Office for Nuclear Regulation

ONR Assessment Report

Generic Design Assessment of the BWRX-300 – Step 2 assessment of Electrical Engineering

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Executive summary

In December 2024, the Office for Nuclear Regulation (ONR), together with the Environment Agency and Natural Resources Wales, began Step 2 of the Generic Design Assessment (GDA) of the BWRX-300 design on behalf of GE Vernova Hitachi Nuclear Energy International LLC, United Kingdom (UK) Branch, the Requesting Party (RP).

This report presents the outcomes of my electrical engineering assessment of the BWRX-300 design as part of Step 2 of the ONR GDA. This assessment is based upon the information presented in the RP's safety, security, safeguards and environment cases (SSSE), the associated revision 3 of the Design Reference Report and supporting documentation.

ONR's GDA process calls for an assessment of the RP's submissions.. The focus of my assessment in this step was to support ONR's decision on the fundamental adequacy of the BWRX-300 design and safety case, and the suitability of the methodologies, approaches, codes, standards and philosophies which form the building blocks for the design and generic safety, security and safeguards cases.

I targeted my assessment, in accordance with my assessment plan, at the areas that were fundamental to the acceptability of the design and methods for deployment in Great Britain, benchmarking my regulatory judgements against the expectations of the expectations of ONR's Safety Assessment Principles (SAPs), Technical Assessment Guides (TAGs) and other guidance which ONR regards as relevant good practice, such as International Atomic Energy Agency safety, security and safeguards standards. Where appropriate, I have also considered how I could use relevant learning and regulatory conclusions from the UK ABWR GDA to inform my assessment of the BWRX-300.

I targeted the following aspects in my assessment of the BWRX-300 SSSE:

- Development of Safety Case for Electrical Engineering
- Electrical Power System Architecture
- Electrical Power System Robustness
- Passive Safety Systems
- Smart Device Strategy
- Through Life Management
- Support to Human Operations
- Grid Code Compliance

Based upon my assessment, I have concluded the following:

- The basic electrical design architecture, with redundant divisions, fed by multiple offsite and onsite power systems, provides the basis for a robust design, should be capable of meeting international guidance and ONR's expectations for redundancy and defence in depth.

- The electrical system has been shown have been developed consistent with the overall aim of developing a passive design, reducing the claims on electrical support systems.

- The design includes permanently installed diesel generators and proposes the provision of connection points for mobile generators to provide multiple sources of power in a loss of offsite power (LOOP), station blackout or total loss of power scenario.

- The proposed mission times for the installed diesel generators and the autonomy times for the safety classified battery systems are shown to be consistent with the safety claims on the systems they support, and consistent with UK expectations for a design basis LOOP event.

- Following a comprehensive assessment, the RP has identified two areas where it does not consider its design can meet the requirements of the Grid Code and has recognised any future development of the design in the UK would need further engagement with the relevant parties to resolve these.

- The rationale for the design and the basis for any requirements is clearly set out, demonstrating the RP's use of operational experience and international standards to safety risk reduction. By continuing with this approach it should have a future ability to demonstrate that the design is reducing the risks so far as is reasonably practicable.

Overall, based on my assessment to date I have not identified any fundamental safety shortfalls that could prevent ONR permissioning the construction of a power station based on the generic BWRX-300 design; noting that any decision to permission a BWRX-300 will require further assessment (in either a future Step 3 GDA or during site specific activities) of suitable and sufficient supporting evidence that can substantiate the claims and proposals made in the GDA Step 2 submissions.

List of abbreviations

AC	Alternating Current
ALARP	As Low As Reasonably Practicable
ABWR	Advanced Boiler Water Reactor
BL	Baseline
BSI	British Standards Institution
BWR	Boiling Water Reactor
C&I	Control and Instrumentation
CAE	Claim, Argument and Evidence
CNSC	Canadian Nuclear Safety Commission
DAC	Design Acceptance Confirmation
DC	Direct Current
DCIS	Distributed Control and Information System
DEC	Design Extension Conditions
DiD	Defence-in-Depth
DPS	Diverse Protection System
DRP	Design Reference Point
DRR	Design Reference Report
EIMT	Examination, Inspection, Maintenance and Testing
EPS	Emergency Power System
ESBWR	Economic Simplified Boiling Water Reactor
FAP	Forward Action Plan
GB	Great Britain
GDA	Generic Design Assessment
GHVA	GE Vernova Hitachi Nuclear Energy Americas LLC
Hz	Hertz
IAEA	International Atomic Energy Agency
IEC	International Electrotechnical Commission
ICS	Isolation Condenser System
IEEE	Institute of Electrical and Electronics Engineers
LOOP	Loss of Offsite Power
MW	Megawatt
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PCSR	Pre-construction Safety Report
PER	Preliminary Environmental Report
PID	Project Initiation Document
PSA	Probabilistic Safety Assessment
PSR	Preliminary Safety Report
RGP	Relevant Good Practice
RP	Requesting Party
RPS	Reactor Protection System
RQ	Regulatory Query
SSSE	Safety, Security, Safeguards and Environment Cases

SAP	Safety Assessment Principle(s)
SBO	Station Blackout
SBWR	Simplified Boiling Water Reactor
SDG	Standby Diesel Generator
SPS	Standby Power System
SSC	Structure, System and Component
TAG	Technical Assessment Guide(s) (ONR)
UK	United Kingdom
UPS	Uninterruptible Power Supply
US	United States of America
VLA	Vented Lead Acid
WENRA	Western European Nuclear Regulators' Association

Contents

1. Introduction

1. This report presents the outcome of my electrical engineering assessment of the BWRX-300 design as part of Step 2 of the Office for Nuclear Regulation (ONR) Generic Design Assessment (GDA). My assessment is based upon the information presented in the Safety, Security, Safeguards and Environment cases (SSSE) head document (ref. [1]) and specifically chapters 2, 3, 8, and 9A (refs. [2], [3], [4], [5]), the appropriate revision of the Design Reference Report (ref. [6]) and supporting documentation.

2. Assessment was undertaken in accordance with the requirements of ONR Management System and follows ONR's guidance on the mechanics of assessment, NS-TAST-GD-096 (ref. [7]), and ONR's risk informed, targeted engagements guidance (ref. [8]). The ONR Safety Assessment Principles (SAPs) (ref. [9]), together with supporting Technical Assessment Guides (TAGs) (ref. [10]), have been used as the basis for this assessment.

3. This is a Major report as per ONR's guidance on the production of reports, NS-TAST-GD-108 (ref. [11])).

1.1. Background

4. The ONR's GDA process (ref. [12]) calls for an assessment of the Requesting Party's (RP) submissions with the assessments increasing in detail as the project progresses. This GDA will be finishing at Step 2 of the GDA process. For the purposes of the GDA, GE Vernova Hitachi Nuclear Energy International LLC, United Kingdom Branch, is the RP. GE Vernova Hitachi Nuclear Energy Americas LLC (GVHA) is a provider of advanced reactors and nuclear services, and is the designer of the BWRX-300. GVHA is headquartered in Wilmington, North Carolina, United States of America (US).

5. In Step 1, and for the majority of Step 2, the RP was known as GE-Hitachi Nuclear Energy International LLC, UK Branch, and GVHA as GE-Hitachi Nuclear Energy Americas LLC. The entities formally changed names in October 2025 and July 2025 respectively. The majority of the submissions provided by the RP during GDA were produced prior to the name change, and thus the reference titles in Section 6 of this report reflects this.

6. In the UK, the RP has been supported by its supply chain partner, Amentum, who has assisted the RP in the development of the UK-specific chapters of the Safety, Security, Safeguards and Environment cases (SSSE) and other technical documents for the GDA.

7. In January 2024, ONR, together with the Environment Agency and Natural Resources Wales, began Step 1 of this two-Step GDA for the generic BWRX-300 design.

8. Step 1 is the preparatory part of the design assessment process and is mainly associated with initiation of the project and preparation for technical assessment in Step 2. Step 1 completed in December 2024. Step 2 is the first substantive technical assessment step, and began in December 2024 and will complete in December 2025.

9. The RP has stated that at this time it has no plans to undertake Step 3 of GDA and obtain a Design Acceptance Confirmation (DAC). It anticipates that any further assessment by the UK regulators of the BWRX-300 design will be on site-specific basis and with a future licensee.

10. The focus of ONR's assessment in Step 2 has been:

- The fundamental adequacy of the design and safety, security and safeguards cases; and
- The suitability of the methodologies, approaches, codes, standards and philosophies which form the building blocks for the design and cases.

11. The objective has been to undertake an assessment of the design against regulatory expectations to identify any fundamental safety, security or safeguards shortfalls that could prevent ONR permissioning the construction of a power station based on the design.

