Optimization of Maintenance for the Turbine Lube Oil System in NPP

Efenji A. Emmanuel [a*], Lee S. Hoon[a], Mostafa A. Hassan[a], Le V. Anh, Lee[a], Choi W. Jun[a], Lee, Yong-kwan[a]
KEPCO International Nuclear Graduate School (KINGS), 14561-1 Shinam-ri, Ulsan, South Korea
[*]Corresponding author: leeyk@kings.ac.kr

1. Introduction

Assets in NPP need to be operated and maintained to reduce as low as possible unanticipated equipment failures, severity of failures, unplanned trips and outages, and lifecycle cost. In an attempt to achieving these goals, various condition based maintenance methods/technologies (periodic, preventive, and planned) have been implemented by nuclear utilities to monitor the health of their fleets.

The purpose of the turbine lubrication oil system is to minimize the friction loss by supplying lube oil to the turbine / generator bearings. For instance, in the APR 1400 Nuclear Power Plant (NPP), there is ten journal bearings (radial) that are installed in the casing of the main turbine system. They support the rotor and absorb the vibration of the rotor during turbine operation. There are also the thrust bearings that maintain the Rotor axial position.

The turbine lube oil system is not a safety system, but the failure of the system could cause turbine trip, unplanned power derate, and violation of Technical Specification. Therefore, supplying turbine lubrication oil with rated pressure and temperature is critical for the safe operation of turbine system. This work seeks to propose a maintenance plan for improved reliability of the Turbine Lubrication Oil System.

2. Methods and Result

2.1 System Description

The Turbine lube oil system (TLB) typically consists of five centrifugal oil pumps, one mounted on the main turbine shaft and the remainder located at the lube oil reservoir which also houses the oil cooler and the oil filter. On some units a sixth centrifugal pump is provided at the reservoir to obtain control oil for the boiler feed pump turbines. Figure1 shows the schematic diagram of lube oil pumping system [1].

2.2 Scoping and Identification of Critical Components

In this stage, the system functional components were scoped, their functional importance determined, and their criticality evaluated based on their failure impact on the system and the plant in general. The Shin Kori unit 1 NPP design (OPR 1000) was referenced and reviewed. 255 components were identified; 40% valves, 17% switches, 13% indicators, 8% pumps, and 5% motors.

2.2.1 Critical Components. Delphi method was used to identify the criticality of the TLB components. The questions were constructed by referencing the sample recommended by INPO AP-913 [2]. Components are classified as Critical if their functions scored a single 'Yes' to any of the 'Critical questions'. Those components whose functions did not score a single 'Yes' to the 'Critical questions,' but did for the 'Non-critical questions,' are classified as Non-critical. The remainder whose functions did not score a single 'Yes' in neither of the above is classified as Run-to-fail.

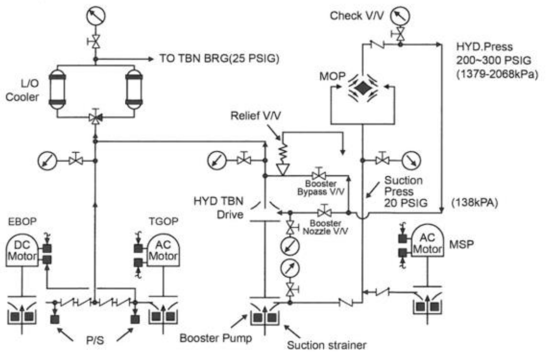

Figure 1: Schematic diagram of lube oil pumping system.

