REGULATORY OBSERVATION

REGULATOR TO COMPLETE

RO unique no.:	RO-UKHPR1000-0038
Revision:	0
Date sent:	07/04/20
Acknowledgement required by:	30/04/20
Agreement of Resolution Plan Required by:	dd/mm/yy [consider when the plan needs agreement]
TRIM Ref:	2020/106581
Related RQ / RO No. and TRIM Ref: (if any)**:**	RQ-UKHPR1000-0628 [CM9 2020/43288] RQ-UKHPR1000-0629 [CM9 2020/43294] RQ-UKHPR1000-0630 [CM9 2020/43299] RQ-UKHPR1000-0640 [CM9 2020/56399]
Observation title:	Demonstration of the appropriate power rating and performance capability of the Electrical Power System
Lead technical topic: 7. Electrical Engineering	**Related technical topic(s):** 3. Control & Instrumentation 8. External Hazards 9. Fault Studies 12. Internal Hazards 14. Mechanical Engineering 19. Severe Accident Analysis

Regulatory Observation

Background

Electrical Power Supplies are important to Nuclear Power Plants (NPP) in providing both the sources of electrical energy and then distributing that energy to safety equipment that delivers the various safety functions to bring the NPP to a controlled and then safe shutdown state.

ONR's "Guidance to Requesting Parties" (Reference 1) states "…the safety assessment in this topic area typically would cover the engineering of the essential electrical power supply systems, examine these under a wide range of transient and fault conditions…". Furthermore, ONR's "Generic Design Assessment Technical Guidance" (Reference 2) provides specific guidance on the aspects of electrical engineering that should be assessed as part of GDA. This includes "a computer based model should be established by the RP [Requesting Party] for the purpose of studying the system under steady state conditions and in response to a range of postulated disturbances which can challenge the system performance. The studies should consider all modes of operation including normal operation, plant shutdown, on line plant maintenance, testing of standby sources and operation from standby sources…The results of the studies should be assessed to confirm compliance with pre-defined acceptance criteria."

In presentations to and interactions with the RP (References 3-4) throughout GDA, ONR has reinforced this regulatory expectation that electrical system studies should be undertaken to cover the "full range of electrical fault analysis" and considered for all "credible modes of operation". ONR has also "reiterated that any assertions or claims on safety or compliance needed to be substantiated." As part of the agreed Step 3 submission schedule, the RP has submitted a suite of documents to fulfil the analysis (Reference 5).

Those submissions do not give sufficient explanation of the process or analysis of the system sizing or performance for ONR to have confidence the electrical power system is adequately designed to perform as required.
ONR is concerned that the RP has not clearly presented the system models or the design data used throughout the studies in a manner which allows it to have confidence that the models adequately reflect the electrical power system or that the modelling data adequately represents the equipment parameters of Systems, Structures and Components (SSC). The choices or assumptions made in the development of the

model or defining equipment characteristics are not consistently presented nor justified.

This lack of clarity continues with the selection of conditions for study, where aspects such as modes of operation, derivation of bounding cases, and limiting conditions of operation are not clearly presented or justified.

Finally, the acceptance criteria are not clearly identified or linked to requirements in the safety case in each of the studies, which results in inadequate demonstration of the design, or identification of gaps and appropriate actions to mitigate those gaps.

Regulatory Queries (RQ) (Reference 6) have been raised to seek clarity on individual aspects of submissions. A subsequent meeting with the RP to discuss these (Reference 7) has highlighted that the gaps are unlikely to be fully addressed through simple responses to the RQs.

This Regulatory Observation has therefore been raised to ensure that there is a robust demonstration of the adequacy of the electrical power system to distribute electrical power in all operating modes and in the presence of a range of postulated disturbances.

Relevant Legislation, Standards and Guidance

Electrical Power Systems provide an essential support function in supplying electrical power to safety functions. A reliable power supply is critical for maintaining control during normal operations, anticipated deviations from normal operation, as well as to power, control and monitor relevant plant safety functions in design basis accidents and design extension conditions. This importance is reflected in a number of standards and guidance documents, both international and national.

