Assessment on Plant-Specific Level 2 PSA for Power Uprates of Westing House Type NPPs

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1. Introduction

Generally, there are three categories of power uprates ; (1) MUR (Measurement Uncertainty Recapture power uprates), which is less than 2 percent and achieved by implementing enhanced techniques for calculating reactor power ; (2) SPU (Stretch Power Uprates), which is typically up to 7 percent and does not involve major plant modifications ; (3) EPU (Enhanced Power Uprates), which is usually as high as 20 percent and requires significant modifications to major BOP (Balance of Plant) equipment. The 4.5% power uprate for Kori 3&4 / Yonggwang 1&2 will be SPU.

This paper discusses the changes of the plant specific level 2 PSA results for Kori 3&4 / Yonggwang 1&2 by SPU. We reviewed the design documents and the operating procedures[1-6], and requantified PDS frequency, containment failure probability including LERF (Large Early Release Frequency) and release amount of source term to analyze the overall effects of power uprate on the level 2 PSA results.

2. Analysis Method and Result

2.1 Review of Level 1 PSA

The Level-1 internal event CDF(Core Damage Frequency) for Kori 3&4 is increased 5.9 percents, and ΔCDF, the difference between the CDF before and after the power uprate, is calculated as 5.0E-7/yr. The value for Yonggwang 1&2 is increased 5.3 percents, and ΔCDF is calculated as 3.9E-7/yr.

Table 1. CDF Changes before and after Power Uprate

Units	ΔCDF(/RY)	Description
Kori 3&4	5.0E-7	5.9% increased
Yonggwang 1&2	3.9E-7	5.3% increased

2.2 PDS frequency and LERF analysis

The PDS(Plant Damage Status) analysis results of Kori 3&4 and Yonggwang 1&2 PSA report and the related documents were reviewed to analyze the effect of power uprate. The PDS frequency analysis results are used to quantify containment failure probability in level 2 PSA.

There were no need to modify the PDS analysis results including the PDS grouping logics and the PDS event tree logics, etc. But, PDS frequencies were increased by the CDF increase in level 1 PSA. The CDF re-assessment results of Kori 3&4 and Yonggwang 1&2 were increased due to the increase of human error probabilities related to the accident response time [7]. The re-assessment (after power uprate) results of total PDS frequencies for Kori 3&4 and Yonggwang 1&2 were 9.43E-06/year and 7.91E-06/year respectively, and the original (before power uprate) results of total PDS frequencies for Kori 3&4 and Yonggwang 1&2 were 8.69E-06/year and 7.50E-06/year respectively. The details of PDS frequency re-assessment results are shown in Table 2.

Table 2 . The PDS frequency re-assessment result
(Kori 3&4)

Before Power Uprate		After Power Uprate	
PDS	Frequency	PDS	Frequency
5	3.04E-06	5	3.24E-06
41	2.85E-06	41	3.24E-06
47	5.08E-07	47	5.08E-07
48	3.25E-07	44	3.70E-07
44	3.19E-07	48	3.25E-07
…	…	…	…

While the success criteria and the human error probabilities were changed by power uprate in level 1 PSA[7], the Kori 3&4 / Yonggwang 1&2 level 2 PSA models were requantified to assess the impact of the proposed power uprate on containment failure probabilities. The results are shown in Table 3 and 4.

From the review of the increased containment failure probability as shown in Table 3, the total internal events LERF for Kori 3&4 has increased to 1.08E-06 /year from 1.05E-06/year. ΔLERF is 3.0E-08/year(2.8% increased) for Kori 3&4. And as shown in Table 4, the total internal events LERF for Yonggwang 1&2 increased to 7.77E-07/year from 7.59E-07/year, so ΔLERF is 1.8E-08/year(2.3% increased) for Yonggwang 1,2. These changes are caused by the PDS frequency change due to the CDF increase.

