the availability of the system. Electrical protection isolates the faults of the system.

9.6.3.3.2 System Operation

9.6.3.3.2.1 Plant Normal Conditions

a) Normal operation conditions

During normal operation conditions, the SBO AC power distribution system is in service and is powered from the 10kV emergency AC power distribution system.

b) Transient operation conditions

During transient operation conditions, the SBO AC power distribution system is in service and is powered from the 10kV emergency AC power distribution system.

9.6.3.3.2.2 Plant Accident Conditions

a) DBC-2/3/4 conditions

During DBC-2/3/4 conditions, the SBO AC power distribution system is in service and is powered from the 10kV emergency AC power distribution system.

b) DEC conditions

When LOOP combined with the failure of all EDGs in the SBO condition occurs, the SBO DG is started up manually. The SBO AC power distribution system is in service and is powered from the SBO DG in case of SBO.

In other DEC conditions, when the 10kV emergency AC power distribution system is available, the SBO AC power distribution system is still powered from the 10kV emergency AC power distribution system.

9.6.3.4 Design Substantiation

9.6.3.4.1 Compliance with Fundamental Safety Functional Requirements

9.6.3.4.1.1 Control of Reactivity

Not applicable.

9.6.3.4.1.2 Removal of Heat

Not applicable.

9.6.3.4.1.3 Confinement

Not applicable.

9.6.3.4.1.4 Extra Safety Functions

The SBO AC power distribution system supports the performance of safety functions by providing the necessary power supplies:

a) The SBO AC power distribution system provides electrical power to safety system, such as the RIS [SIS] and ASG [EFWS], which are performing the reactivity control safety function;

b) The SBO AC power distribution system provides electrical power to safety systems, such as the PTR [FPCTS] and ECS [ECS], which are performing the heat removal safety function;

c) The SBO AC power distribution system provides electrical power to safety systems, such as the EHR [CHRS] and EUF [CFES], which are performing the radioactive materials confinement safety function.

9.6.3.4.2 Compliance with Design Requirements

9.6.3.4.2.1 Compliance with Safety Classification

As the function categorisation of the SBO AC power distribution system is FC1, according to the classification principles in Sub-chapter 4.4.5.2, the safety classification of the SBO AC power distribution system equipment is F-SC1.

Detailed information of safety classification for the SBO power distribution system is in the following table.

T-9.6-5 Categorisation and Classification of the SBO Power Distribution System

System	Categorisation	Classification
LHM/LHN [SBOPDS (NI-10kV)]	FC1	F-SC1
LLA/LLB/LLD/LLG/LLM/LLN [SBOPDS (NI-380V)]	FC1	F-SC1

9.6.3.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

The SBO AC power distribution system consists of two redundant trains and meets the requirement of the SFC. The system and equipment are identical in each train.

The SBO AC power distribution system is capable of performing its tasks in the presence of single failure. Failure of a system or equipment in one train does not affect the system or equipment in the other trains.

T-9.6-6 SFC and Redundancy of the SBO Power Distribution System

Train	10kV	380V		
A	LHM [SBOPDS (NI-10kV)]	LLA [SBOPDS (NI-380V)]	LLD [SBOPDS (NI-380V)]	LLM [SBOPDS (NI-380V)]
B	LHN [SBOPDS (NI-10kV)]	LLB [SBOPDS (NI-380V)]	LLG [SBOPDS (NI-380V)]	LLN [SBOPDS (NI-380V)]

b) Independence

The SBO AC power distribution system is comprised of the LHM/LHN [SBOPDS (NI-10kV)]. The LHM [SBOPDS (NI-10kV)] is located in train A of BSA and the LHN [SBOPDS (NI-10kV)] is located in train B of BSB.

Independence is accomplished in the design of the SBO power distribution system by using electrical segregation and physical separation. They are independent from each other in terms of the system, equipment and layout.

T-9.6-7 Independence of the SBO Power Distribution System

Train	BS*	BD*
A	BSA (LHM [SBOPDS (NI-10kV)], LLA/LLD [SBOPDS (NI-380V)])	BDU (LLM [SBOPDS (NI-380V)])
B	BSB (LHN [SBOPDS (NI-10kV)], LLB/LLG [SBOPDS (NI-380V)])	BDV (LLN [SBOPDS (NI-380V)])

c) Diversity

The SBO AC power distribution system between the two trains is identical and without diversity. It is recognised that diversity is required between the main protection line and the diverse protection line The SBO AC power distribution system, however, is identical with the emergency AC power distribution system for the current design which based on FCG3. Further work will be done to deal with the gap.

9.6.3.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

The equipment of the SBO AC power distribution system required to perform the safety functions are capable of operating under normal conditions and accident conditions, which requires the equipment to be environmentally qualified and seismically qualified.

The qualification category is K3 for the 10kV AC switchboard, 380V switchboard and 10/0.4kV dry-type transformer according to RCC-E 2016.

b) Ageing and degradation

The ageing and degradation of the SBO AC power distribution systems is considered in qualification and EMIT. It is managed in the following aspects:

1) Equipment of the SBO AC power distribution system is qualified according to its service condition, such as seismic testing;

2) Material ageing properties are considered in accelerated ageing tests, such as the activation energy value for transformer insulation materials is considered in the transformer accelerated ageing test;

3) Thermal ageing and ageing caused by operation (including mechanical and electrical) is addressed by type tests, such as the mechanical operation ageing tests (e.g. draw-push circle and close-open circle) and environmental thermal ageing tests (e.g. dry heat and damp heat cyclic) for switchboards;

4) The switchboards are equipped with on-line inspection, such as insulation monitoring;

5) The layout of equipment facilitates EMIT, repair and replacement, such as the distance between two face to face switchboards is defined for equipment the layout design;

6) The replacement period of the equipment is defined according to its individual design life and the plant lifespan, such as the design life of the dry-type transformer which is intended to be used through the whole plant design life is 60 years.

c) Examination, maintenance, inspection and testing

The SBO AC power distribution system and equipment are designed to permit periodic examination, maintenance, inspection and testing. The examination includes visual checks and mechanical checks of the switchboard, and checking of the earthing switch and insulator lamps. The maintenance of the switchboard includes the replacement of circuit breakers or fuses, and adjustment of the protection relay and transformer tap changer. The inspection of the switchboard and transformer includes the insulation of the circuit and the indicator lamps. For periodic testing, switchover from the NI 10kV emergency power distribution system to the SBO DG is done in RCD mode to demonstrate the availability of the system and equipment.

9.6.3.4.2.4 Compliance with Hazard Protection

a) External hazards

1) Earthquake

The SBO AC power distribution system could be in service during and after safety shutdown earthquake. The switchboards and transformers for the system are seismically qualified and could perform their function during or after an earthquake.

2) Electromagnetic interference and space weather

The SBO AC power distribution system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards and meteorological hazards are usually addressed through the structure design or HVAC design of buildings.

b) Internal Hazards

1) Internal fire

For SBO AC power distribution, the risk of internal fires is reduced by the selection of fire-resistance materials and cable penetrations are fire proof where necessary.

The two division of electrical equipment are in two independent fire compartments. The internal fire in one fire compartment could not cause the equipment located in the other fire compartment to fail. Electrical protection will cut off the fault section as soon as possible to reduce the risk of fire.

2) Electromagnetic interference

The SBO AC power distribution system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other internal hazards

Other internal hazards such as high energy pipe failures, dropped load, internal explosion and internal missiles are usually addressed through the system layout, protection degree of equipment or structure design of buildings.

9.6.4 Emergency Diesel Generator

9.6.4.1 Safety Requirements

9.6.4.1.1 Fundamental Safety Functional Requirements

9.6.4.1.1.1 Control of Reactivity

The EDG is not required to directly perform the reactivity control function.

9.6.4.1.1.2 Removal of Heat

The EDG is not required to directly perform the heat removal function.

9.6.4.1.1.3 Confinement

The EDG is not required to directly perform the radioactive material confinement function.

9.6.4.1.1.4 Extra Safety Functions

As the EDG is safety standby AC power source, it is required to provide power through the emergency AC power distribution system to the equipment contributing to the three fundamental safety functions in the event of LOOP. It performs the extra safety function.

9.6.4.1.2 Design Requirements

9.6.4.1.2.1 Safety Classification

According to the safety classification principles presented in Sub-chapter 4.4.5.1, as the EDG provides power to equipment which performs FC1 or FC2 safety functions in case of LOOP, its function categorisation is FC1. Design requirements presented in Sub-chapter 4.4.5.3 are applied to the design of the EDG.

9.6.4.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

As the safety function categorisation of the EDG is FC1, the design principle of SFC and redundancy presented in Sub-chapter 4.4.6.1.2 is required to be applied.

b) Independence

As the safety function categorisation of the EDG is FC1, the design principle of independence presented in Sub-chapter 4.4.6.1.3 is required to be applied.

c) Diversity

As the EDG supplies power to the equipment that contributes to the main protection line, the diversity principle presented in Sub-chapter 4.4.6.1.4 is required to be applied.

9.6.4.1.2.3 Design to Ensure Functionality

a) Equipment qualification

As the safety function categorisation of the EDG is FC1, equipment of the EDG is required to be qualified according to the principles presented in Sub-chapter 4.4.6.2.1.

b) Ageing and degradation

As the EDG is required to remain available during its lifetime, requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As the EDG is required to remain available during its lifetime, EMIT of the EDG is applied according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.6.4.1.2.4 Hazard Protection

a) External hazards

As the safety function categorisation of the EDG is FC1, the EDG is protected against external hazards in accordance with the principles presented in Sub-chapter 18.6.

b) Internal hazards

As the safety function categorisation of the EDG is FC1, the EDG is protected against internal hazards in accordance with the principles presented in Sub-chapter 19.6.

9.6.4.2 Design Basis

9.6.4.2.1 General Assumption

9.6.4.2.1.1 Control of Reactivity

Not applicable. The EDG is not required to directly perform the reactivity control function.

9.6.4.2.1.2 Removal of Heat

Not applicable. The EDG is not required to directly perform the heat removal function.

9.6.4.2.1.3 Confinement

Not applicable. The EDG is not required to directly perform the radioactive material confinement function.

9.6.4.2.1.4 Extra Safety Functions

a) The EDG is designed as a safety standby AC power source in the NPP;

b) The function categorisation of performing the three fundamental safety functions for equipment which the EDG provides power to in case of LOOP is FC1 or FC2;

c) The EDG supplies power to the equipment that contributes to the main protection line in the case of LOOP;

d) The extra safety functions of the EDG are implemented after it supplies power (within normal variation of the frequency and voltage) to the customer loads in case of LOOP.

9.6.4.2.2 Design Assumption

The following key assumptions are applied for the design:

a) Assumption regarding power supplies

   The EDG is in the stand-by state so that it could be started at any time when it receives a start-up signal. The pre-treatment equipment is powered during the stand-by state of the EDG.

b) Assumption regarding control power supplies

   The control power is available during normal and accident condition. The FC1 DCS Protection System (PS) is available in case of LOOP.

c) Assumption regarding qualification

   The qualified equipment of the EDG can perform its function in case of LOOP.

d) Assumption regarding ambient condition

   The HVAC system can ensure the ambient conditions of the EDG in case of LOOP.

9.6.4.3 System Description and Operation

9.6.4.3.1 System Description

9.6.4.3.1.1 General System Description

The design of the EDG is capable of supplying the necessary power in anticipated operational occurrences and design basis accidents and in the event of a LOOP. The EDG provides power supply to the emergency AC power distribution system during a LOOP condition, which can support the necessary structures, systems and components in all DBC-2/3/4 conditions.

EDGs consist of:

a) Train A EDG: LHP [EPSS (NI-10kV)];

b) Train B EDG: LHQ [EPSS (NI-10kV)];

c) Train C EDG: LHR [EPSS (NI-10kV)]).

The LHP [EPSS (NI-10kV)] is connected to the LHA [EPDS (NI-10kV)]; the LHQ [EPSS (NI-10kV)] is connected to the LHB [EPDS (NI-10kV)]; the LHR [EPSS (NI-10kV)] is connected to the LHC [EPSS (NI-10kV)].

The rated voltage of the EDG is 10kV. The active power of the EDG is 8000kW. The frequency is 50Hz and the rated power factor is 0.8.

One EDG set could cope with the design basis condition in case of LOOP. The start-up time is less than 15s. The EDG can operate continuously for at least 7 days at the rated power.

There are some non-safety loads that are connected to the safety electrical power system. Although there are no maximum limits of non-safety loads for the EDG, the non-safety loads are as less as possible.

The neutral point of the EDG is ungrounded, which makes continuous operation of the EDG possible when a single-phase earth fault occurs.

9.6.4.3.1.2 Description of Main Equipment

Each EDG is composed of a diesel engine, an AC generator and auxiliary systems. The engine and the auxiliaries of the EDG are described in Sub-chapter 10.8.3.

a) Diesel engine

The diesel engine is a four-stroke, water cooled, V-type cylinder, supercharged mechanical equipment driving the AC generator with a rated electrical power of approximately 8000 kW. The rated speed of the EDG is 600rpm.

The capacity of the main fuel storage tank of the EDG set can store enough fuel to enable the related DG set to run continuously for 7 consecutive days under the maximum load after an accident occurs accompanied with a LOOP.

b) AC generator

The AC generator is air circulating cooling with self-fans in its axis. The heater medium of the AC generator is ambient air. The anti-condensation heater is set and powered when the AC generator is in stand-by or out of service.

The thermal class of the electrical insulating material is 155 and its thermal class of operation assessment is 130. The over-speed ability of the AC generator is 120% rated speed for 5s and it must trip when it reach 115% rated speed.

c) Auxiliary equipment

The auxiliary equipment includes lubrication oil equipment, fuel oil equipment, cooling water equipment, compressed air start-up equipment and air intake and exhaust equipment.

Diesel fuel is pumped from main storage tank to the daily tank with two transfer pumps. The compressed air start-up equipment is capable of starting the DG at least 5 times. The lubrication equipment and cooling water equipment is designed to make sure the DG set could start up, reach the rated voltage and rated frequency in less than 15s. The air intake and exhaust equipment is used to supply air from and to the outdoor environment with a silencer.

9.6.4.3.1.3 Description of Main Layout

Three EDG trains are arranged in three different buildings. Train A LHP [EPSS (NI-10kV)] is in the BDA, train B LHQ [EPSS (NI-10kV)] is in the BDB, and train C LHR [EPSS (NI-10kV)] is in the BDC. Each redundant DG is located in an independent building, physically separated.

a) Diesel engine

The EDG is seated in the diesel generator hall in the level of +0.00m of the emergency diesel generator building.

b) AC generator

The AC generator is seated together with the DG in the diesel generator hall. The power and control cabinets of the AC generator are seated in the level of +0.00m.

c) Auxiliary equipment

The main oil tank is seated in level of -11.30m and the air compressor set is seated in level of +0.00m. The daily oil tank is seated in level of +8.90m and the silencer and water tanks are located in level of +20.24m.

9.6.4.3.1.4 Description of System Interfaces

a) Support system

The support systems of the EDG include the HVAC system, I&C system and control power system:

1) DVD [DBVS]

2) PS

3) LVA/LVB/LVC [UPS (NI-380V-2h)]

4) LAA/LAB/LAC [DCPS (NI-220V-2h)]

b) Customer system

The customer systems of the EDG are LHA/LHB/LHC [EPDS (NI-10kV)].

9.6.4.3.1.5 Control and Monitoring

The EDG can be started automatically once the auto-start instruction from the DCS is received. Manual start-up can be carried out in the MCR and from the local control panel in the emergency diesel generator buildings. Shutdown of the EDG can only be done manually (except fault trip), regardless of the start-up mode.

Starting and reconnection of the EDG to the busbar are undertaken in the Protection System (PS), which is classified as a F-SC1 I&C system. If there is a failure of the PS coupled with a LOOP condition, start and re-connect of the EDG is not considered and the SBO DG will be used to mitigate the accident.

The EDG can only be shutdown manually when there is no fault, including in backup operation. The EDG could be tripped by protection automatically when a fault occurs.

The voltage and frequency of the EDG can be monitored in the MCR. Alarms are generated and can be sent to the MCR in the event of an electrical or a mechanical fault. Electrical protection isolates the faults of the system.

9.6.4.3.2 System Operation

9.6.4.3.2.1 Plant Normal Conditions

a) Normal operation conditions

During normal operation conditions, the EDG is in the stand-by state and its pre-treatment system is in operation.

b) Transient operation conditions

During transient operation conditions, the EDG is in the stand-by state and its pre-treatment system is in operation.

9.6.4.3.2.2 Plant Accident Conditions

a) DBC-2/3/4 condition

The accident conditions mainly take into account LOOP and LOOP together with other accidents.

The EDG is started if the voltage of the NI 10kV emergency distribution system is lower than 0.8Un for a time delay. If the voltage of the emergency power distribution bus is lower than 0.8Un for a time delay, and the voltage and frequency of the EDG reach the defined values, the EDG is allowed to be connected. At this time, within 15 seconds after receiving the start-up signal for the EDG, the diesel generator set is able to establish the rated frequency and rated voltage and connect with the LHA/LHB/LHC [EPDS (NI-10kV)] as soon as possible.

The emergency plant loads will be reloaded with an interval of 5s, which is determined by the repower requirements of the emergency plant loads and the single step capability of EDG. The unshedded loads will have power restored to them at the beginning of the reloading program. Most of the loads will be reloaded step by step according to the reloading program automatically. Some loads will have power restored to them manually after the end of the automatic reloading program.

b) DEC condition

The EDG is out of service in the event of SBO. In other DEC condition, if the EDG is still available after LOOP, it could be the preferred choice of power supply during DEC conditions.

9.6.4.4 Design Substantiation

9.6.4.4.1 Compliance with Fundamental Safety Functional Requirements

9.6.4.4.1.1 Control of Reactivity

Not applicable.

9.6.4.4.1.2 Removal of Heat

Not applicable.

9.6.4.4.1.3 Confinement

Not applicable.

9.6.4.4.1.4 Extra Safety Functions

The EDG starts up and connects to the NI 10kV emergency power distribution system in case of a LOOP condition. It supports the performance of safety functions by providing the necessary power supplies through the emergency AC power distribution system:

a) The EDG provides power to safety systems such as the RCV [CVCS] and RIS [SIS], which are performing the reactivity control safety function;

b) The EDG provides power to safety systems such as the Reactor Boron and Water Makeup System (REA [RBWMS]) and SEC [ESWS], which are performing the heat removal safety function;

c) The EDG provides power to safety systems such as the Annulus Ventilation System (EDE [AVS] and RRI [CCWS], which are performing the radioactive materials confinement function.

9.6.4.4.2 Compliance with Design Requirements

9.6.4.4.2.1 Compliance with Safety Classification

As the function categorisation of the EDG is FC1, according to the classification principles in Sub-chapter 4.4.5.2, the safety classification of EDG is F-SC1.

Detailed information of safety classification for EDG is as follows:

T-9.6-8 Categorisation and Classification of EDG

System	Categorisation	Classification
LHP/LHQ/LHR [EPSS (NI-10kV)] AC generator	FC1	F-SC1
LHP/LHQ/LHR [EPSS (NI-10kV)] power cabinet	FC1	F-SC1
LHP/LHQ/LHR [EPSS (NI-10kV)] control cabinet	FC1	F-SC1

9.6.4.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

The EDG comprises three trains LHP/LHQ/LHR [EPSS (NI-10kV)]. The LHP [EPSS (NI-10kV)] is in train A, LHQ [EPSS (NI-10kV)] is in train B and LHR [EPSS (NI-10kV)] is in train C. They are redundant and meet the requirement of the SFC. The system and equipment are identical in each train.