Requirement 41 of IAEA Specific Safety Requirement SSR-2/1 (Rev.1) (Reference 8) reflects this expectation:

> "The functionality of items important to safety at the nuclear power plant shall not be compromised by disturbances in the electrical power grid, including anticipated variations in the voltage and frequency of the grid supply."

This is further reflected in many of the sections of the IAEA Specific Safety Guide for Electrical Power Systems SSG-34 (Reference 9). For example, Paragraph 2.19 identifies the need to consider margins and conservatisms in the design and Section 4 outlines the need to identify and consider the design bases, all operational states, all modes of operation and all possible events in the analysis.

BS IEC 62855:2016 (Ref. 10) specifically supports the guidance provided in Reference 9 and provides "guidelines for the analysis of AC and DC electrical power systems in NPPs in order to demonstrate that the power sources and the distribution systems have the capability for safe operation and shutdown of the NPP, bringing it to a controlled state after an anticipated operational occurrence or accident conditions and finally reaching a safe state."

Three principles from ONR Safety Assessment Principles (SAP) for Nuclear Facilities (Ref. 11) provide focus of the expectations in this area:

- SAP EES.3 expects that "each source should have the capacity, duration, availability, resilience and reliability to meet the maximum demands of its dependent systems."
- SAP ESS.10 expects that "The capability of a safety system, and of each of its constituent sub-systems and components, should be defined and substantiated."
- SAP ESS.11 expects that "the adequacy of the system design as the means of achieving the specified function and reliability should be demonstrated for each system."

ONR's Technical Assessment Guide on Essential Services TAG-019 (Ref. 12) provides supporting guidance. It states that:

- "The purpose of the assessment is to confirm, with regard to essential services, that the licensee can demonstrate that they possess the relevant attributes commensurate with the safety significance including capacity, duration, availability, resilience and reliability";
- "The SSC capability should exceed that necessary for the effective delivery of the safety functions in the prevailing operating environment by a clear margin (ESS.10)"; and

- "Each electrical supply source should have the capacity, duration, availability, resilience and reliability to meet the maximum demands of its dependent systems (EES.3). Electrical analysis should be carried out to ensure that the electrical supply, generators and distribution networks are capable of delivering the maximum electrical loading requirements and to determine system resilience to faults and disturbances."

Regulatory Expectations

The above section shows that the expectation that the Electrical Power System is shown to be appropriately sized and resilient to faults and disturbances is therefore not only reflected in ONR's TAG (Ref. 12), but also in IAEA Safety Guides (Ref. 9) and International Standards (Ref. 10).

ONR considers that demonstrating the appropriate rating of equipment and then confirming through analysis that the equipment responds appropriately to load sequences and plant transients is a vital aspect in validating the electrical engineering aspects of a safety case. In so doing, the studies should demonstrate the ability of the electrical power system to continue to support the necessary safety functions.

ONR's regulatory expectation is that the Requesting Party should establish a robust method for determining the ratings of electrical equipment comprising the Electrical Power System, ensuring that such equipment can operate under all postulated conditions, taking conservative decisions where uncertainty may exist.

ONR expects that the Requesting Party should then demonstrate the adequacy of the UK HPR1000 Electrical Power System through the development of a system model and the undertaking of analytical studies of the system under both steady state conditions and in response to a range of postulated disturbances, which could challenge the ability of the system to support the necessary safety functions. It is expected that such studies should consider all modes of operation including normal operation, plant shutdown, on line plant maintenance, testing of standby sources and operation from standby sources.

Where uncertainty could exist in the modelling, system data and parameters or performance requirements, ONR expects a conservative approach to be adopted in the sizing and studies, using, as appropriate, sensitivity analysis to give confidence that the uncertainties do not mask potential design shortfalls, which may not otherwise become apparent until later in the detailed design, construction or operational phase.

ONR expects that the results of any analyses are evaluated against pre-defined acceptance criteria developed from safety case requirements or relevant requirements or good practice. Where such evaluation does not demonstrate analysis, it is expected that the RP should identify and evaluate appropriate changes to the design.

