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Comparative Evaluation of Realistic and Deterministic Approach for Secondary System Piping Break Accidents

Cheol Shin Lee, Shin Whan Kim, and Jong Tae Seo
Korea Power Engineering Company, Inc., 150 Deokjin-dong, Yuseong-gu, Daejeon, 305-353
cslee@kopec.co.kr

1. Introduction

During the recent years, there has been an increasing tendency to replace the conservative deterministic evaluation model calculations with realistic best estimate calculations supplemented by uncertainty quantification method. Recently, some efforts have been made for non-LOCA transient analyses. In this study, a realistic evaluation methodology, CABUE technique, was applied to the analyses of SLB and FLB accidents for UCN 3&4, and their results were compared against the existing licensing calculation results. Based on the comparison, the potential benefits of using the CABUE technique are presented. In addition, several sensitivity studies were performed to identify parameters and assumptions which have significant impact on the calculation results.

2. Evaluation Methodology

2.1 Code Accuracy Based Uncertainty Evaluation (CABUE)

The CABUE technique is an uncertainty quantification method newly developed by Korea Electric Power Research Institute (KEPRI) for the application to the safety analysis for Westinghouse 3-loop nuclear power plants. Compared with the Code Scaling Applicability and Uncertainty (CSAU) method, which has been a general guide for LOCA uncertainty analysis methodology, CABUE treats the uncertainties associated with the physical models implemented in the simulation code in a more reliable manner.

2.2 Uncertainty Analysis Method for CABUE

In this study the DFPE technique with simple random sampling calculation (DFPE/SRSC) is used. Uncertainty distributions of the results of a deterministic computer code results from the combination and propagation of the uncertainties associated with the code models and input parameters. It is the aim of the DFPE/SRSC to obtain approximations to these distributions and derive quantitative uncertainty statements from them. To do this, a simple random sample is drawn from the selected code uncertainty parameters using their specified distributions.

An element of this sample is called the parameter vector and is composed of one value for each selected code parameters. The code is run with each parameter vector in the sample. The set of output values constitutes a simple random sample, which is drawn from the unknown probability distribution of the code calculation results. From this simple random sample, tolerance limit can be stated as a quantitative uncertainty measure.

2.3 Computer Code

RETRAN-3D/MOD3.1 was used in the thermal hydraulic simulation of the secondary system piping break accidents. The most important feature of RETRAN-3D code, that is very useful for uncertainty analysis, is the automatic Steady State Initialization (SSI) capability. RETRAN-3D provides an automatic initialization feature to setup a steady state condition and it saves a lot of efforts and time needed to run a number of simulations in the uncertainty analysis like this study. In this study, separate 59 computer simulations were performed for a single scenario.

2.4 Identification of Uncertainty

Uncertainty parameters were identified through PIRT process for both accidents. Nine parameters were selected out of major influential parameters for both accidents. The selected uncertainty parameters and their statistical characteristics for SLB are presented in Table 1. For SLB, the PIRT process performed for the APR-1400 was applied in this analysis. Since the system configuration of the APR-1400 is almost the same as UCN 3&4 except about 40% higher core power, the trends of overall plant responses to SLB in both plants are almost the same. Therefore, the SLB PIRT results for the APR-1400 can be applied in the present analysis. FLB PIRT was prepared referencing the UCN 3&4 related information.

Uniform distribution is assumed for all parameters except the critical flow CD factors and critical flow model options related with break flow and PSVs (Case A, uniform distribution case). Three sets consisting of 59 randomly sampled inputs were produced for Case A to evaluate the effect of randomness on the safety parameters. To confirm a conservatism of applying uniform distribution, a set of randomly sampled parameter set based on normal distribution type was generated and analyzed using the same methodology (Case B, normal distribution case).