The EDG is capable of performing its task in the presence of a single failure. The failure of a system or equipment in one train does not affect the system or equipment in other trains.

b) Independence

Independence is accomplished in the design of the EDG by using electrical, mechanical segregation, as well as physical separation.

LHP [EPSS (NI-10kV)] is located in the BDA, the LHQ [EPSS (NI-10kV)] is located in the BDB and the LHR [EPSS (NI-10kV)] is located in the BDC. They are independent from each other in terms of system, equipment and layout.

c) Diversity

As the EDG is designed to supply power to the main protection line and the SBO DG is designed to supply power to the diverse protection line, diversity exists between the EDG and SBO DG.

The diversity of the EDG and SBO DG is mainly due to the different suppliers such as the capacity and speed of the DGs. Further analysis for CCF will be done in Step 3 of GDA.

9.6.4.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

The equipment of the EDG is qualified according to its normal conditions and accident conditions. The seismic category of the equipment is SSE1 and it could perform its function during and after earthquakes.

The qualification category is K3 for DG electrical components, power cabinet and control cabinet according to RCC-E 2016.

b) Ageing and degradation

The ageing and degradation of the equipment for the EDG is considered in qualification and EMIT. It is managed in the following aspects:

1) Equipment of the EDG is qualified according to its service condition, such as seismic test;

2) Material ageing properties are considered in accelerated ageing test, such as the activation energy value for generator insulation materials is considered in the stator accelerated ageing test;

3) Thermal ageing and ageing caused by operation (including mechanical and electrical) is addressed by type tests, such as mechanical operation ageing tests (e.g. start-stop circle test and vibration ageing test) and environmental thermal ageing tests (e.g. dry heat and damp heat cyclic) for rotating machinery;

4) The EDG is equipped with on-line inspection, such as insulation monitoring and a start-up time counter;

5) The layout of equipment facilitates EMIT, repair and replacement, such as the distance between the rotating machinery and the wall is defined for the equipment layout design;

6) The replacement period of the equipment is defined according to its individual design life and the plant lifespan, such as the design life of the main rotating machinery which is intended to be used through the whole plant design life is 60 years.

c) Examination, maintenance, inspection and testing

The EDG and equipment are designed to permit periodic examination, maintenance, inspection and testing. The system status surveillance of the EDG includes the system voltage, current, active power, reactive power, frequency and status of the control power. The equipment status surveillance of the EDG includes the start time, accumulated running time and accumulated start-up times (compressed air start-up times and the successful diesel engine start-up times).

The pre-service inspection of the LHP/LHQ/LHR [EPSS (NI-10kV)] is to verify that the DG set can fulfil the pre-heating, pre-lubrication and compressed air storage tests under internal and external hazards to make sure it can perform the safety functions under accidental conditions.

The maintenance cycle of the EDG is required to match the refuelling cycle of the power plant. The maintenance and replacement of the EDG are generally arranged during the RCD. Only one train of the DGs is allowed to be maintained and replaced at a time.

The periodic tests of the EDG include the start-up test, load test and power supply switching test. The purposes of the tests is to make sure the DG set and its auxiliary equipment have the ability to cope with a LOOP condition and are able to supply power to the safety class load. The periodic testing of the EDG is on the network without the grid.

The EDG is designed to permit periodic inspection and testing at power. If there is a LOOP while the EDG is being tested, the EDG can return to repower the necessary loads. Good practice dictates that a standby power source could continue to perform its safety function during testing with a coincident LOOP. The EDG is available during the low power test at the power operation state.

9.6.4.4.2.4 Compliance with Hazard Protection

The three EDGs are located in three different civil buildings, which provide physical separation from each other and provide protection against external and internal hazards.

a) External hazards

1) Earthquake

The EDG could be in service during and after a safety shutdown earthquake. The equipment of the EDG is seismically qualified and could perform their function during or after an earthquake.

2) Electromagnetic interference and space weather

The EDG is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards and meteorological hazards are usually addressed through the structure design or HVAC design of buildings.

b) Internal hazards

1) Internal fire

For the EDG the risk of internal fires is reduced by the selection of fire-resistance materials and cable penetrations are fire proof where necessary.

The three trains of EDG are in three independent fire compartments. The internal fire in one fire compartment could not cause the equipment located in the other fire compartment to fail. Electrical protection will cut off the fault section as soon as possible to reduce the risk of fire.

2) Electromagnetic interference

The EDG is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other internal hazards

Other internal hazards such as high energy pipe failures, dropped load, internal explosion and internal missiles are usually addressed through the system layout, protection degree of equipment or structure design of buildings.

9.6.5 SBO Diesel Generator

9.6.5.1 Safety Requirements

9.6.5.1.1 Fundamental Safety Functional Requirements

9.6.5.1.1.1 Control of Reactivity

The SBO DG is not required to directly perform the reactivity control function.

9.6.5.1.1.2 Removal of Heat

The SBO DG is not required to directly perform the heat removal function.

9.6.5.1.1.3 Confinement

The SBO DG is not required to directly perform the radioactive material confinement function.

9.6.5.1.1.4 Extra Safety Functions

As the SBO DG is an alternate AC power source, it is required to provide power through the SBO AC power distribution system to the equipment contributing to the three fundamental safety functions in the event of the SBO condition. It performs the extra safety functions.

9.6.5.1.2 Design Requirements

9.6.5.1.2.1 Safety Classification

According to the safety classification principles presented in Sub-chapter 4.4.5.1, as the SBO DG provides power to equipment which performs FC3 safety functions in case of a SBO, its function categorisation is FC3. Design requirements presented in Sub-chapter 4.4.5.3 are applied to the design of the SBO DG.

9.6.5.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

   As the safety function categorisation of the SBO DG is FC3, according to Sub-chapter 4.4.5.3.1 and Table T-4.4.5-7, the design principle of the SFC and redundancy presented in Sub-chapter 4.4.6.1.2 is not required to be applied.

b) Independence

   As the safety function categorisation of the SBO DG is FC3, according to Sub-chapter 4.4.5.3.1 and Table T-4.4.5-7, the design principle of independence presented in Sub-chapter 4.4.6.1.3 is required between the SBO DG and the EDG.

c) Diversity

   As the SBO DG supplies power to the equipment that contributes to the diverse protection line, the diversity principle presented in Sub-chapter 4.4.6.1.4 is required to be applied.

9.6.5.1.2.3 Design to Ensure Functionality

a) Equipment qualification

   As safety function categorisation of the EDG is FC3, according to Sub-chapter 4.4.5.3.1 and Table T-4.4.5-7, environmental qualification is analysed on a case by case basis. As the SBO DG is an alternate AC power source, according to Reference [3] "*8.3 The alternate AC power supplies with auxiliaries should be qualified for their intended application*", equipment of the SBO DG is required to be qualified according to the principles presented in Sub-chapter 4.4.6.2.1.

b) Ageing and degradation

As the SBO DG is required to remain available during its lifetime, requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As the SBO DG is required to remain available during its lifetime, EMIT of the SBO DG is applied according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.6.5.1.2.4 Hazard Protection

a) External hazards

As the safety function categorisation of the SBO DG is FC3, according to Sub-chapter 4.4.5.3.1 and Table T-4.4.5-7, the environmental qualification is analysed on a case by case basis. As the SBO DG supplies power to the equipment that contributes to the diverse protection line, the SBO DG is protected against external hazards in accordance with the principle presented in Sub-chapter 18.6.

b) Internal hazards

As the safety function categorisation of the SBO DG is FC3, according to Sub-chapter 4.4.5.3.1 and Table T-4.4.5-7, environmental qualification is analysed on a case by case basis. As the SBO DG supplies power to the equipment that contributes to the diverse protection line, the SBO DG is protected against internal hazards in accordance with the principle presented in Sub-chapter 19.6.

9.6.5.2 Design Basis

9.6.5.2.1 General Assumption

9.6.5.2.1.1 Control of Reactivity

Not applicable. The SBO DG is not required to directly perform the reactivity control function.

9.6.5.2.1.2 Removal of Heat

Not applicable. The SBO DG is not required to directly perform the heat removal function.

9.6.5.2.1.3 Confinement

Not applicable. The SBO DG is not required to directly perform the radioactive material confinement function.

9.6.5.2.1.4 Extra Safety Functions

a) The SBO DG is designed as an alternate AC power source in the NPP;

b) The function categorisation of performing the three fundamental safety functions for equipment which the SBO DG provides power to in the case of a SBO is FC3;

c) The SBO DG supplies power to the equipment that contributes to the diverse protection line in case of a SBO;

d) The extra safety functions of the SBO DG are implemented after it supplies power (within normal variation of the frequency and voltage) to the customer loads in case of a SBO.

9.6.5.2.2 Design Assumption

The following key assumptions are applied for the design:

a) Assumption regarding power supplies

The SBO DG is in the stand-by state so that it could be started at any time when receives a start-up signal. The pre-treatment equipment is powered during standby state of the SBO DG.

b) Assumption regarding control power supplies

The SBO DG could start without any DCS system and control power.

c) Assumption regarding qualification

The qualified equipment of the SBO DG can perform its function in case of a SBO.

d) Assumption regarding ambient condition

The HVAC system can ensure the ambient condition of the SBO DG in case of a SBO.

9.6.5.3 System Description and Operation

9.6.5.3.1 System Description

9.6.5.3.1.1 General System Description

SBO DG consists of:

a) Train A SBO DG: NI 10kV SBO Power Supply System (LHU [SBOPSS (NI-10kV)]);

b) Train B SBO DG: NI 10kV SBO Power Supply System (LHV [SBOPSS (NI-10kV)]).

The LHU [SBOPSS (NI-10kV)] is connected to the LHM [SBOPDS (NI-10kV)]; the LHV [SBOPSS (NI-10kV)] is connected to the LHN [SBOPDS (NI-10kV)]. The SBO DG, as alternate AC power source, provides power supply to the SBO power distribution systems during the SBO condition. The SBO DG is used for DEC, so it mainly provides power to DEC loads.

The voltage of electrical power from the SBO DG is 10kV. The active power of the SBO DG is 3100kW. The frequency is 50Hz and the rated power factor is 0.8.

One SBO DG could cope with the design extension conditions in case of a SBO. The start-up time is less than 15s. The SBO DG can operate continuously at least 72h at the rated power.

The SBO DG has the ability to cope with the consequences of SBO conditions that could occur during all operating modes including full power, low power and shutdown states.

Among all the SBO scenarios, one SBO DG is sufficient to cope with the dominant sequences (e.g. SBO under full power). Two redundant SBO DGs are designed to increase the reliability of the AC power supply and improve the plant safety for these dominant sequences.

In those unlikely SBO sequences (including SBO under maintenance cold shutdown, SBO under refuelling cold shutdown and SBO with seal LOCA), two SBO DGs are used to mitigate the consequences of the SBO condition to further reduce the risk of SBO.

The neutral point of the SBO DG is an ungrounded, which makes continuous operation of SBO DG possible when a single-phase earth fault occurs.

9.6.5.3.1.2 Description of Main Equipment

Each SBO DG is composed of a diesel engine, AC generator and its auxiliary equipment. The engine and the auxiliaries of the SBO DG are described in Sub-chapter 10.8.4.

a) Diesel engine

The diesel engine is a four-stroke, water cooled, V-type cylinder, supercharged mechanical equipment driving the generator. The rated speed of diesel engine is 1000rpm.

The main fuel storage tank of the SBO DG set can store enough fuel to enable the related DG set to run continuously for 3 days under the maximum load after an accident occurrence accompanied with a SBO.

b) AC generator

The AC generator is an air cooled synchronous three-phase generator with self-excitation. The heater medium of the AC generator is ambient air. The anti-condensation heater is set and powered when the AC generator is in stand-by or out of service.

The thermal class of electrical insulating material is 155 and its thermal class of operation assessment is 130. The over-speed ability of the AC generator is 120% rated speed for 5s and it must trip when it reached 115% rated speed.

c) Auxiliary equipment

The auxiliary equipment includes lubrication oil equipment, fuel oil equipment, cooling water equipment, compressed air start-up equipment and air intake and exhaust equipment.

Diesel fuel is pumped from the tank storage tank to the daily tank with two transfer pumps. Compressed air start-up equipment is capable of starting the DG at least 5 times. The lubrication equipment and cooling water equipment is designed to make sure the DG set could start up, reach the rated voltage and rated frequency in less than 15s. The air intake and exhaust equipment is used to supply air from and to the outdoor environment with a silencer.

9.6.5.3.1.3 Description of Main Layout

Two trains of SBO DG sets are arranged in two different SBO diesel generator buildings. Train A LHU [SBOPSS (NI-10kV)] is in the BDU and train B LHV [SBOPSS (NI-10kV)] is in the BDV. Each DG set is located in an independent building with physical separation.

a) Diesel engine

The diesel engine is seated in the diesel generator hall in level of +0.00m of the SBO diesel generator building.

b) AC generator

The AC generator is seated together with the diesel engine in the diesel generator hall. The power cabinets of AC generator are seated in level of +0.00m. The control cabinets of the AC generator are seated in level of +3.24m.

c) Auxiliary equipment

The main oil tank is seated in level of -11.30m. Air compressor set is seated in level of +0.00m. The daily oil tank is seated in level of +8.90m. The water tank is located in level of +14.66m. The silencer for exhaust air vent pipe is in level of +20.24m.

9.6.5.3.1.4 Description of System Interfaces

The support systems of the SBO DG include the HVAC system, I&C system and control power system:

a) Support system

1) DVD [DBVS]

2) PS

3) KDS [DAS]

4) NI 380V AC Uninterruptible Power System (12h) (LVP/LVQ [UPS (NI-380V-12h)])

5) LAP/LAQ [DCPS (NI-220V-12h)]

b) Customer system

The customer system of the SBO DG is the LHM/LHN [SBOPDS (NI-10kV)].

9.6.5.3.1.5 Control and Monitoring

The SBO DGs can be started during SBO conditions. The starting, switchover, load shedding control of the SBO DG is accomplished by the DCS or local control.

The SBO DG can be started and stopped manually. Manual start-up can be carried out in the MCR and at the local control panels in the SBO diesel generator buildings. The SBO DG is connected to the switchboard in less than 2h. Sequenced loading of the SBO DG is also realized manually.

The starting and reconnection to the busbar are undertaken both in the PS and KDS [DAS]. When the PS is unavailable, the KDS [DAS] can be used to start and reconnect the SBO DG.

The voltage and frequency of the SBO DG can be monitored in the MCR. Alarms are generated and can be sent to the MCR in the event of an electrical or a mechanical fault. Electrical protection isolates the faults of the system.

9.6.5.3.2 System Operation

9.6.5.3.2.1 Plant Normal Conditions

a) Normal operation conditions

During normal operation conditions, the SBO DG is in the stand-by state and its pre-treatment system is powered.

b) Transient operation conditions

During transient operation conditions, the SBO DG is in the stand-by state and its pre-treatment system is powered.

9.6.5.3.2.2 Plant Accident Conditions

a) DBC-2/3/4 condition

During DBC-2/3/4 conditions, the SBO DG is in the standby state and its pre-treatment system is powered.

b) DEC condition

In case of a SBO condition and LOOP combined with all EDGs failures, the SBO DG could start up and connect to the NI 10kV SBO power distribution system to cope with the SBO condition.

In the event of a SBO, the operator blocks the auto start-up signal for the ASG [EFWS] pump and LHSI pump from the FC1 DCS system PS manually. Then the operator starts the SBO DG manually from the FC3 DCS system KDS [DAS]. After the voltage and frequency of the EDG reach the defined values, the operator pushes the button of the KDS [DAS] to shed all loads and connects the SBO DG with the NI 10kV SBO power distribution system manually. Then the operator manually reloads the related equipment to the bus according to the SBO DG reloading program.

9.6.5.4 Design Substantiation

9.6.5.4.1 Compliance with Fundamental Safety Functional Requirements

9.6.5.4.1.1 Control of Reactivity

Not applicable.

9.6.5.4.1.2 Removal of Heat

Not applicable.

9.6.5.4.1.3 Confinement

Not applicable.

9.6.5.4.1.4 Extra Safety Functions

In case of SBO conditions, the operator manually starts the SBO DG sets in trains A and B to supply the safety system equipment through switchboards of the SBO AC power distribution system. The SBO DG supports the performance of safety functions by providing the necessary power supplies through the SBO AC power distribution system:

a) The SBO DG provides electrical power to safety systems such as the RBS [EBS] and RIS [SIS], which perform the reactivity control safety function;

b) The SBO DG provides electrical power to safety systems such as ASG [EFWS] and ECS [ECS], which perform the heat removal safety function;

c) The SBO DG provides electrical power to safety systems such as PTR [FPCTS] and EHR [CHRS], which perform the radioactive materials confinement function.

9.6.5.4.2 Compliance with Design Requirements

9.6.5.4.2.1 Compliance with Safety Classification

As the function categorisation of the SBO DG is FC3, according to classification principles in Sub-chapter 4.4.5.2, the safety classification of the SBO DG is F-SC3.

Detailed information of safety classification for EDG is as follows:

T-9.6-9 Categorisation and Classification of SBO DG

System	Categorisation	Classification
LHU/LHV [SBOPSS (NI-10kV)] AC generator	FC3	F-SC3
LHU/LHV [SBOPSS (NI-10kV)] power cabinet	FC3	F-SC3
LHU/LHV [SBOPSS (NI-10kV)] control cabinet	FC3	F-SC3

9.6.5.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

Not applicable.

b) Independence

Independence is accomplished in the design of the SBO DG by using electrical, mechanical segregation, as well as physical separation. They are independent from each other in terms of system, equipment and layout.

The SBO DG comprises the LHU/LHV [SBOPSS (NI-10kV)]. The LHU [SBOPSS (NI-10kV)] is located in the BDU, and the LHV [SBOPSS (NI-10kV)] is located in the BDV. There is no electrical connection between them.

The SBO DG is independent from the EDG. Train A and B of the SBO DG sets and auxiliaries are physically and functionally isolated from each other and from the EDGs. The SBO DG ventilation is independent from the EDG ventilation systems.

T-9.6-10 Independence of SBO DG

Train	SBO DG	Installed Building
A	LHU [SBOPSS (NI-10kV)]	BDU(independent from BDA)

Train	SBO DG	Installed Building
B	LHV [SBOPSS (NI-10kV)]	BDV(independent from BDB)

c) Diversity

As the SBO DG is designed to supply power to the diverse protection line and the EDG is designed to supply power to the main protection line, the diversity is existed between the SBO DG and EDG.

The diversity of the SBO DG and EDG is mainly due to the different supplier such as the capacity and speed of the DGs. Further analysis for CCF will be done in Step 3 of GDA.

9.6.5.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

The equipment of the SBO DG is qualified according to its normal conditions and accident conditions. The seismic category of the equipment is SSE1 and it could perform function during and after earthquakes.

The qualification category is K3 for DG electrical components, power cabinet and control cabinet according to RCC-E 2016.

b) Ageing and degradation

The ageing and degradation of the equipment for the SBO DG is considered in qualification and EMIT. It is managed in the following aspects:

1) Equipment of the SBO DG is qualified according to its service condition, such as seismic testing;

2) Material ageing properties are considered in accelerated ageing tests, such as the activation energy value for generator insulation materials is considered in the stator accelerated ageing test;

3) Thermal ageing and ageing caused by operation (including mechanical and electrical) is addressed by type tests, such as mechanical operation ageing tests (e.g. start-stop circle test and vibration ageing test) and environmental thermal ageing tests (e.g. dry heat and damp heat cyclic) for rotating machinery;

4) The EDG is equipped with on-line inspection, such as insulation monitoring and start-up number counter;

5) The layout of equipment facilitates EMIT, repair and replacement, such as the distance between the rotating machinery and the wall is defined for the equipment layout design;

6) The replacement period of the equipment is defined according to its

individual design life and the plant design life, such as the design life of the main rotating machinery which is intended to be used through the whole plant design life is 60 years.

c) Examination, maintenance, inspection and testing

The SBO DG and equipment are designed to permit periodic examination, maintenance, inspection and testing.

