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Development of Risk Monitoring Models for New Optimized Power Reactors

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1. Introduction

Since the accident of TMI (Three Mile Island) nuclear power plant in 1979, PSA (Probabilistic Safety Assessment) has been widely applied to ensuring the safety of a nuclear power plant. To ensure the increased use of PSA, US NRC (Nuclear Regulatory Commission) developed the PSA Implementation Plan, which would use risk information resulting from PSA in regulatory activities. And, 10CFR50.65(a)(4)[1] requires the licensees of nuclear power plants to conduct risk assessments before performing maintenance activities covered by the maintenance rule and to manage the increase in risk that may result from the proposed activities.

In Korea, KHNP performed Level 1 and 2 PSA and developed risk monitoring models for the 20 operating nuclear power plants by 2007, based on the severe accident policy implementation plan in 2001. The risk monitoring models are used to conduct risk assessments before performing maintenance activities and to evaluate the risk reflecting the current plant configuration. KHNP has managed the risk monitoring models in spite of not being under the regulation of the maintenance rule. After that, three new optimized power reactors have been operated since 2011 and one more reactor is waiting for its commercial operation. Therefore, KHNP has developed the risk monitoring models for these 4 reactors. This paper presents the new models.

2. Method and Results

2.1 Review of the PSA models and configurations

The PSA models[2][3] of new reactors consist of event trees and fault trees using house events and recovery rules, of which concept is similar to that of the previous models. Some changes were, however, identified because of the different design concept in several systems and the depth of modelling. Table 1 shows the differences in design concept. Related to the depth of modelling, the following systems were newly considered in the PSA models.

- Digital Plant Control System
- Condensate System
- Circulating Water System

To develop the models which could evaluate the configuration risk, we reviewed the system operation procedures and operation experiences. The following eight systems were selected for configuration risk monitoring.

- CVCS (Chemical and Volume Control System)
- CCW (Component Cooling Water system)
- ESW (Essential Service Water system)
- TBCCW (TG Building Closed Cooling Water)
- IA (Instrument Air) / CD (Condensate System)
- ECW (Essential Chilled Water system)
- CW (Circulating Water system)

Table 1. Difference in the design concept

	New Reactors	**Previous ones**
AFW	Using Tie line 4 Pumps (50% ; each)	Train isolation 4 Pumps (100% ; each)
CCW & ESW	Using Tie line in normal operation mode	Train isolation
ECW	Using Tie line in winter season	Train isolation
CS	No heat exchanger	One heat exchanger
RPS & ESFAS	Digital based modelling	Analogue based modelling

* AFW: Aux. Feed Water system / CS: Containment Spray system
* RPS: Reactor Protection System
* ESFAS: Engineered Safety Features Actuation System

2.2 Characteristics of risk monitoring models

The risk monitoring models were developed as the format of one large fault tree in order to evaluate the risk impacts quickly. For this, the event trees of the PSA models were reconstructed as the format of a fault tree. The basic event presenting a tag number was added per a sequence causing core damage to consider recovery actions. Figure 1 shows the reconstructed fault tree. And, the fault trees of the PSA models were connected to the failure or success gate of the new fault tree to build one top model.

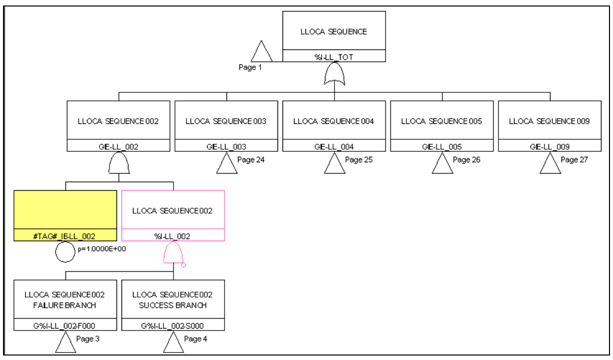

Fig. 1. Fault tree generated by using an event tree

For the eight systems mentioned in chapter 2.1, additional configurations should be modeled to the basic configuration considered in the PSA models. Figure 2 shows the added configuration for the condensate system. While the house events were used in the PSA models to reduce the size of fault trees, they could not be used in one top model. So, the fault trees including a house event should be modified by using an initial event, changing a gate name, etc.

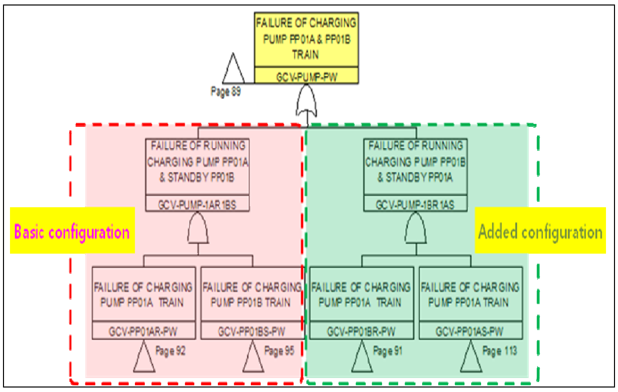

Fig. 2. Example of configuration model for CVCS

2.3 Verification and evaluation of the risk monitoring models

It is necessary to verify the risk monitoring models from two aspects. One is to review that the additional configurations are properly modeled and the results are evaluated correctly. The other is to compare the risk evaluation results from between the PSA model and the risk monitoring model. In this step, all the scenarios causing core damage were reviewed as well as total CDF (core damage frequency).

After the verification of the risk monitoring models, the value of the basic events for test and maintenance should be set to zero. It is because the risk monitoring models could evaluate the actual risk reflecting the current plant status. Therefore, the CDF from the PSA models is a little higher than the CDF from the risk monitoring models with no maintenance activities.

The four new reactors have the same design concept. However, the component cooling water system and the essential service water system are differently operated from the design concept in the two reactors of the four. It means that the tie lines of the systems are not used in normal operation mode in the two reactors. It gives a little difference in CDF.

3. Conclusions

KHNP has managed the risk monitoring models for 20 operating nuclear power plants since 2007 in spite of not being under the regulation of the maintenance rule. According to constructing and operating the new optimized power reactors, the new risk monitoring models should be developed. To develop the models, the PSA models were reviewed and compared with the PSA models of the existing reactors. Some differences were identified in design concept and the level of modeling depth. All the possible configurations were surveyed, and the risk monitoring models considering all the configurations were developed based on the PSA models. These risk monitoring models have been applied to configuration management according to the commercial operation of the new reactors. And, the models would be maintained and updated continuously.

REFERENCES

[1] U.S. NRC, 10 CFR Part 50: Domestic Licensing of Production and Utilization Facilities, Washington, DC.
[2] KHNP, Probabilistic Safety Assessment Report and Model of the reference plant, 2010.
[3] KHNP, Probabilistic Safety Assessment Report and Model of the reference plant, 2011.