2.1.2 High Safety and Low Safety Significance Determination. The critical components as evaluated from 2.2.1 were further subjected to a 2nd Delphi to categorize them as High Safety Significant (HSS) or Low Safety Significant (LSS). The Delphi Risk Ranking Format as used by KHNP [3] was adopted. In this method, four accident response functions and six normal operating functions are identified and weighted according to their risk functional importance as shown in Table (1). The critical components were individually analyzed against each of the four accident response functions and the six normal operating functions. A scale of 0, 0.1, 0.2, 0.3…………, 1 was adopted to grade each critical component to these functions. The scaling factors were multiplied by their corresponding weights and a total score was obtained for each of the components. The total score was then compared to an established threshold; Threshold = Average of Accident Response Function Weight + Average of Normal Operation Function Weight. Components with values equal or greater than the threshold were classified as HSS and those below the threshold were classified as LSS.

$$\text{HSS Threshold} = (31.4/4) + (40.5/6) = 14.6 \quad (1)$$

Table 1: Delphi risk ranking [2]

Accident Response Functions	**Code**	**Weights**
Shutdown the reactor and maintain it in a safe condition	SF-1	7.3
Maintain the reactor coolant pressure boundary	SF-2	7.1
Remove atmospheric heat and radioactivity from containment and maintain containment integrity	SF-3	7.5
Remove heat from the reactor	SF-4	9.5
Sum of Accident Responses	-	31.4
Normal Operating Functions	**Code**	**Weights**
Provide primary side heat removal	NF-1	7.1
Power conversion	NF-2	7.8
Provide primary, secondary, or containment pressure control	NF-3	5.5
Provide cooling water, component or room cooling	NF-4	6.7
Provide electric power (AC, DC power)	NF-5	7.7
Provide other motive or control power	NF-6	5.7
Sum of Normal Operations	-	40.5
Total Sum	-	71.9

2.3 Performance Monitoring

The essence of Performance Monitoring is to establish performance criteria (monitoring parameters) to assess the assets whether their performances satisfies the criteria. According to NUMARC 93-01[4] the safety significance criteria and performance criteria are essential to provide a standard to measure the health of System, Structures, and Components (SSC). The guideline as given by INPO AP-913 [2] was tailored and applied to the TLB.

2.3.1 Performance Criteria. The performance criteria are based on plant, system, or component reliability, availability or their condition. Condition monitoring techniques can be used when performance monitoring cannot be related to component degradation. Performance monitoring plans are established for both risk significant systems and non-risk significant systems that are in standby mode based on existing or user's defined criteria.

2.3.2 System Performance Monitoring Plan. System Engineers perform plant data trending at regular intervals to analyze system performance as against the performance criteria. The System Level performance monitoring plan was developed based on failure modes, referencing KHNP's operating experience and GE's manual.

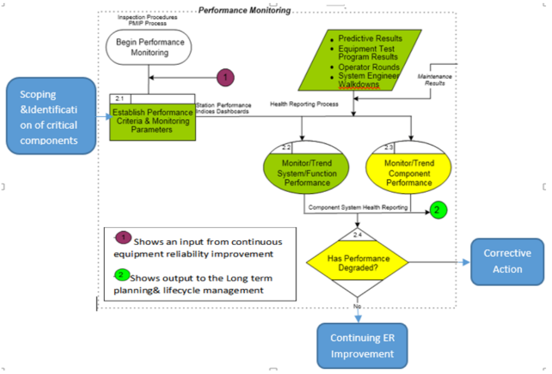

Figure 2: INPO Performance Monitoring Flowchart

2.3.3 Component Performance Monitoring Plan. This is typically a component based trending using industry experience like Equipment Performance Information Exchange (EPIX) to identify equipment faults before they fail. The Component Level performance monitoring plan was developed based on predictive maintenance and preventive maintenance.

Table 2: System Performance Monitoring Plan

Failure mode	Lube oil piping failure
Effect of failure	Turbine trip or power derate
Degradation mechanism	Piping break or tank leakage due to vibration
Degradation indicators	Bearing header pressure decrease
	MOP operating pressure decrease
	Oil tank level decrease
Monitoring Interval	Every other week
Action taken	Work order issued
Failure mode	MOP/Booster pump failure
Effect of failure	MSP and TGOP auto-start
Degradation mechanism	Internal parts aging
Degradation indicators	Bearing supply oil temperature increases
	Booster pump discharge pressure decreases
Monitoring Interval	Every other week
Action taken	Work order issued
Failure mode	Contamination of lube oil
Effect of failure	Bearing temperature and vibration increases
Degradation mechanism	Foreign material in lube oil
Degradation indicators	Degradation of lube oil
Monitoring Interval	Every month
Action taken	Work order issued