Daily examination of the SBO DG and important parameters of pre-lubrication, pre-heating, cooling water, fuel oil, starting air is performed. The preventive maintenance of the SBO DG is performed during unit shutdown. In order to perform the preventive maintenance of the SBO DG, the total number of starts, operating hours at zero power, and operating hours in loaded conditions will be recorded. Periodical inspection and preventive maintenance is scheduled, which are mainly performed during the unit shutdown RCD mode. The availability of the system and equipment is demonstrated by periodic testing, including the start-up test, load carrying test and power supply switchover test.

9.6.5.4.2.4 Compliance with Hazard Protection

The two SBO DGs are located in two different civil buildings, which provide physical separation from each other and provide protection against external and internal hazards.

a) External hazards

1) Earthquake

The SBO DG could be in service during and after a safety shutdown earthquake. The equipment of the EDG is seismic qualified and could perform their function during or after an earthquake.

2) Electromagnetic interference and space weather

The SBO DG is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards and meteorological hazards are usually addressed through the structure design or HVAC design of buildings.

b) Internal hazards

1) Internal fire

The two divisions of the SBO DG are in two independent fire compartments.

The internal fire in one fire compartment could not cause the equipment located in the other fire compartment to fail.

Electrical protection will cut off the fault section as soon as possible to reduce the risk of fire. The risk of internal fires is limited by the selection of fire-resistance materials for the SBO DG and cable penetrations are fire proof where necessary.

2) Electromagnetic interference

The SBO DG is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other internal hazards

Other internal hazards such as high energy pipe failures, dropped load, internal explosion and internal missiles are usually addressed through the system layout, protection degree of equipment or structure design of building.

9.6.6 Mobile Diesel Generator

9.6.6.1 Safety Requirements

9.6.6.1.1 Fundamental Safety Functional Requirements

9.6.6.1.1.1 Control of Reactivity

The mobile DG is not required to directly perform the reactivity control function.

9.6.6.1.1.2 Removal of Heat

The mobile DG is not required to directly perform the heat removal function.

9.6.6.1.1.3 Confinement

The mobile DG is not required to directly perform the radioactive material confinement function.

9.6.6.1.1.4 Extra Safety Functions

For mobile DG is a non-permanent power source and provides only temporary power, the mobile DG is not required to perform extra safety functions.

9.6.6.1.2 Design Requirements

9.6.6.1.2.1 Safety Classification

As the mobile DG does not perform any safety functions, its function categorisation is NC. The safety design requirements presented in Sub-chapter 4.4.5.3 are not required to be applied to the design of the mobile DG.

9.6.6.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

As the safety function categorisation of the mobile DG is NC, it does not need to meet the requirements of the SFC and redundancy.

b) Independence

As the safety function categorisation of the mobile DG is NC, it does not need to meet the requirements of independence.

c) Diversity

As the safety function categorisation of mobile DG is NC, it does not need to meet the requirements of diversity.

9.6.6.1.2.3 Design to Ensure Functionality

a) Equipment qualification

As the safety function categorisation of the mobile DG is NC, it does not need to meet the requirements of equipment qualification.

b) Ageing and degradation

As the mobile DG is required to remain available during its lifetime, requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As the mobile DG is required to remain available during the service life, EMIT of the mobile DG is applied according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.6.6.1.2.4 Hazard Protection

a) External hazards

Although the safety function categorisation of the mobile DG is NC, external hazards presented in Sub-chapter 18.6 are taken into consideration in terms of plant reliability and conventional safety if practicable.

b) Internal hazards

Although the safety function categorisation of the mobile DG is NC, internal hazard presented in Sub-chapter 19.6 are taken into consideration in terms of plant reliability and conventional safety if practicable.

9.6.6.2 Design Basis

9.6.6.2.1 General Assumption

9.6.6.2.1.1 Control of Reactivity

Not applicable. The mobile DG is not required to directly perform the reactivity control function.

9.6.6.2.1.2 Removal of Heat

Not applicable. The mobile DG is not required to directly perform the heat removal function.

9.6.6.2.1.3 Confinement

Not applicable. The mobile DG is not required to directly perform the radioactive material confinement function.

9.6.6.2.1.4 Extra Safety Functions

a) The mobile DG is a non-permanent power source to restore the necessary electrical power supply in the NPP;

b) The mobile DG provides temporary power to equipment in case of a SBO coupled with loss of the SBO power supply;

c) The mobile DG is to mitigate the radiological consequences of significant radioactive release.

9.6.6.2.2 Design Assumption

The following key assumptions are applied for the design:

a) Assumption regarding power supply

   The mobile DG could be in operation without any other power support.

b) Assumption regarding control power supply

   The mobile DG could be in operation without any other control support.

c) Assumption regarding response time

   The vehicle of the mobile DG could be driven to the outside of NI buildings and the DG could be connected in the prescribed time. The fast connection installations are available during the total loss of AC power condition (SBO combined with the failure of all SBO DGs).

d) Assumption regarding ambient condition

   The mobile DG could be in operation without any other HVAC support.

9.6.6.3 System Description and Operation

9.6.6.3.1 System Description

9.6.6.3.1.1 General System Description

To cope with the SBO coupled with SBO DGs failure condition, the mobile DG is expected to provide a temporary power supply to mitigate the consequences of the accident, which also increases the time window for off-site or on-site power recovery.

The mobile DG consists of:

a) 10kV mobile DG;

b) 380V mobile DG.

As a DiD approach, the NPP is equipped with the mobile DG to provide temporary power to the I&C equipment which performs the monitoring functions, control components, necessary communication, main control room emergency lighting, necessary process equipment and related ventilation in case of the SBO coupled with SBO DGs failure condition.

The active power of the 10kV mobile DG is 2100kW. The active power of the 380V mobile DG is 400kW. The design margin of the mobile DG capacity is above 10%. The rated frequency is 50Hz and the rated power factor is 0.8.

The mobile DG is used when the SBO condition coupled with a loss of all SBO DGs occurs. It connects to the on-site power system by the interface connecting box outside of the NI buildings. The SBO DG is not expected to be repaired with in 12h, in this condition, the mobile DG will be connected to the plant before the 12h batteries are exhausted.

The neutral point of the 10kV mobile DG is ungrounded. The earthing type of the 380V mobile DG is TN-S.

9.6.6.3.1.2 Description of Main Equipment

Each mobile DG is composed of a diesel engine, an AC generator and auxiliary systems.

a) Diesel engine

   The diesel engine is a vehicle type diesel engine. The daily oil tank of the mobile DG is capable operating continuously for 4h with rated power. With oil being replenished it could support for longer.

   Each mobile DG is equipped with two independent staring devices. The batteries used for start-up are equipped with self-supported charging devices. The design of the starting system enables 3 successful start-ups without recharging.

b) AC generator

The mobile generator is a synchronous three-phase generator with an air self-cooled fan. The rated power of the 10kV mobile DG is 2100kW and it is 400kW for the 380V mobile generator. The thermal class of the electrical insulating material is 180 and its thermal class of operation assessment is 155.

c) Auxiliary equipment

The auxiliary equipment makes the mobile DG a self-contained system. Two independent start-up devices are set to start the mobile DG reliably. The air for combustion is drawn in from the outside of the vehicle. The necessary devices used to fix the vehicle in place are considered. Lighting for night operation is provided on the outside of the vehicle.

9.6.6.3.1.3 Description of Main Layout

The mobile DG is stored in a safe location where precautions are taken against events similar to what occurred at the Fukushima accident.

a) Mobile DG sets

The mobile DG set is built-in the vehicle.

b) The vehicle

The vehicle is located in the emergency equipment storage and fuel supply centre (BOP scope), where is not located near the NI building.

c) Connection installation

The fast connection box is located outside of the NI building. The connection cable between the fast connection box and the permanent switchboard of the on-site electrical power system is pre-assembled.

9.6.6.3.1.4 Description of System Interfaces

a) Support system

There is no support system for the mobile generator which could be in service without any other support systems.

b) Customer system

The customer system of the 10kV mobile DG is LHM/LHN [SBOPDS (NI-10kV)];

The customer system of the 380V mobile DG is LLD/LLG [SBOPDS (NI-380V)].

9.6.6.3.1.5 Control and Monitoring

Control and monitoring of the mobile DG is performed locally. Electrical protection except for overspeed protection is blocked during emergency operations.

9.6.6.3.2 System Operation

9.6.6.3.2.1 Plant Normal Conditions

a) Plant normal conditions

The mobile generator is out of service during normal conditions.

b) Transient condition

The mobile generator is out of service during transient conditions.

9.6.6.3.2.2 Plant Accident Conditions

a) DBC-2/3/4 condition

The mobile generator is out of service during DBC-2/3/4 conditions.

b) DEC condition

In the DEC conditions where the stationary DGs (SBO DG or EDG) are available, the mobile DG is not needed. In the condition of a total loss of AC power supply, the mobile DG is driven to the outside of the NI building and connected to the fast-connection box. The operator manually starts the mobile DG when the connection is complete.

The mobile DG breaker can be closed if the frequency and voltage of the generator reaches the nominal value. The loads can then be loaded to the mobile generator manually.

9.6.6.4 Design Substantiation

9.6.6.4.1 Compliance with Fundamental Safety Functional Requirements

9.6.6.4.1.1 Control of Reactivity

Not applicable.

9.6.6.4.1.2 Removal of Heat

Not applicable.

9.6.6.4.1.3 Confinement

Not applicable.

9.6.6.4.1.4 Extra Safety Functions

Not applicable.

9.6.6.4.2 Compliance with Design Requirements

9.6.6.4.2.1 Compliance with Safety Classification

The safety classification of the mobile DG is NC. The categorisation and classification of the mobile DG will be reviewed in Step 3 of GDA.

9.6.6.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

Not applicable.

b) Independence

Not applicable.

c) Diversity

Not applicable.

9.6.6.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

Not applicable. The mobile DG is built-in to the mobile vehicle with no qualification requirements. The fast-connection box and fixed cables in the NI buildings (out of the scope of the mobile DG) however, are required to be environmentally qualified and seismically qualified. The seismic categorisation is SSE1.

b) Ageing and degradation

Ageing and degradation of the mobile DG is considered in its EMIT and industry standards. It is managed in the following aspects:

1) Thermal ageing and ageing caused by operation, managed through start-up tests and load tests of the mobile DG;

2) The mobile DG is equipped with on-line inspection, such as insulation monitoring and a start-up number recorder;

3) The replacement period of the equipment is defined according to its individual design life and the plant design life.

c) Examination, maintenance, inspection and testing

The mobile DG set is designed to permit examination, maintenance, inspection and testing. During plant normal operation, to maintain the mobile DG in the stand-by condition, an additional power supply is provided in the building of the emergency equipment storage and fuel supply centre, which can be used for the maintenance of the mobile DG in the standby condition (for preheat and battery charging). Testing and maintenance of the mobile DG is implemented according to the standards and recommendations of the supplier. The periodic testing of the mobile DG includes the availability test, DG operation test and full power test.

9.6.6.4.2.4 Compliance with Hazard Protection

The mobile DG is stored in a safe location where precautions are taken against internal and external hazards.

a) External hazards

1) Earthquake

The mobile generator is built-in the vehicle which is located in the emergency equipment storage and fuel supply centre without any seismic requirements. The fast-connection box and fixed cables in the NI building are available after earthquakes to ensure that the mobile DG could be connected.

2) External flooding

The mobile DG is located higher than the plant level. The design of the building provides protection against the risk of external flooding (including tsunami).

3) Other external hazards

Other external hazards such as EMI, man-made and industrial hazards and meteorological hazards are usually addressed through the earthing system, structure design or HVAC design of buildings.

b) Internal hazards

1) Internal fire

The mobile generator is built-in the vehicle which is located in the emergency equipment storage and fuel supply centre. The vehicle is equipped with fire fighting devices. Internal fire is limited by the fire compartments and electrical protection will cut off the fault section as soon as possible to reduce the risk of fire.

2) Vehicular transport

The vehicular transport is considered in the design of the mobile DG. The transport path is wide enough to allow for the mobile DG to access the NI building. The length of the mobile connecting cable is 70m to ensure that the cable connection to the fast connection box is possible with the vehicle parked in a nearby position.

3) Other internal hazards

Other internal hazards such as high energy pipe failures, EMI, dropped load, internal explosion and internal missiles are usually addressed through the system layout, earthing system, protection degree of equipment or structure design of the building.

9.6.7 CI DC and AC UPS System

9.6.7.1 Safety Requirements

9.6.7.1.1 Fundamental Safety Functional Requirements

9.6.7.1.1.1 Control of Reactivity

The CI DC and AC UPS system is not required to directly perform the reactivity control function.

9.6.7.1.1.2 Removal of Heat

The CI DC and AC UPS system is not required to directly perform the heat removal function.

9.6.7.1.1.3 Confinement

The CI DC and AC UPS system is not required to directly perform the radioactive material confinement function.

9.6.7.1.1.4 Extra Safety Functions

The CI DC and AC UPS system is not required to perform the extra safety functions.

9.6.7.1.2 Design Requirements

9.6.7.1.2.1 Safety Classification

According to the safety classification principles presented in Sub-chapter 4.4.5.1, as the CI DC and AC UPS system provides power to equipment which performs NC safety functions, its function categorisation is NC. Design requirements presented in Sub-chapter 4.4.5.3 are not applicable.

9.6.7.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

   As the safety function categorisation of CI DC and AC UPS system is NC, it does not need to meet the requirements of SFC and redundancy.

b) Independence

   As the safety function categorisation of the CI DC and AC UPS system is NC, it does not need to meet the independence requirement.

c) Diversity

As CI DC and AC UPS system does not contribute to the main and diverse protection line, requirements of diversity presented in Sub-chapter 4.4.6.1.4 are not applicable.

9.6.7.1.2.3 Design to Ensure Functionality

a) Equipment qualification

As the safety function categorisation of the CI DC and AC UPS system is NC, it does not need to meet the requirements of equipment qualification.

b) Ageing and degradation

As the CI DC and AC UPS system is required to remain available during its design life, the requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As the CI DC and AC UPS system is required to remain available during the service life, EMIT of the CI DC and AC UPS systems is applied according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.6.7.1.2.4 Hazard Protection

a) External hazards

As the safety function categorisation of the CI DC and AC UPS system is NC, external hazard protection is taken into consideration in terms of plant reliability and conventional safety if practicable.

b) Internal hazards

As the safety function categorisation of the CI DC and AC UPS system is NC, internal hazard protection is taken into consideration in terms of plant reliability and conventional safety if practicable.

9.6.7.2 Design Basis

9.6.7.2.1 General Assumption

9.6.7.2.1.1 Control of Reactivity

Not applicable. The CI DC and AC UPS system is not required to directly perform the reactivity control function.

9.6.7.2.1.2 Removal of Heat

Not applicable. The CI DC and AC UPS system is not required to directly perform the heat removal function.

9.6.7.2.1.3 Confinement

Not applicable. The CI DC and AC UPS system is not required to directly perform the radioactive material confinement function.

9.6.7.2.1.4 Extra Safety Functions

a) The CI DC and AC UPS system does not directly supply power to the equipment that performs the three fundamental safety functions (control of reactivity, removal of heat and confinement);

b) The CI DC and AC UPS system directly supplies power to the equipment whose function (operation during power supply) categorisation is NC;

c) The CI DC and AC UPS system does not directly supply power to the equipment that contributes to the main protection line and diverse protection line.

9.6.7.2.2 Design Assumption

The following key assumptions are applied for the design:

a) Assumption regarding power supply

   For the CI DC system, the emergency AC power distribution system is available during normal operation and a battery is available in case of the emergency AC power distribution system failure.

   For the CI UPS system, the CI DC system is available during normal operation and the normal AC power distribution system is available in case of CI DC system failure.

b) Assumption regarding control power supply

   The control power supply is available during normal operation.

c) Assumption regarding qualification

   As the function categorisation of the CI DC and AC UPS system is NC, the assumption regarding qualification is not applicable.

d) Assumption regarding ambient condition

   The HVAC system can ensure the ambient conditions of the CI DC and AC UPS system during normal operation.

9.6.7.3 System Description and Operation

9.6.7.3.1 System Description

9.6.7.3.1.1 General System Description

CI DC and AC UPS system consists of:

a) 3 groups of DC systems, which are the CI 220V DC Power Supply and Distribution System (2h) (LAM/LAN [DCPS (CI-220V-2h)]) and the CI 220V DC Power Supply and Distribution System (LAR [DCPS (CI-220V)]);

b) 2 groups of 2h UPS systems, which are the CI 380V AC Uninterruptible Power System (LVM/LVN [UPS (CI-380V-2h)]).

The upstream power supplies of the DC 220V switchboards LAM [DCPS (CI-220V-2h)], LAN [DCPS (CI-220V-2h)] and LAR [DCPS (CI-220V)] are the normal AC power distribution system and emergency AC power distribution system.

The LAM/LAN [DCPS (CI-220V-2h)] systems mainly consist of:

a) A group of lead acid batteries;

b) Two battery chargers;

c) 220V DC distribution switchboards.

The LAR [DCPS (CI-220V)] system mainly consists of:

a) A group of lead acid batteries;

b) One battery charger;

c) 220V DC distribution switchboards.

Each CI AC UPS system mainly consists of:

a) A DC/AC inverter and static bypass;

b) A regulating transformer;

c) 380V AC distribution switchboards.

The CI DC system is ungrounded and the CI AC UPS system is the TN-S system.

The equipment parameters in the specification are verified by electrical system study.

Detailed information is presented in *CI DC and AC UPS System Single Line Diagram*, Reference [8].

9.6.7.3.1.2 Description of Main Equipment

a) A group of lead acid batteries

When the charger fails, or the upstream AC power is lost, the battery will provide DC power.

b) Battery charger

The battery charger provides DC power to DC loads and the inverter of the AC UPS system, and provides charging power for the battery.

c) 220V DC distribution switchboard

The CI DC and AC UPS system provides DC power to loads through the DC switchboards.

d) A DC/AC inverter and static bypass

The inverter converts the 220V DC power to three-phase 380V AC power.

e) A regulating transformer

The regulating transformer provides regulated back-up power to the UPS loads.

f) 380V AC distribution switchboards

The CI DC and AC UPS system provides uninterrupted AC power to loads through the 380V AC distribution switchboards.

9.6.7.3.1.3 Description of Main Layout

a) LAM/LAN [DCPS (CI-220V-2h)] and LVM/LVN [UPS (CI-380V-2h)]

The LAM/LAN [DCPS (CI-220V-2h)] and LVM/LVN [UPS (CI-380V-2h)] are located in the CI electrical building level of +5.50m.

b) LAR [DCPS (CI-220V)] system

The LAR [DCPS (CI-220V)] is located in the turbine hall of the turbine generator building level of +6.00m.

