Thermal-hydraulic Analysis of LOCA to Apply PSA Using MAAP and MARS codes

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1. Introduction

Thermal-hydraulic analysis in Probabilistic Safety Assessment (PSA) is performed to product basic data, which are needed to analyze accident sequence, construct system fault tree and evaluate operator error. Through the thermal-hydraulic analysis, the reactor power level, the pressure and the temperature of primary side, and the pressure, the temperature and the water level of secondary side are calculated. From these data, system success criteria for construction of event tree and the allowable outrage time for human reliability analysis are determined. Until now, system codes such as MAAP, RELAP, MELCOR, RETRAN have been widely used for thermal-hydraulic analysis in PSA. The adequacy of analysis is dependent on the type of accident and the models of codes. As a first step of 'Study on Best-Estimate Thermal-Hydraulic Analysis Methodology Applicable to Probabilistic Safety Assessment', a part of National Nuclear Technology Program of Ministry of Science & Technology, it is required to compare the result of MARS analysis with that of MAAP analysis previously performed, and to evaluate its applicability to PSA.

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2. Analysis Method

In this study, the comparative analysis is performed using MAAP4 and MARS3.0 codes for Large Break Loss of Coolant Accident (LBLOCA) in Korean Standard Nuclear Power Plant (KSNP). The sequence of the accident, the characteristics and nodalization of two codes, which are used in this study, are shown below.

2.1 Accident Sequence

LBLOCA is one of critical accident in the view point of severe accident, because it has a relatively high core damage frequency (CDF) and its accident sequence is very fast once it had taken place. If the cold leg is broken, the coolant is injected from safety injection tank (SIT) into the reactor vessel, and then the coolant in the refueling water storage tank (RWT) is utilized. In this step, although the coolant injection from SIT failed, the core damage can be prevented if the low pressure safety injection (LPSI) pump is available. Moreover, most accidents that have the high frequency do not progress to the core melt down due to the success of safety injection. Thus, the accident scenario is selected such case that both of high pressure safety injection (HPSI) and LPSI failed while the safety injection from SIT works successfully during the long term cooling phase of LBLOCA. We will carry out the analysis of LBLOCA in a conservative manner as conservatively selecting the inflow from HPSI. The major design parameters of KSNP are shown in Table 1.

Table 1. Design parameter of KSNP

Parameter	Operation conditions
Reactor power	281.5 MWth
Vessel inner diameter	13.5 ft
Vessel height	46 ft
Coolant temp. at vessel outlet	621.2
Coolant temp. at vessel inlet	564.5
Operating temp. (average)	592.85 ^{o}F
Operating pressure (nominal)	2250 psia
Coolant flow (nominal)	1.125E8 lb/h
Pressurizer total volume	1815 ft^3
Number of S/G	2
Secondary side steam pressure	1070 psia

2.2 MAAP Model

The Modular Accident Analysis Program version 4 (MAAP4) is a severe accident analysis code that integrates a large number of phenomena and models relevant to severe accident progression into a single plant simulation [1]. Due in part to the simplified form of the conservation equations and the coarser discretization of the reactor systems, MAAP4 has calculation times far shorter than those of the other codes while producing credible results.

Figure 1 shows MAAP4 nodalization for primary side of KSNP. The Nodalization of primary side consists of total 15 nodes. The core is modeled with 7 nodes in radial direction and 13 nodes in axial direction.

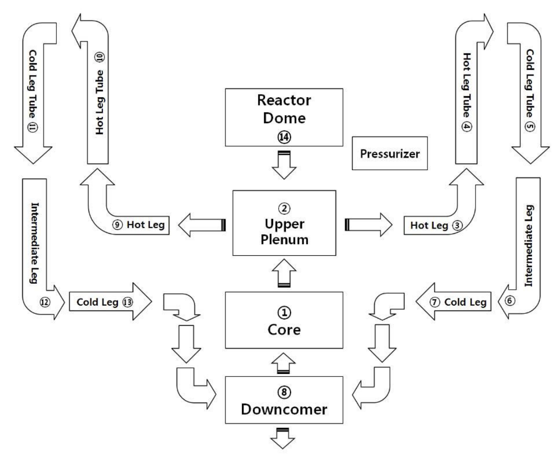

Figure 1. MAAP nodalization for primary side of KSNP

2.3 MARS Model

The MARS code has been developed at Korea Atomic Energy Research Institute (KEARI) by consolidating and restructuring the RELAP5/MOD3.2 code and COBRA-TF code. It has the capability of analyzing the one-dimensional or three-dimensional best estimated thermal-hydraulic system and the fuel responses of the light water reactor transients. The one-dimensional module of the MARS code is based on the RELAP5 code. As such the basic field equations, constitutive relations, and thermal-hydraulic models of the one-dimensional module of the MARS are essentially the same as those of the RELAP5 [2].

MARS3.0 nodalization for KSNP is performed referring previous analysis result with MARS2.1 code as shown in Fig. 2

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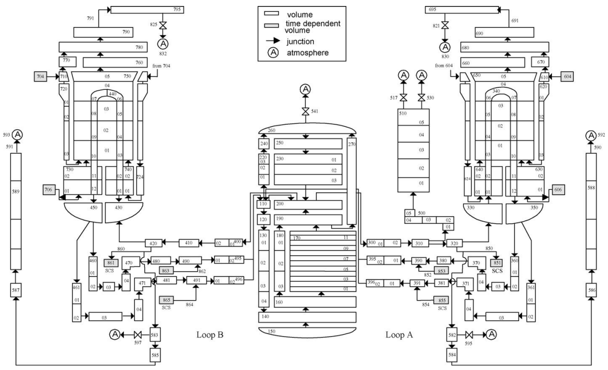

Figure 2. Nodalization used in MARS2.1 for the modeling of the KSNP [3]

3. Conclusion

Comparative analysis with MAAP4.0 and MARS3.0 codes is ongoing herein to evaluate the code capability for thermal-hydraulic analysis in PSA. Previous research shows that although substantial differences exist in code models, some comparison results are consistent [4].

As a future work, we will develop a method of thermal-hydraulic analysis in PSA considering the various uncertainties from the scaling, nodalization, code model and etc. Using the method, the uncertainty generated from thermal-hydraulic analysis will be quantified in PSA.

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