Implementation Status of Risk-Informed Application in KHNP

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1. Introduction

Korea Hydro & Nuclear Power (KHNP) began commercial nuclear operation with Kori unit 1 in April of 1979, and has 20 nuclear power units in operation today. KHNP is currently constructing 6 additional units in the form of OPR-1000 and APR-1400 type plants. Plant operation records from 1998 to 2008 show that KHNP achieved the world's best performance in terms of capacity factors and minimizing unplanned plant shutdowns. KHNP's capacity factor has been above 90% since 1998 and rose to 93.3% in 2008. In addition, per-unit unplanned plant shutdowns have steadily decreased from 1.5 in 1992 to 0.35 in 2008.

As a part of post three-mile Island(TMI) action improve nuclear safety, KHNP completed the Level-I and II probabilistic safety assessments (PSAs) for all operating nuclear power plants by 2007. Moreover, the risk information collected in those assessments has been applied to enhance the operational and maintenance safety of KHNP plants. In addition to successful implementation of the risk-informed application (RIA), KHNP has attempted to strengthen nuclear reactor oversight activities that focus on equipment performance.

In this paper, a comprehensive strategy for the risk-informed application and equipment reliability process is presented. Safety and performance trends are demonstrated in terms of core damage frequency and capacity factors. The implementation status of risk-informed application at KHNP is also described.

2. Risk-Informed Application and Equipment Reliability Process

The U.S. nuclear regulatory commission (NRC) has divided risk-informed regulation work into three areas: Options 1, 2 and 3. To pursue the goal, one needs to have good risk information as well as good plant performance. Good risk information is predicated on good PSA quality. To improve PSA quality, we need to engage in an independent peer review process as well as apply plant-specific data.

For better plant performance, KHNP is focusing on improving and maintaining equipment reliability while strengthening the monitoring of critical functions and plant configuration. Risk monitors are the tools for monitoring plant configuration.

The goal of the equipment reliability process is to achieve risk-informed asset management through the increased use of predictive maintenance and a life cycle perspective. KHNP is pursuing this process for operations and maintenance (O&M) optimization and for safety improvement. Figure 1 illustrates the risk-informed application and equipment reliability (ER) process.

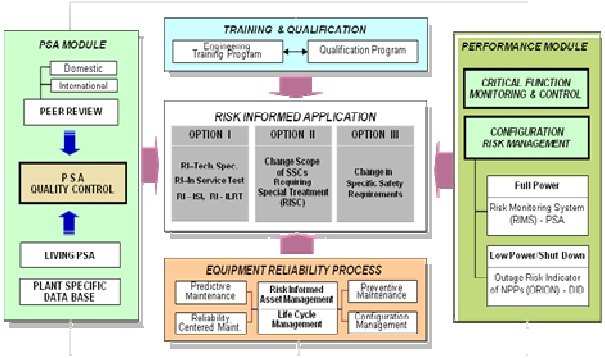

Fig 1. Risk-Informed application and ER process

3. Safety and Performance Trends at KHNP

The primary risk metrics used today are core damage frequency (CDF) and large early release frequency (LERF). Figure 2 illustrates the steady decline in average CDF at KHNP. This improvement has been driven by plant equipment reliability, performance improvements and PSA model improvements.

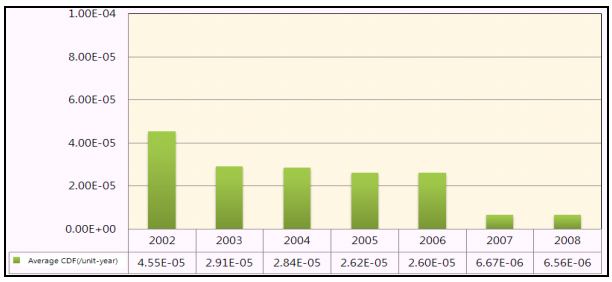

Fig 2. 2002 to 2008 KHNP Average CDF Trend

A nuclear power plant's capacity factor represents its health and operational confidence. The highest capacity factor at KHNP was recorded as 95.5% in 2005. KHNP has endeavored to improve plant performance by minimizing refueling outages, optimizing maintenance, extending fuel cycles and enhancing safety. The average capacity factor at KHNP nuclear power plants increased from roughly 90% to about 93% between 1998 and