9.6.7.3.1.4 Description of System Interfaces

a) Support system

The support system of the CI DC and AC UPS system is the CI HVAC system:

1) Conventional Island Electrical Building Ventilation System (DVF [CIEBVS])

2) DVL [EDSBVS]

b) Customer system

The customer systems of the LAM/LAN [DCPS (CI-220V-2h)] and LVM/LVN [UPS (CI-380V-2h)] mainly include:

1) CI 10kV Normal Power Distribution System

2) CI 380V Emergency Power Distribution System

3) CI 380V Normal Power Distribution System

4) Fire Alarm System (JDT [FAS])

5) Non-safety Process Control Cabinet System (KCP [NPCCS])

6) Generator and Power Transmission Protection System (GPA [GPTPS])

7) Power Transmission System (GEX [PTS])

8) Grid Synchronization and Connection System (GSY [GSCS])

9) Energy Measuring and Metering and Substation I&C System (KKO [EMSS])

The customer systems of the LAR [DCPS (CI-220V)] mainly include:

1) Turbine Hall Emergency Lighting System (DSM [THELS])

2) Turbine Lubrication, Jacking and Turning System (GGR [TLJTS])

3) Generator Seal Oil System (GHE [GSOS]

9.6.7.3.1.5 Control and Monitoring

Each CI DC and AC UPS system is provided with control and monitoring devices, which are intended to control, monitor and protect the system. Start-up and operational controls of the CI DC and AC UPS system are realised locally. Important information of the system can be sent to the MCR for monitoring of the availability of the system. Electrical protection isolates the faults of the system.

9.6.7.3.2 System Operation

9.6.7.3.2.1 Plant Normal Conditions

a) Normal conditions

During normal operation condition, the charger of the CI DC and AC UPS system rectifies the 380V AC power to 220V DC power, provides power to loads and charges the battery. The battery is kept at full charge by the float charge. The inverter converts 220V DC power to three-phase 380V AC power. The bypass circuit is in a standby state.

b) Transient conditions

During transient conditions, the CI DC and AC UPS system is in service and powered by the normal AC power distribution system.

In case of losing 380V AC power, the battery will provide a power supply to the loads. After 380V AC power recovery, the battery charger will provide a power supply to the loads and charging power for the battery.

In case of short-circuit, the failure will be removed selectively and the system will restore operation after proper maintenance.

9.6.7.3.2.2 Plant Accident Conditions

a) DBC-2/3/4 condition

The CI DC and AC UPS system could be out of service during DBC-2/3/4 conditions.

b) DEC condition

The CI DC and AC UPS system could be out of service during DEC conditions. It will, if available, provide a power supply to the loads during plant accident conditions.

9.6.7.4 Design Substantiation

9.6.7.4.1 Compliance with Fundamental Safety Functional Requirements

9.6.7.4.1.1 Control of Reactivity

Not applicable.

9.6.7.4.1.2 Removal of Heat

Not applicable.

9.6.7.4.1.3 Confinement

Not applicable.

9.6.7.4.1.4 Extra Safety Functions

Not applicable.

9.6.7.4.2 Compliance with Design Requirements

9.6.7.4.2.1 Compliance with Safety Classification

The function categorisation of the CI DC and AC UPS system is NC.

According to classification principles in Sub-chapter 4.4.5.2, the safety classification of equipment or components in the CI DC and AC UPS system is NC.

Detailed information of safety classification for the CI DC and AC UPS system is as follows:

T-9.6-11 Categorisation and Classification of the CI DC and AC UPS System

System	Categorisation	Classification
LAM/LAN [DCPS (CI-220V-2h)], LAR [DCPS (CI-220V)]	NC	NC
LVM/LVN [UPS (CI-380V-2h)]	NC	NC

9.6.7.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

The SFC and redundancy are not applicable for the CI DC and AC UPS system.

b) Independence

Independence is not applicable for the CI DC and AC UPS system.

c) Diversity

Diversity is not applicable for the CI DC and AC UPS system.

9.6.7.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

The qualification category of equipment and components for the CI DC and AC UPS system is NC.

b) Ageing and degradation

The ageing of the equipment for the CI DC and AC UPS system is considered in EMIT. It is managed in the following aspects:

1) Physical ageing of operating mechanisms is assessed during the type-test of the switchboard.

2) The layout of equipment facilitates EMIT, repair and replacement, such as the distance between two face to face switchboards is defined for the equipment layout design.

3) The degradation of the battery is monitored by periodic battery discharge tests.

4) The replacement period of the equipment is defined according to its individual design life and the plant design life.

c) Examination, maintenance, inspection and testing

The CI DC and AC UPS system and its equipment are designed to permit periodic examination, maintenance, inspection and testing. For periodic testing, the battery discharge test is carried out during plant shutdown to demonstrate the availability of the system and equipment.

9.6.7.4.2.4 Compliance with Hazard Protection

a) External hazards

1) Earthquake

The CI DC and AC UPS system could be out of service after safety shutdown earthquake.

Only the 10kV circuit breakers for the reactor coolant pump are designed to open reliably in case of an earthquake. The switchboards for the reactor coolant pump are seismically qualified and could perform the disconnection function during or after an earthquake.

2) Electromagnetic interference and space weather

The CI DC and AC UPS system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards and meteorological hazards are usually addressed through the structure design or HVAC design of the buildings.

b) Internal hazards

1) Internal fire

For the CI DC and AC UPS system, the risk of internal fires is reduced by the selection of fire-resistance materials and cable penetrations are fire proof where necessary. Electrical protection will cut off the fault part as soon as possible to reduce the risk of fire.

2) Electromagnetic interference

The CI DC and AC UPS system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, Faraday cage structure, cable shielding and cabling.

3) Other internal hazards

Other internal hazards such as high energy pipe failures, dropped load, internal explosion and internal missiles are usually addressed through the system layout, protection degree of equipment or structure design of the buildings.

9.6.8 NI 2h DC and AC UPS System

9.6.8.1 Safety Requirements

9.6.8.1.1 Fundamental Safety Functional Requirements

9.6.8.1.1.1 Control of Reactivity

The NI 2h DC and AC UPS system is not required to directly perform the reactivity control function.

9.6.8.1.1.2 Removal of Heat

The NI 2h DC and AC UPS system is not required to directly perform the heat removal function.

9.6.8.1.1.3 Confinement

The NI 2h DC and AC UPS system is not required to directly perform the radioactive material confinement function.

9.6.8.1.1.4 Extra Safety Functions

As the NI 2h DC and AC UPS system is required to supply power to the equipment that contributes to the three fundamental safety functions, it performs extra safety functions.

9.6.8.1.2 Design Requirements

9.6.8.1.2.1 Safety Classification

According to the safety classification principles presented in Sub-chapter 4.4.5.1, as the NI 2h DC and AC UPS system provides power to equipment which performs FC1 or FC2 safety functions, its function categorisation is FC1. Design requirements presented in Sub-chapter 4.4.5.3 are applied to the design of the NI 2h DC and AC UPS system.

9.6.8.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

   As the safety function categorisation of the NI 2h DC and AC UPS system is FC1, the design principle of redundancy and the SFC presented in Sub-chapter 4.4.6.1.2 is required to be applied.

b) Independence

   As the safety function categorisation of the NI 2h DC and AC UPS system is FC1, the design principle of independence presented in Sub-chapter 4.4.6.1.3 is required to be applied.

c) Diversity

   As the NI 2h DC and AC UPS system supplies power to the equipment that contributes to the main protection line, the diversity principle presented in Sub-chapter 4.4.6.1.4 is required to be applied.

9.6.8.1.2.3 Design to Ensure Functionality

a) Equipment qualification

   As the safety function categorisation of the NI 2h DC and AC UPS system is FC1, equipment of the NI 2h DC and AC UPS system is required to be qualified according to the principles presented in Sub-chapter 4.4.6.2.1.

b) Ageing and degradation

As the NI 2h DC and AC UPS system is required to remain available during its lifetime, the requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As the NI 2h DC and AC UPS system is required to remain available during its lifetime, EMIT of the NI 2h DC and AC UPS system is applied according to the requirements presented in sub-chapter 4.4.6.2.3.

9.6.8.1.2.4 Hazard Protection

a) External hazards

As the safety function categorisation of the NI 2h DC and AC UPS system is FC1, it is protected against external hazards in accordance with the principle presented in Sub-chapter 18.6.

b) Internal hazards

As the safety function categorisation of the NI 2h DC and AC UPS system is FC1, it is protected against internal hazards in accordance with the principle presented in Sub-chapter 19.6.

9.6.8.2 Design Basis

9.6.8.2.1 General Assumption

9.6.8.2.1.1 Control of Reactivity

Not applicable. The NI 2h DC and AC UPS system is not required to directly perform the reactivity control function.

9.6.8.2.1.2 Removal of Heat

Not applicable. The NI 2h DC and AC UPS system is not required to directly perform the heat removal function.

9.6.8.2.1.3 Confinement

Not applicable. The NI 2h DC and AC UPS system is not required to directly perform the radioactive material confinement function.

9.6.8.2.1.4 Extra Safety Functions

a) The NI 2h DC and AC UPS system supplies power to equipment that performs the three fundamental safety functions (control of reactivity, removal of heat and confinement);

b) The function categorisation of performing the three fundamental safety functions for equipment supplied by the NI 2h DC and AC UPS system is FC1 or FC2;

c) The NI 2h DC and AC UPS system supplies power to the equipment that contributes to the main protection line;

d) The extra functions of the NI 2h DC and AC UPS system are implemented after it supplies power (within normal variation of the frequency and voltage) to the loads.

9.6.8.2.2 Design Assumption

The following key assumptions are applied for the design:

a) Assumption regarding power supplies

For the NI 2h DC system, the SBO AC power distribution system is available during normal operation and a battery is available in case of SBO AC power distribution system failure.

For the NI 2h UPS system, the NI 2h DC system is available during normal operation and the normal AC power distribution system is available in case of NI 2h DC system failure.

b) Assumption regarding control power supplies

The control power supply of the NI 2h DC and AC UPS system is available during normal and accident conditions.

c) Assumption regarding qualification

The qualified equipment of the NI 2h DC and AC UPS system can perform its function during normal and accident conditions.

d) Assumption regarding ambient condition

The HVAC system can ensure the ambient conditions of the NI 2h DC and AC UPS system during normal and accident conditions.

9.6.8.3 System Description and Operation

9.6.8.3.1 System Description

9.6.8.3.1.1 General System Description

NI 2h DC and AC UPS system consists of:

a) 4 groups of 2h DC systems and AC UPS systems, which are the LAA/LAB/LAC/LAD [DCPS (NI-220V-2h)], LVA/LVB/LVC [UPS (NI-380V-2h)] and NI 220V AC Uninterruptible Power System (2h) (LVD [UPS (NI-220V-2h)]). In correspondence with the loads, which consists of 3 trains (Train A, B and C) of plant process systems, and 4 channels (Channel I, II, III and IV) of the PS, the FC1 DC and AC UPS system consists of 4 groups and is divided into 3 trains. The LAA [DCPS (NI-220V-2h)] and LVA [UPS

(NI-380V-2h)] are applied for train A, the LAB [DCPS (NI-220V-2h)] and LVB [UPS (NI-380V-2h)] for train B, and the LAC [DCPS (NI-220V-2h)], LVC [UPS (NI-380V-2h)], LAD [DCPS (NI-220V-2h)] and LVD [UPS (NI-220V-2h)] for train C;

b) 3 groups of stabilized power supply systems, which are the LOA/LOB/LOC [ACRPS (NI-380V)], and 3 groups of sub-distribution systems, which are the NI 380V AC Regulated Power System (LOD/LOE/LOF [ACRPS (NI-380V)]). Corresponding to the loads, the systems are divided into 3 trains. The LOA/LOD [ACRPS (NI-380V)] are applied for train A, the LOB/LOE [ACRPS (NI-380V)] for train B, and the LOC/LOF [ACRPS (NI-380V)] for train C. As the bypass power supply of the UPS systems, LOA/LOB/LOC [ACRPS (NI-380V)] provide a power supply to the loads when the UPS main supply is lost. The LOD/LOE/LOF [ACRPS (NI-380V)] provides a power supply to the isolation valves.

The upstream power sources of the LAA/LAB [DCPS (NI-220V-2h)] are the normal power supply, EDG power supply and SBO DG power supply from the corresponding trains.

The upstream power sources of the LAC/LAD [DCPS (NI-220V-2h)] are the normal power supply and EDG power supply from the same train.

Each NI 2h DC system mainly consists of:

a) A group of lead acid batteries;

b) A battery charger;

c) 220V DC distribution switchboards;

d) A battery charger/discharger.

Each NI 2h AC UPS system mainly consists of:

a) A DC/AC inverter and static bypass;

b) AC distribution switchboards.

Each safety regulated power supply system mainly consists of:

a) A regulating transformer;

b) 380V AC distribution switchboards.

The equipment parameters in the specification are verified by the electrical system study.

The NI 2h DC system is ungrounded and the AC UPS system is the TN-S system.

Detailed information is presented in *NI DC and AC UPS System Single Line Diagram*, Reference [5].

9.6.8.3.1.2 Description of Main Equipment

a) A group of lead acid batteries

When the charger fails, or the upstream AC power is lost, the battery will provide DC power.

b) A battery charger

The battery charger provides DC power to DC loads and the inverter of the AC UPS system, and provides charging power for the battery.

c) 220V DC distribution switchboards

The NI 2h DC and AC UPS system provides DC power to loads through the 220V DC distribution switchboards.

d) A battery charger/discharger

The battery charger/discharger performs battery discharge tests during system shut-down. Its function category is NC and seismic categorisation is SSE2 which ensures the integrity of the equipment in case of earthquakes. It’s connected to the safety cabinets with a breaker, which is normally open in both normal and accident conditions. It will be connected to the system only if the battery discharge test is going to be performed.

e) A DC/AC inverter and static bypass

The inverter converts the 220V DC power to three-phase 380V or single-phase 220V AC power.

f) AC distribution switchboards

The NI 2h DC and AC UPS system provides uninterrupted AC power to loads through the AC distribution switchboards.

g) A regulating transformer

The regulating transformer provides regulated power to the loads.

h) 380V AC distribution switchboards

The regulated power supply system provides regulated power to the loads through the 380V AC distribution switchboards.

9.6.8.3.1.3 Description of Main Layout

a) NI 2h DC and AC UPS system

The NI 2h DC and AC UPS systems are located in the safeguard buildings of the

NI. The LAA [DCPS (NI-220V-2h)] and LVA [UPS (NI-380V-2h)] are located in the BSA, the LAB [DCPS (NI-220V-2h)] and LVB [UPS (NI-380V-2h)] in the BSB, and the LAC/LAD [DCPS (NI-220V-2h)], LVC [UPS (NI-380V-2h)] and LVD [UPS (NI-220V-2h)] in the BSC .

b) Regulated power supply system

The NI regulated power supply systems and sub-distribution systems are located in the safeguard buildings of the NI. The LOA [ACRPS (NI-380V)] and sub-distribution system LOD [ACRPS (NI-380V)] are located in the BSA. The corresponding power supply system LOB [ACRPS (NI-380V)] and sub-distribution system LOE [ACRPS (NI-380V)] in the BSB, power supply system LOC [ACRPS (NI-380V)] and sub-distribution system LOF [ACRPS (NI-380V)] in the BSC.

9.6.8.3.1.4 Description of System Interfaces

a) Support system

The support system of the NI 2h DC and AC UPS system is DVL [EDSBVS].

b) Customer system

The customer system of the NI 2h DC and AC UPS system mainly includes:

1) NI 10kV normal power distribution system
2) NI 10kV emergency power distribution system
3) NI 10kV emergency power supply system
4) NI 380V emergency power distribution system
5) NI 380V normal power distribution system
6) JDT [FAS]
7) Safety Process Control Cabinet System (KCS [SPCCS])
8) KCP [NPCCS]
9) RPS
10) Nuclear Instrumentation System (RPN [NIS])
11) Other I&C systems
12) Process systems

9.6.8.3.1.5 Control and Monitoring

Each NI 2h DC and AC UPS system is provided with control and monitoring devices, which are intended to control, monitor and protect the system. Start-up and operational controls of the NI 2h DC and AC UPS system are realised locally. Important information of the system can be sent to the MCR for monitoring of the availability of the system.

9.6.8.3.2 System Operation

9.6.8.3.2.1 Plant Normal Conditions

a) Normal conditions

During normal operation condition, the charger of the NI 2h DC and AC UPS system rectifies the 380V AC power to 220V DC power, provides power to loads and charges the battery. The battery is kept at full charge by the float charge. The inverter converts the 220V DC power to three-phase 380V or one-phase 220V AC power. The bypass circuit is in a standby state. The regulated power supply system provides a power supply to the load with the regulating transformer which is supplied by the 380V AC emergency power system.

b) Transient conditions

During transient conditions, the NI 2h DC and AC UPS system is in service and is powered by the emergency AC power distribution system.

In case of losing 380V AC power, the battery will provide a power supply to the loads. After 380V AC power recovery, the battery charger will a provide power supply to the loads and charging power for the battery.

In case of short-circuit, the failure will be removed selectively and the system will restore operation after proper maintenance.

9.6.8.3.2.2 Plant Accident Conditions

a) DBC-2/3/4 condition

In the LOOP condition, the EDG start-ups and provides power to the NI 2h DC and AC UPS system. Before the EDG start-ups, the battery of the NI 2h DC and AC UPS system provides the power.

b) DEC condition

In the LOOP condition cumulated with failure of the EDG, the SBO DG start-ups and provides power to the NI 2h DC and AC UPS system except for the regulated power supply system. Before the SBO DG start-ups, the battery of the NI 2h DC and AC UPS system provides the power. For the regulated power supply system, the LOA/LOB/LOC [ACRPS (NI-380V)] will be unavailable and the LOD/LOE/LOF [ACRPS (NI-380V)] can be supplied by the LVP/LVQ [UPS (NI-380V-12h)] through a manual transfer.

9.6.8.4 Design Substantiation

9.6.8.4.1 Compliance with Fundamental Safety Functional Requirements

9.6.8.4.1.1 Control of Reactivity

Not applicable.

9.6.8.4.1.2 Removal of Heat

Not applicable.

9.6.8.4.1.3 Confinement

Not applicable.

9.6.8.4.1.4 Extra Safety Functions

The NI 2h DC and AC UPS systems support the performance of safety functions by providing the necessary power supplies:

a) The NI 2h DC and AC UPS system provides electrical power to safety systems, such as the RIS [SIS] and RCP [RCS], which perform the reactivity control safety function.

b) The NI 2h DC and AC UPS system provides electrical power to safety systems, such as the RRI [CCWS] and ASG [EFWS], which perform the heat removal safety function.

c) The NI 2h DC and AC UPS system provides electrical power to safety systems, such as the REN [NSS] and RCV [CVCS], which perform the radioactive materials confinement safety function.

9.6.8.4.2 Compliance with Design Requirements

9.6.8.4.2.1 Compliance with Safety Classification

The NI 2h DC and AC UPS system supplies power to safety systems, the function categorisation of the NI 2h DC and AC UPS system is FC1.

According to classification principles in Sub-chapter 4.4.5.2, the safety classification of the NI 2h DC and AC UPS system equipment is F-SC1 except for the battery charger/discharger which is NC.

Detailed information of safety classification for emergency power distribution system is as follows:

T-9.6-12 Categorisation and Classification of the NI 2h DC and AC UPS System

System	Categorisation	Classification
LAA/LAB/LAC/LAD [DCPS (NI-220V-2h)]	FC1	F-SC1 and NC (battery charger/discharger)

System	Categorisation	Classification
LVA/LVB/LVC/LVD [UPS (NI-380V-2h)]	FC1	F-SC1
LOA/LOB/LOC [ACRPS (NI-380V)]	FC1	F-SC1
LOD/LOE/LOF [ACRPS (NI-380V)]	FC1	F-SC1

9.6.8.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

The NI 2h DC and AC UPS system consists of three redundant trains and meets the requirement of the SFC. The fourth division is for the fourth protection channel.

The NI 2h DC and AC UPS system is capable of performing its task in the presence of single failure. Failure of a system or equipment in one train does not affect the system or equipment in other trains.

