Online Monitoring of Large Centrifugal Pumps in Nuclear Power Plants

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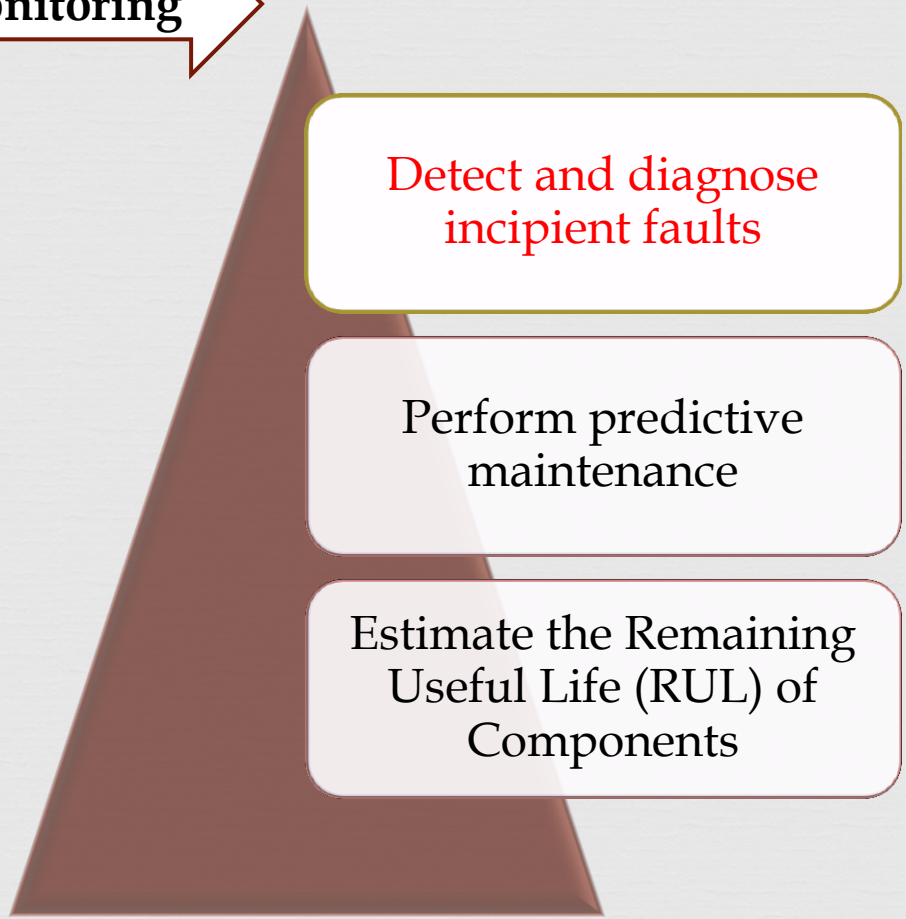
Introduction

