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Study on the Safety Margin Change for Hypothetical Power Uprate of OPR1000 according to the Guidance of SMAP of NEA/CSNI

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1. Introduction

The Organization for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA) Committee on the Safety of Nuclear Installations (CSNI) has developed Action Plan on Safety Margins (SMAP) for the fear that some changes in existing nuclear power plants could challenge safety margins despite fulfilling all the regulatory requirements. Possible examples are power uprates, plant life extension or increased fuel burn-up as well as cumulative effects of simultaneous or subsequent modifications in a plant, which can conceivably be larger than the accumulation of the individual effects of each individual modification [1].

Reference 1 provides guidance on how to address the assessment of changes in safety margins due to significant plant modifications. The methodology proposed by the SMAP group is based on a combination of deterministic and probabilistic approaches and uses the existing analysis technologies (e.g. deterministic safety analysis and PSA). The aggregation of the risk contributions from different event scenarios uses the mathematical concepts of PSA while the evaluation of the consequences is performed using existing transient analysis simulation tools (e.g. best-estimate plus uncertainty (BEPU)) [1].

This paper shows the changes in safety margin for a hypothetical condition of power uprate in OPR1000 plant. Large Break Loss of Coolant Accident (LB LOCA) was representatively selected for the evaluation. The results of analyses for OPR1000 are comparatively discussed with the other plant.

2. Evaluation Method

Actual procedure is composed of following three steps based on the triplets of scenarios, frequency, and consequence;

- Identification of risk space and event.
- Calculating margin in each sequence
- Computing the risk metric

Integrating risk and safety margins starts with generating (1) the risk space (i.e., all the event sequences that the modification affects), and (2) a phenomena/variables identification table used to compute the conditional probability of loss of function for each event sequence. To generate the risk space, one must consider all initiating events that challenge PCT margin. The next step is to identify the variables that determine the amount of PCT margin available in each event sequence. BEPU method was used with 2000 times run for each sequence, and then probability density functions are generated. Final step is to calculated the change of core damage frequency (CDF) based on the 2000 times run and then consolidate the results.

3. Safety Margin for LBLOCA

3.1 Selection of event sequence

The large LOCA event tree of Ulchin Units 3&4 was considered to be used (see Fig. 1). The selected sequence is described as: Large LOCA / SIT Injection / LPSIS Injection / HPSIS Recirculation & Cooling.

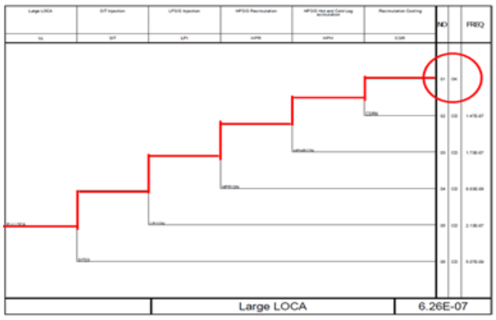

Fig. 1 Large LOCA Event Tree for OPR1000 in PSA [2]

3.2 Selection of uncertainty parameters

Table I shows the whole parameters which were used in the uncertainty analysis. For 10 parameters, total 2000 case input files were generated using MOSAIQUE developed by KAERI to support the uncertainty analysis.

Table I: Selected Parameters for Uncertainty Analysis

No.	Models/Parameters	Distribution
1	Gap Conductance	Uniform
2	Fuel Conductivity	Normal
3	Core Power	Normal
4	Decay Heat	Normal
5	Groeneveld CHF Dial.	Normal
6	Tmin Dial.	Uniform
7	Bromely Dial.	Normal
8	Break CD	Normal
9	Accumulator Water Temp.	Uniform
10	Accumulator K-Factor	Uniform

3.3 Simulation results

Fig. 2 shows the peak clad temperature variation with time for all the 2000 runs taken using best estimate code RELAP5 for the first 400 sec of the transient time.

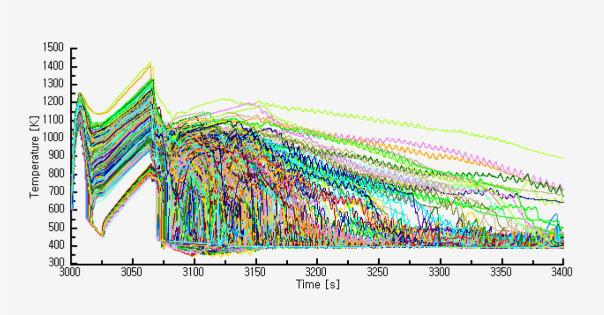

Fig. 2 Peak Clad Temperature for 2000cases at 110% power

Figs. 3 and 4 show the probability density function (PDF) for PCT at 100% and 110% power, respectively. At 100% power, there are no cases to exceed the safety limit, 2200°F (1477K) as shown in Fig. 3, but at 110% power, there are 2 cases to exceed the safety limit, 2200°F (see Fig. 4).