T-9.6-13 SFC and Redundancy of the NI 2h DC and AC UPS System

Train	System
A	LAA [DCPS (NI-220V-2h) LVA [UPS (NI-380V-2h)] LOA/LOD [ACRPS (NI-380V)]
B	LAB [DCPS (NI-220V-2h)] LVB [UPS (NI-380V-2h)] LOB/LOE [ACRPS (NI-380V)]
C	LAC/LAD [DCPS (NI-220V-2h)] LVC [UPS (NI-380V-2h)]/LVD [UPS (NI-220V-2h)] LOC/LOF [ACRPS (NI-380V)]

b) Independence

Independence is accomplished in the design of the NI 2h DC and AC UPS system by using physical separation. The LAC/LAD [DCPS (NI-220V-2h)], LVC [UPS (NI-380V-2h)] and LVD [UPS (NI-220V-2h)] systems in the BSC are installed in different fire compartments to ensure adequate physical separation.

T-9.6-14 Independence of NI 2h DC and AC UPS System

Train	Installed Building
A	BSA (LAA [DCPS (NI-220V-2h), LVA [UPS (NI-380V-2h)], LOA/LOD [ACRPS (NI-380V)])
B	BSB (LAB [DCPS (NI-220V-2h)], LVB [UPS (NI-380V-2h)], LOB/LOE [ACRPS (NI-380V)])
C	BSC (LAC/LAD [DCPS (NI-220V-2h)], LVC [UPS (NI-380V-2h)]/LVD [UPS (NI-220V-2h), LOC/LOF [ACRPS (NI-380V)])

c) Diversity

The NI 2h DC and AC UPS system between the three trains is identical and without diversity. It is recognised that diversity is needed between the main protection line and diverse protection line, but the NI 2h DC and AC UPS system is not diverse with the NI 12h DC and AC UPS system for the current design which based on FCG3. Further work will be completed to deal with the gap.

9.6.8.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

All components required to perform the safety functions are capable of operating under normal conditions and accident conditions, which requires the equipment to be environmentally qualified and seismically qualified.

The qualification category is K3 for NI 2h DC and AC UPS system equipment (except for the battery charger/discharger which is NC) according to RCC-E 2016.

b) Ageing and degradation

The ageing of the equipment for the NI 2h DC and AC UPS system is considered in qualification and EMIT. It is managed in the following aspects:

1) Equipment of the NI 2h DC and AC UPS system is qualified according to its service condition, such as seismic testing;

2) Physical ageing is considered in the qualification testing;

3) The layout of equipment facilitates EMIT, repair and replacement, such as the distance between two face to face switchboards is defined for the equipment layout design;

4) The replacement period of the equipment is defined according to its individual design life and the plant design life.

c) Examination, maintenance, inspection and testing

The NI 2h DC and AC UPS system and its equipment are designed to permit periodic examination, maintenance, inspection and testing. For periodic testing, a battery discharge test is carried out during RCD operating mode to demonstrate the availability of the system and equipment.

9.6.8.4.2.4 Compliance with hazard protection

a) External hazards

1) Earthquake

The NI 2h DC and AC UPS system could be in service during and after a safety shutdown earthquake. The switchboards of the system are seismically qualified and could perform their function during or after an earthquake.

2) Electromagnetic interference and space weather

The NI 2h DC and AC UPS system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards and meteorological hazards are usually addressed through the structure design or HVAC design of building.

b) Internal hazards

1) Internal fire

For the NI 2h DC and AC UPS system, the risk of internal fires is reduced by the selection of fire-resistance materials and cable penetrations are fire proof where necessary.

The three division of electrical equipment are in three independent fire compartments. The internal fire in one fire compartment could not cause the equipment located in the other fire compartment to fail. Electrical protection will cut off the fault section as soon as possible to reduce the risk of fire.

2) Electromagnetic interference

The NI 2h DC and AC UPS system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other internal hazards

Other internal hazards such as high energy pipe failures, dropped load, internal explosion and internal missiles are usually addressed through the system layout, protection degree of equipment or structure design of building.

9.6.9 NI 12h DC and AC UPS System

9.6.9.1 Safety Requirements

9.6.9.1.1 Fundamental Safety Functional Requirements

9.6.9.1.1.1 Control of Reactivity

The NI 12h DC and AC UPS system is not required to directly perform the reactivity control function.

9.6.9.1.1.2 Removal of Heat

The NI 12h DC and AC UPS system is not required to directly perform the heat removal function.

9.6.9.1.1.3 Confinement

The NI 12h DC and AC UPS system is not required to directly perform the radioactive material confinement function.

9.6.9.1.1.4 Extra Safety Functions

As the NI 12h DC and AC UPS system is required to supply power to the equipment that contributes to the three fundamental safety functions, it performs extra safety functions.

9.6.9.1.2 Design Requirements

9.6.9.1.2.1 Safety Classification

According to the safety classification principles presented in Sub-chapter 4.4.5.1, as NI 12h DC and the AC UPS system provides power to equipment which performs FC3 safety functions, its function categorisation is FC3. Design requirements presented in Sub-chapter 4.4.5.3 are applied to the design of the NI 12h DC and AC UPS system.

9.6.9.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

As the safety function categorisation of the NI 12h DC and AC UPS system is FC3, according to Sub-chapter 4.4.5.3.1 and Table T-4.4.5-7, the design principle of the SFC and redundancy presented in Sub-chapter 4.4.6.1.2 is not required to be applied.

b) Independence

As the safety function categorisation of the NI 12h DC and AC UPS system is FC3, according to Sub-chapter 4.4.5.3.1 and Table T-4.4.5-7, the design principle of independence presented in Sub-chapter 4.4.6.1.3 is required between NI 12h DC and AC UPS system and the NI 2h DC and AC UPS system.

c) Diversity

As the NI 12h DC and AC UPS system supplies power to the equipment that contributes to the diverse protection line, the diversity principle presented in Sub-chapter 4.4.6.1.4 is required to be applied.

9.6.9.1.2.3 Design to Ensure Functionality

a) Equipment qualification

As the safety function categorisation of the NI 12h DC and AC UPS system is FC3, according to Sub-chapter 4.4.5.3.1 and Table T-4.4.5-7, environmental qualification is analysed on a case by case basis. Equipment of the NI 12h DC and AC UPS system is required to be qualified according to the principles presented in Sub-chapter 4.4.6.2.1.

b) Ageing and degradation

As the NI 12h DC and AC UPS system is required to remain available during its lifetime, requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As the NI 12h DC and AC UPS system is required to remain available during its lifetime, EMIT of the NI 12h DC and AC UPS system is applied according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.6.9.1.2.4 Hazard Protection

a) External hazards

As the safety function categorisation of the NI 12h DC and AC UPS system is FC3, according to Sub-chapter 4.4.5.3.1 and Table T-4.4.5-7, environmental qualification is analysed on a case by case basis. As the NI 12h DC and AC UPS system supplies power to the equipment that contributes to the diverse protection line, it is protected against external hazards in accordance with the principle presented in Sub-chapter 18.6.

b) Internal hazards

As the safety function categorisation of the NI 12h DC and AC UPS system is FC3, according to Sub-chapter 4.4.5.3.1 and Table T-4.4.5-7, environmental qualification is analysed on a case by case basis. As the NI 12h DC and AC UPS system supplies power to the equipment that contributes to the diverse protection line, it is protected against internal hazards in accordance with the principle presented in Sub-chapter 19.6.

9.6.9.2 Design Basis

9.6.9.2.1 General Assumption

9.6.9.2.1.1 Control of Reactivity

Not applicable. The NI 12h DC and AC UPS system is not required to directly perform the reactivity control function.

9.6.9.2.1.2 Removal of Heat

Not applicable. The NI 12h DC and AC UPS system is not required to directly perform the heat removal function.

9.6.9.2.1.3 Confinement

Not applicable. The NI 12h DC and AC UPS system is not required to directly perform the radioactive material confinement function.

9.6.9.2.1.4 Extra Safety Functions

a) The function categorisation of the equipment supplied by the NI 12h DC and AC UPS system is FC3;

b) The NI 12h DC and AC UPS system supplies power to the equipment that contributes to diverse protection line;

c) The extra safety functions of the NI 12h DC and AC UPS system are implemented after it supplies power (within normal variation of the frequency and voltage) to the loads.

9.6.9.2.2 Design Assumption

The following key assumptions are applied for the design:

a) Assumption regarding power supplies

For the NI 12h DC system, the SBO AC power distribution system is available during normal operation and a battery is available in case of SBO AC power distribution system failure.

For the NI 12h UPS system, the NI 12h DC system is available during normal operation and the normal AC power distribution system is available in case of NI 12h DC system failure.

b) Assumption regarding control power supplies

The control power supply of the NI 12h DC and AC UPS system is available during normal and accident conditions.

c) Assumption regarding qualification

The qualified equipment of the NI 12h DC and AC UPS system can perform its function during normal and accident conditions.

d) Assumption regarding ambient condition

The HVAC system can ensure the ambient condition of the NI 12h DC and AC UPS system during normal and accident conditions.

9.6.9.3 System Description and Operation

9.6.9.3.1 System Description

9.6.9.3.1.1 General System Description

The NI 12h DC and AC UPS system consists of 2 groups of 12h DC systems and AC UPS systems, which are the LAP/LAQ [DCPS (NI-220V-12h)] and LVP/LVQ [UPS (NI-380V-12h)]. Corresponding to the loads for severe accidents, the FC3 DC and AC UPS system are divided into 2 trains. The LAP [DCPS (NI-220V-12h)] and LVP [UPS (NI-380V-12h)] are applied for train A, and the LAQ [DCPS (NI-220V-12h)] and LVQ [UPS (NI-380V-12h)] for train B.

Each 12h DC system mainly consists of:

a) A group of lead acid batteries;

b) A battery charger;

c) 220V DC distribution switchboards;

d) A battery charger/discharger.

Each 12h AC UPS system mainly consists of:

a) A DC/AC inverter and static bypass;

b) 380V AC distribution switchboards.

The equipment parameters in the specification are verified by the electrical system study.

The NI 12h DC system is an ungrounded and the AC UPS system is the TN-S system.

Detailed information is presented in *NI DC and AC UPS System Single Line Diagram*, Reference [5].

9.6.9.3.1.2 Description of Main Equipment

a) A group of lead acid batteries

When the charger fails, or the upstream AC power is lost, the battery will provide DC power.

b) A battery charger

The battery charger provides DC power to DC loads and the inverter of the AC UPS system, and provides charging power for the battery.

c) 220V DC distribution switchboards

The NI 12h DC and AC UPS system provides DC power to loads through the 220V DC distribution switchboards.

d) A battery charger/discharger

The non-safety battery charger/discharger performs the battery discharge test during system shutdown. Its function category is NC and seismic categorisation is SSE2, which ensures the integrity of the equipment in case of earthquakes. It's connected to the safety cabinets with a breaker which is normally open in both normal and accident conditions. It will be connected to the system only if the battery discharge test is going to be performed.

e) A DC/AC inverter and static bypass

The inverter converts the 220V DC power to three-phase 380V AC power.

f) 380V AC distribution switchboards

The NI 12h DC and AC UPS system provides uninterrupted AC power to loads through the 380V AC distribution switchboards.

9.6.9.3.1.3 Description of Main Layout

The NI 12h DC and AC UPS systems are located in the safeguard buildings of the NI. The LAP [DCPS (NI-220V-12h)] and LVP [UPS (NI-380V-12h)] are located in the BSA, and the LAQ [DCPS (NI-220V-12h)] and LVQ [UPS (NI-380V-12h)] are located in the BSB.

9.6.9.3.1.4 Description of System Interfaces

a) Support system

The support system of the NI 12h DC and AC UPS system is the DVL [EDSBVS].

b) Customer system

The customer system of the NI 12h DC and AC UPS system mainly includes:

1) NI 10kV SBO power distribution system

2) NI 10kV SBO power supply system

3) NI 380V emergency power distribution system

4) KCS [SPCCS]

5) Severe Accident I&C System (KDA [SA I&C])

6) Plant Radiation Monitoring System (KRT [PRMS])

7) Safeguard Building Emergency Lighting System (DSS [SBELS])

8) EHR [CHRS]

9) Containment Combustible Gas Control System (EUH [CCGCS])

10) PTR [FPCTS]

11) RCP [RCS]

9.6.9.3.1.5 Control and Monitoring

Each NI 12h DC and AC UPS system is provided with a control and monitoring installation, which is intended to monitor the operation of the system. Start-up and operational controls of the NI 12h DC and AC UPS system are realised locally. Important information of the system can be sent to the MCR for monitoring of the availability of the system.

9.6.9.3.2 System Operation

9.6.9.3.2.1 Plant Normal Conditions

a) Normal conditions

During normal operation condition, the charger of the NI 12h DC and AC UPS system rectifies the 380V AC power to 220V DC power, provides power to loads and charges the battery. The battery is kept at full charge by the float charge. The inverter converts the 220V DC power to three-phase 380V or one-phase 220V AC power. The bypass circuit is in a standby state.

b) Transient conditions

During transient conditions, the NI 12h DC and AC UPS system is in service and powered by the SBO AC power distribution system.

In case of losing 380V AC power, the battery will provide a power supply to the loads. After 380V AC power recovery, the battery charger will provide a power supply to the loads and charging power for the battery.

In case of short-circuit, the failure will be removed selectively and the system will restore operation after proper maintenance.

9.6.9.3.2.2 Plant Accident Conditions

a) DBC-2/3/4 condition

In the LOOP condition, the EDG start-ups and provides power to the NI 12h DC and AC UPS system. Before the EDG start-ups, the battery of the NI 12h DC and AC UPS system provides the power.

b) DEC condition

In the LOOP condition cumulated with failure of the EDG, the SBO DG start-ups and provides power to the NI 12h DC and AC UPS system except for the regulated power supply system. Before SBO DG start-ups, the battery of the NI 12h DC and AC UPS system provides the power.

The SBO condition cumulated with failure of the SBO diesel generator is considered in the power balance for 12h batteries.

9.6.9.4 Design Substantiation

9.6.9.4.1 Compliance with Fundamental Safety Functional Requirements

9.6.9.4.1.1 Control of Reactivity

Not applicable.

9.6.9.4.1.2 Removal of Heat

Not applicable.

9.6.9.4.1.3 Confinement

Not applicable.

9.6.9.4.1.4 Extra Safety Functions

The NI 12h DC and AC UPS systems support the performance of safety functions by providing the necessary power supplies:

a) The NI 12h DC and AC UPS system provides electrical power to safety systems, such as the RCP [RCS] and PTR [FPCTS], which perform the heat removal safety function;

b) The NI 12h DC and AC UPS system provides electrical power to safety systems, such as the EHR [CHRS] and EUH [CCGCS], which perform the radioactive materials confinement safety function.

9.6.9.4.2 Compliance with Design Requirements

9.6.9.4.2.1 Compliance with Safety Classification

The NI 12h DC and AC UPS system supplies power to FC3 loads, the function categorisation of the NI 12h DC and AC UPS system is FC3.

According to the classification principles in Sub-chapter 4.4.5.2, the safety classification of the NI 12h DC and AC UPS system equipment is F-SC3 except for the non-safety battery charger/discharger which is NC.

Detailed information of safety classification for NI 12h DC and AC UPS system is as follows:

T-9.6-15 Categorisation and Classification of the NI 12h DC and AC UPS System

System	Categorisation	Classification
LAP/LAQ [DCPS (NI-220V-12h)]	FC3	F-SC3 and NC (battery charger/discharger)
LVP/LVQ [UPS (NI-380V-12h)]	FC3	F-SC3

9.6.9.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

Not applicable.

b) Independence

Independence is accomplished in the design of the NI 12h DC and AC UPS system by using electrical, mechanical segregation as well as physical separation. They are independent from each other in terms of system, equipment and layout.

T-9.6-16 Independence of the NI 12h DC and AC UPS system

Train	Installed Building
A	BSA (LAP [DCPS (NI-220V-12h)], LVP [UPS (NI-380V-12h)])
B	BSB (LAQ [DCPS (NI-220V-12h)], LVQ [UPS (NI-380V-12h)])

c) Diversity

The NI 12h DC and AC UPS system between the two trains is identical and without diversity. It is recognised that diversity is needed between the main protection line and diverse protection line, but the NI 12h DC and AC UPS system is not diverse with NI 2h DC and AC UPS system for the current design which is based on FCG3. Further work will be completed to deal with the gap.

9.6.9.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

All of the system components are capable of operating under normal conditions and accidental conditions, which requires the equipment to be environmentally qualified and seismically qualified.

The qualification category is K3 for the NI 12h DC and AC UPS system equipment (except for the battery charger/discharger which is NC) according to RCC-E 2016.

b) Ageing and degradation

The ageing of the equipment for the NI 12h DC and AC UPS system is considered in the qualification and EMIT. It is managed in the following aspects:

1) Equipment of the NI 12h DC and AC UPS system is qualified according to its service condition, such as seismic testing;

2) The layout of equipment facilitates EMIT, repair and replacement, such as the distance between two face to face switchboards is defined for the

equipment layout design;

3) The degradation of batteries is monitored by periodic battery discharge testing;

4) The replacement period of the equipment is defined according to its individual design life and the plant design life.

c) Examination, maintenance, inspection and testing

The NI 12h DC and AC UPS system and its equipment are designed to permit periodic examination, maintenance, inspection and testing. For periodic testing, the battery discharge test is carried out during RCD operating mode to demonstrate the availability of the system and equipment.

9.6.9.4.2.4 Compliance with Hazard Protection

The NI 12h DC and AC UPS system is designed with three trains, which are independent from each other. The three independent NI 12h DC and AC UPS systems are located in three safety buildings, which are physically separate from each other and protected against external and internal hazards.

a) External hazards

1) Earthquake

The NI 12h DC and AC UPS system could be in service during and after a safety shutdown earthquake. The switchboards of the system are seismically qualified and could perform their function during or after an earthquake.

2) Electromagnetic interference and space weather

The NI 12h DC and AC UPS system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding, and cabling.

3) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards and meteorological hazards are usually addressed through the structure design or HVAC design of buildings.

b) Internal hazards

1) Internal fire

For the NI 12h DC and AC UPS system, the risk of internal fires is reduced by the selection of fire-resistance materials and cable penetrations are fire proof where necessary.

The three division of electrical equipment are in three independent fire compartments. The internal fire in one fire compartment could not cause the equipment located in the other fire compartment to fail. Electrical protection will cut off the fault section as soon as possible to reduce the risk of fire.

2) Electromagnetic interference

The NI 12h DC and AC UPS system is protected against electromagnetic interference by EMC qualification and application of earthing network, Faraday cage structure, cable shielding and cabling.

3) Other internal hazards

Other internal hazards such as high energy pipe failures, dropped load, internal explosion and internal missiles are usually addressed through the system layout, protection degree of equipment or structure design of buildings.

9.7 Auxiliary Electrical System

9.7.1 Earthing and Lightning Protection System

9.7.1.1 Safety Requirements

9.7.1.1.1 Fundamental Safety Functional Requirements

9.7.1.1.1.1 Control of Reactivity

The earthing and lightning protection system is not required to directly perform the reactivity control function.

9.7.1.1.1.2 Removal of Heat

The earthing and lightning protection system is not required to directly perform the heat removal function.

9.7.1.1.1.3 Confinement

The earthing and lightning protection system is not required to directly perform the radioactive material confinement function.

9.7.1.1.1.4 Extra Safety Functions

The earthing and lightning protection system is not required to perform the extra safety functions.

9.7.1.1.2 Design Requirements

9.7.1.1.2.1 Safety Classification

According to the safety classification principles presented in Sub-chapter 4.4.5.1, as the earthing and lightning protection system provides earthing and lightning protection to equipment, its function categorisation is NC. Design requirements presented in Sub-chapter 4.4.5.3 are not applicable.