Key: MOP-Main oil pump, TGOP- Turning gear oil pump, MSP- Motor suction oil pump

Table 3: Component Performance Monitoring Plan

Component	Risk importance	Duty Cycle	NDE	Duration
Low shaft pump discharge trip switch #1	High	Low	Functional test	Quarterly (3 months)
Low shaft pump discharge trip switch #2	High	Low		
Low shaft pump discharge trip switch #3	High	Low		
Low bearing oil trip switch #1	High	Low	Functional test	Quarterly (3 months)
Low bearing oil trip switch #2	High	Low		
Low bearing oil trip switch #3	High	Low		
Booster pump (BOP)	High	High	Pressure monitoring, vibrational analysis	Continuously
Main oil pump (MOP)	High	High		
Turning gear oil pump (TGOP)	Low	Low	Pressure monitoring, Vibrational analysis	Quarterly (3 months)
Emergency bearing oil pump (EBOP)	Low	Low		
Motor Suction pump (MSP)	Low	Low		
Lift oil pump #1	Low	Low		
Lift oil pump #2	Low	Low		
Lift oil pump #3	Low	Low		
Lift oil pump #4	Low	Low		
Lift oil pump #5	Low	Low		
Lift oil pump #6	Low	Low		
Lift oil pump #7	Low	Low		
Lift oil pump #8	Low	Low		
Oil conditioner gear pump	Low	High	Pressure monitoring, Vibrational analysis	Refuelling Outage
MOP discharge check valve	Low	High		
Booster baffler valve	Low	High		
Bypass baffler valve	Low	High		
Bearing relief valve	Low	High		
Filter #1	Low	High	Disassemble filter housing	Refuelling Outage
Filter #2	Low	High		
Filter #3	Low	High		

Table 4: Overhaul Maintenance Plan

Component	Examination	Corrective Action
Pump & motor items	- Disassemble - Dimension check - Pressure test - Ultrasonic test	- Parts replacement - Functional test
Valves	- Disassemble - Dimension check - Pressure test - Ultrasonic test	- Parts replacement
I&C components (Trip switches)	- Disassemble	- Parts replacement - Functional test
Filters	- Disassemble filter housing	- Filter elements replacement

2.3.4 Discussion of Results. The results on table 2 represent the system performance monitoring plan for the TLB system. The performance parameters identified in the plan were not assigned any particular values in other to make them generic. These parameters should be monitored against user's defined baselines to detect deviations and initiate the appropriate corrective actions if needed.

The results in table 3 are the monitoring plans for the identified critical components which have been further categorized according to their risk importance. The HSS were assigned ‘High’ while the LSS were assigned ‘Low.’ The components which are normally operated were assigned ‘High’ duty cycle, while does on standby were assigned ‘Low’ duty cycle. For the MOP and the BOP whose risk significance and duty cycle are both ‘High’, continuous monitoring was proposed. For the other 11 pumps, with a ‘Low’ duty cycle and ‘Low’ risk importance, periodic tests (quarterly) were proposed since they should start automatically in cases of emergency.

Preventive maintenance at refueling outage was proposed for the remaining components since their risk level is low. An overhaul test (disassemble) has been recommended, in table 4, once every 18 months or at an interval so defined by the utility.

3. Conclusion

The components of the turbine lube oil system have been identified and categorized according to their contribution to the safety and functional requirements of the system in particular, and the plant in general. This was done by conducting two separate Delphi after which an optimized classification was established. They included the high safety and low safety important components.

A performance monitoring plan has been established to monitor parameters at system level. Likewise, a degradation monitoring plan, for the risk important items, has been established to monitor the system at component level.

This work did not develop a preventive maintenance plan for the non-critical components whose failures could pose a maintenance or operational burden. Therefore, future work will be carried out to address the failures for these set of components.

ACKNOWLEDGEMENT

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