2008. Figure 3 illustrates the capacity factor performance at KHNP.

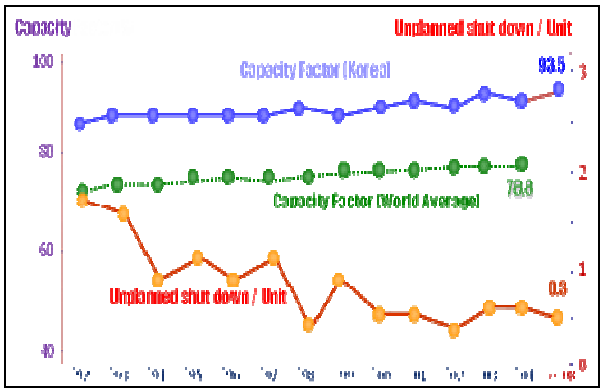

Fig 3. Capacity Factor Performance at KHNP

4. State of Risk-Informed Application at KHNP

4.1 Regulatory Body Requirements for RIA

The Korean nuclear regulatory body specifies particular requirements during the review of PSAs and Risk-Informed Applications.

- General scope: Level 1 and Level 2 PSAs.
- PSA technical adequacy: ASME Category 2.
- The quantitative targets of KINS GT/N-24 must be met.

4.2 KHNP Risk-Informed Application Status

KHNP try to focus on Option 1 areas such as risk-informed integrated leakage rate test (RI-ILRT), risk-informed allowed outage time (RI-AOT), and risk-informed in-service inspection (RI-ISI). KHNP PSA models are adequately maintained for RIA and PSA above ASME Category 1.

- Containment Integrated Leakage Rate Test Interval Relaxation

The containment integrated leakage rate test (ILRT) interval can be relaxed to 10 years (it is currently 5 years) [1]. 11 plants have extended ILRT intervals. RI-ILRT benefits include fewer tests, lower personnel exposures, and increased plant availability and capacity factor due to shorter outages. Most plants will be able to reduce outage durations by one day and thus save millions of dollars. We are preparing to extend ILRT intervals for 5 plants: Kori unit 1, Yonggwang units 5&6, and Ulchin units 5&6.

- Technical Specification Optimization

Kori units 3 and 4 were evaluated for allowed outage time (AOT) based on their plant specific PSA results [2]. The extension of AOT met the criteria specified in R.G. 1.174 and 1.177 [4, 5].

- Risk-informed in-service inspection

RI-ISI is the alternative to the present ISI method (ASME Sec XI). This method requires tests for class 1 and class 2 welding points for 1 period (10 years). The RI-ISI method test was performed on risk significant piping and reduced test points while maintaining safety level. The RI-ISI method was endorsed by Korean nuclear regulatory body for use with OPR1000 plants in 2008 [3]. The nuclear power plants in KHNP are partially engaged in a variety of risk-informed applications, as indicated in Table 1.

Table 1. State of Risk-informed applications at KHNP

Item	status	Description
RI-ILRT	- 11 units extended out of 20 operating units (Kori 2, 4, Yonggwang 1, 4, Ulchin 1, 4)	Test interval (5yr →10yr)
RI-AOT/STI	- K3,4/Y1,2 RPS/ESFAS STI extended in '99 -U3,4 RPS/ESFAS STI extended in '08 -U3,4 Class 1E Inverter AOT extended in '07 U5,6 Battery STI extended in '08	
	Not submitted to regulatory agency (Study only) - Y3~6/ U3,4 AOT study performed in '04 K3,4/Y1,2 AOT study performed in '07	
RI-ISI	- RI-ISI methodology established in '04 RI-ISI methodology endorsed in '08	
PSA adequacy	- K3,4 peer review performed in '05 K3,4 PSA model quality update ('04~'06)	NEI00-02

5. Conclusions

Risk-informed applications contribute to NPP performance through decreasing the volume of unexpected plant trips, reinforcing maintenance, avoiding risks due to unnecessary operation mode changes and improving safety. KHNP has completed the Level I and Level II PSAs for all operating nuclear power plants and is actively pursuing the recommended risk-informed applications for plant safety improvement and operational flexibility.

The Korean regulatory body can focus on safety issues. Risk-informed approaches have proven advantageous for both the regulatory body and for KHNP. Reasonable regulations and support for RIA from the regulatory body would be beneficial.

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