9.7.1.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

As the safety function categorisation of the earthing and lightning protection system is NC, it does not need to meet the requirements of the SFC and redundancy. The earthing grid however can meet the requirement of redundancy by the interconnection of the common earthing grid network.

b) Independence

As the safety function categorisation of the earthing and lightning protection system is NC, it does not need to meet the requirements of independence.

c) Diversity

As the earthing and lightning protection system does not contribute to the main and diverse protection line, the requirements of diversity presented in Sub-chapter 4.4.6.1.4 are not applicable.

9.7.1.1.2.3 Design to Ensure Functionality

a) Equipment qualification

As the safety function categorisation of the earthing and lightning protection system is NC, it does not need to meet the requirements of equipment qualification.

b) Ageing and degradation

Degradation of the earthing and lightning protection system is taken into consideration according to the requirements presented in the in Sub-chapter 4.4.6.2.2.

c) Examination, maintenance, inspection and testing

As the earthing and lightning protection system is required to remain available during the service life, EMIT of the earthing and lightning protection system is applied according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.7.1.1.2.4 Hazard Protection

The earthing and lightning protection system is required of hazard protection.

a) External hazards

Although safety function categorisation of the earthing and lightning protection system is NC, the external hazard protection presented in Sub-chapter 18.6 is taken into consideration in terms of plant reliability and conventional safety if practicable.

b) Internal hazards

Although the safety function categorisation of the earthing and lightning protection system is NC, the internal hazard protection presented in Sub-chapter 19.6 is taken into consideration in terms of plant reliability and conventional safety if practicable.

9.7.1.2 Design Basis

9.7.1.2.1 General Assumption

9.7.1.2.1.1 Control of Reactivity

Not applicable. The earthing and lightning protection system is not required to directly perform the reactivity control function.

9.7.1.2.1.2 Removal of Heat

Not applicable. The earthing and lightning protection system is not required to directly perform the heat removal function.

9.7.1.2.1.3 Confinement

Not applicable. The earthing and lightning protection system is not required to directly perform the radioactive material confinement function.

9.7.1.2.1.4 Extra Safety Functions

Not applicable. The earthing and lightning protection system is not required to directly perform the extra safety functions.

9.7.1.2.2 Design Assumption

The following key assumptions are applied for the design:

a) The civil structural rebar is interconnected and connected with the earthing network;

b) The earthing networks within the buildings are interconnected and only one earthing system exists in the station;

c) The parameters of lightning current are within the range of the design assumption.

9.7.1.3 System Description and Operation

9.7.1.3.1 System Description

9.7.1.3.1.1 General System Description

The earthing and lightning protection system mainly performs the role of limiting the risks of exceeding the allowable voltage of the electrical systems, reducing the electromagnetic effects of lightning currents and ensuring the security of personnel and equipment. The low voltage electrical systems are directly grounded to the earthing system. The protection devices could trip and clear the fault equipment when there is an earthing fault.

This system includes external and internal lightning protection system. The external lightning protection system includes air-termination systems, shielding in outer walls of the buildings, down-conductor systems and an interconnected earthing termination system. The duty of the system is to conduct the lightning current down to the earth safely and disperse it to earth when it is struck by lightning. The structures or equipment (such as chimneys (NI), transformers (BOP) or lamp-posts in the plant) located outside are considered for lightning protection measures. The internal lightning protection system takes measures such as shielding in inner floors of buildings, cable ducts and outdoor cabling to reduce the electromagnetic effects of lightning currents and to protect the internal equipment.

The design of the internal and external earthing system ensures personnel saftey in any possible situation during internal or external events. The following events are taken into account:

a) Short circuits;

b) Isolation failures or lightning strikes.

All measures mentioned above are applied to the communication systems, process control systems, fire alarm systems, etc.

9.7.1.3.1.2 Description of Main Equipment

The main equipment of the earthing and lightning protection system includes:

a) Deep buried earthing network;

b) Surface buried earthing network;

c) Above-ground earthing circuit;

d) Faraday cages;

e) Interconnection with civil structural rebar;

f) Lightning arrestors or surge protectors;

g) Air termination systems.

9.7.1.3.1.3 Description of Main Layout

The deep buried earthing network is arranged around each building. Each buildings is connected to the main earthing network at least at two points. Each sub-network is connected to the earthing network with at least two conductors.

9.7.1.3.1.4 Description of System Interface

All of the SSCs required for lightning protection are connected with the earthing and lightning protection system, such as buildings (structures), electrical system, process system and I&C system.

9.7.1.3.1.5 Control and Monitoring

Not applicable.

9.7.1.3.2 System Operation

9.7.1.3.2.1 Plant Normal Conditions

The occurrence of inadmissible touch voltages and step voltages has to be avoided. Other measures are considered to fulfil the requirements of electromagnetic compatibility for installations. In order to reduce the electromagnetic effects caused by lightning and other interference sources, the following measures are considered:

a) Faraday cages;

b) Treatment of cable shields;

c) Electronic systems reference earth conductor, etc.

All the measures mentioned above are intended to prevent the allowable voltage for I&C equipment from being exceeded. When a short-circuit current flows via the earthing system, it will not lead to unacceptable potential effects on the I&C System.

9.7.1.3.2.2 Plant Accident Conditions

The operation of the earthing and lightning protection system in accident conditions is the same as for the normal conditions.

9.7.1.4 Design Substantiation

9.7.1.4.1 Compliance with Fundamental Safety Functional Requirement

9.7.1.4.1.1 Reactivity Control

Not applicable.

9.7.1.4.1.2 Heat Removal

Not applicable.

9.7.1.4.1.3 Confinement

Not applicable.

9.7.1.4.1.4 Extra Safety Functions

Not applicable.

9.7.1.4.2 Compliance with Design Requirements

9.7.1.4.2.1 Compliance with Safety Classification

The earthing and lightning protection system is NC. Its categorisation and classification will be reviewed in Step 3 of GDA.

9.7.1.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

The SFC and redundancy are not applicable for the earthing and lightning protection system. The earthing network can however meet the requirement of redundancy by the interconnection of the common earthing network.

b) Independence

Independence is not applicable for the earthing and lightning protection system.

c) Diversity

Diversity is not applicable for the earthing and lightning protection system.

9.7.1.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

The earthing and lightning protection system is not required to meet the equipment qualification requirement.

b) Ageing and degradation

Taking into consideration erosion, the buried earthing network of the earthing and lightning protection system is required to be available for its design life.

c) Examination, maintenance, inspection and testing

1) Maintenance plan

The earthing and lightning protection system requires maintenance when the earthing resistance does not meet the specified requirement.

2) In- service inspection

The earthing resistance is required to be inspected annually to ensure that the earthing connection is stable and reliable.

3) Periodical testing

The earthing and lightning protection system is required to be tested at least once each year to ensure the integrity of earthing system.

- Earthing connection test
- Earthing resistance test
- Insulation test

9.7.1.4.2.4 Compliance with Hazard Protection

a) External hazards

1) Earthquake

Not applicable. But the earthing and lightning protection system is designed to be available for buildings in case of an earthquake.

2) Meteorological (including extreme wind, extreme temperature, extreme hail, sleet snow and icing, rainfall, external missile, lightning, drought and space weather).

The earthing and lightning protection system is designed to protect against the basic design lightning in line with the assumption.

3) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards and meteorological hazards are usually addressed through structure design of buildings.

b) Internal hazards

1) Electromagnetic interference

The earthing and lightning protection system provides EMI prevention measures for electrical and I&C systems that perform safety functions.

2) Other internal hazards

Other internal hazards such as internal fire, high energy pipe failures, dropped load, internal explosion and internal missiles are not applicable for the earthing and lightning protection system.

9.7.2 Lighting System

9.7.2.1 Safety Requirements

9.7.2.1.1 Fundamental Safety Functional Requirements

9.7.2.1.1.1 Control of Reactivity

The lighting system is not required to directly perform the reactivity control function.

9.7.2.1.1.2 Removal of Heat

The lighting system is not required to directly perform the heat removal function.

9.7.2.1.1.3 Confinement

The lighting system is not required to directly perform the radioactive material confinement function.

9.7.2.1.1.4 Extra Safety Functions

The lighting system is not required to perform the extra safety functions.

9.7.2.1.2 Design Requirements

9.7.2.1.2.1 Safety Classification

Safety classification principles and general safety principles presented in Sub-chapter 4.4.5.1 are applied to the design of the escape lighting system and main control room lighting system. Other normal lighting systems and standby lighting systems are NC. The design requirements presented in Sub-chapter 4.4.5.3 are not applicable.

9.7.2.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

As the categorisation of the escape lighting system and main control room lighting system are FC3, the design principle of the SFC and redundancy presented in Sub-chapter 4.4.6.1.2 is required to be applied.

As other normal lighting systems and standby lighting systems are NC, they do not need to meet the requirements of the SFC and redundancy.

b) Independence

As the categorisation of the escape lighting system and main control room lighting system are FC3, the design principle of independence presented in Sub-chapter 4.4.6.1.3 is required to be applied.

c) Diversity

As other normal lighting systems and standby lighting systems are NC, they do not need to meet the requirements of independence.

As the lighting system does not contribute to the main and diverse protection line, requirements of diversity presented in Sub-chapter 4.4.6.1.4 are not applicable.

9.7.2.1.2.3 Design to Ensure Functionality

a) Equipment qualification

Components performing safety functions in the lighting system are appropriately qualified according to the principles presented in Sub-chapter 4.4.6.2.1.

b) Ageing and degradation

As the lighting system is required to remain available during its lifetime, the requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As the lighting system is required to remain available during the service life, EMIT of the lighting system is applied according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.7.2.1.2.4 Hazard Protection

The lighting system is protected against internal and external hazards in accordance with the principles of Sub-chapter 19.6 and Sub-chapter 18.6.

9.7.2.2 Design Basis

9.7.2.2.1 General Assumption

9.7.2.2.1.1 Control of Reactivity

Not applicable. The lighting system is not required to directly perform the reactivity control function.

9.7.2.2.1.2 Removal of Heat

Not applicable. The lighting system is not required to directly perform the heat removal function.

9.7.2.2.1.3 Confinement

Not applicable. The lighting system is not required to directly perform the radioactive material confinement function.

9.7.2.2.1.4 Extra Safety Functions

Not applicable. The lighting system does not directly support the equipment that performs the three fundamental safety functions (control of reactivity, removal of heat and confinement).

9.7.2.2.2 Design Assumption

The following key assumptions are applied for the design:

a) Assumption regarding power supplies

The normal power supply is available during normal operation conditions.

The corresponding emergency power supply is available during accident operation conditions.

b) Assumption regarding qualification

The equipment of the lighting system can perform its function under qualified environmental and seismic conditions.

9.7.2.3 System Description and Operation

9.7.2.3.1 System Description

9.7.2.3.1.1 General System Description

This lighting system consists of the following parts:

a) Normal lighting system;

b) Emergency lighting system: including standby lighting, safety lighting and emergency escape lighting.

Normal lighting and emergency lighting are to ensure the following functions:

a) The lighting system can cover the whole area of the buildings;

b) The lighting system is designed to perform all operating tasks during normal operation.

The illumination of standby lighting is not lower than normal lighting in the following areas:

a) Fire pumps room;

b) Diesel generator room;

c) Electricity distribution room;

d) Building smoke control (extraction) room;

e) Rooms containing fire-fighting equipment which still needs to work when a fire occurs.

Safety lighting is designed to provide necessary lighting for all operating tasks during normal operation in case of total loss of normal lighting and standby lighting.

The emergency escape lighting powered by batteries is turned on automatically to provide necessary illumination for the emergency exits and escape routes when the normal lighting and standby lighting is unavailable. The escape route direction signs and emergency exit signs with batteries are designed to be permanently illuminated, and will indicate the evacuation direction for personnel for at least 2 hours in case of loss of power.

9.7.2.3.1.2 Description of Main Equipment

The main equipment of the lighting system includes:

a) Lighting distribution boards;

b) Cables and cable trays;

c) Various luminaires, etc.

9.7.2.3.1.3 Description of Main Layout

The main layout of the lighting system in the NI includes:

a) The escape lighting is located in the exits and escape routes;

b) The lighting system covers all of the NI buildings.

9.7.2.3.1.4 Description of System Interface

The interfaces with lighting system are as follows:

a) NI 380V emergency and SBO power distribution system;

b) CI and NI 380V normal power distribution system;

c) NI 380V AC uninterruptible power system.

9.7.2.3.1.5 Control and Monitoring

Not applicable.

9.7.2.3.2 System Operation

9.7.2.3.2.1 Plant Normal Conditions

The normal and standby lighting system provides lighting required to perform all operating tasks during normal operation.

9.7.2.3.2.2 Plant Accident Conditions

The emergency lighting system provides lighting during all plant operating conditions including LOOP, fire and accident conditions. It includes the following three parts:

Standby lighting system makes up the general lighting of the plant together with the normal lighting system and provides lighting for each buildings and areas under normal working conditions. Standby lighting can provide 1/3 illumination continually for buildings and areas when losing normal lighting, so that the staff can continue necessary work.

The emergency escape lighting system provides lighting for the emergency exits and escape routes for facilitating personnel evacuation.

Safety lighting system provides lighting in case of a total loss of external and internal power supply in the MCR. The normal lighting and standby lighting in the MCR is available during plant accident conditions.

9.7.2.4 Design Substantiation

9.7.2.4.1 Compliance with Fundamental Safety Functional Requirement

9.7.2.4.1.1 Control of Reactivity

Not applicable.

9.7.2.4.1.2 Removal of Heat

Not applicable.

9.7.2.4.1.3 Confinement

Not applicable.

9.7.2.4.1.4 Extra Safety Functions

Not applicable.

9.7.2.4.2 Compliance with Design Requirements

9.7.2.4.2.1 Compliance with Safety Classification

According to the classification principles in Sub-chapter 4.4.5.2, the safety classification of the escape lighting system and main control room lighting system is F-SC3 and the safety classification of other equipment or components in the other lighting systems is NC.

9.7.2.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

The lighting system of the MCR is required to meet the redundancy requirement:

1) The normal lighting is designed in train A and train B;

2) The standby lighting is designed in train C;

3) The safety lighting is designed in train A and train B.

b) Independence

The lighting system is required to meet the independence requirement. Normal lighting and emergency lighting does not route through the same cable tray.

c) Diversity

Not applicable. The lighting system is not required to meet the diversity requirement. The MCR lighting system however achieves the requirements of diversity.

9.7.2.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

The luminaires of the escape lighting system required to perform the safety functions are capable of operating under normal conditions and accident conditions, which requires the equipment be seismically qualified.

The lighting system of the MCR required to perform the safety functions is capable of operating under normal conditions and accident conditions, which requires the equipment be seismically qualified.

The luminaires used in specific radioactivity environments, which are required to perform the safety functions, are capable of operating under normal conditions and accident conditions, which requires the equipment to be radioactivity and anti-pressure qualified.

b) Ageing and degradation

Taking into consideration radioactivity ageing and degradation, the lighting system is required to be available in its design life.

c) Examination, Maintenance, Inspection and Testing

The lighting system is designed to permit periodic examination, maintenance, inspection and testing.

The escape lighting equipment with batteries requires periodic testing.

The lighting equipment is required to be disconnected to be maintained.

The normal lighting system is required to be maintained while the standby lighting system is in operation.

9.7.2.4.2.4 Compliance with Hazard Protection

a) External hazards

1) Earthquake

Emergency lighting is required to ensure various operations and work can be carried out during and after an earthquake.

2) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards and meteorological hazards are usually addressed through the structure design of buildings.

b) Internal Hazards

1) Internal fire

Internal fire could not cause escape lighting system failure.

2) Electromagnetic interference

The lighting system is protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other internal hazards

Not applicable.

9.7.3 Communication Systems

9.7.3.1 Safety Requirements

Communication systems are not required to directly perform the safety functions.

9.7.3.1.1 Fundamental Safety Functional Requirements

9.7.3.1.1.1 Control of Reactivity

Communication systems are not required to directly perform the reactivity control function.

9.7.3.1.1.2 Removal of Heat

Communication systems are not required to directly perform the residual heat removal function.

9.7.3.1.1.3 Confinement

Communication systems are not required to directly perform the radioactivity confinement function.

9.7.3.1.1.4 Extra Safety Functions

The functions delivered by several communication sub-systems are linked to the emergency response plan.

9.7.3.1.2 Design Requirements

9.7.3.1.2.1 Safety Classification

According to the safety classification principles presented in Sub-chapter 4.4.5.1, as the communication systems allow for communication throughout the nuclear power plant its function categorisation is NC. Design requirements presented in Sub-chapter 4.4.5.3 are not applicable.

9.7.3.1.2.2 Design for Reliability

a) Single failure criterion and redundancy

As the safety function categorisation of communication systems is NC, they do not need to meet the requirements of the SFC and redundancy.

b) Independence

The principle of independence is taken into consideration in the design of communication systems in terms of the emergency response.

c) Diversity

The principle of diversity is taken into consideration in the design of communication systems in terms of the emergency response.

9.7.3.1.2.3 Design to Ensure Functionality

a) Equipment qualification

As the safety function categorisation of communication systems is NC, they do not need to meet the requirements of equipment qualification.

b) Ageing and degradation

As communication systems are required to remain available during their lifetime, requirements on ageing and degradation in Sub-chapter 4.4.6.2.2 are applied.

c) Examination, maintenance, inspection and testing

As communication systems are required to remain available during the service life, EMIT of the communication systems is performed according to the requirements presented in Sub-chapter 4.4.6.2.3.

9.7.3.1.2.4 Hazard Protection

Although the safety function categorisation of communication systems is NC, external and internal hazard protection principles presented in Sub-chapter 18.6 and Sub-chapter 19.6 are taken into consideration in terms of plant reliability and conventional safety if practicable.

9.7.3.2 Design Basis

9.7.3.2.1 General Assumption

9.7.3.2.1.1 Control of Reactivity

Not applicable. Communication systems are not required to directly perform the reactivity control function.

9.7.3.2.1.2 Removal of Heat

Not applicable. Communication systems are not required to directly perform the heat removal function.

9.7.3.2.1.3 Confinement

Not applicable. Communication systems are not required to directly perform the radioactive material confinement function.

9.7.3.2.1.4 Extra Safety Functions

Communication systems do not directly perform safety functions (control of reactivity, removal of heat and confinement). The functions delivered by alarm system, public address system, secondary telephone system and wireless communication system however, support the emergency response.

9.7.3.2.2 Design Assumption

The following key assumptions are applied for the design:

a) Assumption regarding power supplies

The normal power supply is available during normal operation condition.

The corresponding emergency power supply is available during accident operation conditions.

b) Assumption regarding ambient condition

The HVAC system can ensure the ambient conditions of communication systems.

c) Assumption regarding communication equipment

The equipment of communication systems adopts mature technology and both commercial and industrial standards.

9.7.3.3 System Description and Operation

9.7.3.3.1 System Description

Communication systems are designed to provide reliable and efficient communication.

Effective means of communication are provided throughout the nuclear power plant to facilitate safe operation in all modes of normal operation and to be available for use after all postulated initiating events and in accident conditions.

Suitable and diverse means of communication necessary within the nuclear power plant and in the immediate vicinity, and for communication with relevant off-site agencies, are provided.

Suitable alarm systems and other means of communication are available so that all people on the site can be given warnings and instructions in operational states and accident conditions.

9.7.3.3.1.1 Plant Internal Communications

a) Telephone communications

Several telephone systems are provided to ensure that at least one telephone communication system is available to provide necessary communication in normal operational states and accident conditions.

1) Normal telephone system

The normal telephone system provides general voice communication for all the staff involved in work at the plant to satisfy the communication requirements.

2) Secondary telephone system

The secondary telephone system is a back-up telephone system which provides telephone communication related to the emergency response. The system network is separated from the normal telephone system.

b) Public address system

The public address system provides the broadcasting function for the operator to inform staff on site in both normal operational states and accident conditions.

c) Alarm system

The alarm system provides audible and visible alarms for incidents and accidents.

