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A Study on Developing a PSA based Integrated Framework for Maintenance Rule and MSPI

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1. Introduction

U.S Maintenance Rule(MR)[1], which became effective in July 1996 in U.S.A, will be adopted in Korea within a few years. Mitigating Systems Performance Index(MSPI)[2] will be adopted in U.S.A from 2006 as a performance indicator for the Reactor Oversight Process(ROP)[3]. However, although both MR and MSPI are somewhat based on Probabilistic Safety Assessment(PSA), currently, they are not well integrated with each other.

U.S MR was developed around 1991, and at that time, PSA was not so well known by the maintenance engineers of Nuclear Power Plants(NPPs). Thus, the Performance Criteria(PC) of the MR was not fully determined by PSA at that time and neither is it at present. Of course, MR focuses on the maintenance effectiveness while PSA focuses on the safety of the systems and components.

Since MSPI could be fully based on the PSA, if MR could be based on PSA, MR and MSPI could be integrated well based on PSA.

This paper proposes a new method which integrates MR and MSPI with each other.

2. Methods and Results

In the current framework, MR Reliability Performance Criteria(RPC) and Availability Performance Criteria(APC) are related to a components' reliability DB rather than being based on PSA. For example, RPC is based on the number of failures detected by the test.

Let's compare the current method with the proposed new method by using the illustrative AFWS example.

2.1 The Conventional MR Method

At first, let's review the current method for the RPC and APC of the AFWS Motor Driven Pump(MDP) train for UCN 3.

- The probability of 'fail to start' of AFWS MDP(=AFMPS01AA) is '7.069E-3' and the pump is tested 18 times for 3 years.
- By assuming a binomial distribution, the failure probability is: P(0)=0.880, P(1)=0.1128, P(2)=0.0068 . Thus, RPC= 1.
- The AFWS MDP 'UNAVAILABLE DUE TO T&M' (= AFMPM01AA) is 6.29E-4:

  6.29E-4 yr/yr = 0.62day/3yr/ MP train
- Actual APC is 9days/3yr/MDP train by considering the maintenance period and the failures of the other components.

2.2 The Proposed MR Method

The following is how to derive RPC and APC based on PSA for the AFWS Motor Driven Pump(MDP) train by using AIMS[4].

Step 1. Identification of the top event for the AFWS Motor Driven Pump(MDP) train using AIMS. 'GAFSTR-AA' is the top event as shown in Figure 1.

Step 2. Quantification of the top event by using FTREX of AIMS.

Step 3. By using the sensitivity module of AIMS, neglect the supporting system events. Figure 1 shows the sensitivity module.

Step 4. By setting the maintenance unavailability '0', the unreliability of the train is derived.

Step 5. The maintenance unavailability is the difference value before and after applying step 4.

The quantification results of the top event 'GAFSTR-AA' after applying steps 3 and 4 are changed from 5.53E-2 to 2.64E-2 as shown in Figure 2. Thus, the unreliability of the AFWS Motor Driven Pump(MDP) train is 2.64E-2 and the maintenance unavailability is 3.4E-3 (= 2.98E-2 – 2.64E-2). Thus, these two values could be used for the RPC and APC in the new MR framework, and they can be easily used for the following MSPI.

$$MSPI = W_A (UA_C - UA_B) + W_R (UR_C - UR_B)$$

where, W_A= Availability Risk Worth

W_R= Reliability Risk Worth

UA = Unavailability

UR = Unreliability

However, since APC and RPC are constructed to be easily understood by the plant engineers in the current MR, and since the purpose of MR is to check the maintenance effectiveness by monitoring the number of failures, the new unreliability and the new maintenance unavailability may be further modified as below.

