REGULATORY OBSERVATION

REGULATOR TO COMPLETE

RO unique no.:	RO-ABWR-0042
Date sent:	16th March 2015
Acknowledgement required by:	8th April 2015
Agreement of Resolution Plan Required by:	*To be determined by Hitachi-GE Resolution Plan*
Resolution of Regulatory Observation required by:	*To be determined by Hitachi-GE Resolution Plan*
TRIM Ref.:	2015/99947
Related RQ / RO No. and TRIM Ref. (if any)**:**	RQ-ABWR-0449 – TRIM Ref: 2015/100000
Observation title:	Probabilistic Safety Analysis (PSA) internal initiating events at power
Technical area(s) 4. PSA	**Related technical area(s)** 5. Fault Studies 13. Human Factors 10. Radiation Protection & (Level 3 PSA) 6. Control & Instrumentation 7. Electrical Power Supply

Regulatory Observation

Summary

ONR's assessment during Step 3 of GDA of the Hitachi-GE submission "Initiating Events (IE) analysis internal event PSA at power" (Ref.1) has identified shortfalls related to the traceability and completeness of the initiating events for the internal events PSA at power. The main objective of this Regulatory Observation (RO) is to state ONR's expectations related to the identification and grouping of initiating events for the UK ABWR PSA and request Hitachi-GE to respond to the shortfalls identified by ONR's review.

Background and Regulatory Expectations

ONR's assessment during Step 3 of GDA of the Hitachi-GE submission "IE analysis internal event PSA at power" (Ref.1) has identified shortfalls related to the identification and grouping of initiating events such that the traceability and completeness are not evident. The review has also identified additional concerns related to the initiating events frequencies. The general concerns identified by the review have been summarised below.

Identification of Initiating Events

Overall, Ref.1 does not provide a definition of each initiating event and its impact on the plant. In some PSAs, this information is provided in a dependency notebook, but this is not identified for the UK ABWR. Tables 5-1 and 5-2 of Ref. 1 provide some of this information but they do not address all system dependencies for all initiators. It is a relevant good practice expectation that the impact of each initiator on plant normally operating and standby systems will be documented in the PSA.

Ref.1 does not describe a systematic assessment process to identify special initiating events. Instead, the special initiators are primarily identified from outside sources. This results in a lack of clarity and accuracy regarding the justification for existing initiators as well as the completeness of initiators. ONR acknowledges that selected systems have been reviewed through Failure Mode Effects Analyses (FMEA) exercises, which is welcomed. Ref.1 also indicates that additional FMEA is being produced (e.g., as part of response to RO-ABWR 7, 8, 10) and is due in October 2015. However, this appears to be late in the process and a potential threat to timely PSA completion.

ONR expectation is that Hitachi-GE should undertake an investigation into every system in the UK ABWR list of systems to determine if they could lead to an initiating event because of system failure or spurious operation that needs to be included in the PSA. For example, FMEA for the Control and Instrumentation (C&I), Electrical Distribution System and Essential services, and other support systems (e.g. Heating Ventilating and Air Conditioning and Cooling HVAC, Reactor Cooling Water system RCW/ Reactor Service Water system RSW,

Air system, etc.) should be undertaken to support the PSA.

ONR's review has identified that a number of IEs are missing or not explicitly considered in the PSA. Specific examples have been provided to Hitachi-GE in Ref.4. It is ONR's expectation that the RP will provide a more comprehensive evaluation of the possible initiating events, demonstrate their completeness and how these are to be incorporated in the UK ABWR PSA.