In high noise areas, light alarm signals are used.

d) Wireless communication system

The wireless communication system enables personnel paging and emergency information transmission. The system can also provide voice communications.

The terminal can be set in vibration mode to make sure the personnel in high noise area can be alerted.

9.7.3.3.1.2 Interface to Off-site

Diversified means of communications are provided between the plant and the outside, including telephone links to the grid, public telephone network, public authorities and service organisations such as the fire department and police station, etc.

9.7.3.3.2 System Operation

9.7.3.3.2.1 Plant Normal Conditions

During plant normal operation, communication systems shall be permanently in service.

9.7.3.3.2.2 Plant Accident Conditions

In accident conditions, the communication systems related to emergency response shall be in service. They are supplied from uninterrupted power supplies where the upstream source comes from the diesel power supply.

9.7.3.4 Design Substantiation

9.7.3.4.1 Compliance with Fundamental Safety Functional Requirement

9.7.3.4.1.1 Control of Reactivity

Not applicable. Communication systems do not perform this fundamental safety function.

9.7.3.4.1.2 Removal of Heat

Not applicable. Communication systems do not perform this fundamental safety function.

9.7.3.4.1.3 Confinement

Not applicable. Communication systems do not perform this fundamental safety function.

9.7.3.4.1.4 Extra Safety Functions

The functions delivered by the alarm system, public address system, secondary telephone system and wireless communication system can support the emergency response plan.

9.7.3.4.2 Compliance with Design Requirements

9.7.3.4.2.1 Compliance with Safety Classification

The classification of communication systems is NC.

T-9.7-1 Categorisation and Classification of Communication Systems

System	Categorisation	Classification
Normal Telephone System	NC	NC
Secondary Telephone System	NC	NC
Alarm System	NC	NC
Public Address System	NC	NC
Wireless Communication System	NC	NC

9.7.3.4.2.2 Compliance with Reliability

a) Single failure criterion and redundancy

As the safety function categorisation of communication systems is NC, they are not required to meet the requirements of the SFC and redundancy.

b) Independence

The design of communication systems ensures that the failure of one communication sub-system do not affect other communication sub-systems.

c) Diversity

Suitable and diverse means of communication are provided to meet the diversity requirements of communication systems. Different kinds of alarms can be transmitted by the alarm system and public address system. Voice communication is realised by the normal telephone system, secondary telephone system and wireless communication system.

9.7.3.4.2.3 Compliance with Ensure Functionality

a) Equipment qualification

Communication systems are not required to meet the qualification requirement.

b) Ageing and degradation

Taking into consideration radioactivity ageing and degradation, the communication systems are required to remain available.

c) Examination, maintenance, inspection and testing

Periodic testing is necessary for the alarm system and public address system. Testing and maintenance of the system equipment are implemented at the manufacturer’s recommended intervals.

9.7.3.4.2.4 Compliance with Hazard Protection

a) External hazards

1) Earthquake

Not applicable.

2) Electromagnetic interference and space weather;

The requirement of electromagnetic compatibility is considered by EMC qualification and the application of an earthing and lightning network, faraday cage structure, cable shielding and cabling.

3) Other external hazards

Other external hazards such as flooding, man-made and industrial hazards and meteorological hazards are usually addressed through the structure design or HVAC design of buildings.

b) Internal hazards

1) Internal fire

   Not applicable.

2) Electromagnetic interference

   Communication systems are designed to meet the requirement of electromagnetic compatibility. They are protected against electromagnetic interference by EMC qualification and the application of an earthing network, faraday cage structure, cable shielding and cabling.

3) Other internal hazards

   Other internal hazards such as high energy pipe failures, dropped load, internal explosion and internal missiles are usually addressed through the system layout, protection degree of equipment or structure design of buildings.

9.8 Specific Principles

9.8.1 Cabling Design Principles

9.8.1.1 General Cabling Design Principles

The NI and CI electrical distribution systems are installed in separate buildings. Those on the CI are located in a non-classified electrical building and those on the NI are mainly located in electrical equipment rooms within the safeguard buildings and diesel generator buildings. The separation principle is applied in the different trains within the same DiD level. Separation of the main line and the back-up line is not required. The cables are unarmoured. All measures described herein follow the aim of avoiding unacceptable effects between different divisions.

Cables or the associated cables from the same train are arranged in different cable ways than the cables or the associated cables from the other safety trains. Cables of different trains have to be physically separated by fire barriers, protection walls, sufficient distance or other measures.

9.8.1.2 Requirements for Separation between Cableways

The main aim of the separation of cables and cable ways is to limit the probability of effects caused by internal or by external hazards. The following items are taken into account:

a) Separation of divisions and trains;

b) Separation of different voltage levels.

The NI electrical power system is divided into normal, emergency and SBO power systems. Non-safety class cables can be run along the cable tray of a safety train. They are then taken to be associated with the safety train and are subject to the requirements for safety train cables, Reference [9].

Each redundant train of the emergency power system is installed in separate divisions. The divisional separation guarantees that failure inducing events like internal hazards or single failures may not affect other divisions. Cables belonging to different trains have to be routed physically separated to each other, all electrical trains are considered as individual fire compartments and are physically separated from adjacent trains by fire barriers, protection walls or other adequate means (distance or wrapping). The soft wrapping is only used as measure to deal with fire CCF when there are no other options available. The use of wrapping will be kept to a minimum.

Cables of different trains in mechanical system rooms have to be totally separated by fire barriers, protection walls, sufficient distance or other measures. Cables of different trains in one of the mechanical system rooms have to comply with the requirements of separation as much as possible.

9.8.1.3 Installation of Cableways

9.8.1.3.1 Cable Voltage Levels and Routing Requirements

Cables of different voltage levels will be arranged on different cable trays to avoid electromagnetic interferences according to the following table:

T-9.8-1 Cable Voltage Levels

Voltage Level	Cable Type	Voltage Rating	Number of Layers
1	Medium voltage cables	> 1kV	single layer or in △-bundles
2	Low voltage cables	⩽ 1kV > 50V	Volume rate is less than 70%
3	I&C cables, communication cables, bus cables, optical fiber	⩽ 50V	Multilayer arrangement, volume rate is less than 70%
4	Neutron flux and dedicated monitoring cables		In the totally enclosed cable tray, single layer or routing through steel pipes and separated from the I&C cable
5	Communication special NC cables		Multilayer arrangement, volume rate is less than 70%

9.8.1.3.2 Cable Arrangement of Adjacent Trains

The cables from other trains are required to be arranged on separate cable trays.

9.8.1.3.3 Cable Connections between Trains through a Third One

Cable connections between 2 trains passing through a third one has to fulfil the separation requirements. It means that a failure in one train or failure within this connection may only affect the train itself. They have to be separate from the cables within the third train.

9.8.2 Electrical Relaying Protection Measures

9.8.2.1 General Description

The electrical relaying protection detects and responds to electrical faults in order to minimise equipment damage. Electrical protective schemes minimise hazards to personnel, equipment and the plant by isolating the faulty portion of the power system. The electrical relaying protection consists of independent standalone devices and it is independent of any I&C platforms.

The relaying protection complies with requirements on reliability, selectivity, sensitivity and quick-action. The back-up protection can clear the fault if the primary protection fails.

Selective overcurrent coordination can generally be achieved by ensuring that overcurrent protective installations are rated or set to operate at optimum set points (current and time) during fault conditions, and that they remain selective with other installations on the system.

9.8.2.2 Generator-transformer Protection

The main generator-transformer protection system provides protection to the generator and power transmission system equipment against electrical and non-electrical faults, and isolates fault section from the system with an as short delay as possible in order to ensure safe protection and minimise damage.

The generator-transformer protection system adopts microprocessor-based protection devices and has a redundant configuration. The measuring circuits and tripping circuits of the redundant protection devices are independent from each other. However, only one set of the non-electrical protection system is necessary to ensure the operational reliability of the generator and transmission protection system. The generator is equipped with generator differential protection, stator earth fault protection, generator negative current protection, loss of field protection, reverse power protection, etc. The UT and ATs are equipped with transformer differential protection, over current protection, over field protection, etc.

9.8.2.3 Medium-Voltage System Protection

9.8.2.3.1 General Description

The protection of the on-site electrical power distribution system detects different kinds of faults and isolates them as quickly as possible in order to limit the effects on the equipment.

The medium-voltage system protection adopts microprocessor-based protection devices. Smart installations are required to be qualified, refer to the Chapter 8 Instrumentation and Control.

9.8.2.3.2 The Power Source Incoming and Outgoing Feeder Circuit

The power source incoming and outgoing feeder circuit is equipped with overcurrent protection with a time delay.

9.8.2.3.3 Motor Feeder Circuit

The motor feeder circuit is equipped with overcurrent protection, single phase earth fault protection and overload protection.

9.8.2.3.4 Low-voltage Transformer Circuit

The low-voltage transformer circuit is equipped with overcurrent protection and single phase earth fault protection.

9.8.2.3.5 Earth Fault Detection

Each medium-voltage bus is equipped with an earth fault detection installation that reflects the zero sequence voltage. The motor and low-voltage transformer feeder circuits are equipped with zero sequence current transformers, which detect earth faults of the circuit.

9.8.2.3.6 Under Voltage Protection

The medium-voltage bus bar is equipped with the under voltage relay to detect the under voltage signal of the bus. For the normal AC power distribution medium-voltage bus, an alarm will be generated, and the motor will trip after a time delay. For the emergency distribution medium-voltage bus, an alarm will be generated, and no trip will be actuated. Automatic power supply transfer is provided when undervoltage is detected after a time delay.

9.8.2.4 Low-Voltage System Protection

9.8.2.4.1 The Power Source Incoming and Outgoing Feeder Circuit

In general, no circuit breaker is installed between the transformer low voltage side and the low-voltage bus, and only single-phase earth fault protection is equipped. The protection will trip the medium-voltage side circuit breaker. For the low voltage load centre feeder circuit, short circuit protection (with short circuit time delay) and overload protection are provided.

9.8.2.4.2 Motor Feeder Circuit

For the fuse-contactor circuit, a fuse is used for short circuit protection. For the circuit breaker-contactor circuit, a circuit breaker is used for short circuit protection. All the motor circuits are equipped with thermal relays for overload protection.

9.8.2.4.3 Under Voltage Protection

The low-voltage bus bar is equipped with the under voltage relay to detect the under voltage signal of the bus. For the normal distribution low-voltage bus, an alarm will be generated, and the motor will be tripped after a time delay. For the emergency distribution low-voltage bus, only an alarm will be generated, and no trip will be actuated.

9.8.3 Allocation of Loads

The allocation of electrical loads is based on their safety function categorisation derived from the fault analysis, which includes the identification of Postulated Initiating Events (PIEs), Deterministic Safety Analysis (DSA) and PSA.

a) The loads whose function categorisation is NC are assigned to the NC function electrical systems, such as the normal AC power distribution system and CI DC and AC UPS system;

b) The loads whose function categorisation is FC1 or FC2 are assigned to the FC1 function electrical systems, such as the emergency AC power distribution system and NI 2h DC and UPS system;

c) The loads whose function categorisation is FC3 are analysed on a case by case basis:

    1) For the loads performing FC1 or FC2 functions at other conditions, they are assigned to FC1 function electrical system, such as the SBO AC power distribution system and NI 2h DC and UPS system;

    2) For the loads designed only to cope with SBO conditions, they are assigned to the SBO AC power distribution system and NI 2h DC and UPS system;

    3) For the loads designed to cope with Severe Accident conditions (DEC-B or total loss of AC power), they are assigned to the SBO AC power distribution system and NI 12h DC and UPS system.

The allocation of electrical loads is subject to that requirement that the classification of loads is aligned with the classification of electrical systems.

a) The switchboards whose safety classification is FC1 could supply FC1, FC2, FC3 or NC loads;

b) The switchboards whose safety classification is FC3 could supply FC3 or NC loads;

c) The switchboards whose safety classification is NC could supply NC loads;

d) If the higher classification switchboards supply power to the lower classification electrical loads, the classification of the interconnecting isolation devices is the same as the classification of the higher classification switchboards. The capability of the isolation devices performing the isolation function is demonstrated by qualification.

The non-safety loads are connected to the safety electrical power systems for particular reasons such as for equipment protection or human protection. If it is necessary to power non-safety loads from electrical safety power systems, the non-safety loads are isolated by means of safety classified isolation devices. The non-safety loads include:

a) The equipment which has to be available during or after a fire hazard;

b) The equipment which has to be available for important equipment security, which is useful for investment protection. Otherwise, it may cause damage to the important equipment;

c) In terms of the process system requirements, the equipment has to be available during or after seismic accidents;

d) The emergency lighting has to be available when there is a failure of the normal lighting in particular areas, which is useful for human protection.

The character of the loads (the electrical parameters of the loads, sensitivity to loss of voltage and duration of load operation) and the relationship between the loads (the process connection between the loads and the sequence that the loads are put into service) are also considered in the allocation of loads.

The criteria of load allocation refer to *The General Principles of Electrical Power Distribution*, Reference [10].

9.8.4 Rating of Electrical Equipment

All items of equipment used in the electrical power system in the plant are required to have a sufficient margin in the operating parameters in comparison with their nominal rating.

The power balance enables to set up the design of the main electrical equipment such as ATs, EDGs, SBO DGs, and batteries. The main electrical equipment is tabulated along with the power balance conditions in Table T-9.8-2.

T-9.8-2 Electrical Equipment Power Balance Conditions

9.8.5 Electrical Power System Study

Analytical studies validate the robustness and adequacy of design margins and demonstrate the capability of electrical power system to support plant operation for normal, abnormal, degraded and accident conditions.

The electrical power system studies for the UK HPR1000 GDA will be performed according to BS IEC 62855, Reference [11]. The studies mainly include the off-site power analyses (for the not site-specific requirements), AC on-site power system analyses (including EDG load sequencer study), DC system and uninterruptible AC system analyses, and some miscellaneous analyses.

9.8.6 Resilience to Electrical Disturbance

9.8.6.1 External Disturbances

The electrical disturbances originating externally to the electrical power system are tabulated along with the electrical power system measures taken to withstand or protect against them in Table T-9.8-3.

T-9.8-3 External Disturbance for Electrical Power System

No.	Disturbance	Counter-measures
1	Grid voltage & frequency variations due to planned or unplanned load switching (on or off).	a) Equipment capability and associated protection devices b) Generator voltage regulator c) Turbine governor d) AT on-load tap-changers e) Generator and UT protection / GCB f) House Loading g) Surge suppression h) AT/ST transfer i) EDG automatic start-up and power supply transfer j) UPS capability and protection
2	Grid short-circuit faults.	a) Close faults 1) Generator and UT protection / GCB 2) House load b) Area faults 1) Generator voltage regulator
3	Transmission system voltage imbalance or loss of phase	Equipment capability and associated protection devices.
4	Lightning strike to transmission line or high voltage switchyard	a) Aerial earth wires b) Surge suppression c) Earthing network
5	Lightning strike to facility	a) Lightning protection system b) Surge suppression c) Shielding, screening and separation.
6	EMI from outside plant	a) Shielding, screening and separation. b) Earthing network
7	Geomagnetic Induced Current (GIC)	The means to measure and protect against GIC will be finalised with the Transmission System Operator when a specific plant site is selected.

9.8.6.2 Internal Disturbances

The electrical disturbances originating in the electrical power system are tabulated along with the electrical power system measures taken to withstand or protect against them in Table T-9.8-4. Some of these disturbances arise as a result of hazards identified in the system sub-chapters.

T-9.8-4 Internal Disturbance for Electrical Power Systems

No.	Disturbance	Counter-measures
1	Voltage & frequency variations due to main generator transient and fault conditions, including house loading.	a) Equipment capability and associated protection devices b) Generator voltage regulator c) Turbine governor d) Generator and UT protection / GCB e) AT/ST transfer f) EDG automatic start-up and source transfer g) UPS capability and protection
2	Voltage variations due to load switching (on or off)	a) Equipment capability and associated protection devices b) Surge suppression
3	Voltage imbalances or loss of a phase.	Equipment capability and associated protection devices
4	Voltage & frequency variations due to DG transient and fault conditions.	a) Equipment capability and associated protection devices b) UPS capability and protection c) DG speed governing and automatic voltage regulator
5	Short-circuit faults between phases	a) Breakers or fuses (Selectivity to minimise impact of fault) b) Equipment capability and associated protection devices
6	Earth faults	a) Isolated neutral or floating DC supplies. With earth fault detection. b) Breakers or fuses (Selectivity to minimise impact of fault) c) Earthing network
7	Overloading	Breakers or fuses (Selectivity to minimise impact of fault)
8	EMI from inside the plant, generated by the electrical power system or by other electromagnetic transmitting installations.	a) Shielding, screening and separation. b) EMI filters c) Earthing network

No.	Disturbance	Counter-measures
9	Harmonics	a) Electrical power converting equipment design b) EMC filters c) Equipment capability
10	Ferroresonance	Electrical power system designed to eliminate switching that could result in ferroresonance.

9.8.7 CCF and Diversity Analysis of Electrical Power System

According to the IAEA safety glossary, Reference [12], CCF is defined as failure of two or more structures, systems and components due to a single specific event or cause. For the electrical power system, an event, hazard or electrical disturbance may causes the failure of redundant divisions or different levels of DiD. For the UK HPR1000, CCF of the electrical power system is considered in the loss of power supply analysis, which is part of the loss of support system analysis. CCF of the electrical power system is also considered in the PSA. CCF is analysed basing on a deterministic basis and is supported by probabilistic analysis.

The CCF analysis of the electrical power system of the UK HPR1000 NPP will be performed as the following steps, Reference [13].

a) Identify electrical CCFs caused by functional dependencies, spatial dependencies, inherent dependencies and human error related dependencies;

b) Along with fault schedule, identify the electrical CCFs with a risk to nuclear safety;

c) Assess the current design to determine the CCFs which need risk reduction;

d) Apply optioneering to reduce the CCF risk to as low as reasonably practical.

9.8.8 Smart Devices

The definition of smart devices is provided in Sub-chapter 8.14.4. Smart devices may be used in safety classified electrical equipment. Typical examples in electrical applications include protective relays, EDG controllers and controllers associated with uninterruptible power supplies. The justification will be undertaken through a two-legged approach: Production Excellence and Independent Confidence Building Measures, which are detailed in Sub-chapter 8.14.4.

9.8.9 Human Factors

Systematic consideration of human factors, including the Human Machine Interface (HMI), is included at an early stage in the electrical design process for a nuclear power plant and shall be continued throughout the entire design process.

The design of systems, components, layout, HMIs and operator working environments is in accordance with the human factors requirements presented in Chapter 15.

The electrical design will be assessed by the Human Factors Engineering (HFE) task analysis, especially operator actions identified as initiating events or as safety measures in the fault schedule impose specific requirements and expectations on the HMI design.

Human factors which have been considered in electrical system design mainly include the following aspects:

a) Human action optimization

The design of workplaces and the working environment of the operating personnel are in accordance with ergonomic concepts. The human-machine interface of electrical equipment is designed to provide the operators with comprehensive but easily manageable information, such as the controller (handle, button) and display (indicator, screen) on the switchboards.

The lighting of the operation areas considers the illuminance, colour rendering and correlated colour temperature to optimize the operation environment. The lighting in the MCR is sufficient for operation during normal and accident conditions.

b) Human error prevention

The electrical design supports operating personnel in the fulfilment of their responsibilities and in the performance of their tasks and shall limit the effects of operating errors on safety.

