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Sampling Methods for Uncertainty Analysis Using MAAP5

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1. Introduction

The evaluations of physical phenomena of severe accident by using available computer code model has inherent limitations in accuracy and precision. There are uncertainties that limit the capability of any model to predict how a core damage accident will evolve and those make it difficult to draw appropriate conclusions with only a single scenario simulation. Therefore, the probabilistic assessment is necessary considering their uncertainties.

This paper focuses on the sampling methods to make uncertainty analysis more efficient. 2 different sampling methods are reviewed. One is Monte-Carlo (random) Sampling (MCS) which is independent of the other variables. The other is Latin Hypercube Sampling (LHS) which is a sampling method that provides sufficient reliability with smaller size of samples.

2. Methods

2.1 Accident Scenario

Assuming 6-inch coldleg LOCA of APR1400 according to the LLOCA assessment of Level 2 PSA, the passive SITs are operated by pre-setting pressure and then the active safety injection system failure leads to core damage. (Figure 1)

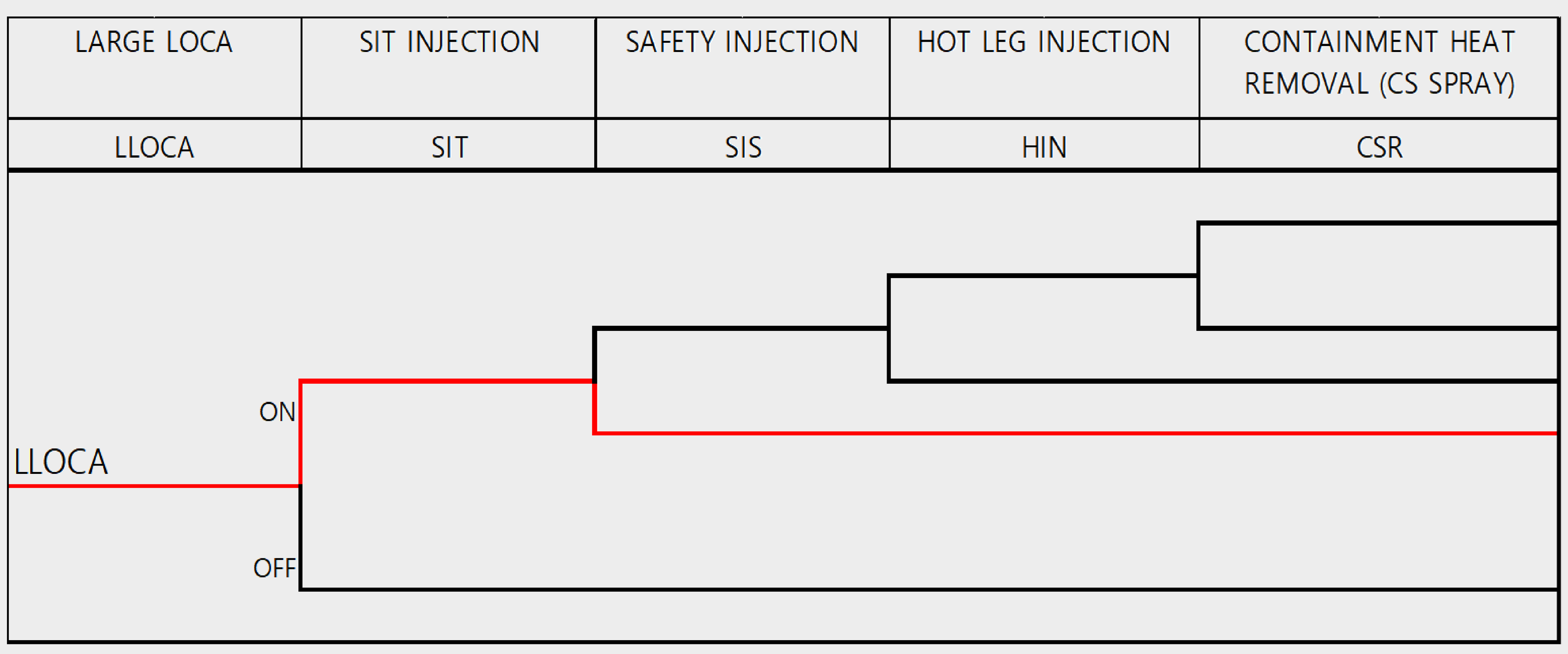

Fig. 1. Event Tree for Selected LLOCA Scenario.

For the combination of MAAP5 inputs in Table 1[1], it is assumed that the parameters follow triangular distributions with the recommended values as the peak. Because triangular distributions are simple and easy to apply but, can balance the min-max probabilities effectively.