References

[1] New nuclear reactors: Generic Design Assessment Guidance to Requesting Parties. ONR-GDA-GD-001. Revision 3. ONR, September 2016 www.onr.org.uk/new-reactors/ngn03.pdf

[2] New Nuclear Power Plants: Generic Design Assessment – Technical Guidance, ONR-GDA-GD-007, Revision 0, ONR, May 2019

[3] Introduction to Electrical Engineering, ONR Presentation to CGN, ONR, March 2017 [CM9 2017/81859]

[4] UK HPR1000 GDA Step 3 – Electrical Engineering Level 4 Workshop in China and UK, ONR-NR-CR-19-399, Revision 0, ONR, November 2019 [CM9 2019/363403]

[5] Requesting Party Electrical Power System Power Balance and System Study Reports

- Emergency Diesel Generator Power Balance Calculation Report, GHX05000020DEDQ45GN, Revision A, CGN, November 2019
- SBO Diesel Generator Power Balance Calculation Report, GHX05000021DEDQ45GN, Revision A, CGN, November 2019
- Mobile Diesel Generator Power Balance Calculation Report, GHX05000025DEDQ45GN, Revision A, CGN, November 2019
- Dry Transformer Power Balance Calculation Report, GHX05000023DEDQ45GN, Revision A, CGN, November 2019

- Regulating Transformer Calculation Report, GHX05000024DEDQ45GN. Revision A, CGN, November 2019
- 2h/24h Battery Power Balance Calculation Report, GHX05000022DEDQ45GN, Revision A, CGN November 2019

- Electrical Power System Studies based on BS IEC 62855:2016, GHX05000009DEDQ45GN, Revision A, CGN, December 2019
- Load Flow Studies for AC on-site Power System, GHX05000030DEDQ45GN, Revision A, CGN, December 2019
- Short-circuit and Earth Fault Studies for AC on-site Power System, GHX05000038DEDQ45GN, Revision A, CGN, December 2019
- AT/ST Transfer Studies, GHX05000031DEDQ45GN, Revision A, CGN, December 2019
- Motor Starting and Reacceleration Studies for AC On-site Power System, GHX05000032DEDQ45GN, Revision A, CGN, December 2019
- Voltage Disturbance Studies, GHX05000034DEDQ45GN, Revision A, CGN, November 2019
- Voltage Surge Studies, GHX05000036DEDQ45GN, Revision B, CGN, December 2019
- Load Sequencer Studies, GHX05000037DEDQ45GN, Revision A, CGN, December 2019
- Motor Starting and Reacceleration Studies for AC On-site Power System, GHX05000032DEDQ45GN, Revision A, CGN, December 2019
- Loss of Phase Studies, GHX05000035DEDQ45GN, Revision A, CGN, December 2019
- Ferroresonance Studies, GHX05000042DEDQ45GN, Revision B, CGN, December 2019
- Frequency Compliance Analysis Report, GHX05000029DEDQ45GN, Revision A, CGN, November 2019
- Electrical Protection Coordination Report, GHX05000017DEDQ45GN, Revision A, CGN, October 2019

- Load Flow Studies for DC and AC UPS, GHX05000039DEDQ45GN, Revision A, CGN, December 2019
- Short-Circuit and Earth Fault Studies for DC and AC UPS, GHX05000041DEDQ45GN, Revision A, CGN, December 2019
- Transient Studies for DC and AC UPS, GHX05000040DEDQ45GN, Revision A, CGN, November 2019

[6] ONR Regulatory Queries relating to Power Balance and System Studies

- Electrical System Studies – Development of Models, RQ-UKHPR1000-0628, ONR, February 2020 [CM9 2020/43288]
- Electrical System Studies – Assumptions and Acceptance Criteria, RQ-UKHPR1000-0629, ONR, February 2020 [CM9 2020/43294]
- Electrical System Studies – Studies and Interpretation, RQ-UKHPR1000-0630, ONR, February 2020 [CM9 2020/43299]
- House Load Operation Studies, RQ-UKHPR1000-0640, ONR, February 2020 [CM9 2020/56399]