The necessary information of electrical system is provided to operators, such as voltage, current, insulation and status, to make sure the operator action is based on the correct information. Operators with the correct certification carry out the specific tasks based on the plant procedures to minimise the potential human error. Furthermore, devices preventing incorrect operations are implemented in the electrical switchboards and control panels, such as the mechanical or electrical interlocks.

9.9 ALARP Assessment

An ALARP assessment of the electrical power system is performed according to the ALARP methodology provided in Sub-chapter 33.4. A brief introduction to the ALARP assessment of electrical power system is provided below:

a) Identification of RGP

Specific IAEA guidance, WENRA reports and BS IEC standards are identified as RGP for the UK HPR1000 electrical power system design.

b) Consistency review against RGP

A consistency review against the RGP has been carried out, Reference [14].

c) Operating experience review

Applicable operating experience and UK NPPs' good practice has been identified and reviewed.

d) Potential improvement identification

According to the review against RGP and operating experience, gaps or potential gaps are identified.

e) The ALARP demonstration for each specific potential improvement and forward action plan

According to the design schedule of the UK HPR1000 electrical power system, dedicated reports on the gaps or potential gaps will be produced.

For electrical power, the ALARP principle has been considered throughout all of the design process:

a) Worldwide operational experience has been recognised and considered during the design and evolution of the electrical system design. For power supply, the mobile DG has been designed according to experience from the Fukushima nuclear accident. To design the system to be robust against external interference, feedback from the Forsmark event has been adopted and tolerance for over voltage of the DC and AC UPS system has been improved;

b) RGP has been identified and a gap analysis against RGP has been carried out. Gaps and potential gaps have been recognised and further action is planned to deal with the gaps.

However, as hazard protection, fault analysis, probabilistic safety assessment and some other technical areas are still in development, the output of the areas will show the contribution of the electrical power system to the overall risk of the plant, and therefore the conclusion as to whether the risk of the electrical power system is ALARP will arrive at after the related work is completed.

The ALARP demonstration of this chapter is detailed in *ALARP Demonstration Report of PCSR Chapter 9*, Reference [14].

9.10 Commissioning

The plant overall commissioning phase is divided into two phases (Pre-operational test phase and initial start-up test phase) and three stages (Stage I preliminary tests period, stage II functional tests period and stage III initial start-up tests period), which is described in the Chapter 30. There are commissioning plans to verify that the electrical power systems meet their function requirement.

Stage I: Every system of the electrical power system has component tests and system tests to verify that the equipment and the control logic are able to meet their function requirements.

Stage II: Before the cold function test, switchover of the off-site electrical power supply will be implemented to verify the manual and automatic transfer of the electric supply from the ATs to the ST and vice versa.

Before the hot function test, the EDGs and SBO DGs load performance test will be implemented. This test can verify that the voltage and frequency of the EDGs and SBO DGs meet the design requirements during starting, load shedding and reloading sequence program or procedure. The mobile DG performance test will also be implemented in this stage.

During the hot functional test, the loss of off-site power test will be implemented. In this test, the main off-site power and the standby off-site power will be tripped manually one by one. The objective of this test is to validate the design of the following scenario: switchover between the main off-site power source and the standby off-site power source, then loss of standby off-site power leading to switchover to EDGs.

Stage III: The house load test is to be implemented to verify the ability of the system control loop to support house loads and to bring back the plant in a stable condition of power operation, without protection actuation.

9.11 Examination, Maintenance, Inspection and Testing and Ageing Management

9.11.1 Examination, Maintenance, Inspection and Testing

In general, electrical power system equipment is examined, maintained, inspected and tested in accordance with the requirements from the following factors in the development of EMIT for the electrical system, which are carried out as the measures to verify that the performance of the electrical system satisfies the requirements intended in the design:

a) The safety function and operation requirements of the electrical system, including the function categorisation and the safety classification of the electrical equipment;

b) Regulation framework, codes and standards, the equipment technical specification;

c) Operating experience and feedback from existing nuclear power plants, RGP;

d) The maintenance strategy of the nuclear power plant and the outage schedule for electrical equipment;

e) Operating modes during which the test is to be performed, the equipment fault study, the equipment state during service and potential damage and dynamic fault development, and the influence of the equipment failure consequences to safety;

f) The requirement of the EOMM provided by the equipment supplier.

The EMIT regime is performed on each electrical system in order to guarantee the availability and the functional capability of the electrical equipment in the design and operation of the electrical systems.

In order to define the EMIT regime of the electrical system, an analysis must be carried out based on the list of safety features of the system. The methodology of the electrical system analysis will be provided.

9.11.2 Ageing Management

Ageing management for electrical SSCs mainly concerns physical ageing and will be taken into account throughout the electrical design process. The ageing issues of electrical SSCs will be addressed in the electrical design on the following aspects:

a) The design basis conditions, including transient conditions and postulated initiating event conditions, are taken into account in equipment qualification programmes;

b) Adequate testing regarding ageing mechanisms will be addressed during the type test of the electrical equipment;

c) The use of advanced materials with greater ageing resistant properties will be required in equipment specifications;

d) Possible on-line monitoring methods will be applied during system operation;

e) The layout of electrical SSCs facilitates EMIT, repair and replacement;

f) Adequate and qualified methods of non-destructive testing and ageing monitoring for early detection of flaws will be applied during system operation;

g) Operations, maintenance, repair and replacement actions to mitigate detected ageing effects and/or degradation of the structure or component.

9.12 Concluding Remarks

This chapter provides an introduction to the claims and arguments of the electrical power system together with the design information of the electrical power system including design requirements, design basis, system description and operation and design substantiation etc. This chapter demonstrates that the electrical power system satisfies the performance requirements.

A preliminary ALARP analysis has been performed on the electrical power system. Gaps or potential gaps have been identified and the forward action plan to bridge the gaps is also identified.

Since the general principles have only recently been delivered and are not yet finalised at this stage, the system design is still based on the design of the HPR1000 (FCG3). A review of the consistency of the system design against the newly developed principles is currently being undertaken.

At this stage, requirements from some technical areas, such as cross cutting, hazard protecting, fault analysis, probabilistic safety assessment and human factors are still in development. New requirements for the design of electrical power system may be raised in the future and therefore, the review against the new requirements will then be continued.

9.13 References

[1] CGN, Basis of Safety Case on Electrical Power System, GHX05000010DEDQ45GN, Rev B, 2018.

[2] CGN, Justification of Codes and Standards on Electrical Engineering, GHX00800007DEDQ02GN, Rev C, 2018.

[3] IAEA, Design of Electrical Power Systems for Nuclear Power Plants, No. SSG-34, March 2016.

[4] CGN, Plant Auxiliary Electrical System Wiring Diagram, GHX00500001DEDQ03DD, Rev A, 2018.

[5] CGN, NI DC and AC UPS System Single Line Diagram, GHX13000001DEDQ45DD, Rev A, 2018.

[6] CGN, Unified Technical Regulation for Electrical Design, GH000500001DEDQ03GN, Rev B, 2018.

[7] CGN, NI Electrical Equipment Layout Diagram, GHX52211001DEDQ44DD, Rev A, 2018.

[8] CGN, CI DC and AC UPS System Single Line Diagram, GHX13000002DEDQ45DD, Rev A, 2018.

[9] CGN, NI Cable Routing Guidelines (The Translation Version of FCG Unit 3) , NE15BW-X-DQ-0000-000138, Rev. A, 2018. This HPR1000 (FCG3) document is applicable for UK HPR1000.

[10] CGN, The General Principles of Electrical Power Distribution, GHX05000002DEDQ45GN, Rev A, 2018.

[11] BS IEC, Nuclear power plants - Electrical power systems - Electrical power systems analysis, IEC 62855-2016.

[12] IAEA, IAEA Safety Glossary, 2017 Edition, June 2007.

[13] CGN, Common Cause Failure and Diversity Analysis on Electrical Design, GHX05000004DEDQ45GN, Rev B, 2018.

[14] CGN, ALARP Demonstration Report of PCSR Chapter 9, GHX00100052KPGB03GN, Rev B, 2018.

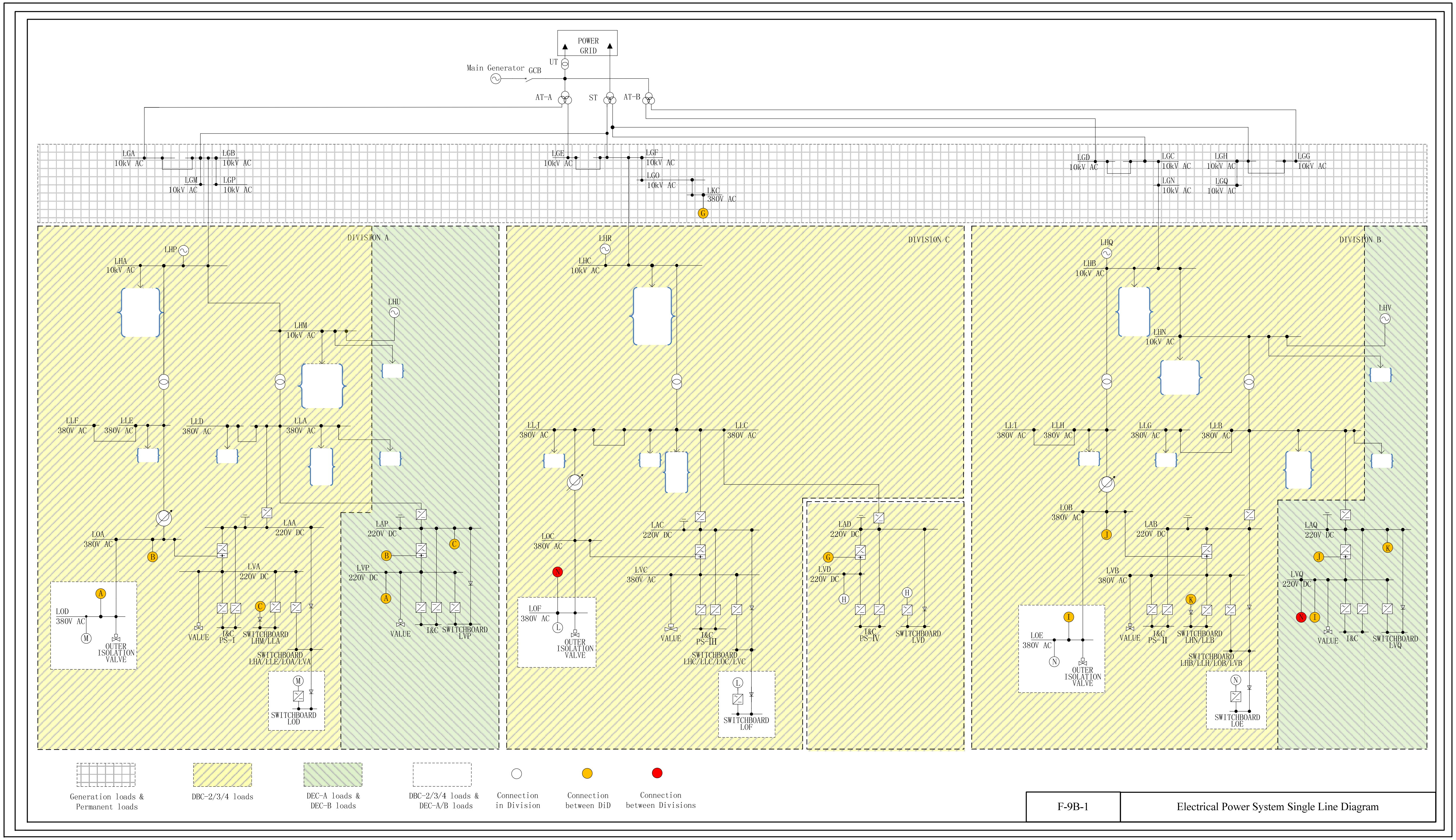
Appendix 9A Claim-Argument Guidance

Sub-claim	Argument	Breakdown of Argument	PCSR Sub-chapter and Content
Sub-claim 1: The safety functional requirements (Design Basis) have been derived for the system.	Argument 1.1: The electrical power system safety function has been derived from the safety analysis: the electrical power system supports SSCs in performing the fundamental safety function of reactivity control (R) by providing required power supplies.	The fundamental safety functions are decomposed to high level safety functions, then low level safety functions, which are delivered by SSCs. The fault schedule identifies the SSCs to the low level safety functions to which electrical power system provides electrical support: 1) Duty & prevention and control of abnormal; 2) Main protection line; 3) Diverse protection line; 4) Severe accident.	9.4: Architecture of electrical power system – provides an overview of the electrical power system architecture and its relationship to safety functional requirements (Design Basis for the overall electrical power system); 9.5/9.6/9.7: Sub-systems for the off-site electrical power system, on site electrical power systems and auxiliary electrical system: 1) Duty + prevention and control of abnormal line: 9.5.2 Main connection; 9.5.3 Standby connection; 9.6.1 NPDS; 9.6.7: CI DC&UPS; 2) Main protection line: 9.6.2 EPDS; 9.6.4 EDG; 9.6.8 NI 2h DC&AC; 3) Diverse protection line: 9.6.3 SBOPDS; 9.6.5 SBO DG; 9.6.8 NI 2h DC&UPS; 9.6.9 NI 12h DC&UPS; 4) Severe accident: 9.6.9 NI 12h DC&UPS; 9.6.6 Mobile DG.
	Argument 1.2: The electrical power system safety function has been derived from the safety analysis: the electrical power system supports SSCs in performing the fundamental safety function of heat removal (H) by providing required power supplies.		
	Argument 1.3: The electrical power system safety function has been derived from the safety analysis: the electrical power system supports SSCs in performing the fundamental safety function of confinement (C) by providing required power supplies.		
Sub-claim 2: The system design satisfies the safety functional requirements.	Argument 2.1 The electrical power system features are identified according to the safety function.	Categorisation and Classification: The Categorisation and Classification of the electrical power system is consistent with the general Categorisation and Classification approach of the UK HPR1000 NPP.	9.4: Architecture of electrical power system – provides an overview of the electrical power system architecture and its relationship to Categorisation and classification; 9.X.X.1.2.1 & 9.X.X.4.2.1 identify the categorisation and classification requirement and substantiation for each sub-system of the electrical power system.
		Defence in Depth (DiD): The DiD approach in the electrical power system is consistent with the overall DiD levels of the UK HPR1000 NPP.	9.4: Architecture of electrical power system – provides an overview of the electrical power system architecture and its relationship to requirements of the plant DiD.
		Redundancy and Single Failure Criterion: The redundancy approach in the electrical power system is consistent with the overall redundancy and Single Failure Criterion requirement of the UK HPR1000 NPP.	9.X.X.1.2.2 a) & 9.X.X.4.2.2 a) Requirement and substantiation of SFC and Redundancy for each sub-system of electrical power system.

Sub-claim	**Argument**	**Breakdown of Argument**	**PCSR Sub-chapter and Content**
		Independence: The independence approach in the electrical power system is consistent with the overall independence principle of the UK HPR1000 NPP.	9.X.X.1.2.2 b) & 9.X.X.4.2.2 b) Requirement and substantiation of independency for each sub-system of electrical power system; 9.8.1 Overview of cabling design principle; 9.4.4 Interconnection between divisions.
		Common Cause Failure (CCF): The electrical power system offers resilience to CCF.	9.8.7 overview of CCF; 9.X.X.1.2.2 c) & 9.X.X.4.2.2 c) Requirement and substantiation of diversity for each sub-system of the electrical power system.
		Human factor: The design of the electrical power system meets the overall human factor requirement of the UK HPR1000 NPP.	9.8.9 overview of human factor aspects of electrical power system; 9.7.2 Lighting system; 9.7.3 Communication system.
		Qualification: The equipment of the electrical power system is qualified for its service conditions.	9.X.X.1.2.3 a) & 9.X.X.4.2.3 a) Requirement and substantiation of qualification for each sub-system of electrical power system; 9.8.8 Overview of SMART devices for electrical power system.
		Hazards: The electrical power system is robust with respect to the internal and external hazards.	9.X.X.1.2.4 & 9.X.X.4.2.4 Requirement and substantiation of hazards for each sub-system of electrical power system; 9.7.1 Earthing and lightning protection system.
	Argument 2.2: The electrical power system features are identified according to the electrical design requirements.	Load allocation: The loads are allocated to the electrical power system according to the operating condition and continuity requirement of the power supply.	9.8.3 Overview of the allocation of electrical loads.
		Rating: The equipment of the electrical power systems has a sufficient margin in all identified operating modes in comparison with its nominal rating.	9.8.4 Overview of the electrical equipment sizing and rating.
		Electrical Protection: The electrical protection scheme limits the effect of the failures.	9.8.2 General description of the electrical relaying protection measures.
		Design Analysis: The design of the electrical power system is analysed and verified by electrical power system studies.	9.8.5 Electrical analysis based on BS IEC 62855.
	Argument 2.3: The electrical power system features are identified according to the interface requirements and effects from / to interfacing systems.	Grid connection: The electrical power system design takes into account the power grid connection requirements and the plant can be connected with the grid.	9.5.5 Grid connection compliance analysis.
		Electrical disturbances: The electrical power system is designed to be resilient to electrical disturbances originating in the off-site power grid and on-site power network.	9.8.6 Countermeasures for internal and external electrical disturbance.

Sub-claim	Argument	Breakdown of Argument	PCSR Sub-chapter and Content
Sub-claim 3: All reasonably practicable measures have been adopted to improve the design.	Argument 3.1: The design of the electrical power system meets applicable standards, based on Relevant Good Practice (RGP) and operating experience, suitable for the UK context.		9.9 a) and 9.9 b) Identification of RGP; 9.3 Applicable codes and standards.
	Argument 3.2: The electrical power system is analysed in fault analysis and the result is acceptable.		9.4: Architecture of electrical power system – provides an overview of the electrical power system architecture and its relationship to safety functional requirements (Design Basis for the overall electrical power system); 9.5/9.6/9.7: Sub-system for the off-site electrical power system, on site electrical power systems and auxiliary electrical system.
	Argument 3.3: Design improvements have been considered and adopted where reasonably practicable.		9.9 c) and 9.9 d) Potential improvement identification and ALARP demonstration.
Sub-claim 4: The system performance will be validated by suitable commissioning and testing.	Argument 4.1: The electrical power system has been designed to take benefit from a suite of pre-construction tests, to provide assurance of the initial quality of the manufacturing.		9.X.X.1.2.3 a) & 9.X.X.4.2.3 a) Requirement and substantiation of qualification for each sub-system of electrical power system.
	Argument 4.2: The electrical power system has been designed to take benefit from a suite of commissioning tests, to provide assurance of the initial quality of the build.		9.10 Overview of commissioning for electrical power system.
Sub-claim 5: The effects of ageing of the system have been addressed in the design and suitable Examination, Maintenance, Inspection and Testing (EMIT) specified.	Argument 5.1: An initial EMIT strategy has been developed for electrical power system, identifying components that are expected to be examined, maintained, inspected and tested.		9.11.1 General description of EMIT; 9.X.X.1.2.3 c) & 9.X.X.4.2.3 c) Requirement and substantiation of EMIT for each sub-system of electrical power system.
	Argument 5.2: The components that are not intended to be replaced have been shown to have an adequate design life.		9.11.1 General description of Ageing management; 9.X.X.1.2.3 b) & 9.X.X.4.2.3 b) Requirement and substantiation of ageing and degradation for each sub-system of electrical power system.
Note 1: As Fault Schedule is not yet available, the function supporting categorisation and classification and ALARP demonstration will be reviewed after the completion of fault analysis.			
Note 2: The content of PCSR Chapter 9 for the Argument 4.1 pre-construction tests is not yet fully fleshed out, including not only the qualification test, but also the type tests, routine tests, field tests, etc.			

Appendix 9B Electrical Power System Single Line Diagram



F-9B-1 Electrical Power System Single Line Diagram