Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, November 2-3, 2006

A Study on the Maintenance Effectiveness Assessment for Active Components

Woo Sang Lim, Seung Jong Oh
KHNP, 103-16, Munji-Dong, Yueong-Gu, Daejun, 305-380, Korea, wslim@khnp.co.kr

1. Introduction

One of the key tasks in the periodic safety review (PSR) of nuclear power plant is to assess the aging management of structures, systems and components (SSC). The evaluation can be categorized by two parts, passive and active components. Unlike the passive components, active components are periodically maintained and replaced with new components, so the evaluation of aging mechanism of the passive components such as erosion, corrosion is not applicable to the evaluation of active components of nuclear power plant. For active components, they will maintain capability to fulfill its design function if preventive maintenance effectiveness is proper. In this paper, the assessment based on the reliability and availability of the active components of the domestic nuclear power plants is examined..

2. Methods and Results

In this section, some of methods used to assess maintenance effectiveness are described. Performance evaluation of the active component in PSR is to establish performance criteria and to confirm recent operating history data meeting them. The scope of assessment includes safety-related systems and components that are relied upon to remain functional during and following design basis events to ensure the integrity of the reactor coolant boundary, the capability to shut down the reactor and maintain it in a safe shut down condition, and the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to the 10CFR part 100 guidelines. Non safety-related systems and components whose failure could prevent safety- related systems and components from fulfilling their safety-related function, or whose failure could cause a reactor scram or actuation of a safety-related system, are also included in the scope [1].

2.1 Risk Significant SSC and Performance Criteria

Importance measures such as Risk Reduction Worth (RRW) and Risk Achievement Worth (RAW) in the probabilistic safety assessment (PSA) are used to identify risk significant SSCs. An SSC is considered risk significant if its RRW exceeds 0.5 percent of the overall core damage frequency (RRW>1.005). If the RAW of a SSC exceeds 2, it is also classified as risk significant [2, 3].

Performance criteria for each SSC function are established after risk level classification. Performance criteria for evaluating SSCs are necessary to identify the standard against which performance is to be measured. Criteria are established to provide a basis for determining satisfactory performance. The actual performance criteria used is SSC availability and reliability [4].

All the SSCs do not need to be established individual performance criteria. The performance criteria such as reliability performance criteria (RPC) and unavailability performance criteria (UPC) are established only for the risk significant SSCs. In case of non risk-significant, standby (S/B) components also need to establish their performance criteria as shown in Figure 1.

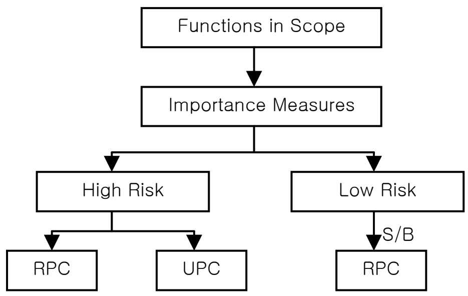

Figure 1. Performance criteria establishing process

2.2 Unavailability Performance Criteria

Unavailability performance criteria are established by assessing maintenance history during recent two refueling cycles, especially unavailability due to maintenance under assumption that events occurred in the past times affect those in the future. To determine UPC for individual system function classified as risk significant, unavailable time assumed in the plant specific PSA and maximum actual unavailable time are compared each other. Unavailable time during recent two refueling cycles indicates out of service time of the component. If this actual unavailable time is shorter than unavailable time assumed in the PSA, the actual unavailable time is determined as performance criteria without further analysis. If an actual unavailable time is longer than that assumed in the PSA, sensitivity analysis is performed to see impact on the core damage frequency and determine whether it is acceptable as an UPC [5].

2.3 Reliability Performance Criteria

To establish reliability performance criteria, operating history of component during recent two refueling cycles is collected and calculated each component failure rates.

In case of standby SSC, acceptable functional failures are estimated by using following binary distribution equation;

$$P(r) = \frac{n!}{r!(n-r)!} P^r (1-P)^{n-r}$$

Where, n; total numbers of the start demands, r; numbers of the start failure, P; failure probability

For RPC of operating components, following Poisson equation is used.

$$P(n) = \frac{(\lambda T)^n}{n!} e^{\lambda T}$$

Where, n; numbers of failures, T; operating time, λ ; failure rate

In above equation, a smaller value of n (or r) among an individual failure probability exceeds 0.05 and cumulative failure probability exceeds 0.95 is selected as RPC of the component.

For example, residual heat removal pumps have functions of reactor coolant heat transfer to the component cooling water system to lower the temperature to the level of cold shutdown, and of partial role for emergency cooling water system. Thus they are included in the assessment scope because they correspond to the functions of maintaining reactor safe shutdown and prevention and mitigation of offsite radiological release. The RHR pump is a high risk significant component as RRW calculated in the PSA is larger than 1.005. As a RHR pump has four starting demand a year and the demand failure rate is 2E-3. So failure frequency is estimated as 0.016 per two years. Since the probability of no occurrence P(0) during the given period of time is 0.98, the RPC is such that no occurrence of functional failure is permitted during recent two years.

2.4 Results

76 component groups in 31 systems were selected as risk significant. 54 components groups in 25 systems were selected as the result of PSA review. 18 Standby component groups in 6 systems were also selected. 4 components in 3 systems were added to the risk significant category based on the expert panel recommendation. As a result of operating history review, all the components met the reliability performance criteria. Some components such as charging pump and component cooling water pump were found to exceed the unavailability performance criteria slightly. In the case of a pump failure, it took longer time to determine the cause of failure. There were failure causes in a motor operated valve. So for a corrective action, a predictive maintenance was recommended to monitor equipment condition with a thermography rather than existing time directed maintenance.

3. Conclusion

Maintenance effectiveness of active components for a nuclear power plant was assessed in the PSR. The developed methodology is found to be desirable since the safety of a plant can be maximized with small corrective actions. Maintenance Rule (10CFR50.65) is anticipated to be in place also in Korea in the near future. The methodology can be used as implementing as a ground work for it.

REFERNCES

[1] 10CFR50.65, Requirement for Monitoring the Effectiveness of Maintenance at Nuclear Power Plant, U.S. Nuclear Regulation Commission, 1991

[2] Reliability Improvement Guideline, Korea Hydro and Nuclear Power Co., May 2003

[3] EPRI PSE 1009735, Critical Component Identification Process-Licensee Examples; Scoping and Identification of Critical Components in Support of INPO913, EPRI, December 2003

[4] NUMARC 93-01, Industry Guide for Monitoring the Effectiveness of Maintenance at Nuclear Power Plant, Rev.1, Nuclear Management and Resource Council, May 1993

[5] NUREG-1648, Lessons Learned from Maintenance Rule Baseline Inspections, U.S. Nuclear Regulation Commission, October 1999