12. Prior to the start of Step 2, I prepared a detailed Assessment Plan for electrical engineering (ref. [13]). This has formed the basis of my assessment and was also shared with the RP to maximise openness and transparency.

13. This report is one of a series of assessments which support ONR's overall judgements at the end of Step 2 which are recorded in the Step 2 Summary Report (ref. [14]) and published on the regulators' website.

1.2. Scope

14. The assessment documented in this report is based upon the SSSE for the BWRX-300 (refs. [1], [2], [3], [4], [5], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46] and [47]).

15. The RP's GDA scope has been agreed between the regulators and the RP during Step 1. This is documented in an overall Scope of Generic Design Assessment report (ref. [48]). This is further supported by its DRR (ref. [6]) and the Master Document Submission List (ref. [49]). The GDA scope report documents the submissions which were provided in each topic area during Step 2 and provides a brief overview of the physical and functional scope of the nuclear power plant (NPP) that is proposed for consideration in the GDA. The DRR provides a list of the systems, structures and components (SSCs)

which are included in the scope of the GDA, and their relevant GDA reference design documents.

16. The RP has stated it does not have any current plans to undertake GDA beyond Step 2. This has defined the boundaries of the GDA and therefore of my own assessment.

17. The GDA scope includes the Power Block (comprising the Reactor Building, Turbine Building, Control Building, Radwaste Building, Service Building, Reactor Auxiliary Structures) and protected areas as well as the balance of plant. It includes all modes of operation.

18. The regulatory conclusions from GDA apply to everything that is within the GDA scope. However, ONR does not assess everything within it or all matters to the same level of detail. This applies equally to my own assessment, and I have followed ONR's guidance on the mechanics of assessment, NS-TAST-GD-096 (ref. [7]) and ONR's guidance on Risk Informed, Targeted Engagements (ref. [8]).

19. As appropriate for Step 2 of the GDA, information has not been submitted for all aspects within the GDA Scope during Step 2. The following aspects of the SSSE are therefore out of scope of this assessment, as noted in the RP's Scope document (ref. [48]):

- Design Substantiation
- Computer based modelling of the Electrical Power System

20. As set out in (ref. [13]), my assessment has considered the following areas:

- Electrical system safety case
- Electrical system architecture
- Electrical system robustness, including categorisation and classification of electrical systems and withstand to internal and external hazards
- Electrical support to passive safety systems
- Smart device strategy
- Through-life management
- Support to human operations
- Grid Code compliance
- Demonstration of how risks in the electrical design are being reduced as low as is reasonably practicable (ALARP)

2. Assessment standards and interfaces

21. The primary goal of the GDA Step 2 assessment is to reach an independent and informed judgment on the adequacy of the RP's SSSE for the reactor technology being assessed.

22. ONR has a range of internal guidance to enable Inspectors to undertake a proportionate and consistent assessment of such cases. This section identifies the standards which I have considered in this assessment. This section also identifies the key interfaces with other technical topic areas.

2.1. Standards

23. The ONR Safety Assessment Principles (SAPs) (ref. [9]) constitute the regulatory principles against which the RP's case is judged. Consequently, the SAPs are the basis for ONR's assessment and have therefore been used for the Step 2 assessment of the BWRX-300.

24. The International Atomic Energy Agency (IAEA) safety standards (ref. [50]) and nuclear security series (ref. [51]) are a cornerstone of the global nuclear safety and security regime. They provide a framework of fundamental principles, requirements and guidance. They are applicable, as relevant, throughout the entire lifetime of facilities and activities.

25. Furthermore, ONR is a member of the Western European Nuclear Regulators Association (WENRA). WENRA has developed Reference Levels (ref. [52]), which represent good practices for existing NPPs, and Safety Objectives for new reactors (ref. [53]).

26. The relevant SAPs, IAEA standards and WENRA reference levels are embodied and expanded on in the TAGs (ref. [10]). The TAGs provide the principal means for assessing the electrical engineering aspects in practice.

27. The key guidance is identified below and referenced where appropriate within Section 4 of this report. Relevant good practice, where applicable, has also been cited within the body of this report.

2.1.1. Safety Assessment Principles (SAPs)

28. The key SAPs applied within my assessment are:

- EKP.3 (Defence in depth);
- EDR.2 (Redundancy, diversity and segregation);
- EDR.3 (Common cause failure);
- EDR.4 (Single failure criterion);

- ECS.2 (Safety classification of structures, systems and components);
- ESS.8 (Automatic initiation); and
- EMT.1 (maintenance, inspection and testing – identification of requirements).

29. A full list of the SAPs used in this assessment is recorded in Appendix 1.

2.1.2. Technical Assessment Guides (TAGs)

30. The following TAGs have been used as part of this assessment:

- NS-TAST-GD-003 – Safety Systems (ref. [54])
- NS-TAST-GD-005 – Regulating duties to reduce risks ALARP (ref. [55])
- NS-TAST-GD-019 – Essential Services (ref. [56])
- NS-TAST-GD-051 – The purpose, scope and content of safety cases (ref. [57])
- NS-TAST-GD-094 – Categorisation of Safety Functions and Classification of Structures, Systems and Components (ref. [58])
- NS-TAST-GD-096 – Guidance on Mechanics of Assessment (ref. [59])

2.1.3. National and international standards and guidance

31. The following international standards and guidance have been used as part of this assessment:

- IAEA, Safety of Nuclear Power Plants: Design SSR 2/1 Rev.1 (ref. [60])
- IAEA, Design of Electrical Power Systems for Nuclear Power Plants, Specific Safety Guide No. SSG-34 (ref. [61])
- IAEA, Format and Content of the Safety Analsyis Report for Nuclear Power Plants, Specific Safety Guide No. SSG-61 (ref. [62])
- IAEA, Design of Auxiliary Systems and Supporting Systems for Nuclear Power Plants, Specific Safety Guide No. SSG-62 (ref. [63])
- IAEA, Design Provisions for Withstanding Station Blackout at Nuclear Power Plants, IAEA-TECDOC-1770 (ref. [64])
- IAEA, Applicability of IAEA Safety Standards to Non-Water Cooler Reactors and Small Modular Reactors, Safety Reports Series No.123 (ref. [65])

- WENRA, WENRA Safety Objectives for New Nuclear Power Plants and WENRA Report on Safety of new NPP designs - RHWG position on need for revision (ref. [53])
- BSI, Nuclear Power Plants – Instrumentation, control and electrical power systems important to safety – Categorization of functions and classification of systems, BS EN IEC 61226 (ref. [66])
- BSI, Nuclear Power Plants – Electrical power systems – General requirements, BS EN IEC 63046 (ref. [67])

2.2. Integration with other assessment topics

32. To deliver the assessment scope described above I have worked closely with a number of other topics to inform my assessment. Similarly, other assessors sought input from my assessment. These interactions are key to the success of GDA to prevent or mitigate any gaps, duplications or inconsistencies in ONR’s assessment.

33. The key interactions with other topic areas were:

- Fault Studies, Control and Instrumentation, Mechanical Engineering – To ensure a consistent assessment of the approach to categorisation and classification of equipment important to safety.
- External and Internal Hazards, Fault Studies and Mechanical Engineering – To ensure a consistent assessment of the approach to management of extreme environmental conditions.
- Fire Safety – To ensure a consistent assessment of the consideration of battery hazards and fire evacuation.

2.3. Use of technical support contractors

34. During Step 2, I have not engaged Technical Support Contractors to support my assessment of the electrical engineering aspects of the BWRX-300 GDA.

3. Requesting Party's submission

35. The RP submitted the SSSE at the start of Step 2 in four volumes that integrate environmental protection, safety, security, and safeguards. This was accompanied by a head document (ref. [1]), which presents the integrated GDA environmental, safety, security, and safeguards case for the BWRX-300 design.

36. All four volumes were subsequently consolidated to incorporate any commitments and clarifications identified in regulatory engagements, regulatory queries and regulatory observations, and were resubmitted in July 2025. This consolidated revision is the basis of the regulatory judgements reached in Step 2.

37. This section presents a summary of the RP's safety case for electrical engineering. It also identifies the documents submitted by the RP which have formed the basis of my Step 2 assessment of the BWRX-300 design.

3.1. Summary of the GE-Hitachi BWRX-300 Design

38. The BWRX-300 is a single unit, direct-cycle, natural circulation, boiling water reactor with a power of ~870 MW (thermal) and a generating capacity of ~300 MW (electrical) and is designed to have an operational life of 60 years. The RP claims the design is at an advanced concept stage of development and is being further developed during the GDA in parallel with the RP's SSSE.