Interface –System Loss of Coolant Accidents (ISLOCA) Initiating Event:

ONR review of Hitachi-GE document "ISLOCA frequency for IE PSA at power" (Ref.2) has identified that the evaluation of ISLOCA events is limited and based on simplified methods from NUREG/CR-5124. As a result both omissions and conservatisms are introduced in the analyses (which can have an impact on the risk profile), for example (this is not an exhaustive list):

- The treatment of shock failures of components due to rupture of one valve and consequential pressure shock wave effect on the second boundary valve is not currently addressed. The PSA should include appropriate modelling of combinations of the failures that include shock wave effects.
- Exclusion of blowdown of relief valves to Reactor Building.
- Ref.2 assumes pipe failure given that the low pressure pipe is exposed to reactor normal operating pressure (1000 psig). However, it is believed that the ABWR has been specifically designed such that realistic modelling of the pipe failure pressure indicates no failure of the pipe. The design of low pressure pipe such that the "realistic assessment" of the failure pressure is >1000 psig means that the pipe would likely not fail when exposed to normal operating pressure. Use of a conservative assessment of pipe over pressure failure results in a not realistic assessment. Therefore, proper accounting for this significant prevention capability is needed to provide a realistic assessment of the risk metrics.

ONR expects the approach adopted to address ISLOCA in the UK ABWR PSA is revised in line with modern standards and a more detailed analyses and documentation are developed (eg. comprehensive and justified list and description of potential ISLOCA pathways that may lead to containment bypass, complete and justified identification of failure modes, a justified approach and criteria for the identification of scenarios for detailed analysis, quantification and grouping, characterisation of uncertainty and identification of assumptions etc.).

Modelling of locations of LOCA:

The treatment of LOCA events in the UK ABWR PSA are defined in broad categories (e.g., small, medium, and large). The treatment of these events under these definitions does not fully address the adverse impact of the initiator on the plant response and mitigation capability. Specific examples are provided in Ref.4. These aspects of accident response can be both conservatively and non-conservatively affected by how these LOCAs are modelled in the PSA. Modelling more precisely the location of the LOCA in addition to the size would allow a best estimate (more realistic) modelling of the accident response.

Definition of LOCA sizes:

The definition of LOCA sizes is usually contingent upon the success criteria established to support the mitigation of the accident. This can be viewed in terms of the number of system trains required for mitigation and the timing of required response. However, the technical analysis to support the definition of the LOCA break size and their success criteria including the mission time for which the success criteria apply are not clear. For example, Ref. 1 describes the following:

- Small LOCA: The RP's accident sequence notebook (Ref.3) cites that RCIC is adequate for core cooling for a small LOCA. However, for small LOCAs, Reactor Presure Vessel (RPV) depressurization may occur or be required by containment conditions. Therefore, RCIC may not be adequate for the entire mission time.
- Large LOCA: The accident sequence notebook asserts that one Low Pressure Flooder (LPFL) pump is sufficient for core cooling without operation of any SRVs. This is usually the case for BWRs, however, thermal hydraulic calculation should be provided for the UK ABWR PSA to demonstrate this.

Conditional LOOP:

The occurrence of a sudden reactor shutdown has the potential to cause a grid disturbance that can

subsequently lead to a failure of the local grid. Therefore, it is appropriate to include a gate in the Loss of Offsite Power (LOOP) initiating event frequency characterization that combines the initiating event AND the applicable conditional LOOP probability.

While the way in which the conditional LOOP probabilities are included in the PSA has some merit as an approximation, it is considered inappropriate for modern state-of-technology PSA. For example, the approach adopted does not address the combined effect of the initiator (e.g. degraded condition such as bus failure, RSW failure, etc.) and the plant response under loss of offsite AC power. ONR expectation is that the approach to model the conditional LOOP is revised to ensure it adequately addresses:

- Conditional LOOP probability given different initiating events should be consistent with international good practice. It should be noted that the LOCA induced conditional LOOP may have a significantly higher probability than currently cited (eg. some PSA consider the conditional probability of a LOOP approximately a factor of 10 higher given a LOCA).
- The unique aspects of the plant response under LOOP or station black out conditions should be adequately treated when they arise from transient, special initiators, or LOCA initiators.
- The treatment of AC recovery following a conditional LOOP for the accident sequences initiated by transients, LOCAs, and special initiators should be adequately modelled and characterized by the recovery probability for a loss of grid event.

