Optimization of Maintenance for the Turbine Lube Oil System in NPP

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CONTENTS

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INTRODUCTION

- The turbine lubrication oil system supply lube oil to
  - ✓ the turbine / generator bearings,
  - ✓ turning gears, couplings and thrust bearing.

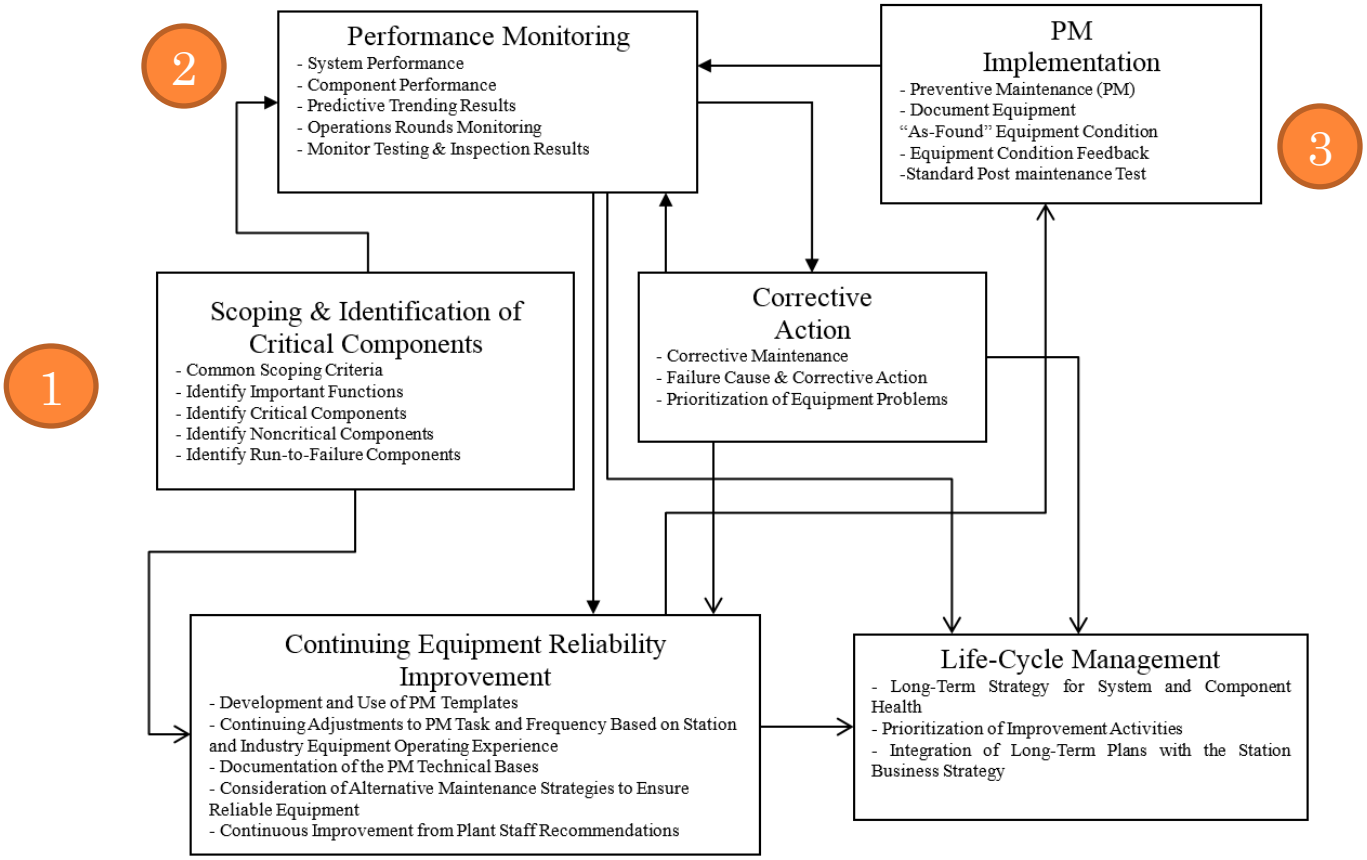
- The turbine lube oil system is not a safety system, but the failure of the system could cause
  - ✓ turbine trip
  - ✓ unplanned power derate
  - ✓ Violation of Technical Specification LCO.

