Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2011

PSA Model Improvement Using Maintenance Rule Function Mapping

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1. Introduction

The Maintenance Rule (MR) program, in nature, is a performance-based program. Therefore, the risk information derived from the Probabilistic Safety Assessment model is introduced into the MR program during the Safety Significance determination and Performance Criteria selection processes. However, this process also facilitates the determination of the vulnerabilities in currently utilized PSA models and offers means of improving them.

To find vulnerabilities in an existing PSA model, an initial review determines whether the safety-related MR functions are included in the PSA model. Because safety-related MR functions are related to accident prevention and mitigation, it is generally necessary for them to be included in the PSA model.

In the process of determining the safety significance of each functions, quantitative risk importance levels are determined through a process known as PSA model basic event mapping to MR functions. During this process, it is common for some inadequate and overlooked models to be uncovered.

In this paper, the PSA model and the MR program of Wolsong Unit 1 were used as references.

2. Finding Vulnerabilities and Improvement of PSA Model

In this section, the method to find the vulnerabilities of the PSA model is described.

2.1 Comparison with MR Function Analysis

The first step of the MR program development is a function analysis. During this step, all functions of the target plant are identified and then classified as Safety-Related (SR), Non-Safety-Related (NSR), or Out-of-Scope functions. The SR function is divided into three categories as follows [1]:

1) SR-1: related to the integrity of the reactor coolant pressure boundary
2) SR-2: signifying that it is necessary to shut down the reactor and maintain it in a safe shutdown condition
3) SR-3: signifying the need to prevent or mitigate the consequences of accidents that may result in incidences of potential offsite exposure comparable to that outlined in the 10CFR100 specification

Generally, the PSA model considers a number of basic events that are important to accident prevention and mitigation. Therefore, it is necessary for most of the functions evaluated as SR-1, 2, or 3 in the MR program to be modeled in the PSA.

According to this concept, we examined whether the SR functions are modeled in the PSA model properly.

Among the total 667 functions of Wolsong Unit 1, the SR functions are 160 functions. In addition, among the 160 SR functions, 46 SR functions are not modeled in the current Wolsong Unit 1 PSA model from the viewpoint of the MR function analysis [2]. The reasons for excluding the PSA model are detailed below.

(1) Forty SR functions are not modeled because their functions are out of the PSA scope (e.g., the function of manual valve forming containment extension, functions related to the spent fuel bay and the fuel changing machine)
(2) Two SR functions are modeled only in terms of operator action
(3) Two SR functions are related to initiating events and special basic events

For these 44 functions, it was judged that the reasons for exclusion from the PSA model were appropriate. However, it should be noted that two additional functions should be reviewed. These are outlined below.

(1) 34610-03, Emergency makeup function of the RCS: acording to the opinion by the PSA model developer, this function is described in the design manual but not confirmed in the Emergency Operation Procedures or publications. Moreover, it was judged that an injection into the RCS is impossible considering the RCS pressure during a LOCA event. Therfore, this function is excluded in the PSA model.
(2) 43230-04 - Backward flow prevention of the feedwater system: in case the main feedwater pump stops, the MOVs on the feedwater line and check valves 4323-V1, V2, V3, and V4 are closed. Considering the status of the water in the feedwater line and other check valves, there is no possibility of a backward flow. Thus, this function is excluded in the PSA model

2.2 PSA Basic Event Mapping

During the process of determining the safety significance of each functions, the quantitative risk importance level is typically determined via a PSA model basic event as selected by cutoff value mapping to MR functions. However, in this study, to find PSA model vulnerabilities, all of the basic events in the Wolsong 1 PSA model are mapped to MR functions.

As a result of this mapping, three types of improvement items were derived, as outlined below.

1) The names of 30 basic events were required to be revised according to the naming rules [3]; this problem mainly applies to I&C model basic events. For example, the basic event of "63432-LT08K Loop Unavailable due to T&M" is modeled as "ECCIM-63432-L08K." However, the description of "L08K" does not adhere to the PSA BE naming rule. Therefore, this basic event should be renamed as "ECCIM-63432-LT08K."
2) Errors with 13 basic events made by the PSA model developer were uncovered and were immediately corrected. For example, the transfer closed failure mode for the manual inlet valve 4321-P103 was modeled as "CDVVT-4321-V109" and mapped into "43210-04 Aux. condensate water supply function." However, the actual name of that valve is 4321-V019. Additionally, "temperature transmitter 63432 TT204K fails transfer closed" is modeled as "ECPTY-63432-TT204K" and mapped into "34320-05 LOCA automatic detection function." This basic event, however, should be corrected to "ECTTY-63432-TT204K" because "PT" denotes the pressure transmitter.
3) It was necessary to reconfirm 32 basic events. Of these 21 basic events related to 9 relays were mapped into the "68211-01 Reactivity test logic function," which is an out-of-scope function. In the PSA model, these relays were considered as the final relays that provide the control rod insertion signal. If this is true, the function analysis of 68211-01 should be revised, making it a scope function. Moreover, the test rectifiers 5561-RF5A & 5C and related facilities were modeled in the PSA, but the MR functions related to those facilities are not defined because the simple test facility is outside the scope of the MR. Therefore, reconfirmation of the functions of 5561-RF5A & 5C and the related facilities should be performed, after which the appropriate revision should be done from the PSA or MR side. Several other cases should be confirmed as to whether the associated facilities actually exist. For example, 5290-DS9 was analyzed as component included in Wolsong Unit 2, but this component was modeled in the Wolsong Unit 1 PSA model.

Among the three types of improvement items, the first two items were relatively simple cases which could be corrected directly. On the other hand, for the items in the last category, because modification of the PSA model or an MR function analysis may occur, appropriate confirmations and/or additional fundamental considerations are required..

3. Conclusions

Generally it is known that the PSA and MR have a complementary relationship. The PSA provides risk information to the MR program, and the MR program makes the PSA model more robust. In the previously developed MR program, the vulnerabilities of the PSA model uncovered during the development of the MR program were limited because the focus was on determining the vulnerabilities only associated with the PSA mapping process given that not all of the basic events were mapped.

In this study, to find the vulnerabilities of the current PSA model more rigorously, we used the two different approaches. First, we compared the SR function defined in the MR function analysis with the PSA model, although the objectives of the MR and the PSA are different. Second, we mapped all of the basic events of the Wolsong Unit 1 PSA model to the MR functions of Wolsong Unit 1. As a result of these processes, we found a greater number of vulnerabilities in the current PSA model as well as a number of missing points of the MR functions analysis.

Because finding the vulnerabilities of PSA model and improving it are essential to the PSA quality improvement process and to the Risk-Informed Application process, this study concludes that the MR program is a good tool to achieve these goals.

REFERENCES

[1] Nuclear Management and Resource Council, NUMARC 93-01, Rev. 3, "Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," July, 2000.

[2] Second-Year Interim Report for "Maintenance Effectiveness Monitoring Program Development for Wolsong Unit 1&2 and Methodology Improvement Study," KHNP, 2011. 6.

[3] Draft Report for "Probabilistic Safety Assessment for Wolsong Unit 1", KHNP, 2011. 6.