Step 1. By the assumption that when a main component(usually pump) is tested, the train is also tested, the RPC for the train can be derived. For example, since the number of AFW MDP test exposures is 18 for the two refueling cycles, the possible failure number of the train is:

$$2.64E\text{-}2 \times 18 = 0.475 = \lambda T$$

By assuming the Poisson distribution,

$$P(n) = [(\lambda T)^n e^{-\lambda T}]/n!$$

$$P(0) = e^{-0.475} = 0.62$$

$$P(1) = 0.30,\ P(2) = 0.07,\ P(3) = 0.01,\ \ldots$$

Thus, RPC for GAFSTR-AA is 1.

Step 2. By using the maintenance unavailability of the train, the APC for the train can be similarly calculated as it is done in the current MR framework.

Step 3. When a component fails, if the failure significantly affects the unreliability or maintenance unavailability of the train to which the component belongs, then the event can be counted as one failure for the RPC or APC of the train. If it is not so, the failure could be counted separately as one failure for the RPC or APC for the component.

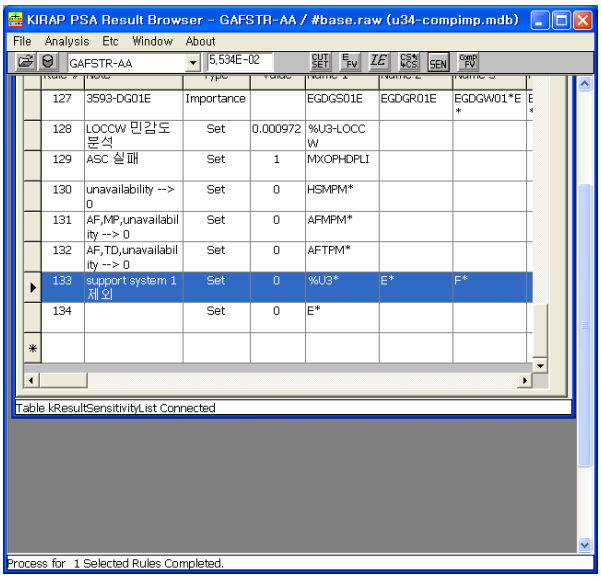

Figure 1. Sensitivity Analysis by Using Rules.

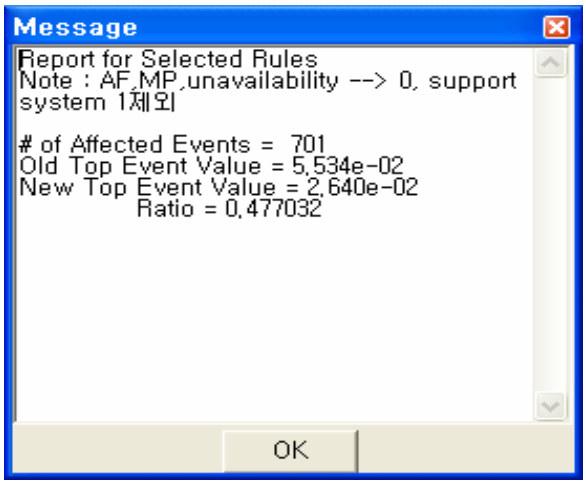

Figure 2.The Quantification Results After Deleting Supporting Systems and Setting the Maintenance Term '0'

3. Conclusions

The benefit of the new framework for MR is to closely integrate MR and MSPI based on PSA. In the conventional MR, the failures among the components within the same train do not make differences. It only counts the number of failures if the failures mean the MR function failures. However, in the new framework, only the failures of important components within the same train are counted as failures for RPC or APC of the train. The importance of the components is determined by the changed amount in the train unreliability and maintenance unavailability when the components fail. Thus, it is not necessary to check whether or not the failure belongs to the MR function failure when a component fails.

Acknowledgement

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REFERENCES

[1] NRC, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants", 10CFR 50.65, July 1991.

[2]. NEI, Mitigating Systems Performance Index, NEI 99-02, Appendix F, Revision N, January, 2005

[3] NRC, Recommendations for Reactor Oversight Process Improvements, SECY-99-007, Jan. 1999

[4] S.H. Kim, S.H. Han, "The Development of an Advanced Information management System(AIMS)", The Conference of Korea Nuclear Society, Oct. 2005