Grouping of Initiating Events

ONR has identified a number of cases where the process for grouping initiating events is not clear, i.e., the grouping criteria and the mapping to derive the final initiating event groups are not transparent. For example:

- The generalized support system initiating event groups (e.g., loss of Division 1 support system, loss of turbine support system) have been generally defined such that decomposing and understanding the true nature of the initiator is masked. This would likely prevent the uncovering of specific vulnerabilities. A detailed cause and effect of each initiator is not provided, which is relevant good practice expectation (refer to ONR's PSA TAG).
- Manual shutdowns can be caused by different reasons (eg. shutdown for refuel outage, forced shutdown because required equipment becomes inoperable, planned shutdown for preventative maintenance). The proposed modelling of equipment failures that cause unplanned forced manual shutdowns in the PSA does not appear to adequately incorporate degraded configuration equipment declared inoperable into the quantitative evaluation of the system response for these scenarios.

Examples of initiators that could be made more explicit or treated as separate initiating events have been provided to Hitachi-GE in Ref.4.

A "Master Logic Diagram Structure" that serves to present a concise diagram to outline the relation among IE groups and lists the sources and their contributions to that group could prove useful to reviewers and future users of the PSA. This information is already addressed in the text of the UK ABWR analysis; however, a diagram is a useful supplement.

Initiating Events Frequencies:

ONR's review of the initiating events frequencies have identified the following areas that require follow up:

- According to Ref.1, the grouping of LOOP IEs appears to be based solely on the recovery time frame (<.5h, .5 - 8h, 8 - 18h, and >18h) which is inconsistent with more typical approaches: LOOP initiators are usually grouped by the cause of the LOOP then divided into specific time frames. The causal categories are important in ensuring that the recovery probabilities and recovery times are appropriately included in the PSA. ONR expects that the approach adopted for the modelling of the LOOP in the GDA PSA for the UK ABWR is bounding in comparison to the frequencies of these causal categories for the site (or site envelop) along with their impact on recovery.
- Ref. 1 indicates that NUREG-1829 is used for the LOCA frequency estimation in the PSA. However, the justification of the adequacy of this approach is not clear as NUREG-1829 was not developed considering an ABWR plant. Rather, the NUREG-1829 frequencies represent those for BWR/2/3/4/5/6 plants.
- Ref.1 approach to address Breaks Outside Containment (BOC) frequency is not fully consistent with international good practice in BWR PSAs.

- In response to RQ-ABWR-0328, the RP has indicated that different units are used for different IE frequencies in the PSA. The intention of the RP is to convert the PSA results into calendar year basis when integrated for full scope Level 3 PSA. ONR considers that the proposed approach does not represent relevant good practice.

References:

1. HGNE COMMERCIAL - UK ABWR - GA91-9201-0003-00148 - AE-GD-0184 - Rev 2 - IE analysis internal event PSA at power
2. HGNE COMMERCIAL - UK ABWR - GA91-9201-00321 Rev 1 - AE-GD-0223 - ISLOCA frequency for IE PSA at power
3. HGNE COMMERCIAL - UK ABWR - GA91-9201-0003-00151 - Rev 3 - AE-GD-0187 -ET for Internal Event PSA at Power

RQ-ABWR-0449 - UK ABWR GDA PSA - Examples of IE identification and grouping findings. March 2015. TRIM 2015/100000.

Regulatory Observation Actions

RO-ABWR-0042.A1: Justification of the list of initiating events

1. Hitachi-GE is requested to provide adequate documentation that explains and justifies the impact of each initiator on plant normally operating and standby systems and the cause of each initiator.
2. Hitachi-GE is requested to provide the complete records of a comprehensive investigation into every system in the UK ABWR list of systems to determine if they could lead to an initiating event because of the system failure or spurious operation. ONR expectation is that this investigation will identify a comprehensive list of initiating events.
3. Hitachi-GE is requested to provide a complete list of BOC initiators.
4. Hitachi-GE is requested to explain the applicability of the identified initiators to low power conditions.
5. Hitachi-GE is requested to identify other initiating events that are unique to low power conditions (e.g., prompt criticality during start-up, high containment pressure during deinerting operation).
6. Hitachi-GE is requested to update the PSA to include a comprehensive list of initiating events, including but not limited to the initiating events identified in Ref.4.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan.

