

## Development of an Enhanced Uncertainty Analysis for the Level 2 PSA Results

Baehyeuk Kwon<sup>a\*</sup>, Inchul Ryu<sup>b</sup>, Changhwan Lim<sup>b</sup>

<sup>a, b</sup>KEPCO-E&C, 269 Hyeoksin-ro, Gimcheon-si, Gyeongsangbuk-do 39660, Republic of Korea

\*Corresponding author: [kbh1@kepc0-enc.com](mailto:kbh1@kepc0-enc.com)

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### 1. Introduction

Currently, the Saeul units 3 and 4 NPPs (Nuclear Power Plants) under construction are the first domestic nuclear power plants which the PSA (Probabilistic Safety Assessment) of level of ASME/ANS PRA Standard Capability Category II (CC-II) [1] is being performed. Accordingly, various efforts are being made to improve the quality of PSA in accordance with the ASME/ANS PRA Std. CC-II.

As part of these efforts, an enhanced uncertainty analysis method for the Level 2 Probabilistic Safety Assessment (PSA) results [Large Early Release Frequency (LERF), Containment Failure Frequency (CFF), etc] was developed in this task.

### 2. Methods and Results

This section describes the tasks performed to enhance the existing uncertainty analysis method for the Level 2 PSA results using SAREX (Safety and Reliability Evaluation eXpert) software program developed by KEPCO-E&C.

For the enhanced uncertainty analysis of the Level 2 PSA results, the SAREX software program was upgraded from version 1.3 to version 2.0 by KEPCO-E&C. In addition, uncertainty analysis of the CET/DET (Containment Event Tree / Decomposition Event Tree) in the Level 2 PSA was performed based on realistic or plant-specific information, and the structure of the CET/DET model was improved [2], to meet the supporting requirements for ASME/ANS PRA Std. CC-II.

This section presents the key developments implemented to perform the enhanced uncertainty analysis of the Level 2 PSA results.

#### 2.1 Comparison of Uncertainty Analysis Approached

Both the existing and enhanced uncertainty analyses for the Level 2 PSA results were performed using the Monte-Carlo method, and the differences between the two approaches are presented in Table 1.

Table I: Comparison Between Existing and Enhanced Uncertainty Analyses Methods for Level 2 PSA Results

Category	Existing	Enhanced
Sampling method	Monte-Carlo method	Monte-Carlo method
Uncertainty analysis	[Step 1] : Branch probabilities of each DET in the CET	[Step 1] : Quantified Cutsets of the PDSET <sup>1)</sup> (with Database) [Step 2] : Grouping using PDSGLD <sup>2)</sup> [Step 3] : Branch probability of DET
Applied Distribution	Discrete Distribution (only)	Lognormal, Beta, Gamma, Constant., etc
Software program	SAREX 1.3	SAREX 2.0
Database	.MDB	.DBS
Note. 1) PDSET – Plant Damage State Event Tree 2) PDSGLD – Plant Damage State Grouping Logic Diagram		

In the existing approach, uncertainty analysis is performed only on the DET branch probabilities in the CET using SAREX 1.3, with discrete distribution assumed.

In the enhanced uncertainty analysis approach based on SAREX 2.0, quantified PDSET's Cutsets incorporating database-based distributions are grouped using PDSGLD, and uncertainty analysis is performed by propagating these grouped Cutsets through the CET with the corresponding DET branch probabilities. In this process, the probability distributions (Lognormal, Beta, Gamma, Constant., etc) of the DET branch probabilities can be user-defined.

#### 2.2 Definition of distribution of DET branch probability

In this task, probability distributions were determined for the engineering judgment-based branch probabilities derived from the uncertainty analysis based on plant-specific information, rather than from conventional reference-based engineering judgment, as follows.

- The branch probability values are assumed as the 'Mean' [3].

- The branch probabilities are assumed as Log-normal Distribution [4].
- The Error Factor (EF) is assumed as the maximum integer value within the range of 1 to 10, such that the 95th percentile probability does not exceed '1.0' [5].
- For branch probability values in the case of system unavailability, uncertainty analysis was performed using Monte-Carlo sampling based on the modeled Fault Tree (FT). The resulting data were then used to apply the Range Factor (RF) and to determine the Error Factor (EF) values, assuming a Log-normal distribution [6].

$$RF = \sqrt{95 \text{ percentile} / 5 \text{ percentile}}$$

### 2.3 Input of DET Branch Probability Distributions in SAREX

For the enhanced uncertainty analysis, the SAREX software program was updated to enable the input of distribution for DET branch probabilities, as shown in the example below.

- General input rules

'UNCER_DIST_NAME' 'MEAN_VALUE' 'PAR1' 'PAR2'
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- Distribution input example

[Lognormal distribution]
: LOGNORMAL mean_value EF dummy
: LOGNORMAL 1.E-3 10. 0.0
[BETA distribution]
: BETA mean_value dummy1 dummy2
: BETA 1.0E-3 2 10
[GAMMA distribution]
: GAMMA mean_value dummy1 dummy2
: GAMMA 1.0E-3 2 10
[Constant]
: CONST const_value dummy1 dummy2
: CONST 0.0 0.0 0.0

### 3. Conclusions

The uncertainty analysis in the Level 2 PSA was performed only for the DET branch probabilities within CET. Accordingly, to perform an uncertainty analysis at level of ASME/ANS PRA Standard Capability Category II (CC-II), this study updated the SAREX software program and established criteria for determining the distributions of DET branch probabilities, enabling an uncertainty analysis based on the quantitative results (with Cutsets of PDSET) of the Level 2 PSA. The enhanced uncertainty analysis method for Level 2 PSA results presented in this paper is expected to contribute to the review and evaluation of Level 2 PSA results for domestic operating NPPs and newly constructed NPPs.

### REFERENCES

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