39. The BWRX-300 is the tenth generation of the boiling water reactor (BWR) designed by GVHA and its predecessor organisations. The BWRX-300 design builds upon technology and methodologies used in its earlier designs, including the Advanced Boiling Water Reactor (ABWR), Simplified Boiling Water Reactor (SBWR) and the Economic Simplified Boiling Water Reactor (ESBWR). The ABWR has been licensed, constructed and is currently in operation in Japan, and a UK version of the design was assessed in a previous GDA with a view to potential deployment at the Wylfa Newydd site. Neither the SBWR or ESBWR have been built or operated.

40. The BWRX-300 reactor core houses 240 fuel assemblies and 57 control rods inside a steel reactor pressure vessel. It uses fuel assemblies (GNF2) that are already currently widely used globally (ref. [16]).

41. The reactor is equipped with several supporting systems for normal operations and a range of safety measures are present in the design to provide cooling, control criticality and contain radioactivity under fault conditions. The BWRX-300 utilises natural circulation and passive cooling rather than active components, reflecting the RP's design philosophy.

42. In developing the design, the BWRX-300 designers have focused on using passive safety measures to deliver the necessary safety functions. Whilst the use of passive systems can reduce the safety claims on support systems such as standby alternating current (AC) power sources, this approach can increase the importance of battery-backed electrical systems to initiate, control and monitor these measures. Consideration of this aspect has formed a significant element of my assessment of the electrical power system architecture during Step 2.

3.2. GE-Hitachi BWRX-300 Case Approach and Structure

43. The RP has submitted information on its strategy and intentions regarding the development of the SSSE (refs. [68], [69], [70] and [71]). This was submitted to ONR during Step 1.

44. The RP has submitted a SSSE for the BWRX-300 that claims to demonstrate that the standard BWRX-300 can be constructed, operated, and decommissioned on a generic site in GB such that a future licensee will be able to fulfil its legal duties for activities to be safe, secure and will protect people and the environment. The SSSE comprises a Preliminary Safety Report (PSR) which also includes information on its approach to safeguards and security, a security assessment, and a Preliminary Environment Report (PER), and their supporting documents.

45. The format and structure of the PSR largely aligns with the IAEA guidance for safety cases, SSG-61 (ref. [62]), supplemented to include UK specific chapters such as Structural Integrity and Chemistry. The RP has also provided a chapter on ALARP, which is applicable to all safety chapters. The RP has stated that the design and analysis referenced in the PSR is consistent with the March 2024 Preliminary Safety Analysis Report submitted to the US Nuclear Regulatory Commission (NRC). PSR Chapter 8, for the electrical power aspects, is an exception and is based on a later November 2024 reference to incorporate the 50Hz aspects of the design. The Security Assessment and PER are for the same March 2024 design but have more limited links to any US or Canadian submissions.

3.3. Summary of the RP's case for electrical engineering

46. The aspects covered by the BWRX-300 safety case in the area of electrical engineering can be broadly grouped under eight headings which are summarised as follows:

3.3.1. Development of Safety Case for Electrical Engineering

47. The main entry point to the RP's safety case for electrical engineering is through PSR Chapter 8 (ref. [4]).

48. This sets out the approach to the claims, arguments and evidence (CAE) and the set of sub-claims in this topic area to achieve the overall claim, which is described in the BWRX-300 UK GDA Safety Case Development Structure (ref. [71]):

> ‘Overall Claim: The BWRX-300 is capable of being constructed, operated, and decommissioned in accordance with the standards of environmental, safety, security and safeguard protection required in the UK.’

49. (Ref. [71]) decomposes this claim into “Level 1 claims relating to environment, safety, security, and safeguards, which are then broken down again into Level 2 area related sub-claims and then finally into Level 3 (chapter level) sub-claims to provide the granularity that the PSR chapters will refer to”. This shows that Chapter 8 has a key role in supporting two Level 2 Claims:

> ‘Claim 2.1: The functions of systems and structures have been derived and substantiated taking into account RGP [Relevant Good Practice] and OPEX [Operational Experience], and processes are in place to maintain these through-life. (Engineering Analysis)
>
> Claim 2.4: Safety risks have been reduced as low as reasonably practicable.’

50. (Ref. [71]) then identifies eight Level 3 sub-claims that the electrical system is designed to meet.

51. PSR Chapter 8 (ref. [4]) provides a series of arguments that link each of these Level 3 sub-claims to the evidence provided in Step 2 GDA. Considering the developing design of the BWRX-300, the RP notes that it does not identify a comprehensive suite of evidence to support the sub-claims at this time, but provide examples commensurate with the maturity of the design and depth of a Step 2 GDA assessment.

52. PSR Chapter 8 (ref. [4]) is based on the development of the design, corresponding to the RP’s Design Reference Point (DRP) (ref. [6]). The establishment of this DRP sets a baseline for the design as assessed in GDA and introduces change control for consideration either during a future Step 3 GDA or during licensing.

53. PSR Chapter 8 (ref. [4]) describes the BWRX-300 electrical systems, how the design is informed by the safety analysis of the design, their respective safety and non-safety functions and how the design of the electrical systems aligns with the expectations of IAEA guidance and other national regulatory expectations.

3.3.2. Electrical Power System Architecture

54. PSR Chapter 3 (ref. [3]) sets out how the design incorporates multiple layers of defence against initiating events, describing how these layers of defence comprise 'features, safety functions and practices' to prevent the release of radioactivity. The submission states that the design incorporates five Defence Lines (DL), consistent with five levels of defence in depth of the IAEA Specific Safety Requirements SSR-2/1 (ref. [60]).

55. PSR Chapter 8 (ref. [4]) sets out the design of the electrical power system consisting of a number of different sub-systems. The Plant Electrical Systems Architecture report (ref. [72]) sets out how each of these systems contributes to a Defence-in-Depth (DiD) structure through alignment to these Defence Lines.:

- Preferred Power System – Provides connection to export and import power from the off-site transmission system and ensures disconnection of pumps following an initiating event, which could otherwise challenge safe shutdown (aligns to DL 2 and 4a)
- Emergency Power System (EPS) (Uninterruptible Power Supply (UPS) system) – Provides uninterruptible supplies, supported by batteries, to SSCs demanded during Loss of Offsite Power (LOOP) conditions, to ensure safe shutdown (aligns to DL 3)
- Standby Power System (UPS system) – Provides uninterruptible supplies, supported by batteries, to SSCs demanded during Station Blackout (SBO) conditions (LOOP and failure of DiD Level 3 functions) (aligns to DL 4a)
- Standby Power System (Interruptible Alternating Current (AC) system) – Provides backup power through two redundant divisions to SSCs to detect and mitigate abnormal operational occurrence postulated events, provide long term backup electrical supplies and during design extension conditions that lead to core damage (aligns to DL 2 and 4b)

3.3.3. Electrical Power System Robustness

56. PSR Chapter 8 (ref. [4]) sets out how the structure of the Electrical Power System is informed by the requirements from the design principles supported by the deterministic and hazards analyses through the following PSR chapters:

- PSR Chapter 2 – Generic Site (ref. [2])
- PSR Chapter 3 – Safety Objectives and Design Rules (ref. [3])
- PSR Chapter 15.5 - Deterministic Safety Analysis (ref. [30])

- PSR Chapter 15.7 – Internal Hazard Analysis (ref. [32])
- PSR Chapter 15.8 – External Hazard Analysis (ref. [33])

3.3.4. Smart Device Strategy

57. PSR Chapter 8 (ref. [4]) sets out how the BWRX-300 electrical systems are monitored and controlled by the various Distributed Control and Information Systems (DCIS), which are further described in PSR Chapter 7 (ref. [19]).

58. PSR Chapter 8 (ref. [4]) also sets out the relevant merits of digital and analogue protective relays; noting these are part of a separate DCIS network, highlighting how such relays are considered critical digital assets and require appropriate cyber security monitoring and physical access protection.

3.3.5. Through Life Management

59. PSR Chapter 8 (ref. [4]) sets out how the through life management of electrical equipment is considered in the design and includes the following specific claim:

> ‘Claim 2.1.5: Ageing and degradation mechanisms will be identified and assessed in the design. Suitable examination, inspection, maintenance, and testing will be specified to maintain systems/structures fit-for-purpose through-life.’

60. The RP has provided a set of arguments to support how it intends to meet this claim. The RP claims through life management through design and examination, inspection, maintenance and testing (EIMT) arrangements demonstrate that this claim will be met. Noting that the design is still to be completed, the RP considers the evidence to substantiate this claim to not yet be determined . However, to demonstrate how this claim could be met, reference is made to the BWRX-300 In Service Inspection Requirements (ref. [73]).

3.3.6. Support to Human Operations

61. (Ref. [4]) identifies the various lighting systems which provide support to operators during normal and emergency operation of the plant.

