Consideration for PRA configuration control program at KEPCO's nuclear power plants

Koki Tawa[a*], Kensuke Toyoshima[a], Hiroaki Yoshikawa[a], Takamasa Kurokawa[a], Ryusei Ogawa[b], Kenichiro Ikuno[b], Takeshi Numata[b]
[a] Nuclear Engineering, Ltd., Osaka, Japan
[b] The Kansai Electric Power Co., Inc., Osaka, Japan

Abstract: For restart of Nuclear Power Plants (NPPs), KEPCO has been implementing measures to improve the plant safety, including the installation of severe accident countermeasures, in compliance with the new regulatory requirements established incorporating the lessons learned from the severe accident at Fukushima Daiichi induced by off the Pacific coast of Tohoku Earthquake in 2011. At the NPPs that have resumed operation after the Fukushima accident, the Probabilistic Risk Assessment (PRA) Model has been developed and the effectiveness of the countermeasures has been confirmed in the evaluations of safety improvement measures. In addition, Risk-Informed Decision Making (RIDM) approach for the management of the nuclear power plants has been incorporated into the management of the power plants [1]. In RIDM, it is necessary to implement PRA based on the inputs (e.g., the latest plant design) at the time of decision-making. For this purpose, it is necessary to track plant changes continuously, and reflect inputs into the PRA models when any changes would be able to affect PRA, such as PRA models and RIDM applications. KEPCO has been working on the PRA configuration control program to maintain and manage the PRA models for continuous implementation of RIDM, and this paper describes the current status of the study.

Keywords: PRA, Configuration Control Program, RIDM

1. Introduction

The Kansai Electric Power Co., Inc. (hereinafter referred to as "KEPCO") is working on the improvement of the plant safety by installing severe accident countermeasures. In addition, we are quantitatively evaluating the effectiveness of our severe accident countermeasures through the development of a PRA model. Furthermore, we are continuously reviewing equipment modifications and accidental response procedures in order to promote safety improvements even after restarting operations. Therefore, it is necessary to establish a PRA configuration control program in order to conduct risk assessment based on the latest plant status (as-built, as-operated) and use the assessment results for decision making.

2. Results of the study of the PRA configuration control program

2.1. Results of the Study of the overview of the PRA configuration control program

First, we developed the overview of the PRA configuration control program. The overall flow diagram of the PRA configuration control program is shown in Figure 1.
The implementation items for each step in Figure 1 are as follows.

(1) Collection of PRA update requests
This is the process of collecting information related to the PRA model and determining whether or not it affects the PRA. Through this work, requirements that need to be reflected in the PRA (hereinafter referred to as "PRA update requests") will be analyzed in detail in the next step.

(2) Analysis for PRA Update Requests
This is the process of analyzing the necessary modifications to be made to the current PRA model based on the collected PRA update requests. Additionally, in this step, we organize the criteria for planning the timing of updating the PRA model. The criteria to be organized include the following items:
- Quantitative impact of reflecting the PRA model
- The amount of work required to reflect the PRA model

(3) Development of PRA update plan
This is the process of determining the priorities of PRA update requests to be reflected in the current PRA model based on the analysis results from previous step.

(4) Updating the PRA model
This is the process of updating PRA model according to the established PRA update plan.

(5) Updating PRA application
This is the process of updating PRA applications that use the evaluation results of PRA model.