RO-ABWR-0042.A2: ISLOCA Initiating Event

Hitachi-GE is requested to provide a revised, detailed and well documented analyses and model of ISLOCA IE in line with modern standards.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan

RO-ABWR-0042.A3: Identification of the LOCA initiators by location

1. Hitachi-GE is requested to revise the basis for the LOCA initiators considering the location. This should include but not be limited to consideration of the following items:
    a. The loss of injection capability from the affected loop of Emergency Core Cooling System (ECCS).
    b. The difference in success criteria for long term core cooling.
    c. The effect of the LOCA on causing release of debris into the suppression pool.
    d. The adverse effects on mitigation capability due to a LOCA below Top Active Fuel (TAF).
2. Hitachi-GE is requested to revise the PSA to include location specific LOCA initiators, including but not

being limited to LOCA events identified in Ref.4.

3. Hitachi-GE is requested to revise the PSA to ensure that all penetrations and RPV vessel locations that could be susceptible to a LOCA are incorporated in the probabilistic framework. This should include but not be limited to penetrations identified in Ref.4.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan

RO-ABWR-0042.A4:Technical analysis to support the definition of the LOCA break size

Hitachi-GE is requested to provide the technical analysis to support the definition of the LOCA break size and their success criteria including the mission time for which the success criteria apply. This should include but not be limited to:

1. The bases for the small LOCA definition that supports the success criteria for small water and steam LOCA events.
2. The calculations supporting the definition of LLOCA at >6.2 in. dia and the evidence that a single LPFL pump can supply adequate core cooling without SRV operation.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan

RO-ABWR-0042.A5 : Treatment of Conditional LOOP

Hitachi-GE is requested to revised the conditional LOOP treatment in the PSA in line with international good practice, including:

- Conditional LOOP probability given different initiating events should be consistent with international good practice.
- The unique aspects of the plant response under LOOP or station black out conditions should be adequately treated in the PSA when they arise from transient, special initiators, or LOCA initiators.
- The treatment of AC recovery following a conditional LOOP for the accident sequences initiated by transients, LOCAs, and special initiators should be adequately modelled and characterized.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan

RO-ABWR-0042.A6 : Process for the grouping of Initiating Events

1. Hitachi-GE is requested to review the grouping of initiating events and provide a robust justification that demonstrate that:
    a. The initiating event groups have been defined in a way that vulnerabilities are not masked.
    b. Each initiating event group is clearly defined and characterised. The information provided is sufficient for the quantification of initiating event frequencies (i.e., its causes are identified) and for the development of accident sequence models (i.e., its impact on plant is stated).
2. Hitachi-GE is requested to provide a “Master Logic Diagram Structure” that serves to present a concise diagram to outline the relation among IE groups and lists the sources and their contributions to that group.
3. Hitachi-GE is requested to revise the PSA to reflect the groups defined to sub-action 1. Examples (this is not an exhaustive list) of possible initiators that could be made more explicit or treated as separate initiating events are provided in Ref.4
4. Hitachi-GE is requested to review the treatment of the equipment failures that cause unplanned forced manual shutdowns in the probabilistic model.

Resolution required by: To be determined by the Hitachi-GE Resolution Plan

RO-ABWR-0042.A7 : Initiating Events Frequencies

1. Hitachi-GE is requested to define and justify the causes of LOOP that are important to be considered in the analyses of recovery probabilities. For example, these should include but not be limited to:
    a. Loss of grid
    b. Weather
    c. Switchyard
    d. Plant Centred
    e. Off Site Common Cause Events that are not covered by the external hazards analyses for the PSA as they may not have a direct impact on the site but that would trigger a LOOP (for example seismic, space weather, flood, etc)

2. Hitachi-GE is requested to demonstrate that the LOOP model in the UK ABWR PSA for GDA is bounding in comparison to the frequencies of these causal categories for the site (or site envelop) along with their impact on recovery.

3. Hitachi-GE is requested to provide a detailed derivation of the frequencies of Breaks Outside of Containment (BOC) in line with international good practice.

4. Hitachi-GE is requested to provide the justification for using the NUREG-1829 for the LOCA frequency estimation in the PSA.

5. Hitachi-GE is requested to update the IE frequencies as necessary so the PSA is quantified in units of per calendar year (per reactor year).

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