62. The Plant Electrical Systems Architecture report (ref. [72]), which is referenced from (ref. [4]) provides further detail on the role and expectations for the design of systems in support of operator action, including lighting.

3.3.7. Grid Code Compliance

63. At the start of Step 2, PSR Chapter 8 (ref. [74]) identified the importance of meeting the requirements of the Grid Code (ref. [75]) in facilitating connection of a facility to the GB electricity transmission system.

64. During Step 2, the RP undertook a structured assessment (ref. [76]) of the BWRX-300 to the Grid Code (ref. [75]).

65. The findings from (ref. [76]) have been incorporated into the updated PSR Chapter 8 (ref. [4]) submitted to regulators in July 2025.

3.3.8. Demonstration of an ALARP design

66. The RP states in PSR Chapter 8 (ref. [4]) that whilst it is not possible to demonstrate that nuclear safety risks have been reduced ALARP at this time, when the detailed design is not complete, the RP considers that a reasoned justification can be provided that the design aspects set out so far show the design is being developed consistent with this objective. The CAE structure includes a specific electrical claim in (ref. [4]):

> ‘Claim 2.4.3: All reasonably practicable measures have been implemented to reduce risk.’

67. The corresponding arguments set out how this optioneering has been completed in line with a developed process, has considered all measures and how those reasonably practicable measures have been implemented.

68. Within (ref. [4]) the RP sets out that the design of the systems is in line with the project plan, uses operational experience, and appropriate codes and standards to provide a reasoned justification that the electrical design of the BWRX-300 will effectively contribute to the development of a future ALARP statement.

3.4. Basis of assessment: RP’s documentation

69. The principal documents that have formed the basis of my electrical engineering assessment of the SSSE are:

- PSR Chapter 3 (ref. [3])
- PSR Chapter 8 (ref. [4])
- PSR Chapter 9A (ref. [5])
- Plant Electrical Systems Architecture Requirement and Design Plant Specification (ref. [72])
- Plant Cable and Component Separation Requirements (ref. [77])

- Plant Electrical Systems Nuclear Regulations and Standards Compliance Plan (ref. [78])
- BWRX-300 UK Grid Code Assessment (ref. [76])
- Forward Action Plan (ref. [79])
- Safety Case Manual (ref. [80])

70. As well as a providing PSR chapters at the start of Step 2, the RP provided updated versions at the end of Step 2; which incorporated clarification from engagement with regulators, details from additional analysis work undertaken during Step 2, and updates to any future commitments. Unless specifically identified in this report, any reference to PSR chapters refers to the final Step 2 version.

3.5. Design Maturity

71. My assessment is based on revision 3 of the Design Reference Report (ref. [6]). The design reference report presents the baseline design for GDA Step 2, outlining the physical system descriptions and requirements that form the design at that point in time.

72. The reactor building and the turbine building, along with the majority of the significant SSCs are housed within the ‘power block’. The power block also includes the radwaste building, the control building and a plant services building.

73. The GDA Scope Report (ref. [48]) describes the RP’s design process that extends from baseline (BL) 0 (where functional requirements are defined) up to BL 3 (where the design is ready for construction).

74. In (ref. [6]), SSCs in the power block are stated to be at BL1. BL1 is defined as:

- System interfaces established;
- (included) in an integrated 3D model;
- Instrumentation and control aspects have been modelled;
- Deterministic and probabilistic analysis has been undertaken; and
- System descriptions developed for the primary systems.

75. The balance of plant remains at BL0 for which only plant requirements have been established, and SSC design remains at a high concept level.

4. ONR assessment

4.1. Assessment strategy

76. The objective of my GDA Step 2 assessment was to reach an independent regulatory judgement on the fundamental aspects of the BWRX-300 design, relevant to electrical engineering as described in sections 1 and 3 of this report. My assessment strategy is set out in this section and defines how I have chosen which matters to target for assessment. My assessment is consistent with the project delivery strategy for the BWRX-300 GDA (ref. [81]).

77. GVHA is currently engaging with regulators internationally, including the US NRC and the Canadian Nuclear Safety Commission (CNSC). It is proposing a standard BWRX-300 design for global deployment with minimal design variations from country to country. My assessment takes cognisance of work undertaken by overseas regulators.

78. Whilst there is no operating BWR plant in the UK, ONR has previously performed a four-step GDA on the Hitachi-GE UK ABWR (ref. [82]). I have taken learning from this previous activity, targeting my assessment on those aspects of the BWRX-300 which are novel or specific to this design. I have not looked to reassess inherent aspects of BWR technology which were considered in significant detail for the UK ABWR and judged to be acceptable.

79. During this GDA Step 2 assessment, I have sampled the RP's submissions identified in section 3.4, above, to gain confidence that the RP is developing a robust safety case based on fundamental claims supported by evidence, that will meet the expectations in the ONR SAPs and are consistent with international guidance. At this time, my assessment has focused on seeking assurance that the RP is developing a safety case structure, based on sound design principles, which when applied, should ensure a case that can be demonstrated through design evidence during a future Step 3 or as part of licensing.

80. My assessment has involved regular engagement with the RP's electrical engineering team, including 12 progress and technical meetings.

81. During my GDA Step 2 assessment, I have identified a number of aspects with the RP's submissions which have needed clarification. Consistent with ONR's Guidance to Requesting Parties (ref. [12]), I have raised a series of Regulatory Queries (RQ) to seek clarity. Over the course of this assessment, I have raised 22 RQs (ref. [83]) to facilitate my assessment.

82. The details of my GDA Step 2 assessment of the safety case for the BWRX-300 design in the area of electrical engineering, including the conclusions I have reached, are presented in the following sections of this report.

4.2. Assessment Scope

83. My assessment scope and the areas I have chosen to target for my assessment are set out in this section. This section also outlines the submissions that I have sampled, the standards and criteria that I will judge against and how I have interacted with the RP and other assessment Topics.

84. My assessment scope is consistent with the GDA scope agreed between the regulators and the RP during Step 1 and detailed in Section 1.2 of this report. I have targeted my assessment within this scope.

85. In line with the objectives for Step 2, I have undertaken a broad review of the highest level, fundamental claims and supporting arguments related to electrical engineering. To support this, I have sampled a targeted set of the claims or arguments as set out below. Where applicable, I have also sampled the evidence available to support any claims and arguments.

86. In order to fulfil the aims for the Step 2 assessment of the BWRX-300, I have assessed the following items, which I consider important:

- Electrical system safety case – to assess the RP's submissions to seek assurance that fundamentally the safety case will have appropriate scope and structure, is consistent with relevant standards, is sufficient to support assessment and represents a baseline for a future licensee to develop. This Step 2 GDA assessment focuses on the claims and arguments.

- Electrical system architecture - to assess the RP's safety submissions to seek assurance that:

    - the integrity of the electrical system complies with the functional safety requirements of the systems it supports;

    - the BWRX-300 architecture is based on strong deterministic principles; and

    - the BWRX-300 architecture is capable of being connected to a nominal 50Hz electrical system.

- Electrical system robustness – to assess the RP's submissions to seek assurance that the electrical system is being designed to withstand a wide range of internal and external events through an architecture based on defence in depth.

- Electrical support to passive safety systems – to assess the RP's submissions to seek assurance that the fundamental design of the electrical systems supporting passive safety measures are suitably categorised and classified to fulfil their safety function.

- Smart device strategy – to assess the RP's submissions to seek assurance that its approach to the use of smart devices can ensure a robust demonstrable design.
- Through-life management – to assess the RP's submissions to gain confidence that the electrical system proposed can be operated and maintained in line with the RP's operational lifecycle and design lifetime.
- Support to human operations – to assess the RP's submissions to seek assurance that the electrical system is being designed to support the operators in fulfilling their safety roles.
- Grid Code compliance – to assess the RP's submissions to gain confidence that the design could be connected to the GB transmission system.
- Demonstration that risks are likely to be reduced ALARP as applied by the RP to the design of electrical systems.

4.3. Assessment

4.3.1. Development of Safety Case for Electrical Engineering

87. The overall claim for the BWRX-300 as presented in (ref. [71]) states:

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

88. (Ref. [71]) provides a structured breakdown of this claim through sub-claims to topic specific claims. (Ref. [4]) provides a clear link between the sub-claims relevant to electrical engineering and how individual evidence would substantiate those claims via specific arguments through a CAE Route Map. All of the RP submissions considered in my Step 2 assessment are either identified directly in the claims structure set out in (ref. [4]) or are references to documents that are.

89. The claims structure sets out how the safety functions associated with the BWRX-300 design have been derived from the fault and hazard analyses and takes those requirements as the basis for the design of Structures, Systems and Components (SSC), including those of the electrical system. This approach is set out succinctly and is consistent with both PSR Chapter 3 (ref. [3]) and the BWRX-300 Safety Strategy (ref. [68]).