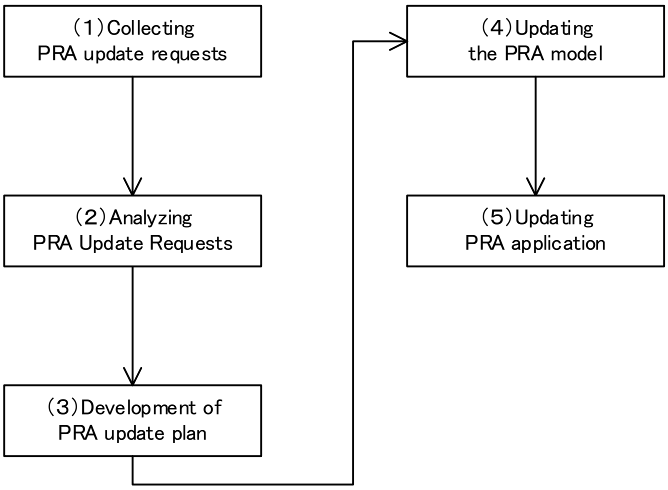

Figure 1. Overall flow of PRA maintenance program

2.2. Results of the Study of the Methodology for Collecting PRA update requests

In performing the PRA configuration control program, it is necessary to identify the information that serves as input to the PRA model in advance and clearly define the process for collecting the identified information. It is also important to maintain a traceable state of the process until the collected information is reflected in the PRA model. However, it is difficult to clearly identify all information sources and clarify the information collection process prior to the start of the configuration control process, because the input information for a PRA is diverse and different departments and organizations have different responsibilities for different types of information. Therefore, the study focused on plant information (e.g., design information and revised accident procedures) among all the information that will be used as inputs to the PRA.

Examples of plant information used in the PRA model include piping and instrumentation diagram, single-wire electrical diagrams, and logic diagrams used for system reliability analysis, and accident procedures used for human reliability analysis. It is not realistic for the department in charge of PRA to track each piece of document change and analyze its impact on the PRA model. Therefore, we considered a method to efficiently collect information by collaborating with multiple departments and screen out information with no impact on the PRA focusing on information that requires detailed analysis, which is then handed over to the department in charge of PRA. The results of the investigation on information collection methods are shown in Figure 2. Additionally, the implementation items for each step in the information collection flow are shown below:

(a)Advance Preparation
A diagram (Figure 3) showing the scope of PRA modeling in the system chart is created and shared between the department in charge of construction and the department in charge of PRA.

(b) Screening by the department in charge of construction
During the construction planning phase, the department in charge of construction checks whether or not the construction site is included in the diagram indicating the scope of PRA modeling. If the construction site is included within the scope of PRA modeling, the next step is taken.

(c) Detailed analysis by the department in charge of PRA
The PRA department obtains from the construction department the documents and changes that will be made as a result of the construction. The PRA department will review the changes to analyze whether or not modifications to the PRA model are necessary. If it is determined that the PRA model needs to be modified, steps are taken to manage the items that should be reflected in the PRA model in the future (hereinafter referred to as PRA update requests).