[7] UK HPR1000 GDA Step 4 – Electrical Engineering Level 4 Meeting, ONR-NR-CR-19-567, Revision 0, ONR, March 2019 [CM9 2020/74659]

[8] Safety of Nuclear Power Plants: Design. Specific Safety Requirements No SSR-2/1, Rev. 1, IAEA, February 2016

[9] Design of Electrical Power Systems for Nuclear Power Plants, Specific Safety Guide SSG-34, IAEA, March 2016

[10] Nuclear power plants – Electrical power systems – Analysis, BS IEC 62855:2016, British Standards Institution

[11] Safety Assessment Principles for Nuclear Facilities. 2014 Edition Revision 1, ONR, January 2020. www.onr.org.uk/saps/saps2014.pdf

[12] Essential Services – Technical Assessment Guide, NS-TAST-GD-019 Revision 4, ONR, July 2019 http://www.onr.org.uk/operational/tech_asst_guides/index.htm

Regulatory Observation Actions

RO-UKHPR1000-0038.A1 – Develop an appropriate UK HPR1000 Electrical System Sizing and Study Strategy

In response to this Regulatory Observation Action, the RP should:

- Develop a strategy to establish the rating of electrical power supply (EPS) equipment and analyse the UK HPR1000 EPS against anticipated events and disturbances. The strategy should seek to:
    - Identify and justify how it is intended to structure the electrical system model(s) and analyse the EPS;
    - Identify how it is intended to demonstrate the verification and validation of any analytical tools (such as software) or methods it intends to use to support its analysis;
    - Identify and justify any assumptions to be made in the development of the model, underlying System, Structures and Components (SSC) parameters, and intended analysis;
    - Identify and justify the different 'study conditions' that it is intended to analyse; (The term "study condition" is used here to include, but not limited, to modes of operation, plant configurations, fault scenarios and environmental conditions)
    - Identify and justify the identification of any 'bounding cases' that are used to reduce the number of study conditions; and
    - Identify the acceptance criteria for each of the studies, explaining how these have been derived from the safety case requirements.

In developing the strategy, the RP should consider:

- How it is ensuring that where it uses different software or different models for different studies, it demonstrates that the representations of the EPS remain consistent and do not compromise any assumptions or the study results; and
- How it is demonstrating it is adopting a conservative approach when considering the design maturity of the overall UK HPR1000 design, SSC parameters and the supporting analysis.; and
- How in defining the "study conditions" it has shown traceability from the fault and hazard analyses

Resolution required by '*to be determined by General Nuclear System Resolution Plan*'

RO-UKHPR1000-0038.A2 – Analyse the UK HPR1000 Electrical Power System

In response to this Regulatory Observation Action, the RP should:

- Using the strategy developed in response to RO-UKHPR1000-0038.A1:
    - Develop the system model(s);
    - Determine the minimum electrical ratings of the EPS equipment;
    - Analyse the performance of the UK HPR1000 EPS in response to the identified "study conditions"; and
    - Analyse the results against the acceptance criteria, identifying any gaps against the extant safety case and system design.

In undertaking the sizing and analysis, the RP should consider the:

- Justification for any changes to the assumptions or acceptance criteria that have been necessary during the sizing or analyses; and
- Sensitivity of the analysis findings to uncertainties in the model data or assumptions.

Resolution required by '*to be determined by General Nuclear System Resolution Plan*'

RO-UKHPR1000-0038.A3 – Identify and manage any gaps resulting from the analysis of the UK HPR1000 Electrical Power System

In response to this Regulatory Observation Action, the RP should:

- Based on the completion of the analysis undertaken in response to RO-UKHPR1000-0038.A2:
    - Identify the implications for any shortfalls against the extant safety case arising from the

system studies; o Undertake optioneering studies to identify appropriate solutions to address those shortfalls; o Explain the implications of any modifications on the safety case, including the impact on the Electrical Power System design and the other electrical system studies; and o Explain how those modifications could be implemented and the UK HPR1000 GDA safety case updated. **Resolution required by '*to be determined by General Nuclear System Resolution Plan*'**

REQUESTING PARTY TO COMPLETE	
Actual Acknowledgement date:	
RP stated Resolution Plan agreement date:	