90. (Ref. [4]), and specifically the CAE, provide a clear link to the Plant Electrical Systems Architecture Requirement and Design Plan Specification (ref. [72]). This document sets out how it 'defines the architecture of the BWRX-300

EDS, defines the electrical systems and associated boundaries, and establishes the initial set of electrical system requirements derived from CNSC, U.S., and Polish regulations and industry standards'; noting these three regulatory regimes were those that have led the development of the design.

91. I have assessed (ref. [72]) and consider it provides a comprehensive set of requirements for the design for the electrical systems in the BWRX-300. The structure of the document enables the clear identification of requirements of an individual system, whether that be, for example, the Emergency Power System, Cable Raceways or Lighting, but also sets the basis for each requirement. Noting that the document supports the development of BWRX-300 designs for both 50Hz and 60Hz operation, the structure of the document makes clear where requirements are applicable to only one system frequency, or one regulatory jurisdiction.

92. (Ref. [72]) identifies 50Hz specific requirements for the BWRX-300 design and references appropriate International Electrotechnical Commission (IEC) standards as relevant. The RP, in its initial review of Codes and Standards (ref. [84]), has assessed all of the electrical standards that are a part of the BWRX-300 design. It identifies that the design identifies a number of Institute of Electrical and Electronics Engineers (IEEE) standards, for which it considers equivalent IEC standards would need to be considered for a UK plant, or puts forward arguments that the IEEE standard remains good practice, in the absence of an equivalent IEC. The report also recognises that the electrical installation aspects of a UK plant will be expected to comply with the UK Requirements for Electrical Installations (ref. [85]). Noting that the RP has not developed a full UK compliance plan at this time, together with (ref. [84]). It submitted for information the compliance plan that was developed to support the BWRX-300 design for Canada (ref. [78]). I consider this provides a clear hierarchical breakdown of the codes and standards at national and international level to be used and the justification for their use. I consider that a similar review approach would ensure an appropriate justification for the design in the UK.

93. I am satisfied that (ref. [72]) identifies the RP is developing a robust set of individual requirements which can be considered as proxies for the sub-claims in the CAE structure or in line with relevant good practice set out in IAEA guidance or international standards. This includes, where appropriate, aspects such as the single failure criterion, independence and limits of operation. Whilst the document is currently focused on alignment to North American regulatory requirements, I consider in the area of electrical engineering that these are consistent with UK expectations. The RP has also identified as a Forward Action Plan (FAP) action (ref. [79]), PSR8-81, to ensure the detailed design of the installation is reviewed against relevant UK expectations.

94. From a review of the individual requirements, I consider that they provide a consistent base aligned to the ONR SAPs relating to the deterministic principles of EKP.3 (Defence in depth), EDR.2 (Redundancy, diversity and segregation), EDR.3 (Common cause failure), EDR.4 (Single failure criterion) and ECS.2 (Safety classification of structures, systems and components).

95. I have assessed the Design Reference Report (ref. [6]), which sets out the basis for the design and the control of its development, and consider that it is consistent with the information provided in PSR Chapters 3 and 8 (refs. [3] and [4]) and supporting references. I consider that it provides a sound basis on which the electrical design can be controlled beyond Step 2.

96. In summary, I consider that through the submissions made during Step 2, the RP has demonstrated how it is developing a robust safety case through a claims, arguments and evidence structure. It has also set out how it controls the development of the safety case and the design. Whilst it is not expected that evidence is presented during Step 2 to substantiate the design, the RP has shown the forms of submissions it expects will provide that evidence beyond Step 2.

4.3.2. Electrical Power System Architecture

97. I have assessed the electrical power system architecture of the BWRX-300 design based on the information provided in PSR Chapter 3 (ref. [3]), PSR Chapter 8 (ref. [4]), Plant Electrical Systems Architecture (ref. [72]), Plant Cable and Component Separation (ref. [77]), responses to RQs (ref. [83]) and supported by discussions with the RP during progress meetings.

98. Noting that the design is evolving, and the detailed substantiation is not yet available, I have focused my assessment on establishing whether the basic architecture supports:

- Connection of offsite power supplies;
- Onsite power supplies;
- Divisional segregation of the power systems;
- Resilience to LOOP and SBO situations;
- Appropriate diesel generator mission and battery autonomy times;
- Application of categorisation and classification principles to the electrical systems;
- Resilience to common cause failure; and
- Impact of operating modes and maintenance on the system.

99. As a result, I have considered the following SAPs:

- EKP.3 (Defence in depth),
- ECS.2 (Safety classification of structure, systems and components)
- EDR.2 (Redundancy, diversity and segregation),
- EDR.3 (Common cause failure),
- EDR.4 (Single failure criterion), and
- ESS.8 (Automatic initiation)

100. I have considered the WENRA Safety of new NPP designs (ref. [53]), IAEA Specific Safety Requirements SSR-2/1 (ref. [60]), IAEA Specific Safety Guide SSG-34 (ref. [61]), IAEA Technical Document on Design Provisions for Withstanding Station Blackout (ref. [64]) as well as the ONR TAGs on Safety Systems (ref. [54]) and Essential Services (ref. [56]) to support my judgements.

101. PSR Chapter 3 (ref. [3]), PSR Chapter 8 (ref. [4]) and the Plant Electrical Systems Architecture report (ref. [72]) set out how the passive design approach of the BWRX-300 minimises the reliance on electrical power to support safety category functions. This design strategy has two significant impacts on the electrical system design:

- It is not dependent upon AC power sources to mitigate a Design Basis Accident.
- It is designed to automatically initiate all Safety Category 1 functions on loss of power.[1]

102. I consider the overall electrical system architecture provides a robust defence in depth approach, with the RP's DL strategy and associated electrical systems aligned with the IAEA's five levels of defence-in-depth. I am satisfied that the architecture is generally consistent with that identified in IAEA SSG-34 (ref. [61]), reflecting the provision of two offsite transmission system connections, supplying the main electrical switchboards of the preferred power system, which includes loads associated with normal operation of the plant. (Ref. [4]) highlights that whilst it is not considered that the BWRX-300 design requires two connections due to the limited role electrical power has in ensuring safe shutdown, as outlined above, two connections are still provided in the design to reduce the claims on on-site power sources and provide flexibility to provide offsite power during maintenance conditions. As a result of this limited role, no automatic

[1] With the exception of a fault requiring isolation of the Isolation Condenser System (ICS)

switching between offsite power sources is intended. I consider this a reasonable approach.

103. The Emergency Power System (EPS) consists of three independent Safety Class 1 Uninterruptible Power Systems (UPS) to provide power to the three channel Safety Class 1 Reactor Protection System (RPS) used to initiate and then monitor the plant to ensure it achieves a controlled and safe state. The RP claims the passive design of the BWRX-300, through the use of natural circulation and failsafe valves, means that electrical power is generally not required to achieve this. The exception is for faults associated with the Isolation Condenser System (ICS) which require isolation. In these instances, the RPS uses direct current (DC) power from the EPS to close associated Safety Class 1 valves.

104. To mitigate against LOOP and common cause failure of the Safety Class 1 RPS or EPS, (Ref. [4]) sets out how the design includes two independent Safety Class 2 Standby Power System (SPS) UPS to provide power to the two channel Diverse Protection System (DPS) and four further Safety Class 2 UPS to support the Fine Motion Control Rod Drives (FMCRD). These two systems provide diverse lines of protection to the safety classified functions supported by the EPS.

105. The use of three redundant Safety Class 1 UPS divisions of the EPS to support the RPS and two redundant Safety Class 2 UPS divisions of the SPS to support the DPS is consistent with the design redundancy and classification of the two respective Control and Instrumentation (C&I) systems. The RP has set out in (refs. [4] and [72]) the independence requirements between divisions and diversity requirements between the EPS and SPS. I consider the approach being adopted is consistent with the expectations of the ONR SAPs considered in this section.

106. The BWRX-300 design sets out autonomy times of 72 hours for both the EPS and SPS UPS batteries. Noting the limited role of electrical systems in delivering the plant to a safe state, I consider these durations are reasonable in establishing these states and ensuring ongoing plant conditional awareness until electrical supplies could be restored from either onsite diesel generators or offsite supplies. These autonomy times are consistent with systems that deliver similar functionality on other reactor designs (ref. [86]).

107. The EPS and SPS UPSs of each division include two fully rated redundant chargers per division. Each EPS UPS includes the use of two redundant inverters whilst the SPS UPS includes a single inverter per division. The RP has set out that each charger is sized to support the respective loads and the recharging of the battery simultaneously, whilst a single inverter is capable of supporting all associated loads. Each system incorporates a capacity margin to facilitate future increases in demand from plant modifications. I consider this design approach is consistent with the expectations of the IEC standard for uninterruptible supplies (ref. [87]) and

the redundant charger/inverter arrangement improves the availability of the systems, giving a future licensee the ability to perform maintenance whilst at power, if required.

