

## An Analysis of the Impact of Power Up-rating on the PSA and Allowed Outage Time

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### 1. Introduction

As an effort to enhance the economics of power generation, the power up-rate of Kori 3 & 4 was completed in 2006, resulting in an increase of 4.5 % of the rated power. The power up-rate was so-called Stretch Power Up-rate (SPU) through which the rated power was increased by exploiting excess design margins without significant design changes.

In order to investigate the impact of the power up-rate on the Allowed Outage Time (AOT), the Kori 3&4 PSA was re-evaluated as the AOT should be based on the plant specific PSA results. Extending the AOT as sufficiently as possible is crucial to avoid unnecessary shutdowns for maintenance and consequently to obtain the flexibility of the plant operation.

This paper will introduce the analysis result for Kori 3&4 PSA considering the power up-rate from the NPP utility's perspectives. The assessment includes the Level-1 internal events, Level-2 containment analysis, and the impact on the AOT especially for the Emergency Diesel Generator (EDG). The analysis introduced in this paper focuses on identifying the major element affecting the PSA results due to the power up-rating and their impacts on the AOT of a specific system, i.e., the EDG.

### 2. The Status of the AOT extension

Since the mid-80's, the nuclear power utilities in the United States have been applying the PSA technique for the risk-informed operation and maintenance (O&M). Utilizing the risk-informed O&M, the nuclear power utilities have been able to record higher availability of their nuclear power plants (NPPs.) Along the efforts of the industry, the USNRC recommended the NPP operators to reasonably improve Tech. Spec. (TS) requirements based on the risk analysis as suggested in NUREG-1366 "Improvements to Technical Specifications Surveillance Requirements" issued in December 1992. In 1998, the USNRC published the guidance of TS by issuing RG 1.174 "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis" and RG 1.177 "An Approach for Plant-Specific, Risk Informed Decision making : Technical Specification". According to these guidances, Westinghouse Owner's Group(WOG) and CE Owner's

Group(CEOG) have performed several studies on the optimization of AOTs and STIs.

### 3. PSA Re-assessment Results

The re-assessment of the plant specific PSA was performed to investigate the impact of the power up-rate on the plant risk. The analysis of PSA due to the power up-rate indicated that initial events frequencies, event/fault tree logics, system success criteria and component failure rates were unaffected. As a result of the increase power, however, it was found that the time before the core uncover was reduced through the MAAP-4 code analysis resulting in the increase of probability of human errors. Especially, it was observed during the offsite power recovery actions in case of the SBO (Station Black-Out) event as well as during post-accident operator interventions.

Table 1. Probabilities to Fail to Recover the Offsite Power

Basic Events	Operator Available Times		Probabilities	
	Before PU	After PU	Before PU	After PU
B-101	17 hours	16 hours	1.00E-02	1.30E-02
B-103	10.9 hours	10.6 hours	4.00E-02	4.50E-02
B-201	9 hours	8 hours	6.30E-02	8.10E-02
B-203	2.9 hours	2.6 hours	3.30E-01	3.60E-01

Table 2. Operator Error Probability Changes after Power Up-rate

Basic Events	Operator Available Times		Probabilities	
	Before PU	After PU	Before PU	After PU
HRTCFRPC1-10	42 minutes	36 minutes	4.48E-03	5.70E-03
HRS2FRPC1-10	42 minutes	36 minutes	1.31E-03	2.53E-03

Consequently, the Level-1 internal event CDF (Core Damage Frequency) for Kori 3&4 was increased by 5.97 percent, i.e., from 8.38E-06/year to 8.88E-06/year.

Table 3. CDF value changes after Power Up-rate

Before PU	After PU	$\Delta$ CDF	Description
8.38E-6/yr	8.88E-6/yr	5.0E-7/yr	5.97% increased

The results of Level-2 PSA re-assessment due to the power up-rate showed that there was no significant

change in the CET (Containment Event Tree), DET (Decomposed Event Tree) and their fractions after the power up-rate. The Large Early Release Frequency (LERF) for Kori 3&4 was however increased from 1.05E-06/year to 1.08E-06/year, which was approximately a 2.85 percent increase after power up-rating. This increase was found due to the change in the PDS (Plant Damage Status) frequency caused by the CDF increase.

