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Audit Calculations of LBLOCA for Ulchin Unit 1&2 Power Uprate

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1. Introduction

The best estimate (BE) calculation with uncertainty evaluation of large break loss-of-coolant-accident (LBLOCA) has been increasingly applied to the licensing applications such as fuel design change, power uprate, and licensing renewal of nuclear power plants (NPPs). The KINS-Realistic Evaluation Model (KINS-REM) was developed for the independent audit calculation in 1991 [1], and the code accuracy and statistical method have been improved [2]. To support the licensing review and to confirm the validity of licensee's calculation, regulatory auditing calculations have been also conducted.

Currently, the modification of Ulchin 1&2 operating license for 4.5% power uprate is under review [3]. In this study, the regulatory audit calculation for LBLOCA of Ulchin Unit 1&2 with 4.5% power uprate was performed by applying KINS-REM.

2. Design Modification due to Power Uprate

The Ulchin 1&2 is Framatome 3-loop plant, and thermal power is increased from 2,775 MW to 2,900 MW through the power uprate. In addition, some modifications of reactor coolant system (RCS) flow rate, steam generator (SG) pressure, accumulator pressure etc. are made. Especially, the peaking factor (F_Q) was increased from 2.45 to 2.6 at initial application, and then finally set to 2.5 during review process.

3. Application of KINS-REM

The KINS-REM has three elements subdivided by fourteen steps. In this study, MARS-KS 1.3 was used as analysis code, while RELAP5/Mod3.3 is originally used as a frozen code in KINS-REM. The Ulchin 1&2 ECCS performance against LBLOCA was assessed according to following KINS-REM procedure.

1. Specify Scenario: The LBLOCA by 100% double-ended guillotine break at the reactor coolant pump discharge leg which are the limiting break size and location, was selected as accident scenario.

2. Select NPP: The Ulchin 1&2 with 4.5% power uprate was chosen to be analyzed.

3. Identify and Rank Phenomena: The important phenomena identified in the previous work including CSAU can be used. Since the present method was designed to have no limitation in number of uncertainty parameters, the ranking process is not so much emphasized.

4. Select Frozen Code: The MARS-KS 1.3 code was selected as a frozen BE code. It has improved reflood model, and its dialing method was modified to apply to KINS-REM appropriately.

5. Determine Code Applicability & 6. Establish Assessment Matrix & 7. Define Nodalization for Experiment & SET/IET Assessment: The assessment of MARS-KS code against various SET/IET was already performed by going through verification and validation phase. From the assessment results, MARS-KS can justify predictive capability for thermal hydraulics in primary system and it is applicable to KINS-REM.

8. Determine Parameter Ranges: The range and distribution of code model and system uncertainties for LBLOCA have been widely evaluated by comparing with SET/IET results. Table 1 shows the range and distribution of uncertainty parameters used in this study.

Table 1. Uncertainty Parameter Range and Distribution

No	Models/ Parameters	Dis.	Range	Mean
1	Gap conductance	Uniform	0.67-1.5	1.085
2	Fuel conductivity	Uniform	0.845-1.155	1.0
3	Core power	Normal	0.969~1.031	1.0
4	Decay heat	Normal	0.898~1.102	1.0
5	Groeneveld CHF	Normal	0.17~1.8	0.985
6	Chen nucleate boiling	Normal	0.53~1.46	0.995
7	Chen transition boiling	Normal	0.54~1.46	1.0
8	Dittus-Boelter liquid	Normal	0.606~1.39	0.998
9	Dittus-Boelter vapor	Normal	0.606~1.39	0.998
10	Bromley film boiling	Normal	0.428~1.58	1.004
11	Break CD	Normal	0.729~1.165	0.947
12	Pump 2-f head multiplier	Uniform	0~1	0.5
13	Pump 2-f torque multiplier	Uniform	0~1	0.5
14	Accumulator pressure (MPa)	Uniform	4.35~4.59	4.47
15	Accumulator water inventory (m^3)	Uniform	26.9~28.6	27.75
16	Accumulator temp. (K)	Uniform	298.15~318.15	308.15
17	Pressurizer pressure (MPa)	Uniform	14.969~16.057	15.513
18	RWST temp. (K)	Uniform	280.15~313.15	296.65

9. Define NPP Nodalization & Perform NPP Base Calculation: The modeling of Ulchin 1&2 was based on the steady state input deck of the replacement of steam generator case. On the basis of that, all design modifications due to power uprate were applied in the modeling as shown in Fig 1. The base calculation was performed and the PCT_{Base} was calculated to be 1244.1 K.