108. Whilst no electrical systems are required to maintain a safe state between 72 hours and 7 days, as discussed in the ONR Fault Studies assessment (ref. [88]), the BWRX-300 design includes a Safety Class 3 AC Standby Power System which consists of two redundant electrical divisions, each of which is backed by an auto-starting Standby Diesel Generator (SDG). Whilst the two divisions are designed to be run independently, each SDG is sized to supply 100% of the required EPS and SPS loads for at least seven days without offsite support. This includes recharging the EPS and SPS UPS systems. Each is controlled either from the main control room, secondary control room or local to plant.

109. The intended seven days autonomy for an SDG is consistent with the expectations of IAEA guidance (refs. [61] and [64]) as well as previous GDAs. I also consider this level of resilience is consistent with wider electricity supply expectations (ref. [89]) which mean that it may take up to 5 days to fully recover from a nationwide blackout.

110. As a result of the passive nature of the safety systems in this design, no generator backed power is required to achieve a safe state, which means there is no requirement in this design for a Standby AC Power Source, as defined in (ref. [61]). As a result, the role of the SDG of the SPS is more aligned to that of the Alternate AC Power Source quoted in (ref. [61]), providing a source of electrical power during an extended period of loss of offsite power.

111. The RP has also indicated that temporary external power connections are intended to be provided to enable mobile generators to be connected should a LOOP event occur and supplies not be available from the SDGs; noting that the EPS and SPS UPSs will provide power for 72 hours. The RP has indicated it has not yet identified the optimum location for these at this time. I consider the inclusion of this is consistent with the expectations of (ref. [61]), whilst the passive nature of design reduces the urgency to connect. This overall approach is consistent with the international expectations of (refs. [64], [67] and [90]) and the fact that the location of these has not been determined yet does not constitute a fundamental shortfall which would prevent the RP from further developing the generic BWRX-300 design and associated SSSE evidence to support any future permissioning activities.

112. Based on the outcome of my GDA Step 2 assessment of the AC power system architecture, I have concluded that the fundamental architecture appears to be robust and consistent with ONR SAPs EKP.3, ECS.2, EDR.2, EDR.3, EDR.4, ESS.8, IAEA Safety Guide SSG-34, and WENRA guidance.

113. From my sample, in my opinion, there are no fundamental shortfalls which would prevent the RP from further developing the generic BWRX-300 design

and associated SSSE evidence to support any future permissioning activities.

4.3.3. Electrical Power System Robustness

114. International events have shown the importance of the electrical system being designed to sound deterministic principles, such as defence-in-depth and independence, as well as to withstand specific internal and external hazards, which could challenge the safety of design.

115. Noting that the detailed design of the BWRX-300 is still to be completed, I have sought confidence that the RP has established a robust approach to identifying the factors that could impact the ability of the various electrical systems to successfully support the respective safety functions and to gain confidence that the RP is designing those systems to be sufficiently robust.

116. In my assessment, I have considered the following SAPs:

- EKP.3 (Defence in Depth)
- EDR.2 (Redundancy, diversity and segregation)
- EDR.3 (Common cause failure)
- EHA.14 (Fire, explosion, missiles, toxic gases etc – sources of harm)

117. As discussed in Section 4.3.2, above, the basic electrical architecture of the BWRX-300 is consistent with the arrangements set out in (refs. [61] and [67]). This includes the requirement for diversity between systems which provide support to DiD Level 3 and those that provide support to DiD Levels 2 or 4. The RP has set out that this expectation of diversity applies to the complete lifecycle of the equipment including design and EIMT. This provides a good deterministic foundation for a robust design.

118. The ONR internal and external hazards assessors have considered the RP's approach to hazard identification and screening as part of their assessments (refs. [91] and [92]). To gain confidence on how this is influencing the design of the electrical system, for Step 2, I have considered two aspects. Firstly, I have considered the proposed seismic resilience of the safety classified electrical systems. Secondly, I have reviewed how the RP is ensuring the design is resilient to ventilation and cooling failures that could affect the availability of the electrical systems. This latter aspect has focused on two facets:

- Battery system hazards
- Electrical room temperatures

119. In respect of seismic resilience of the electrical system, the RP set out in PSR Chapter 8 (ref. [4]) that the Safety Class 1 EPS is to be seismically qualified in line with the design basis set out in PSR Chapter 2 (ref. [2]). It is noted neither the Safety Class 2 SPS nor FMCRD system are to be seismically qualified. Noting that as discussed in Section 4.3.2, above, the BWRX-300 is designed to be inherently passive, with safe shutdown assured even in a loss of electrical power situation, I consider this approach to seismic classification reasonable for the SPS system. However, I noted that it is foreseeable that the initiating LOOP condition could be caused by a seismic event resulting in the loss of the transmission system connection, noting that the transmission network is not likely to be designed to the same design basis as the NPP. A co-incident common cause failure of the control rod hydraulic control units, which use high pressure water to insert the control rods into the core, is likely to result in an event frequency that ONR would expect to be explicitly considered in the analysis.

120. Whilst the design includes a Safety Class 3 Boron Injection System (BIS) as a third means of ensuring a controlled state is achieved, and does not itself require electrical power to initiate, I noted that neither the Safety Class 2 FMCRD electrical and control system nor the BIS are seismically qualified. This could mean that in this scenario there is a risk that no means of ensuring the controlled state could be achieved.

121. I raised this concern with the ONR Fault Studies Assessor, who has led on the assessment of this aspect of the safety case. Their assessment report (ref. [88]) considers this and their wider concerns with the arguments/evidence provided by the RP that the various systems support an ALARP demonstration that the plant can achieve a controlled state. Their assessment concludes that taking into account commitments made by the RP for further analysis and development of the safety case together with design developments that have been made to the BWRX-300 for Canada, which could be expected to apply to the UK, they are content a future BWRX-300 safety case would be able to provide an ALARP demonstration for such circumstances. As part of this, I expect the safety case to fully demonstrate that a controlled state is assured in a LOOP condition.

122. Considering the risks from battery systems, the RP has identified that it is employing vented lead acid (VLA) technology for the Safety Class 1 batteries and Lithium Iron Phosphate for the Safety Class 2 and 3 batteries.

123. In (ref. [4]), the RP has set out how each battery is located in an independent room, that is both fire and flood protected. The RP has recognised the risk of fire from both battery types as the greatest hazard, with the potential for acid leakage also a concern from the VLA batteries.

124. The RP has indicated that detection and preventative measures are proposed. This includes fire protection systems to limit fire propagation to

other areas and systems and, in the case of VLA batteries, hydrogen detection and SDG backed exhaust ventilation, including fan failure alarms.

125. This hazard identification is consistent with PSR Chapter 15.7 (ref. [32]), which identifies the risk of internal explosions and fires associated with battery induced incidents. (Ref. [79]) which captures the forward action plan from that chapter, notes that as part of the development of a future PCSR, further definition and justification will be required.

126. The combination of redundant battery systems, segregated locations, and the identification and the detection and preventative measures mean I am satisfied that at this time the RP has demonstrated appropriate understanding of the risks associated with each technology and how they could be managed. I would expect a future safety case to fully demonstrate that the specific risks with each technology are reduced so far as is reasonably practicable. The information provided in the PSR and the future activities identified in the Forward Action Plan in this area mean I am content that there are no fundamental shortfalls which would prevent the RP from further developing the generic BWRX-300 design and associated SSSE evidence to support any future permissioning activities.

127. Considering the management of electrical room temperatures, it is noted that the passive nature of the BWRX-300 reduces the reliance on electrical systems of high safety classification. The limited actions which do require electrical power to actuate will be complete within a few minutes of the start of an event and, therefore, the loss of electrical power to any ventilation system is unlikely to result in excessive temperatures that prevent a safety function from being successful completed.

128. PSR Chapter 9A (ref. [5]) sets out the fundamental approach to the design of ventilation systems, setting out the various subsystems of the heating, ventilation and air conditioning systems supporting the power, control and turbine blocks.

129. The RP sets out how the safety classifications of the various ventilation systems are consistent with that of the equipment it supports, and how each is supported by an electrical supply of an equivalent classification and availability. It is claimed that rooms containing Safety Class 1 electrical equipment, located in the reactor building, will be passively cooled for their required 72 hour mission time without exceeding their qualification temperature. Similar arrangements are provided for the Safety Class 2 electrical equipment, located in the control building. When an SDG is available, it is noted that active ventilation can be provided to both locations.