Table 3 . Containment failure probability re-assessment result
(Kori 3&4)

Types of Containment Failure		Before Power Uprate	After Power Uprate
NO CF		5.83E-06	6.42E-06
CF	ECF	2.18E-07	2.39E-07
	LCF	1.27E-06	1.40E-06
	ISO FAIL	2.28E-07	2.29E-07
	CFBRB	5.30E-07	5.30E-07
	BYPASS	6.06E-07	6.11E-07
	Subtotal	2.86E-06	3.01E-06
LERF		1.05E-06	1.08E-06
Total (PDS)		8.69E-06	9.43E-06

Table 4 . Containment failure probability re-assessment result (Yonggwang 1&2)

Types of Containment Failure		Before Power Uprate	After Power Uprate
NO CF		4.73E-06	5.02E-06
CF	ECF	1.81E-07	1.95E-07
	LCF	1.14E-06	1.24E-06
	ISO FAIL	3.98E-08	3.99E-08
	CFBRB	8.69E-07	8.69E-07
	BYPASS	5.39E-07	5.42E-07
	Subtotal	2.77E-06	2.89E-06
LERF		7.59E-07	7.77E-07
Total (PDS)		7.50E-06	7.91E-06

Even though there is no quantitative target in Korea, ΔCDF and ΔLERF by the power uprate are compared to the acceptable level of RG-1.174 and all meet the criteria.

2.3 Sensitivity analysis

In the 4.5% uprated condition, sensitivity analysis is also performed to consider the combined effects of the AAC (Alternate Alternating Current) system which was installed in the Kori site recently and scheduled in the Yonggwang site in year 2008. The results showed that the whole effect was improved up to approximately more than 30% within the framework of CDF[7] and 12% within the framework of LERF. Since the safety improvement by the design change is much more effective than the slight increase due to the power uprate, entire safety is relatively improved.

Table 5. Sensitivity Analysis with AAC installed (Kori 3&4)

Model	ΔLERF(/RY)	Description on the LERF Changes
Reference Model	3.0E-08	2.85% increase compared to the reference model before power uprate
AAC Model	4.0E-09	- 0.4% increase compared to the AAC model before power uprate - 12.9% decrease compared to the reference model before power uprate

Table 6. Sensitivity Analysis with AAC installed (YG 1&2)

Model	ΔLERF(/RY)	Description on the LERF Changes
Reference Model	1.8E-07	2.4% increase compared to the reference model before power uprate
AAC Model	9.0E-08	- 0.47% increase compared to the AAC model before power uprate - 15.81% decrease compared to the reference model before power uprate

3. Source term analysis

The average amount of fission product in fuel of Kori 3&4 and Yonggwang 1&2 was re-assessed using ORIGEN-2 code, and the result is shown in table 7. The amount of fission product was increased, mainly because the fuel enrichment was changed from 3.1 w/0 to 4.5 w/0 and the effective full power days was changed from 840 days to 1,461 days in current FSAR compared to FSAR referenced in original PSA.[4,5]

By using the result of table 7 as an input, the amount of source term release for 18 STC (Source Term Category) for Kori 3&4 / Yonggwang 1&2 was re-assessed using MAAP4 code.

Generally, the amount of source term release was increased because of the increase in the fuel enrichment and the larger burn-up, as well as the core power were changed in the current FSAR compared to the FSAR referenced in original PSA.

Table 7 . The amount of fission product re-assessment result (Kori 3,4 , Yonggwang 1,2)

Source Term No	Before Power Uprate (Kg)	After Power Uprate (Kg)
XE	3.59E+02	5.01E+02
KR	2.51E+01	3.58E+01
I	1.76E+01	2.32E+01
…	…	…
PU	7.50E+02	8.65E+02

4. Conclusion

The effects of power uprate of Kori 3&4 / Yonggwang 1&2 on the containment failure probabilities and the amount of source term release were evaluated in PSA aspects.

The CDF and the LERF increase levels after the power uprates for Kori 3&4 and Yonggwang 1&2 have been compared to the limiting value for the risk informed licensing in RG 1.174, and this confirmed that these increased CDFs and LERFs met the RG 1.174 limit sufficiently. Additionally, if the AAC diesel generator is considered, the CDF due to the power uprate is decreased 33.2 percents for Kori 3&4, and 32.9 percents for Yonggwang 1&2. And the LERF due to the power uprate is decreased 12.9 percents for Kori 3&4, and 15.8 percents for Yonggwang 1&2.

Even if there are some changes for the operator action probabilities and the plant system design modifications by the power uprates for Kori 3&4 and Yonggwang 1&2, these have ignorable effects on the quantified safety goals.

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