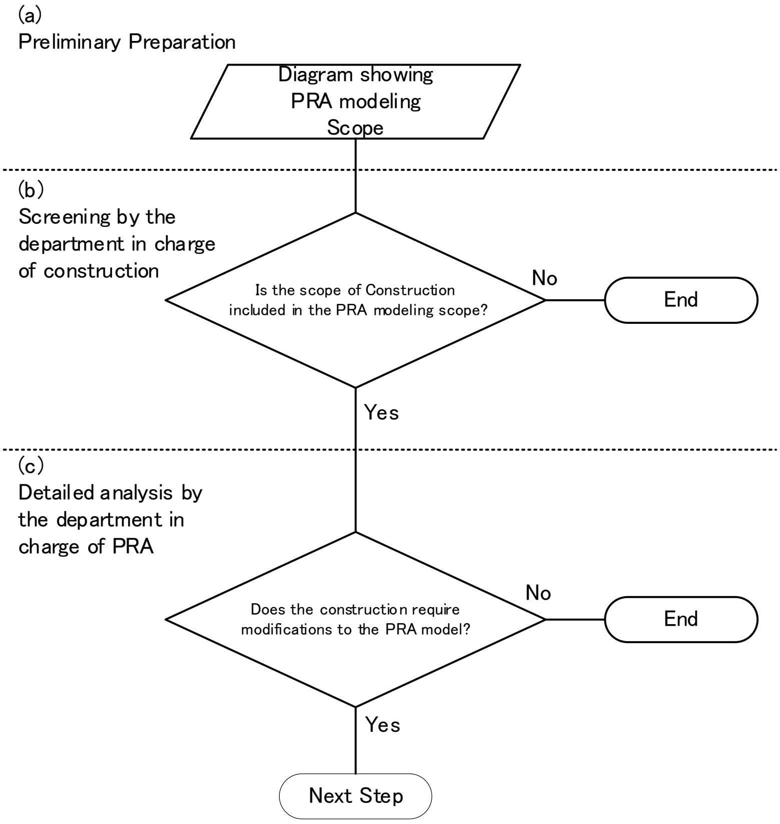

Figure 2. Plant information collection flow

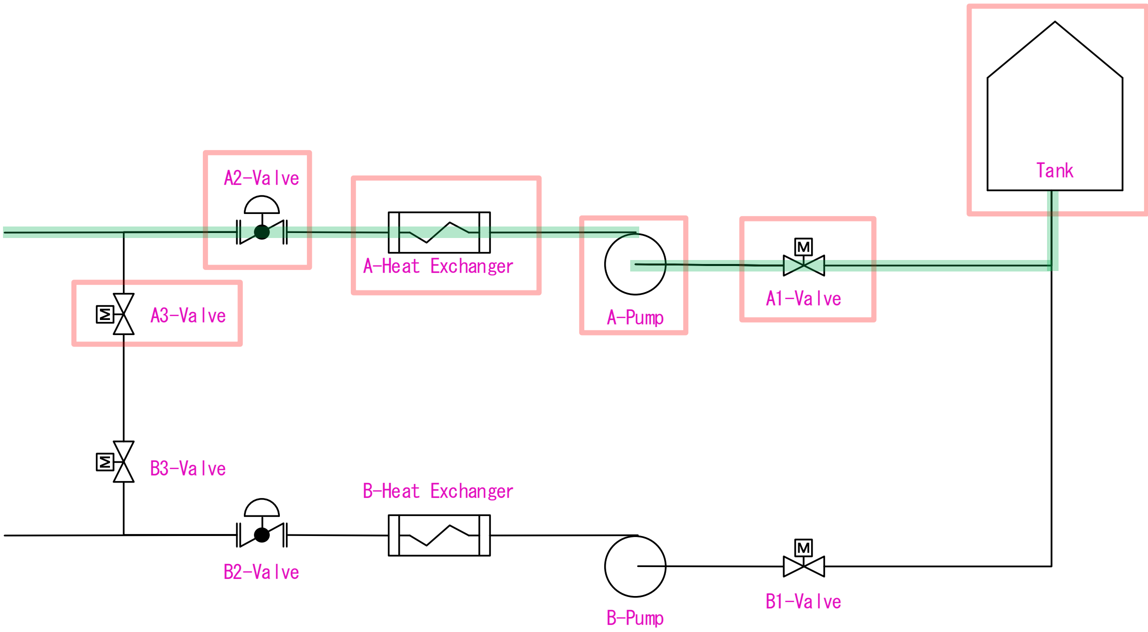

Figure 3. Image of a diagram showing the modelling scope in the PRA

This information gathering process has the following advantages.

- It reduces the burden on the PRA department by narrowing down the subjects that need to be analyzed in detail.
- The screening process by the construction department can be simplified to reduce the increased burden on existing operations.

This method of information collection has been in operation since before the start of the PRA configuration control program, establishing an efficient method of collecting plant information.

2.3. Results of the study on how to analyze the PRA update request

In the previous step, information was collected to identify items that may affect the PRA model. However, it is not realistic to immediately reflect the collected information in the PRA model from the viewpoint of man-hours required to revise the PRA model. Therefore, we considered introducing a work step to analyze the risk impact of reflecting the collected information in the PRA model (hereinafter referred to as "risk impact") and the level of cost required for modifying the PRA model and organizing the evidence (hereinafter referred to as "level of cost"). In addition, when developing a schedule for updating the PRA model in a later step, we considered categorizing the work based on the risk impact level and the level of cost to create an efficient schedule. Considering the possibility that the categorization itself may increase man-hours and that the classification work may not work out because a lot of information is categorized in a high-priority group, the criteria of risk impact at the start of the PRA configuration control program are set as shown in Table 1. The CDF/CFF values corresponding to Risk Impact “High” in Table 1 are set with reference to Implementation Standard Concerning Risk-Informed Decision Making for Continuous Safety Improvement of Nuclear Power Plants : 2019 [2]. It is planned to optimize the criteria of risk impact by accumulating findings through the practical operation of the PRA configuration control program.