OBJECTIVE

- To propose a maintenance plan for the Turbine Lubrication (TLB) Oil System.
- To improve the reliability and availability of the components of the TLB Oil system
- To enhance the continuous operation of the plant

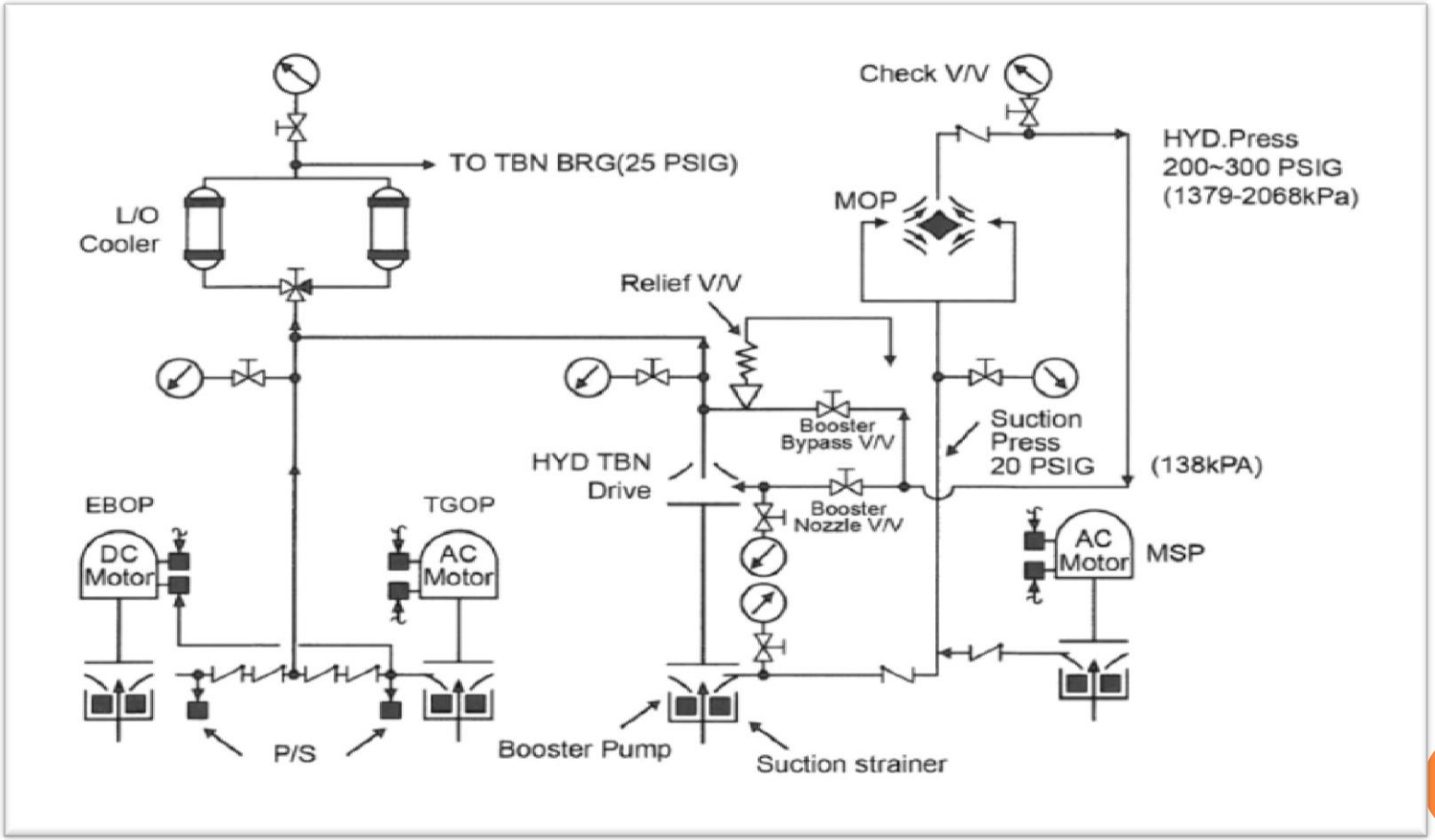
METHODOLOGY

Equipment Reliability Process – INPO AP-913



METHODOLOGY

Apr 1400 lube oil pumping system



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METHODOLOGY

1. Scoping and Identification of Critical Components

Scoping

- The Shin Kori unit 1 NPP design (OPR 1000) was referenced
- 255 components were identified; 40% Valves, 17% Switches, 13% Indicators, 8% Pumps, and 5% Motors.

Critical Components Determination

- Delphi by **INPO AP-913 [2]**
- '**Yes**' to any critical questions ⇒ **Critical**
- '**Yes**' to any non-critical questions ⇒ **Non-Critical**
- Others were **Run to Failure**.