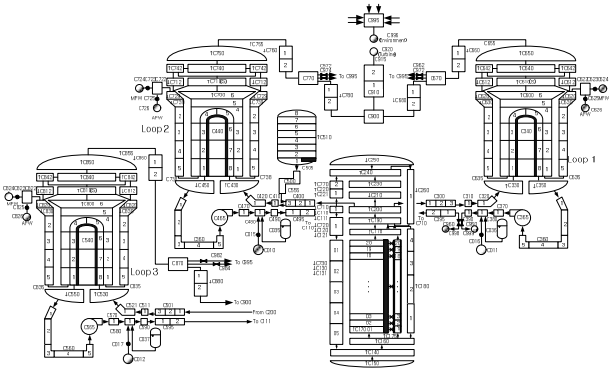

Fig. 1. MARS-KS Nodalization for Ulchin 1&2 LBLOCA

10. Determine Code/Model Accuracy: From the SET/IET assessment results, all the biases were already reflected to the ranges of relevant parameters ($B_{SET} = B_{IET} = 0.0$ K).

11. Determine Effect of Scale: The scale bias for ECC bypass and steam binding phenomena was evaluated. Figure 2 shows the bypass water mass of accumulators in intact leg. The fraction of ECC bypass of accumulators in intact cold leg until PCT occurs was calculated to be 41.8% and it is more than UPTF 4A experiment result of 16.4%. And that of overall ECCS until the quenching was calculated to be 68%. Therefore, there was no scale bias due to ECC bypass. Figure 3 compares the PCT of case that heat is provided into SG tube after the reflood starts with that of base case. As shown in this figure, the PCT due to steam binding during reflood period increased by 4.2 K, and the quenching time is delayed. Therefore, the scale bias due to steam binding was estimated to be 4.2 K ($B_{SCALE} = 4.2$ K)

12. Determine Effect of System Parameters: The important system parameters were already reflected to uncertainty parameters ($B_{PLANT} = 0.0$ K).

13. Combine Uncertainties & Estimate Biases: To determine $PCT_{95/95}$, 124 sets of parameters were generated by random sampling. Figure 4 shows the PCTs for 124 cases and base case, and $PCT_{95/95}$ was estimated to be 1442.57 K.

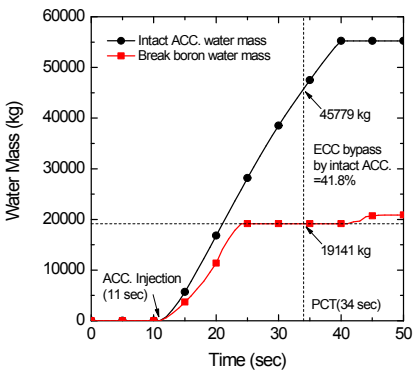

Fig. 2. Bypass water mass of accumulators in intact leg

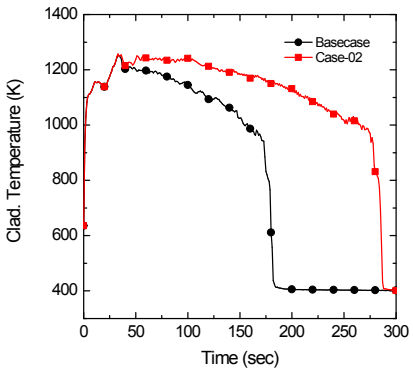

Fig. 3. PCT variation due to steam binding

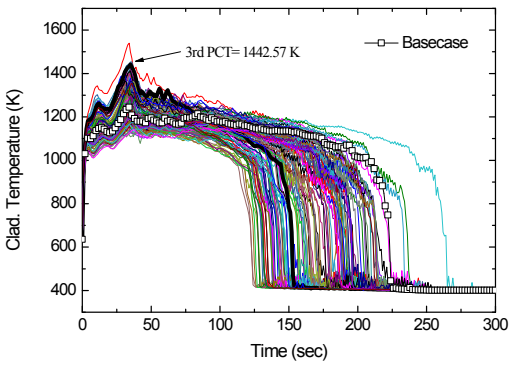

Fig. 4. PCTs for 124 cases and base case

14. Determine Overall Uncertainty: The final PCT was estimated by combining $PCT_{95/95}$ and biases as follows;

$$PCT_{final} = PCT_{95/95} + B_{SCALE} + B_{SET/IET} + B_{PLANT}$$
$$= 1442.57 + 4.2 + 0.0 + 0.0$$
$$= 1446.77 \text{ K}$$

The final PCT meets the acceptance criteria of 1477 K.

4. Conclusion

In this study, the regulatory audit calculation for LBLOCA of Ulchin Unit 1&2 with 4.5% power uprate was performed by applying KINS-REM. It is confirmed that the analysis results of LBLOCA for Ulchin 1&2 power uprate meets the PCT acceptance criteria.

REFERENCES

[1] Hho J. Kim, et al., Development of Korean ECCS EM and Its Application, KINS/GR-021, 1991.
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[3] KHNP, Safety Analysis Report for Ulchin 1,2 Stretch Power Uprate, 2012.