Table 1. Some Input Parameters for Uncertainty Analysis

Parameters	Recommended	MIN	MAX
FFRICX	0.25	0	1
TCLMAX	2500	100	3000
LMCOL0	53	48	54
EPSCUT	0.1	0	0.25
EPSCU2	0.2	0.001	0.35
FGBYPA	1	0	1
…	…	…	…
FACT	0.3	0.1	1
TOTAL	42		

2.2 Monte-Carlo (Random) Sampling

Monte-Carlo sampling is a simple random sampling method. Each selection of a variable is independent of the others. Because each sample doesn't affect the other samples, the distribution would be easily concentrated on the mode.

2.3 Latin Hypercube Sampling

LHS, proposed by McKay et al in 1979[2], is a method designed for more even extraction than random sampling, dividing each S_1, S_2, … and S_K into N probability sections in the entire population S to make the entire S into N_K rooms and extract one point from each of the different rooms, but extract one point from each of the selected N points into each section of the S_t.

The sampling is relatively even and may show the same accuracy with fewer samples statistically than random sampling.

Based on work by Wilks [3], for two-sided statistical tolerance intervals, the minimum number of random samples required is given by the equation (1):

$$1 - a^N - N(1-a)a^{N-1} \geq b \quad (1)$$

where N is the number of samples and b×100 is the confidence level (%) that the maximum result will not be exceeded with the probability a×100 (%) of the corresponding output distribution. This formula yields 93 required samples to have a 95% confidence level that the code results encompass the 5th and 95th percentile of the population.

In this study, the sample size is chosen as 100 so that it can have tolerance interval of 95 percent or more.

3. Results

The core exit temperature (CET) after the initial event is calculated in this study and the spectra of core damage time are evaluated according to the sampling methods. Based on the time core damage, the results of 100 analyses, highlighting 5%, 50%, and 95%, are as follows.