HSS and LSS Determination

- The critical components were subjected to a 2nd Delphi

METHODOLOGY

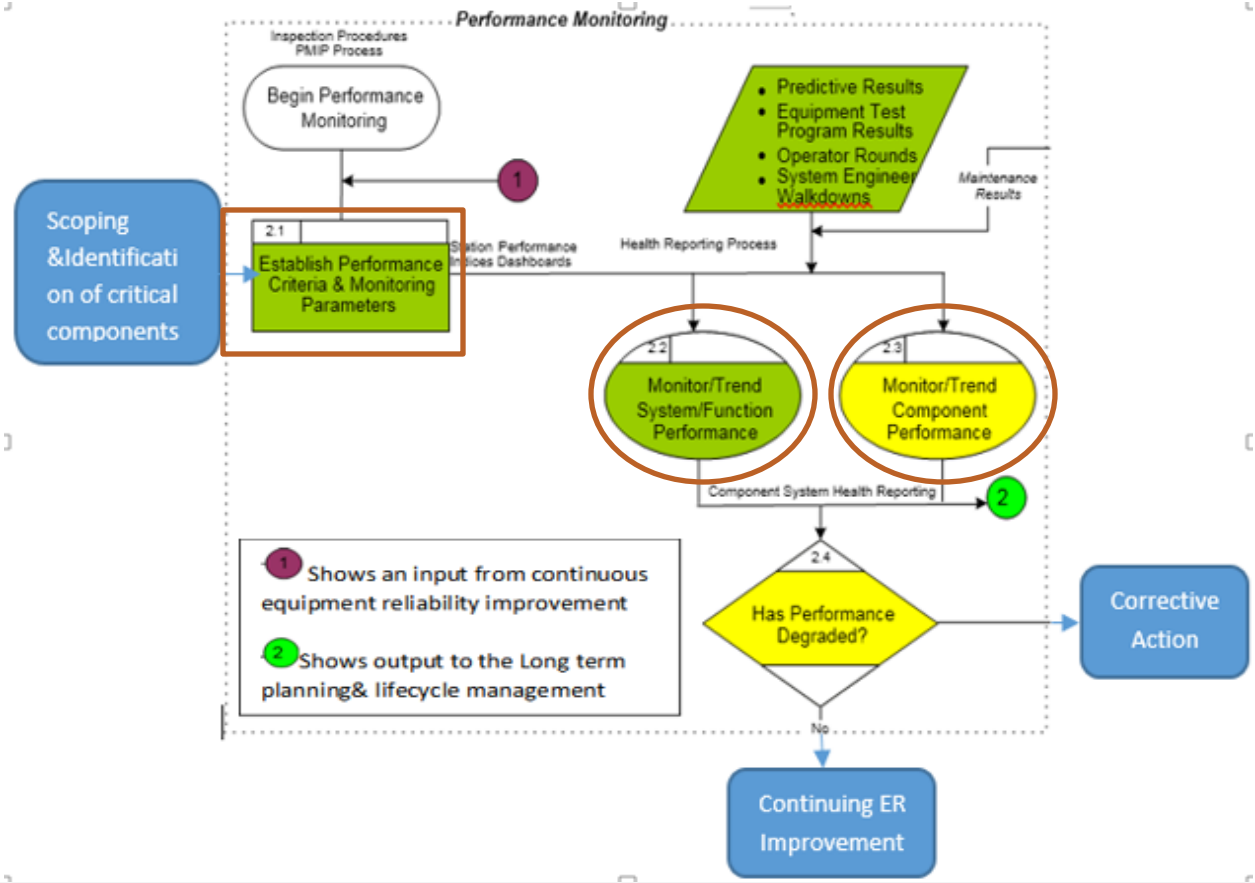
- The Delphi Risk Ranking Format by KHNP was used to categorize HSS and LSS [3] .

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

METHODOLOGY

2. Performance Monitoring

- The guideline given by INPO AP-913 [2].



METHODOLOGY

Performance Monitoring Plan (PMP)

- Can be developed based on Reliability, Availability, or Condition criteria.
- SSCs service and health Conditions were used for PMP.
- **System Performance Monitoring Plan** was based on failure modes & effect (KHNP & GE Manual).
- **Component Performance Monitoring Plan** was based on Risk importance and duty cycle.

RESULT

Table 1 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

RESULT

Table 2 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		

RESULT

Table 3 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

RESULT

Discussion of Result

- For the HSS MOP and the BOP with ‘High’ duty cycle , continuous monitoring is proposed.
- For the standby pumps with LSS and ‘Low’ duty cycle, periodic tests (quarterly) is proposed
- Preventive maintenance at refuelling outage is proposed for the remaining components since their risk level is low.

CONCLUSION

- The components of the turbine lube oil system have been identified and categorized using Delphi.
- A performance monitoring plan has been established to monitor the TLB at system and component level.
- A future work is proposed to develop a preventive maintenance plan for the non-critical components, whose failures could pose a maintenance or operational burden.

REFERENCES

[1] APR 1400 Turbine, Generator and Auxiliary Systems, KHNP Nuclear Power Education Institute.

[2] Equipment Reliability Process Description, INPO AP-913, March 2011

[3] Sang- Dae Lee, Safety Significance Determination Lecture Presentation, KINGS 2016.

[4] NUMARC 93-01, Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants, Rev.4, 2011.

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Thank you for your attention

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