Table 1. Criteria of risk impact and modeling cost

Risk Impact	Critical	• If PRA users determine that special priority should be given to updates. • If an upgrade is required to support the application.
	High	• If there is an increase in CDF of 10^{-6} (/reactor year) or more, or if there is a high probability of such an increase. • If there is an increase in CFF of 10^{-7} (/reactor year) or more, or if there is a high probability of such an increase. • If there are changes in the top 20 cut sets of CDF or CFF, or if there is a high probability of such changes (in the direction of CDF/CFF increase).
	Medium	• If there is an increase in CDF of 10^{-7} (/reactor year) or more, or if there is a high probability of such an increase. • If there is an increase in CFF of 10^{-8} (/reactor year) or more, or if there is a high probability of such an increase. • If there is a decrease in CDF of 10^{-6} (/reactor year) or more, or if there is a high probability of such a decrease. • If there is a decrease in CFF of 10^{-7} (/reactor year) or more, or if there is a high probability of such a decrease. • If there are changes in the top 20 cut sets of CDF or CFF, or if there is a high probability of such changes (in the direction of CDF/CFF decrease). • If there are changes in the top 20 cut sets within specific initiating events, PDS, POS, or containment function loss modes, or if there is a high probability of such changes (in the direction of CDF/CFF increase).
	Low	• Other than the above.
Cost	High	• If the work hours required for modeling and/or evidence development exceed one month.
	Medium	• If the work hours required for modeling and/or evidence development range from one week to one month.
	Low	• If the work hours required for modeling and/or evidence development are within one week.

2.4. Results of the study on how to develop a PRA update schedule

In this step, for each PRA update request categorized based on risk impact and level of cost in the previous step, the time of starting/completing the work to reflect the PRA update request in the PRA model will be set; the time when the Safety Assessment Report (hereinafter referred to as "SAR") is filed can be used as a reference for determining the time of completing the work to reflect the PRA update request in the PRA model. By calculating backward the period until the next SAR and selecting PRA update requests that can be implemented, the peak of PRA model modification work can be suppressed. Also, by planning to modify the PRA model on an ongoing basis, it is expected to update the knowledge of the PRA model.

2.5. Results of the Study of PRA Model Update Methods

In this step, the PRA model will be revised, evidences will be organized, and the PRA documents will be revised based on the schedule established in the previous step. It is also important to record the reflected items by correlating the version of the PRA model and PRA documents; in the initial phase of the PRA configuration control program, records will be kept in the spreadsheet format, but we will consider creating a database in the future.

2.6. Results of the study on how to update the PRA application

In this step, the various PRA-based applications will be updated based on the PRA results updated in the previous step.

3. Identification of issues based on analysis of U.S. standards

The Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications [3] has been published to define the requirements to be incorporated into a PRA configuration control program. A survey of the requirements of this standard reveals the following points that need to be considered.
- Establishing the scope of monitoring changes in PRA technology and industry experience and the frequency of information gathering
- Establishing a process for collecting information affecting external events
- Consideration of the criteria for update requests in light of their impact on risk applications

4. Future prospects

As described in the above, we have worked on the study as the advance preparation for the launch of the PRA configuration control program. In order to furthermore enhance the PRA configuration control program, we should pursue more intensive studies about the following issues:
- Further upgrading of the PRA configuration control program through repeated trials, identification of areas for improvement, and recursive implementation of the practice cycle.
- PRA update requests are managed in the spreadsheet format at this stage, but in order to cope with the number of requests that will accumulate in the future, it is necessary to consider the creation of a database and the introduction of management tools.

5. Conclusion

In order to establish a complete PRA configuration control program, KEPCO has studied the overview of the PRA configuration control program. Prior to the introduction of the PRA configuration control program, KEPCO studied the method of collecting plant information and conducted information gathering. In the future, based the preliminary PRA configuration control program established in the study, it is planned to reflect the collected information in the PRA model. For items for which detailed analysis was difficult, we will accumulate knowledge gained through actual application of the preliminary PRA configuration control program and improve the PRA configuration control program on a continuous basis with the aim of improving its effectiveness.

References

[1] FEPC, “Status of efforts on strategic planning and developing action plans for achieving risk-informed decision making”, December 2023
[2] Atomic Energy Society of Japan, “Implementation Standard Concerning Risk-Informed Decision Making for Continuous Safety Improvement of Nuclear Power Plants : 2019(AESJ-SC-S012:2019)”, 2020
[3] The American Society of Mechanical Engineers, “Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications”, 2022