Technical Advisory Committee of the Nuclear Risk Research Center
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SUBJECT: SUITABILITY OF MODELS FOR IKATA SITE PROBABILISTIC RISK ASSESSMENT

Dear Dr. Apostolakis:

During the first meeting of the Technical Advisory Committee of the Nuclear Risk Research Center (NRRC), October 27-31, 2014, we met with representatives of Shikoku Electric Power Company, Inc. and their contractor, Mitsubishi Heavy Industries, Ltd. (MHI) to review the probabilistic risk assessment (PRA) models for Ikata Unit 3. The purpose of our review was to determine the suitability of the available models to serve as a basis for the NRRC's planned PRA for the Ikata site.

Due to scheduling conflicts, only three of our members were present at the meetings on this topic. This report provides the consensus conclusions and recommendations from members Amir Afzali, Nilesh Chokshi, and John Stetkar. Because a majority quorum of our membership did not participate in the deliberations on this topic and concur with our conclusions and recommendations, this report should be treated as a minority opinion that has not benefitted from consideration by the full Committee.

CONCLUSIONS AND RECOMMENDATIONS

1. The event sequence models that have been developed to support the planned restart of Ikata Unit 3 do not represent the as-built, as-operated plant; will not provide a realistic assessment of the risk from that unit; and cannot be used to identify the contributors to that risk. Those models are not technically suitable as the foundation for a full-scope PRA. They should not be used in the NRRC project.

2. The event sequence models that have been developed to support the Ikata Unit 3 Periodic Safety Review (PSR) process should be used as the technical foundation for eventual development of a full-scope Level 2 PRA.

3. To fully confirm the technical scope and depth of the existing PSR PRA event sequence models, the NRRC project team should perform an in-depth review of each event tree, including:

    - Event sequence branching logic
    - Success criteria for each top event, and their technical justification
    - Scope of the system models for each top event
    - Definitions and scenario context for each modeled post-initiator human action
    - All modeling assumptions and simplifications

4. The NRRC project team should examine differences in the designs, normal system configurations, and operating practices at Ikata Unit 2 and Unit 3. The team should confirm that the Unit 2 event sequence models, initiating events, and system models are developed to the same technical scope and depth as those for Unit 3, and accurately portray the respective plant-specific features of that unit.

5. Based on our limited review of the PSR PRA models, we have also identified the following items that merit additional attention:

    - The list of internal initiating events does not include a complete set of plant-specific support system failures such as loss of power at individual or multiple AC buses or DC buses, partial losses of cooling water systems, loss of instrument air, losses of room cooling or ventilation, etc. A systematic and thorough evaluation of all systems at each unit should be performed to identify failures that will cause an automatic plant shutdown or require a rapid manual shutdown.

    - Initiating event frequencies, equipment failure rates, and equipment maintenance unavailabilities should consistently account for Ikata plant-specific operating experience.

    - Ikata plant personnel should be actively involved in the development and review of the PRA models. Examples include:
        - Experienced senior licensed operators should confirm that the event sequence models accurately represent expected plant response and that each operator action is consistent with current plant-specific procedural guidance, training, and practical feasibility.
        - Ikata plant risk analysts should participate actively in all major technical tasks to ensure that they are personally familiar with the methods, models, and analysis techniques, and can use the PRA as a tool to support decision making throughout the plant organization.

BACKGROUND

An important NRRC objective is to support the development of a plant-specific Level 2 PRA for a multi-unit site that initially evaluates the risk from internal initiating events, seismic events, and tsunamis during plant power operation. The eventual goal is to extend that PRA to include a full-scope Level 3 evaluation of the risk from all internal events, all external hazards, and all major site radiological sources during all operating modes for all units at the site. The PRA models and supporting analyses will be developed according to the current international state-of-practice in PRA methods, models, and technical quality.

Shikoku Electric Power Company, Inc. has agreed that this PRA will be performed for the Ikata site, and it is cooperating with NRRC as a partner in this project. The scope of the PRA is currently focused on Unit 2 and Unit 3.

The Committee will perform periodic reviews of all technical tasks in the PRA, its supporting analyses, and results, and report its conclusions and recommendations to the NRRC project team. To promote efficiency and optimize available resources, it is advantageous to use existing Ikata models and analyses as a starting point for this project, to the extent that they are technically suitable. This report provides our observations, conclusions, and recommendations from a very limited review of the event trees, initiating events, and selected success criteria for the available Ikata Unit 3 PRA models. The intent of this review was to determine whether those models provide an adequate foundation for the first NRRC project tasks.

