Equipment Reliability Improvement for Koeberg Nuclear Power Plant Auxiliary Feedwater System

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1. Introduction

The purpose of this study is to apply maintenance rule [1] to enhance the Auxiliary Feedwater System (AFWS) maintenance strategy at Koeberg Nuclear Power Plant (KNPP). Currently, Koeberg AFWS health status is red, needing an improvement.

This study seeks to use maintenance rule to identify components that enable AFWS to fulfill its essential functions so as to focus maintenance resources and have the greatest beneficial impact on improving reliability and availability of the system.

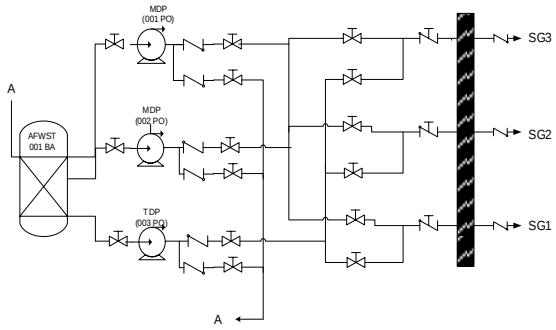

Figure 1: KNPP Auxiliary Feedwater System (modified from KNPP AFWS P&ID [2])

Figure 1 shows a simplified flow diagram of the AFWS. The AFWS consists of two (50% capacity) motor-driven pumps (MDPs) and one (100% capacity) steam turbine-driven feedwater pump (TDP).

2. Methodology

The maintenance rule guide requires that a panel of experts be established. The panel which consists of KNPP experts from various groups like Operating, System Engineering (chairman), Design Engineering, Component Engineering, Maintenance Engineering and the PSA Group was established.

The main function of the AFWS is to ensure a sufficient water supply to the Steam Generator (SGs) for removal of decay heat from the core when the main feedwater system fails. In accordance with the process shown in Figure 2 AFWS is classified as SR-2; SR-2 is a system with the capability to shutdown the reactor and maintain it in a safe shutdown condition [1].

The expert panel performed scoping and identification of risk significant components, basically establishing which components should be within the scope of the maintenance rule. This means consideration of functions that must be performed for safe operation of the system and components that are performing those functions. AFWS functions are identified in Table 1.

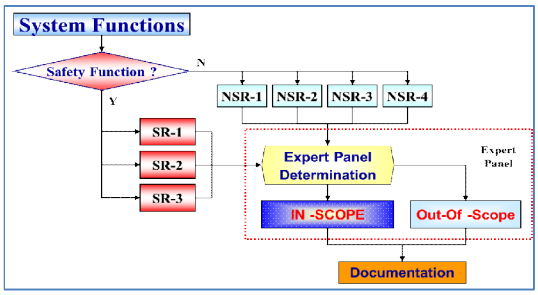

Figure 2: Maintenance rule process

The expert panel utilized the Delphi approach (as indicated in the process in Figure 2) incorporating their understanding of the plant system, system failure experience and potential failures to answer a questionnaire to determine the functions that are High safety Significant (HSS) or Low safety Significant (LSS). The Delphi process requires each panel member to complete a questionnaire in three rounds. The Delphi questionnaire has four questions that can be answered by a score ranging from one to ten. For each question a score is multiplied by a weighting factor. The weighted score then determines if the function is HSS or LSS.

Table 1: AFWS Functions

ID	Function Description
AF-01	Supplying feedwater to the SGs at startup during heat up of the reactor coolant system, during hot standby or during hot shutdown when it is impossible to use the main feedwater supply system.
AF-02	Supplying feedwater to the SGs for removal of stored and decay heat at the beginning of a cold shutdown before the start-up of the residual heat removal system.
AF-03	Filling up of the steam generators.

The panel decided that AF-01 and AF-02 should be HSS while AF-03 should be LSS. In the next phase of the process (Figure 3) risk significant functions are identified to initially determine which components must have goals established and monitoring activities performed.