Table 1. Uncertainty Parameter for SLB

Parameter	Distribution Type		Nominal Value
	Case A	Case B[2]	
Break flow CD factor	Normal	Normal	1.0
Break flow model option	DPD[1]	DPD	Option 2
AFW flow rate	Uniform	Normal	650 gpm
MSIS setpoint	Uniform	Normal	885.5 psia
Initial PZR pressure	Uniform	Normal	2250 psia
Initial PZR liquid volume	Uniform	Normal	52.6%
Inverse boron worth	Uniform	Normal	88 ppm/%Δρ
Safety injection delay time	Uniform	Uniform	25 sec.
High core power trip	Uniform	Normal	109.4 %

1) Discrete Probability Distribution
   Option 1 : Extended Henry and Moody
   Option 2 : Isentropic Expansion HEM model
2) Upper and lower limits are truncated with 99% probability.

3. Analysis Results

A comparative evaluation of realistic and deterministic approach was performed for UCN 3&4 secondary system piping break accidents, SLB and FLB. CABUE technique was applied as a realistic approach and the results were compared with the licensing calculation performed using CESEC-III computer code, a non-LOCA thermal hydraulic simulation code currently used for the UCN 3&4.

SLB results of comparative evaluation are summarized in Table 2 and presented in Fig. 1. Comparison with licensing calculation shows that the highest value of total reactivity out of random sampling calculation is less than that of licensing calculation. As shown in Table 2, total reactivity is not quite sensitive to the different set of random sampling for Case A. Moreover, the distribution type (uniform vs. normal) does not have significant impact on the safety parameter.

Results of comparative evaluation for the FLB are summarized in Table 2 and presented in Fig. 2. The models for heat transfer and break flow implemented in the CESEC-III and RETRAN-3D codes are quite different. In CESEC-III, the licensing code, very conservative assumptions on the heat transfer capability and the thermodynamic state of discharged break flow were used. As shown in Table 2, peak primary system pressure is not much affected by the different set of random sampling for Case A. And the distribution type (uniform vs. normal) does not pose serious impact on the safety parameter. The highest value of peak primary system pressure out of random sampling calculation is much less than that of licensing calculation.

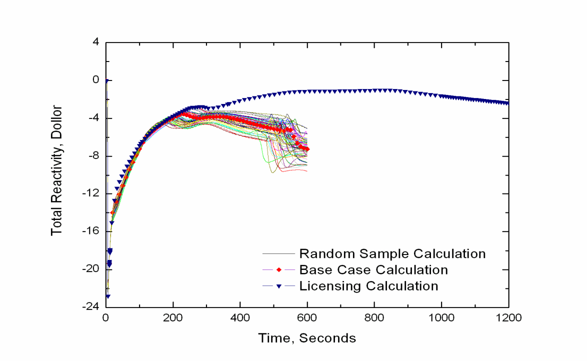

Fig. 1 Total Reactivity Variation (SLB)

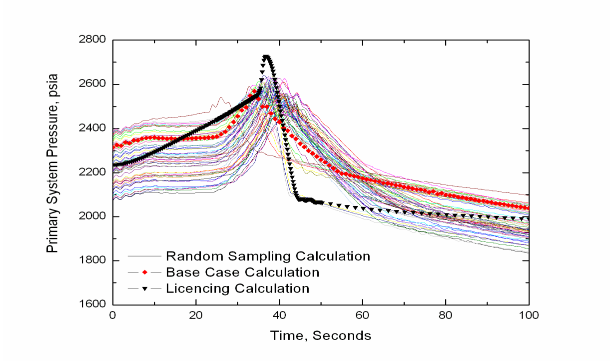

Fig. 2 Primary System Pressure Variation (FLB)

Table 2. Summary of results (Best Estimate)

Case			SLB	FLB
			Peak Total Reactivity, $/Time, sec	Peak RCS Press., psia/Time, sec
Realistic	Uniform	Case 1	-2.739/269	2,640/36.4
		Case 2	-2.629/272	2,667/37.3
		Case 3	-2.962/257	2,649/38.9
	Normal		-2.854/269	2,651/36.3
Licensing			-1.015/826	2,727/36.8

4. Discussion

A comparative evaluation of realistic and deterministic approach was performed for UCN 3&4 secondary system piping break accidents, the SLB and the FLB. The study shows that the distribution type has no significant impact on the safety parameters for both accidents.

It was shown that the results of realistic approach using uncertainty quantification method yield more margin than those of conservative licensing calculation.

ACKNOWLEDGMENTS

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