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Evaluation of Risk Metrics for KHNP Reference Plants Using the Latest Plant Specific Data

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1. Introduction

As Risk-Informed Applications (RIAs) are actively implemented in the nuclear industry, an issue associated with the technical adequacy of the Probabilistic Safety Assessment (PSA) arises in its data sources. The American Society of Mechanical Engineers (ASME) PRA standard [1] suggests the use of component failure data that represent the as-built and as-operated plant conditions. Furthermore, the peer reviews for the KHNP reference plants stated that the component failure data should be updated to reflect the latest plant specific data available [2].

For ensuring the technical adequacy in PSA data elements, we try to update component failure data to reflect the as-operated plant conditions, and a trend analysis of the failure data is implemented. In addition, by applying the updated failure data to the PSA models of the KHNP reference plants, the risk metrics of Core Damage Frequency (CDF) and Large Early Release Frequency (LERF) are evaluated.

2. Method and Results

2.1 Analysis method of component failure data

To improve the technical adequacy of the PSA models used in the KHNP reference plants, the component failure data were analyzed using the Bayesian method [3] with generic data from the Advanced Light Water Reactor Utility Requirements Document (ALWR URD) [4] and plant specific data. In the analysis, the generic data of the ALWR URD were assumed to have a lognormal distribution and used as the prior distribution. Also, the plant specific data were used as the likelihood function.

The number of component failures in the KHNP reference plants was examined in conjunction with the number of total demands or total running times. Using these data, the failure probability and rate representing the plant specific data were evaluated. To perform the Bayesian analysis, the failure probability representing the demand failure was assumed to have a binomial distribution, and the failure rate that signified a running failure was assumed to have a Poisson distribution. The error factors of the distributions also referred to NUREG/CR-4639 [5] and NUREG/CR-5500 [6].

2.2 Trend analysis of component failure data

In the previous PSA models of the KHNP reference plants, the plant specific data collected from 1991 to June 2002 were used to evaluate the component failure data. Guidance-PSA-01 [7] recommends that the PSA models of KHNP nuclear power plants should be revised every five years. Accordingly, the latest plant specific data collected from July 2002 to June 2007 were analyzed in this study.

In the PSA models of the KHNP reference plants, the component failure data are composed of thirty-seven types of components and fifty-eight failure modes. Among these data, Table 1 shows the failure data of the main components. In Table 1, Rev. 0 and Rev. 1 present the previous failure data and the updated failure data, respectively. As a result of reflecting the latest plant specific data, more than 85 % of the component failure data showed a decreasing trend.

Table I: Bayesian results of failure rate/probability

Component	Failure Mode	Rev. 0*	Rev. 1**	Increase Rate
AFW Pump (MDP)	Fail to start	1.23E-03	9.89E-04	-19.6%
AFW Pump (MDP)	Fail to run	1.42E-04	1.39E-04	-2.1%
AFW Pump (TDP)	Fail to start	3.17E-03	2.84E-03	-10.4%
AFW Pump (TDP)	Fail to run	1.40E-03	1.29E-03	-7.9%
CCW Pump	Fail to start	1.78E-03	1.43E-03	-19.7%
CCW Pump	Fail to run	1.92E-06	1.60E-06	-16.7%
CS Pump	Fail to start	8.69E-03	6.53E-03	-24.9%
CS Pump	Fail to run	1.75E-03	1.58E-03	-9.7%
SI Pump	Fail to start	4.37E-03	3.35E-03	-23.3%
SI Pump	Fail to run	1.78E-05	1.28E-05	-28.1%
RHR Pump	Fail to start	1.27E-03	1.10E-03	-13.4%
RHR Pump	Fail to run	1.06E-05	1.06E-05	0.0%
NSCW Pump	Fail to start	2.39E-03	1.87E-03	-21.8%
NSCW Pump	Fail to run	4.64E-06	3.46E-06	-25.4%
ECW Pump	Fail to start	6.90E-03	5.27E-03	-23.6%
ECW Pump	Fail to run	1.02E-04	8.84E-05	-13.3%
Central Chiller	Fail to start	8.23E-02	5.94E-02	-27.8%
Central Chiller	Fail to run	2.13E-04	2.01E-04	-5.6%
Essential Chiller	Fail to start	2.21E-02	1.58E-02	-28.5%
Essential Chiller	Fail to run	9.29E-04	1.03E-03	10.9%
Diesel Generator	Fail to start	3.52E-03	4.54E-03	29.0%
Diesel Generator	Fail to run	9.82E-04	7.30E-04	-25.7%
IA Compressor	Fail to start	9.80E-02	7.59E-02	-22.6%
IA Compressor	Fail to run	8.39E-05	5.80E-05	-30.9%

