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PSA Re-evaluation on the Kori 3&4/Yonggwang 1&2 Power Uprates

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1. Introduction

PSA re-evaluation has been performed to identify the effects on the 4.5 percents power uprates for Kori unit 3&4 and Yonggwang unit 1&2. The power uprates for these plants are categorized as SPU(Stretch Power Uprate) which implements the uprate only through the available safety margin without the large design changes.

This assessment includes the Level-1 internal events and external events including earthquakes, fires and floods, the re-evaluation of Level-2 LERF(Large Early Release Frequency) and ST(Source Term) analyses. The sensitivity analyses have been performed with the basis on the recent PSA results, "Kori 3&4 PSA evaluation report (Jun. 20, 2003)" and "Yonggwang 1&2 PSA report (Dec. 31, 2003)".

2. Reassessment Results

The analyses of PSA due to the power uprate indicated that initial events frequencies, event fault tree logics, system success criteria and component failure rates were not changed. But, the MAAP-4 code analyses showed that the time before the core uncovery was reduced, and this resulted in the increase in the human error probabilities for the offsite power recovery actions in SBO(Station Black-Out) scenarios and some post-accident operator errors.

The basic events affected by the power uprate are the probabilities to fail to recover the offsite power within 17 hours, 10.9 hours, 9 hours, and 2.9 hours. In addition, human reliability analyses showed that there were changes in the two human error probabilities among the operator actions after initial events (IE) occurrences. The changed operator error probabilities due to the power uprate were the core cooling recovery failure during the loss of CCW and the core cooling recovery failure during the small LOCA. For both cases, MAAP-4 analyses showed that the available time for operator to recover the core cooling is reduced after the power uprate, and this caused these operator error probabilities to increase. The other human error probabilities except the above six cases were not changed due to the power uprate.

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

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

The results of Level-2 PSA effects due to the power uprate indicated that there were no changes in the CET(Containment Event Tree), DET(Decomposed Event Tree) and their fractions after the power uprate. The LERF for Kori 3&4 is increased approximately 2.8 percents after the power uprate, and the LERF for Yonggwang 1&2 is increased about 2.3 percents. These changes are caused by the PDS(Plant Damage Status) frequency change due to the CDF increase.

Table 2. LERF Changes before and after Power Uprate

Units	Δ LERF(/RY)	Description
Kori 3,4	3.0E-8	2.8% increased
Yonggwang 1&2	1.8E-8	2.3% increased

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

3. Sensitivity Studies

Sensitivity analysis also is performed to consider the uncertainty in design changes. It includes the initial break-in failure increase due to the replacement of turbine components and one CCW(Component Cooling Water) heat exchanger, the relaxation of the acceptable criteria for a steam dump system, and the plant transients due to the operating condition change of Main Feed Water pumps. Comparing additional 10% failure rate considering the uncertainty showed that the power uprates for Kori 3&4 and Yonggwang 1&2 resulted in only about 0.1% and 0.2% increase of CDF respectively.

In addition, the combined effects of the AAC (Alternating Alternate Current) system which was installed in the Kori site recently and scheduled in the Yonggwang site in year 2008 have been reviewed in the 4.5% uprated condition. The results showed that the whole effect was improved up to approximately 30%. Since the safety improvement by the design change is much more effective than the slight increase due to the power uprate, the entirely safety is relatively improved.

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

Model	ΔCDF(/RY)	Description on the CDF Changes
Reference Model [1]	5.0E-07	5.9% increase compared to the reference model before power uprate
AAC Model	1.0E-07	1.8% increase compared to the AAC model before power uprate 33.2% decrease compared to the reference model before power uprate

Table 4. Sensitivity Analysis with AAC installed (YG 1&2)

Model	ΔCDF(/RY)	Description on the CDF Changes
Reference Model	3.9E-07	5.3% increase compared to the reference model before power uprate
AAC Model	9.0E-08	1.8% increase compared to the AAC model before power uprate 33.9% decrease compared to the reference model before power uprate

4. Conclusion

The CDF 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 met the RG 1.174 limit sufficiently. Also, despite the factors such as the potential increase in the initial fault rate of the replaced equipment and the potential rise of the probability entering into the transient conditions due to the design changes, the sensitivity analyses for the level-1 internal event PSA indicated that the results 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.

Consequently, 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.

[1] Reference model is the PSA model before an AAC diesel generator is installed (that is, the model without AAC).

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