130. Assessments from previous GDAs (refs. [93] and [94]) have shown that maintaining electrical equipment operability during LOOP and SBO conditions can be challenging. The focus of this design on providing passive systems, which need either no or limited actuation to initiate, can ensure the

plant will achieve and maintain a controlled and safe state without the need for electrical systems, that then require cooling.

131. Based on my targeted review of how the RP has considered two significant challenges to the robustness of an electrical system together with the basic architecture, I have concluded that the fundamental approach appears to be robust and consistent with ONR SAPs EKP.3, EDR.2, EDR.3, EHA.14, IAEA Safety Guide SSG-34, and WENRA guidance.

132. I am content that there are no fundamental shortfalls which would prevent the RP from further developing the generic BWRX-300 design and associated SSSE evidence to support any future permissioning activities.

4.3.4. Passive Safety Systems

133. As discussed in Sections 4.3.2 and 4.3.3, above, the BWRX-300 design strategy is one of being inherently passive, reducing the reliance on electrical systems to both initiate and maintain the controlled and safe states.

134. In the design set out in (ref. [4]), the RP has generally achieved this for both the main and diverse lines of reactor protection, supported by independent electrical systems and enacted through redundant valves which operate on a failsafe principle. The net effect of this is that following a complete loss of electrical supplies, for design basis faults, reactor trip and establishment of natural circulation can be assured. The exceptions, as discussed in Section 4.3.2, above, are for faults which require the isolation of a division of the ICS system and as a diverse means of control rod insertion. In these cases, battery supplies are required for a short period of time to either close the respective system isolation valve in the affected train or to mechanically drive the rods into the reactor core. The RP through (ref. [4]) has set out how the safety classification and autonomy times of the UPS systems that support these functions are appropriate.

135. I am content that through its approach to design, the RP is reducing the reliance, and therefore claims, of the design on electrical power, so far as is reasonably practicable. In so doing, I consider the approach for electrical power system design has appropriately taken into consideration the guidance set out in the IAEA assessment of applicability of safety standards to SMRs (ref. [65]).

4.3.5. Smart Device Strategy

136. Smart devices are instruments, sensors, actuators or other previously electro-mechanical components (e.g. relays, positioners and controllers) which are controlled by a built-in microprocessor or hardware description language programmable device. They are becoming increasingly the only commercially available solution across both C&I and electrical systems as manufacturers seek advances in functionality and self diagnostics whilst

reducing development times and production cost. However, their complexity introduces new risks and makes it harder to demonstrate adequate reliability.

137. For GDA Step 2, I have considered if the RP recognises the risks from the use of such devices and if an appropriate strategy for their identification and use is being developed.

138. In (Refs. [4]and [72]), the RP sets out how digital devices can be used for Safety Class 3 Standby Power System. This is consistent with PSR Chapter 7 (ref. [19]) which states 'Smart devices/digital technology equipment is only used in SC3 [Safety Class 3] and SCN [Non-Safety Classified] applications.' In its response to an RQ relating to protection relays, the RP reaffirmed this limitation to the use of this technology for components no higher than Safety Class 3.

139. (Ref. [72]) includes specific requirements for all electrical systems that are susceptible to cyber attacks to be assessed and incorporate cyber security features, whilst (ref. [19]) in reference to control equipment identifies how equipment will meet the qualification expectations of the nuclear sector IEC standards, including IEC 61513 (ref. [95]).

140. Noting that the detailed design of the BWRX-300 has not yet been undertaken, I consider the statements made at this time to be consistent with our expectations. A future safety case would need to demonstrate a robust process for substantiation of smart devices.

141. Noting that the availability of non-digital devices are becoming increasingly limited, there is a risk that the RP is unable to limit their use to low safety class systems and that this strategy has to be reconsidered. However, I do not consider this a fundamental risk as other duty holders in the UK have qualified digital equipment for electrical use to higher safety classifications..

142. Based on the information and strategy of the RP, I am content that in this area there are no fundamental shortfalls at this time which would prevent the RP from further developing the generic BWRX-300 design and associated SSSE evidence to support any future permissioning activities.

4.3.6. Through Life Management

143. It is important the electrical system is not only designed to deliver its safety functions but also constructed in a way that enables it to be operated, maintained and, where necessary, replaced throughout the life of the facility.

144. Noting the design is evolving, I have focused my assessment on whether the RP has established fundamental expectations for the design life of the plant and is considering ageing management and EIMT as part of the design development.

145. In my assessment, I have considered the following SAPs:

- EMT.1 (Identification of requirements), and
- EAD.1 (Safe working life).

146. The safety case claim identified in (ref. [74]) provides a clear link to the requirement to consider ageing and degradation in the design and future operation of the plant. The specific arguments that support this claim provide a direct link to expectations during design and for EIMT, taking into consideration operational experience as a part of this process. (Ref. [72]) sets out the requirement for safety classified electrical equipment to be periodically tested to demonstrate its availability and duty capability. Such expectations would need to be developed alongside the detailed design.

147. The RP's In Service Inspection Requirements (ref. [73]), which is given as an example of how the RP will develop these arrangements, is focused on the inspection of high integrity mechanical components. However, the document sets out the reason and purpose for how and why it is undertaking the EIMT activities on the equipment considered. It shows how the RP, in its approach, draws on good practice techniques that are set out in IAEA guidance (ref. [96]). I consider that following a similar structured approach could result in a demonstrable ageing and lifetime management of electrical equipment, using targeted EIMT activities to assure a future operator of the equipment availability.

148. Furthermore, through discussions with the RP, its response to RQ-1724 (ref. [83]), and a review of the plant layout drawings (ref. [97]), the RP has set out that it has included additional space reservation for 50Hz aspects of the design, including electrical equipment and cabling, which may be larger. Through the evidence provided, I am satisfied that the RP is appropriately considering the need to provide sufficient space around electrical equipment important to safety to facilitate routine EIMT activities.

149. I consider that the approach to date is consistent with the expectations of the ONR SAPs EMT.1 and EAD.1. As a result, I am content that there are no fundamental shortfalls which would prevent the RP from further developing the generic BWRX-300 design and associated SSSE evidence in this area to support any future permissioning activities.

4.3.7. Support to Human Operations

150. Whilst the use of passive safety systems reduces the expectations or reliance of human operators, it is important that designs still appropriately take into account the need for operators to monitor situations and to be able to safely take action when required.

151. In my assessment, I have considered the following relevant SAPs:

- ELO.1 (Access)

152. I have also considered the IAEA Specific Safety Guide SSG-62 (ref. [63]) and Technical Document 1770 (ref. [64]) to support my judgements.

153. It is my expectation that the electrical design shall be designed to support operators in fulfilling their safety roles, whether this be through the provision of appropriately robust lighting systems or communication systems to support local to plant actions or through station emergency alarm systems to protect personnel.

154. PSR Chapter 9A (ref. [5]) sets out the basic design principles for both the lighting systems and communication systems, supported by (ref. [72]). Noting that the detailed design of these systems has not yet been performed, (ref. [72]) sets out the principal aims of these systems including the safety role they provide in a DiD capability and the power supply requirements.

155. Considering the lighting systems, (ref. [72]) sets out how emergency lighting shall be provided in control rooms, control and maintenance of equipment used for safe shutdown, firefighting response and access to and from each of these areas. It sets out how lighting in these areas shall be supported by either the main safety batteries, providing 72 hour mission time in the case of the control rooms, or local luminaire batteries, providing an 8 hour mission time for local to plant actions or 90 minutes for those specifically for a safe means of escape. In all cases, these systems are to be supported by the SDGs. The document also sets out how the design of the lighting system shall be designed to be consistent with the expectations of IEC standards on workplace lighting.

156. I am satisfied that the strategy for lighting is consistent with the expectations set out in IAEA SSG-62 (ref. [63]) for such systems. The architecture of the lighting systems to the MCR and SCR, which I consider are appropriately classified as Safety Class 3, is arranged so that each location is resilient to the loss of an electrical division. I also consider the mission time of 72 hours, that can be extended by the use of the SDGs, to be reasonable.

157. The recognition by the RP that local to plant operations may be needed as the design is developed and that appropriate lighting would need to be provided to support these is important. A future UK safety case for the BWRX-300 would need to identify those locations and demonstrate that the lighting being provided is consistent with this claim.

158. Considering the communication systems, (ref. [72]) sets out the RP design which includes for a plant public address system, normal plant telephone system, radio system and sound-powered system to provide effective communication during normal and accident conditions. The plant public address system, which is to be supported by a dedicated 8 hour UPS that itself is SDG backed, provides an effective means to communicate plant wide communications to all plant personnel. The radio system is designed to provide a dedicated site communication system, in support of the delivery of

operator actions or fire fighting activities, again backed by an 8 hour UPS system that is SDG supported. The design also includes for a sound-powered system which includes telephone units located in the control rooms and at locations around the plant where critical activities are expected to be undertaken during an event. This system does not require an external power source.