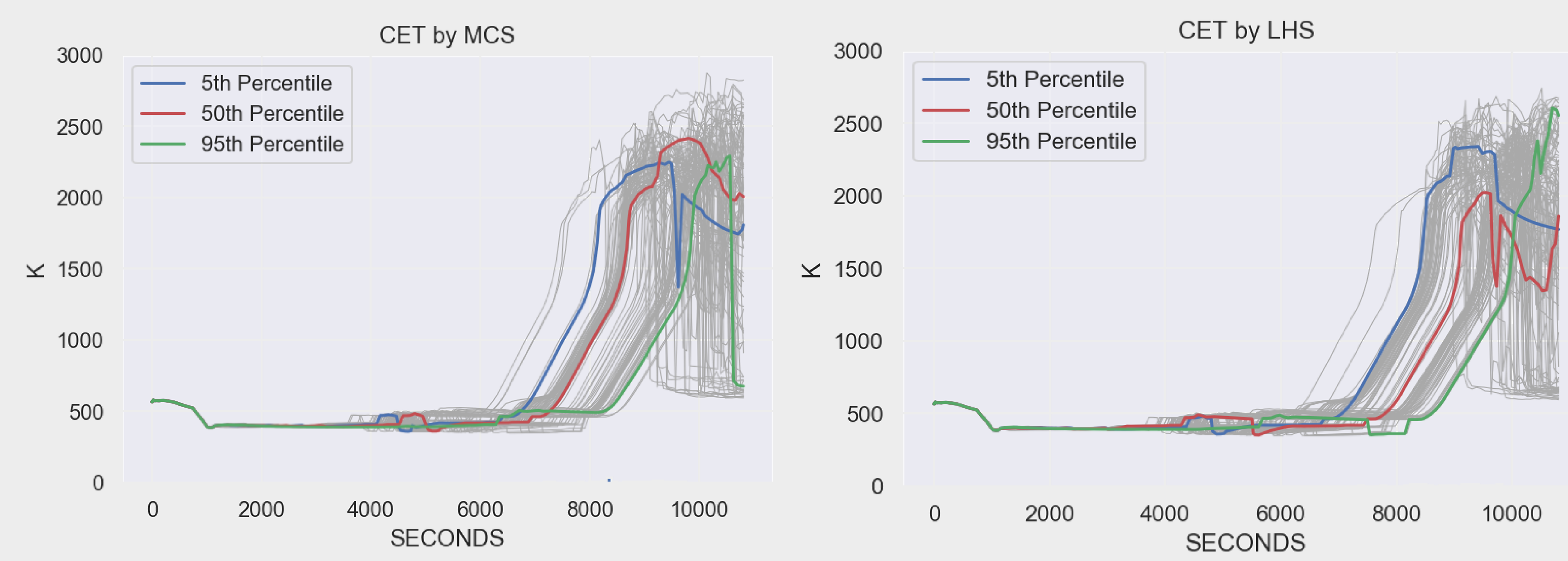

Fig. 2. CET Uncertainty Analysis, by MCS and LHS

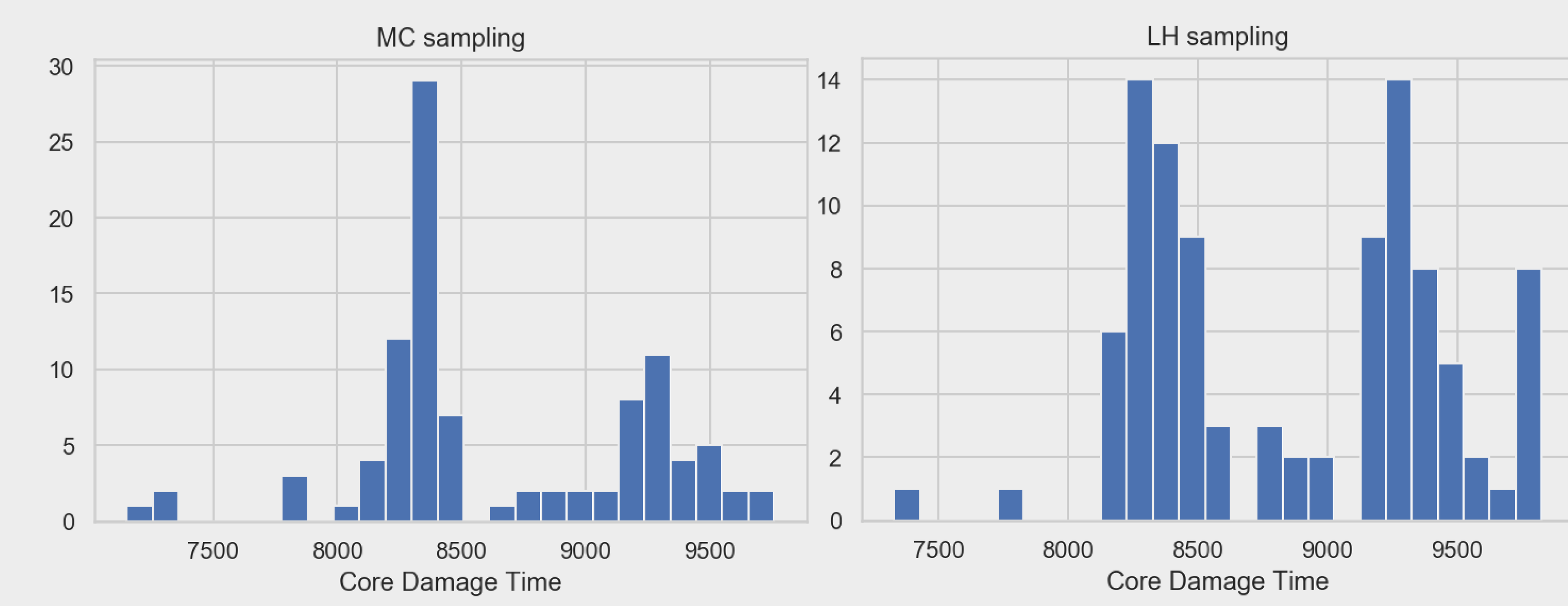

Fig. 3. Core Damage Time Distribution by MCS and LHS

4. Conclusions

As expected, the LHS method is able to cover the general range of results, while the MCS method concentrates on relatively narrow ranges.

This confirmed that the random sampling method requires a larger number of samples in order to take greater reliability in the uncertainty analysis.

Despite the core damage occurred at 9,819 seconds in the analysis using the recommended combination of parameters, the MCS range doesn't include this result. In addition, most uncertainty analysis results indicate earlier core damage time, indicating that uncertainty analysis is essential for a more conservative evaluation.

A further study will be performed to expand the calculation after core damage to analyze uncertainty about various phenomena throughout severe accidents, such as core relocation time, corium generation, and vessel failure time. And it will be used as data for operator decision making in case of severe accident.

REFERENCES

[1] Electric Power Research Institute, Inc., MAAP 5 User's manual, 2008.
[2] M. D. McKay, R. J. Beckman, W. J. Conover, A Comparison of Three Methods for Selecting Values of Input Variables in the Analysis of Output from a Computer Code, Los Alamos Scientific Laboratory, 1979
[3] S. S. Wilks, Princeton University, Determination of Sample Sizes for Setting Tolerance Limits, The Annals of Mathematical Statistics, Vol. 12, No. 1 (Mar., 1941), pp. 91-96, 1942