*: Using the plant specific data from 1991 to June 2002
**: Using the plant specific data from 1991 to June 2007

A trend analysis of the failure data of the main components in Table 1 was performed using combined unreliability (UR) [8] which is shown in Eq. (1).

$$Combined\ UR = P_{FTS} + P_{FTR} \quad Mission\ Time \qquad (1)$$

In this equation, P_{FTS} is the probability of a fail to start and P_{FTR} is the rate of a fail to run. In order to calculate the P_{FTR}, the mission time was assumed to be 24 hours.

As shown in Fig. 1, all the combined UR of Rev. 1 was evaluated lower than that of Rev. 0, which means that the reliability of the main component is improved. It could be considered that the recent maintenance processes and procedures have been systematically and properly managed and operated.

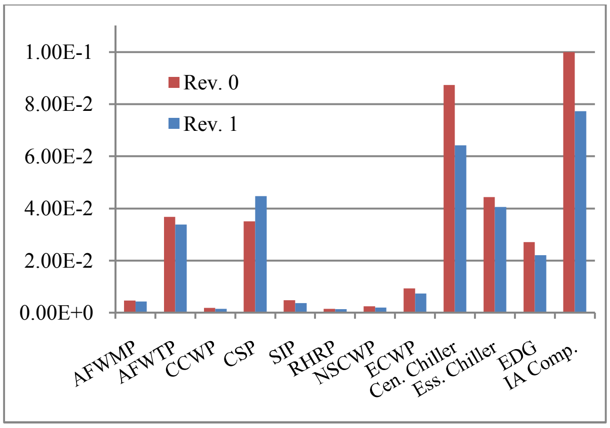

Fig. 1. Trends of the combined UR of the main components.

2.3 Comparison of risk metrics

Applying the new component failure data to the PSA models, the risk metrics such as CDF and LERF of the KHNP reference plants were evaluated and compared. Table 2 shows the CDF and LERF with the decrease rates.

Table : Comparison of the CDF and LERF between the previous PSA models and the revised PSA models.

Risk Metrics	Rev. 0	Rev. 1	Decrease Rate
CDF	1.19E-05	1.11E-05	6.72%
LERF	2.24E-06	2.04E-06	8.93%

Note: The units for CDF and LERF are events per a reactor year.

According to reflecting the latest plant specific data on the PSA models of the KHNP reference plants, the reliability of the main components was improved as described above. It resulted in a decrease of the risk metrics. The CDF and LERF decreased by 6.72 percent and 8.93 percent, respectively.

3. Conclusions

The component failure data were updated using the latest plant specific data of the KHNP reference plants. To evaluate the component failure data, the plant specific data were combined with the generic data from the ALWR URD through a Bayesian analysis. The updated failure data showed improved results with respect to component reliability.

By applying the new component failure data to the PSA models of the KHNP reference plants, the CDF and LERF as risk metrics of the plants were estimated. As a result of reflecting the latest plant specific data on the component failure data, both of CDF and LERF decreased. When revising the PSA models of the other KHNP plants, the analysis method in this paper could be applied to the updating of the component failure data.

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