Table 4. LERF value changes after Power Uprate

Before PU	After PU	Δ LERF	Description
1.05E-6/yr	1.08E-6/yr	3.0E-8/yr	2.86% increased

Although there were small increases in the CDF and LERF, it was concluded that the changes in CDF and LERF by the power up-rate were acceptable in consideration of the guidance and criteria suggested in RG 1.174.

#### 4. AOT Assessment

Incorporating the changes of the operator available times due to the power up-rate shown in Tables 1 and 2, the change of the CDF and LERF were shown in Table 5. It should be noted that the reinforcement of the safety systems for the Kori 3&4 power up-rating such as an addition of the Alternate AC source is reflected in the CDF and LERF results in Table 5.

The search of the maximum extension of the EDG AOT was performed by increasing the EDG outage time assumption in the base model with power up-rating conditions from 3 days (base case) to 7, 10, and 14 days, and calculating the incremental changes of the CDF and LERF. As shown in Table 6, the CDF and LERF were increased as the EDG AOT increased. The LERF in Table 6, however, did not exceed 1.0E-6/yr with Δ LERF less than 1.0E-7/yr, when the AOT was set to be 14 days.

Table 5. Change of the PSA results due to power up-rating in Kori 3&4 (with AAC)

	Base model	After power up-rating
CDF(/yr)	5.17E-06	5.28E-06
LERF(/yr)	9.57E-07	9.62E-07

Table 6. CDF and LERF Sensitivity Analysis Results due to the Changes of the EDG Allowed Outage Time

System	Items	Results (/yr)		
		7days	10days	14days
EDG	EGDGZ001MA	1.92E-02	2.74E-02	3.84E-02
	EGDGZ002MB			
	EGDGZ003MZ			
	Proposed CDF	5.62E-06	5.82E-06	6.08E-06
	Delta CDF	3.40E-07	5.36E-07	7.99E-07
	Proposed LERF	9.76E-07	9.84E-07	9.95E-07
	Delta LERF	1.41E-08	2.24E-08	3.37E-08

Table 7. ICCDP and ICLERFP Sensitivity Analysis results on AOT change

Systems	ICCDP			ICLERP		
	7days	10days	14days	7days	10days	14days
EDG	2.89E-07	3.60E-07	4.54E-07	1.28E-08	1.60E-08	2.04E-08

Table 7 showed the results of ICCDP (Incremental Conditional Core Damage Probability) and ICLERP (Incremental Conditional Large Early Release Probability). The ICCDP and ICLERP represent the changes of probabilities of the Core Damage and Large Early Release due to the out-of-service of a particular equipment/system.

According to the RG 1.177, the acceptance criteria for the equipment/system out-of-service are to be ICCDP < 5.0E-6, and ICLERP < 5.0E-7. Also, the acceptance domain for the change of CDF and LERF due to the increase of the out-of-service duration is represented in Fig.1. Through Table 6 and 7, it was concluded that the ΔCDF and ΔLERF due to the EDG AOT extension up to 14 days were in the acceptance domain (Region III) even with the power up-rating. Also, the ICCDP and ICLERP were found to meet the RG 1.177 acceptance criteria.

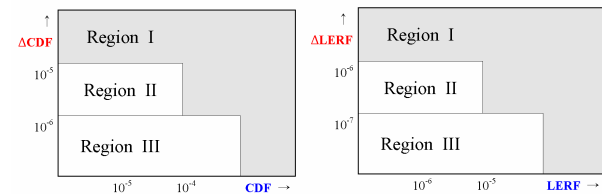


Figure 1. Acceptance Guidelines for ΔCDF and ΔLERF

#### 5. Conclusion

It was found that the power up-rating slightly affected the AOT extension in the risk analyses. The possibility of the AOT extension was investigated by analyzing the changes of CDF, LERF, ICCDP, and ICLERP. For the Kori 3&4 power up-rating case, the extension of the EDG AOT was found acceptable, meeting the criteria of RG 1.174 and RG1.177 even with the power up-rating conditions.

#### REFERENCES

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