DISCUSSION

We were informed that two sets of models are currently available for Ikata Unit 3. A set of Level 2 PRA models for internal initiating events was developed several years ago and has been maintained and updated as necessary to support the PSR process. Another set of models, henceforth referred to as the restart models, was developed more recently for the specific purpose of complying with regulatory requirements for the planned restart of the Ikata units.

Restart Models

It was explained that these models are intended to identify "design extension" scenarios. They contain only systems and functions that are explicitly credited in the Ikata licensing design basis accident analyses. They do not include "accident management" measures, design enhancements that have evolved from the Fukushima accident lessons learned, or other emergency response measures. These models are not technically suitable as the foundation for a full-scope PRA. Due to their artificial restrictions and applied assumptions, they cannot provide a realistic assessment of the risk from Ikata Unit 3, the contributors to that risk, or an integrated evaluation of the effectiveness of proposed severe accident management functions and associated personnel actions. Some examples of the bases for our conclusions are:

- The models do not include personnel actions and functions such as feed and bleed cooling, active secondary cooldown, active reduction of reactor coolant system pressure, and alternate long-term core cooling alignments that can have an important effect on overall risk and the contributions from specific initiating events. These actions and functions use existing plant equipment, are included in the plant Emergency Operating Procedures, and are covered by current operator training programs. However, they are curiously characterized as "accident management measures" and are therefore excluded from the models. This interpretation is not consistent with the common international understanding of accident management measures. Because of these limitations, the restart models cannot appropriately characterize the realistic contributions to core damage and potential offsite releases. Therefore, they cannot adequately assess the actual effectiveness of proposed additional equipment and personnel actions that are intended to reduce risk.

- The event sequence models for transient initiating events that occur during power operation are overly simplified and do not account for the as-built, as-operated plant configuration.

- The event sequence models for almost all events that occur during plant shutdown modes contain no evaluation of any possible accident prevention or mitigation functions.

These limitations and stylized assumptions are fundamentally contrary to the scientific principles and technical rigor of a systematic and comprehensive assessment of risk and its contributors. Therefore, these models should not be characterized as a "probabilistic risk assessment". They should not be used in the NRRC project.

PSR PRA Models

The scope of functions, systems, personnel actions, and the level of event sequence delineation in the models that were developed to support the Ikata Unit 3 PSR process are much more consistent with international PRA practice than the restart models that are discussed above. The PSR PRA models contain alternatives for primary and secondary heat removal, reactor coolant system pressure control, and reactor coolant system makeup that are consistent with installed plant equipment and personnel guidance in the Emergency Operating Procedures. For example, they include main feedwater and auxiliary feedwater makeup to the steam generators, feed and bleed cooling, active secondary cooldown and primary pressure reduction, evaluations of high pressure and low pressure injection and recirculation possibilities during LOCA scenarios, and alternative long-term heat removal through the Containment fan coolers. Additionally, they include expanded models for loss of offsite power, steam generator tube rupture, loss of component cooling water, interfacing system LOCAs, and ATWS scenarios. The low power and shutdown models include multiple options for reactor vessel makeup and core decay heat removal. The Level 2 PRA models evaluate Containment isolation, heat removal, and pressure control, and they assess major phenomenological issues associated with in-vessel and ex-vessel accident progression. These models should be used as the technical foundation for the NRRC project.

During our very brief review of these models, we raised a few questions about details of the logic in some event trees, possible inconsistencies in some success criteria or assumptions, and potential premature termination of some event scenarios before stable long-term core cooling conditions are assured. Insufficient time was available during this meeting for an adequate examination of these selected issues or a systematic review of each event tree. Therefore, to fully confirm the technical scope and depth of these event sequence models, the NRRC project team should perform an in-depth review of each event tree, addressing the items in our recommendations.

The event sequence models that were discussed during this meeting were presented as applicable to Ikata Unit 3. We did not have an opportunity to examine any models that apply for Unit 2. Since the units have different designs, different power ratings, and were constructed approximately 14 years apart, it is likely that some elements of the Unit 2 PRA models and success criteria are different from those for Unit 3. Therefore, to support a site-level PRA that includes realistic models for both units, the NRRC project team should examine differences in the designs, normal system configurations, and operating practices at Ikata Unit 2 and Unit 3. The team should confirm that the Unit 2 event sequence models, initiating events, and system models are developed to the same technical scope and depth as those for Unit 3, and accurately portray the respective plant-specific features of that unit.