159. I consider that the approach to communication systems in terms of the roles and ability to function during a degraded electrical system, is consistent with the expectations of IAEA guidance (ref. [63]). Furthermore, the use of sound-powered system is consistent with the RP's strategy of passive design, using systems that are robust to a loss of electrical supplies. Whilst the RP currently identifies the detailed requirements (ref. [72]) to be driven by US, Canadian and Polish regulatory requirements I am satisfied that these are consistent with IAEA and UK expectations. As the design develops, I expect the RP to consider relevant British Standard and IEC standards.

160. In summary, I am content that the RP recognises the importance of the lighting and communications to support human operations in the design of the BWRX-300. I consider that it is developing an approach to both which is aligned to the expectations of the ONR SAP ELO.1 and is consistent with the IAEA guidance (ref. [63]).

161. As a result, I am content that there are no fundamental shortfalls which would prevent the RP from further developing the generic BWRX-300 design and associated SSSE evidence in this area to support any future permissioning activities.

4.3.8. Grid Code Compliance

162. The ability to connect the NPP to the GB transmission system through compliance with The Grid Code (ref. [75]) is important not only from a commercial perspective but also from a safety perspective. Whilst ONR (ref. [98]) and IAEA (ref. [61]) expectations are that a facility should be able to provide power from on site sources to support delivery of the controlled and safe state, the normal, or preferred power supply, is from the offsite power supply, if available. In addition, it is important to ensure that technical compliance with the operational requirements of (ref. [75]), including the ability to provide frequency response, do not challenge nuclear safety.

163. In my assessment, I have considered whether the design is able to connect to the GB transmission system providing electrical supplies to equipment important to safety and export power to the GB transmission system within the operational limits specified in (ref. [75]), without affecting nuclear safety.

164. Chapter 8 (ref. [4]) recognises the importance of meeting the requirements of (ref. [75]) in facilitating connection of a facility to the GB electricity transmission system. The RP has undertaken a BWRX-300 UK Grid Code Assessment (ref. [76]), describing in a methodical way how it has identified

the performance or capability requirements of (ref. [75]) and then assessed the BWRX-300 capability against them to 'identify requirements that are inherently met and those where gaps exist'.

165. The RP's assessment identifies two areas that require further study:

- Operation within the full voltage/frequency range.
- Fault-ride through requirement of an anticipated transmission system electrical fault.

166. In its assessment of these two aspects, it notes that assessments of the 60Hz variant of the BWRX-300 design to similar requirements of other transmission systems have shown compliance.

167. The RP has also identified two areas where it does not consider it can meet the requirements with the current design of the plant:

- Frequency response capability.
- Re-synchronisation time.

168. (Ref. [76]) sets out how the difficulty with providing frequency response is a result of dynamic behaviour of the boiling water reactor technology; due to it adopting a 'turbine follows boiler control scheme' meaning fast modulation in response to grid frequency changes is not feasible. The ONR electrical assessment of the ABWR design (ref. [99]) highlighted a similar finding.

169. For these areas, the RP has identified that further technical discussions should be held with the relevant UK regulators during future permissioning activities. I consider this a reasonable conclusion at this stage and allows the RP to engage with the UK electricity regulator and operator on whether a design solution needs to be found or whether a derogation from this functionality can be sought.

170. Noting that the RP has recognised these actions within a forward action plan commitment in (refs. [4] and [79]), and whilst I am content that there are no fundamental shortfalls which would prevent the RP from further developing the generic BWRX-300 design and associated SSSE evidence in this area to support any future permissioning activities, I do consider that should the BWRX-300 design be considered for further development in the UK, clarity on a strategy acceptable to the UK electricity regulator and system operator should be developed early on.

4.3.9. Demonstration of an ALARP design

171. Until detailed design, it is difficult to judge whether the design can be shown to have reduced risks so far as is reasonably practicable, or ALARP.

172. However, from the CAE presented in (ref. [4]) and the supporting submissions including the Codes and Standards review (ref. [78]), I consider the RP is developing an electrical system that is consistent with the expectations of international good practice as set out in relevant IAEA technical guidance. I note that the RP is identifying both national and international codes and standards for electrical equipment design and performance, and whilst it is aiming for a design which meets both IEEE and IEC standards to support a global market with a single basic design, it recognises that due to different regulatory expectations (prescriptive vs. goal setting) in different parts of the world, it may need to be selective and justify its approach. This will only be fully known as the detailed design of equipment is undertaken.

173. As part of my Step 2 GDA assessment, I have found that the RP's rationale for the design is clear and that through (ref. [72]), the basis for any requirements is well set out, demonstrating safety risk reduction is a high priority.

174. This strategy in combination with the recognition of this risk, means that as the detailed design is completed, I consider the RP should be able to demonstrate that the design is consistent with UK regulatory expectations. I am content that there are no fundamental shortfalls which would prevent the RP from further developing the generic BWRX-300 design and associated SSSE evidence in this area to support any future permissioning activities.

5. Conclusions

175. This report presents the Step 2 electrical engineering assessment for the GDA of the BWRX-300 design. The focus of my assessment in this step was towards the fundamental adequacy of the design and safety case. I have assessed the SSSE chapters and relevant supporting documentation provided by the RP to form my judgements. I targeted my assessment, in accordance with my assessment plan (ref. [13]), at the content of most relevance to electrical engineering against the expectations of ONR's SAPs, TAGs and other guidance which ONR regards as relevant good practice, principally IAEA standard SSG-34 (ref. [61]).

176. Based upon my assessment, I have concluded the following:

- PSR Chapter 8 provides a good high level introduction to the role and purpose of the BWRX-300 electrical system; setting out how it supports safety functions.
- The CAE Route Map provides a good initial structure to the case and clear indication of how it intends to use evidence to demonstrate that case. The RP recognises that the evidence is not developed at Step 2 GDA but has provided examples of the types of information that it might intend to use.
- The basic electrical design architecture, with redundant divisions fed by multiple offsite and onsite power systems, provides a design which is consistent with international guidance and ONR's expectations for redundancy and defence in depth.
- The architecture is consistent with the overall aim of developing a passive design, reducing the claims on electrical support systems. The design includes permanently installed diesel generators and proposes the provision of connection points for mobile generators to provide power as may be required in a LOOP, SBO or total loss of power scenario.
- The proposed mission times for the installed diesel generators and the autonomy times for the Safety Class 1 and 2 battery systems are shown to be consistent with the safety claims on the systems they support, and consistent with UK expectations for a design basis LOOP event.
- The RP has undertaken a comprehensive assessment of the design against the requirements of the Grid Code. It has identified two areas where it does not consider its design can meet the expectations. I support its conclusion that it would need to engage with the relevant organisations to understand the options available.
- The RP has generally shown that the electrical power systems are being designed consistent with the hazards under which they may be expected

to operate. The ONR Fault Studies Assessor has identified wider concerns with the RP's ALARP justification for the safety systems that ensure a controlled state is achieved. I consider that the concerns I have raised in my assessment with the seismic resilience of the electrical aspects of those systems can be addressed through the wider commitments identified by the RP and captured in the ONR Fault Studies assessment.

- The rationale for the design and the basis for any requirements is clearly set out, demonstrating its use of operational experience and international standards to safety risk reduction. By continuing with this approach a future BWRX-300 safety case is likely to be able to demonstrate that the design is reducing the risks so far as is reasonably practicable.

177. Overall, based on my assessment, and subject to the provision and assessment of suitable and sufficient supporting evidence in either a future Step 3 GDA or during site specific activities, I have not identified any fundamental safety shortfalls that could prevent ONR permissioning the construction of a power station based on the generic BWRX-300 design.

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Appendix 1 – Relevant SAPs considered during the assessment

SAP reference	SAP title
EKP.3	Engineering principles: key principles – Defence in depth
ECS.2	Engineering principles: safety classification and standards – Safety classification of structures, systems and components
EDR.2	Engineering principles: design for reliability – Redundancy, diversity and segregation
EDR.3	Engineering principles: design for reliability - Common cause failure
EDR.4	Engineering principles: design for reliability – Single failure criterion
EMT.1	Engineering principles: maintenance, inspection and testing – Identification of requirements
EAD.1	Engineering principles: ageing and degradation – Safe working life
EHA.14	Engineering principles: external and internal hazards – Fire, explosion, missiles, toxic gases etc – sources of harm
ESS.8	Engineering principles: safety systems – Automatic initiation
ELO.1	Engineering principles: layout – Access