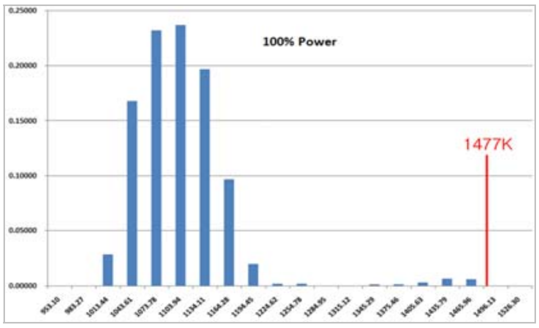

Fig. 3 PDF for 2000cases at 100% power

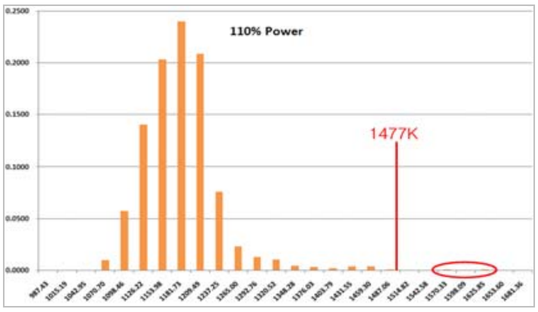

Fig. 4 PDF for 2000cases at 110% power

Overall results for large LOCA (total 4000 cases) are summarized in Table II. By the power uprate, the probability of exceedance frequency and PCT increased.

Table II: Overall Results for Exceedance Frequency

	100% Power	110% Power
No. of Cases (>2200°F)	0	2
Prob. of Ex. Frequency	0%	0.1%
Average PCT [K]	1103.96	1167.85
Max. PCT [K]	1470.87	1616.96

3.4 Evaluation of Exceedance Frequency

Table III shows the evaluation results of the safety margin, or delta CDF, as an overall conclusion in this study. Here, the CDF is obtained from conditional exceedance frequency multiplied by the sequence frequency; moreover, the delta CDF is obtained by the difference of CDFs at each power. By the power uprate, the change of safety margin in OPR1000 for LBLOCA is 1.70E-07. Although this value is larger than the delta CDF calculated from ZION plant (see Table IV), considering the acceptance guidelines for CDF in RG1.174 (see Fig. 5), it could be found that the calculated delta CDF is in the REGION III where the modification of the plant is acceptable.

Table III: Evaluation Results for Safety Margin (OPR1000)

	100% Power	110% Power
Sequence Frequency	1.7 E-4	
Conditional Ex. Prob.	0	0.001
Core Damage Freq.(CDF)	0	1.70E-07
Delta CDF		1.70E-07

Table IV: Evaluation Results for Safety Margin (ZION)

	100% Power	110% Power
Sequence Frequency	4.8 E-7	
Core Damage Freq.(CDF)	2.49E-9	2.52E-9
Delta CDF		2.8E-11

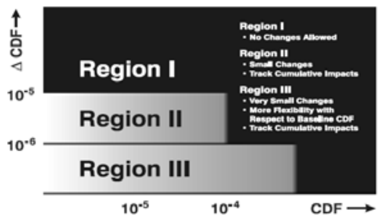

Fig. 5 Acceptance Guidelines for CDF in RG1.174 [3]

5. Conclusions

In this study, the change of safety margin in OPR1000 for hypothetical power uprate was evaluated by using the Guidance of SMAP. From the evaluation results, it was found that the modification for power uprate of OPR 1000 is acceptable. Moreover, it is expected that the delta CDF is used to determine the regulatory policy.

REFERENCES

[1] OECD NEA/CSNI/R(2007), Task Group on Safety Margins Action Plan (SMAP) Safety Margins Action Plan - Final Report, 2007
[2] Probabilistic Safety Assessment for Ulchin Units 3&4 [Level 1 PSA for Internal Events : Main Report], 2004
[3] Regulatory Guide 1.174 Rev. 1, An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis, U.S. Nuclear Regulatory Commission, 2002