After the existing baseline event sequence models are reviewed and refined, the NRRC project team should consider expanding and enhancing the models to systematically include additional consequential failures and associated scenarios that are evaluated in contemporary full-scope PRAs. These include conditions such as transient-induced losses of offsite power, excessive cooling through stuck-open secondary steam release paths, consistent assessment of reactor coolant pump seal failures, and LOCAs that are caused by imbalances between charging and letdown flows (e.g., through the pressurizer relief valves or through an unisolated letdown line).

Other Topics

The list of internal initiating events that are currently quantified in the Ikata Unit 3 PRA is small and generic in nature. With the exception of a general category for Loss of Component Cooling Water / Sea Water, the list does not contain any initiating events that are caused by partial or total failures of plant-specific support systems. In fact, even the category of Loss of Component Cooling Water / Sea Water may inappropriately combine two potentially important initiating events with different functional impacts. Experience from numerous contemporary PRAs has shown that failures of support systems can be important to overall plant risk. State-of-the-practice PRAs contain a systematic and comprehensive search for failures of these systems that can cause an initiating event, functionally disable accident mitigation equipment, and affect personnel performance. Examples of these failures include losses of power at individual or multiple AC buses or DC buses, partial losses of cooling water systems, loss of instrument air, losses of room cooling or ventilation, etc. Identification of these events, quantification of their frequencies, and determination of their functional impacts depends on very specific features of the plant design and its operating configurations, and they cannot be evaluated realistically by reference to a tabulation of generic initiators. Omission of these initiating events is a potentially significant deficiency in the scope and technical quality of the overall PRA. A systematic and thorough evaluation of all support systems at each unit should be performed.

Initiating event frequencies and equipment failure rates have been quantified primarily using generic data from Japanese industry operating experience and, in some cases, operating experience from the United States or selected research reports. State-of-the-practice methods, such as Bayesian techniques, should be used to consistently combine Ikata Unit 2 and Unit 3 plant-specific operating experience data with the generic estimates to more realistically quantify expected performance at each unit. Use of plant-specific data is especially important for evaluating the unavailability of equipment due to planned maintenance, corrective maintenance, and any other condition that requires a component to be removed from normal service. For example, a component may be removed from service for inspection, troubleshooting of an unusual noise, upgrades and modifications, prevention of personnel injuries during nearby work, or many other reasons that are not directly related to a functional failure. Actual operating experience data compiled from plants throughout the world has demonstrated that the Ikata PRA practice of multiplying the component failure rate by the Technical Specifications allowed outage time can substantially underestimate actual component unavailabilities. Therefore, the NRRC team should compile Ikata plant-specific data that account for all causes for equipment unavailability, without restricting those causes to a narrow interpretation of "maintenance".

International experience has shown that the technical quality, realism, and practical use of a PRA depend very strongly on active involvement of plant personnel in its development, maintenance, and applications. Use of the PRA for effective risk-informed decision making can be best achieved only when plant personnel have direct working technical knowledge and personal responsibility for the risk models, data, and analysis techniques. This will assure that the PRA accurately represents the as-built, as-operated facility. Additionally, communications of plant-specific risk insights and information to regulatory authorities and the public is most effective when it is accomplished by the "owner" of the risk models, who has a fundamental understanding of plant engineering, operations, and maintenance. Therefore, as the PRA models and analyses are extended and refined, it is essential that Ikata plant personnel should be actively involved in their development and review.

Examples of specific involvement during the extension of the existing PSR PRA models include:

- Experienced senior licensed operators should confirm that the event sequence models accurately represent expected plant response and that each operator action is consistent with current plant-specific procedural guidance, training, and practical feasibility.

- Ikata plant risk analysts should participate actively in all major technical tasks and be familiar with the methods, models, and analysis techniques.

We look forward to continuing our review of this benchmark NRRC project and its key technical tasks as it evolves toward a state-of-the-practice full-scope PRA.

Sincerely,

John W. Stetkar

John W. Stetkar
Chairman

REFERENCES

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2. "Ikata Unit 3 Level 1 PRA, At-Power with Accident Management," MHI Presentation to NRRC Technical Advisory Committee, October 28, 2014, Proprietary.

3. "Ikata Unit 3 Level 1 PRA, Low Power and Shutdown with Accident Management," MHI Presentation to NRRC Technical Advisory Committee, October 28, 2014, Proprietary.

4. "Ikata Unit 3 Level 2 PRA, Event Trees with Accident Management," MHI Presentation to NRRC Technical Advisory Committee, October 28, 2014, Proprietary.

5. "Ikata Unit 3 Level 2 PRA, Table No. 4.2.6-3, C/V Event Tree Branching Probability," MHI Presentation to NRRC Technical Advisory Committee, October 28, 2014, Proprietary.