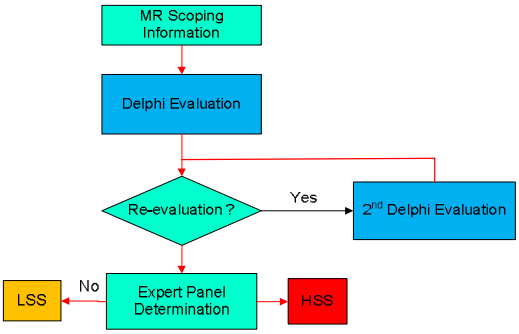

Figure 3: Maintenance rule importance determination process

KNPP Operating Experience was used to narrow down the expert panel results into the worst performing components. The results of that analysis highlighted the following components: ASG 001/002/003 PO ï Pumps (MDP & TDP) and TDP Control System ï (Speed Acquisition System).

For the identified components, goals and performance criteria need to be established as a reference point against which to judge the system performance.

Table 2: AFWP Expected number of failures

Pumps	FTS	FTR	No. of demands/ pump in 3 years	Expected No. of failure in 3 years
TDP	4.8E-03	2.5E-03	30	1
MDP	1.6E-03	1.03E-03	30	0

Determining the Performance Criteria requires the estimation of the expected number of failures as shown in Table 2. This was done using the EPRI calculator [3].

Using the calculator projections can be made on the expected number of pump failures in one cycle. The results are shown in Table 3 (M-month(s), RO-refueling outage, S-shift, AR-as required, NR-not recommended).

3. Maintenance Strategy

The KNPP Corrective Action Program (CAP) database analyzed revealed that the turbine driven pumps (TDP) are the most problematic. Failures associated with the turbine driven pump are having the most adverse impact on system reliability. The proposed solution is a revision to the current Preventive Maintenance Strategy.

EPRI guidelines [4] have been used to develop degradation mechanisms for the pumps, degradation indicators, monitoring frequency, trending method, acceptable band and the required actions. The TDP is a horizontal centrifugal pump.

The horizontal pumps EPRI PM Template [4] was modified, reducing the monitoring frequency to allow for early detection of negative trend. A monitoring frequency of two months is most feasible for the AFWS pumps. The system engineer will trend the results every three months.

The principal root cause of the failure of the TDP is the turbine control circuitry. The proposed solution for the speed control circuit is a modification. The modification is aimed at improving the reliability of the speed control circuit.

Table 3: AFWP PM template

Functional Importance Determination		
Condition Monitoring Task	**Old Frequency**	**Proposed Frequency**
Vibration Analysis	1M	2M
Oil Analysis	1RO	3M
Performance Trending	6M	2M
System Engineer Walkdown	3M	3M
Operator Rounds	1S	1S
Time Directed Task		
Oil Filter Change, Clean, and Inspection	AR	3RO
Coupling Inspection	3RO	3RO
Nozzle NDE Inspection	AR	NR
Partial Disassembly	AR	AR
Refurbishment	AR	1RO
Functional Testing	AR	2M

4. Conclusions

This paper investigated how the performance of the Koeberg Auxiliary Feedwater System could be improved using the ómaintenance ruleô. As a conclusion, this paper figured out AFWS pumps and the TDP control circuit need special attention in improving the reliability of the AFWS, this lead to an improved maintenance strategy for the system.

REFERENCES

[1] ñIndustry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power
Plantsò, NUMARC 93-01, Revision 2, April 1996, Nuclear Energy Institute.
[2] Koebeg Safety Analysis Report, Rev 4, 2009.
[3] Performance Criteria Calculation Spreadsheet, May 2004, Electric Power Research Institute.
[4] ñEquipment Condition Monitoring Templates: Addendum to the Preventive Maintenance Basis, EPRI TR-106857 (Volumes 1-3) September 2000.