Online Monitoring

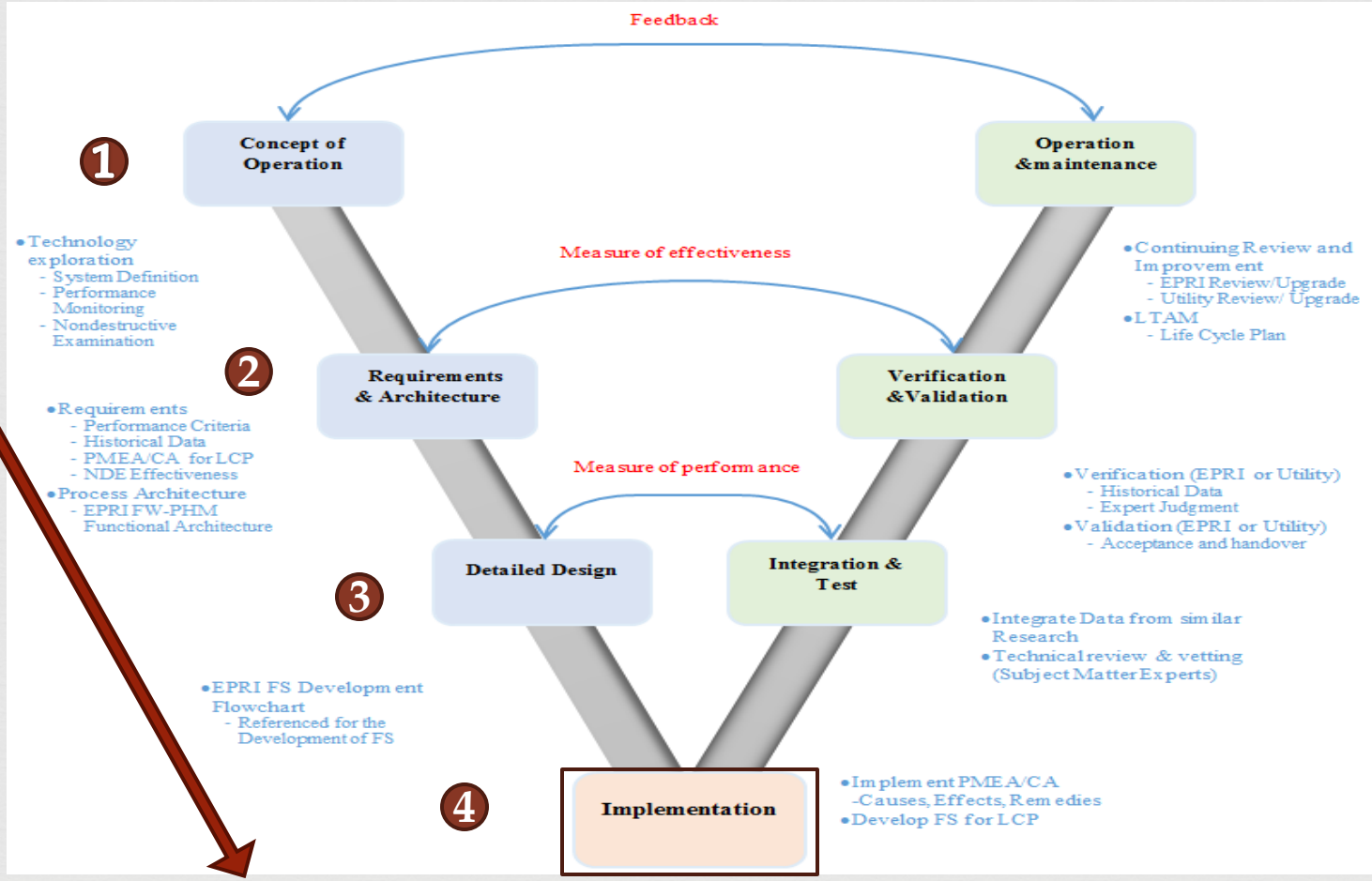


Objective

- **Purpose**
  - ✓ To investigate Fault Signatures (FS) for Large Vertical Centrifugal Pumps (LCP) in NPP
- **Goal**
  - ✓ To develop a FS Database for Online fault detection in LCP
- **Scope**
  - ✓ Safety Class Motor Driven LCP for Safety Injection, Containment Spray, and Residual Heat Removal.

Methodology

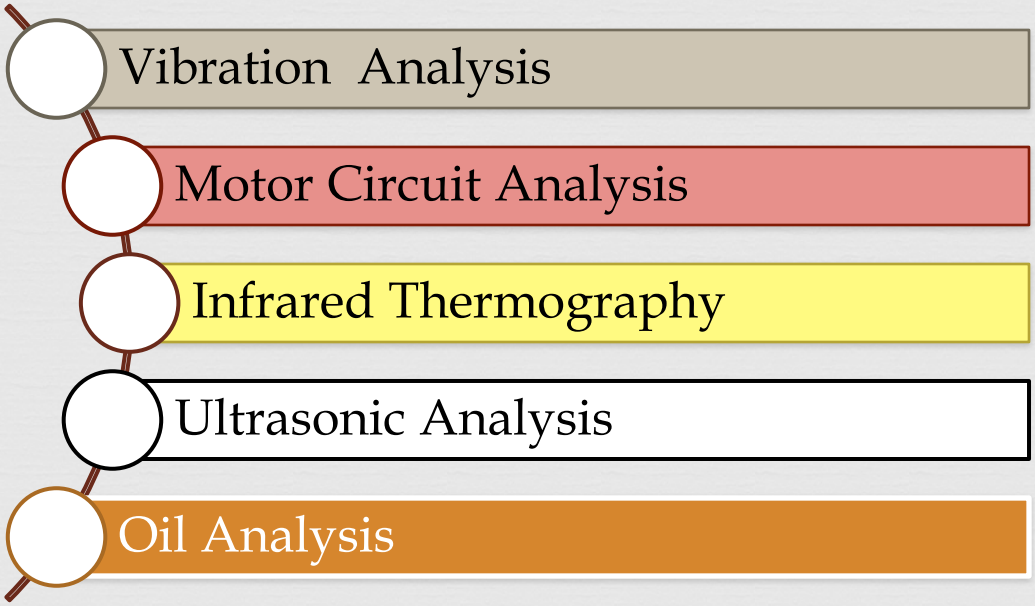
INCOSE V-model for systems development



Methodology

1. Technology Exploration

- Five predictive technologies were defined for faults detection in LCP [7]



Methodology

2.0 Requirements and Architecture

- **Historical Failure Data**

✓ Plant O&M documents, EPRI documents, and Technical Reports.

- **Preventive Maintenance based 'Failure Mode and Effect Analysis' (PMEA)**

✓ Historical data & Subject Matter Experts [3] - **INPUTS**

✓ LCP Components and Fault Type

✓ Causes, Effects, and Remedies

✓ Time to failure and **Criticality Analysis**

Methodology

❑ Fault Signature Development

- ✓ Fault type and Fault Feature
- ✓ Non-destructive examination and Location
- ✓ Non-Destructive Examination Effectiveness (NDE)

Fault Signature

Fault signatures basically comprises of an asset type, fault type, and fault features which are representative symptoms [1]

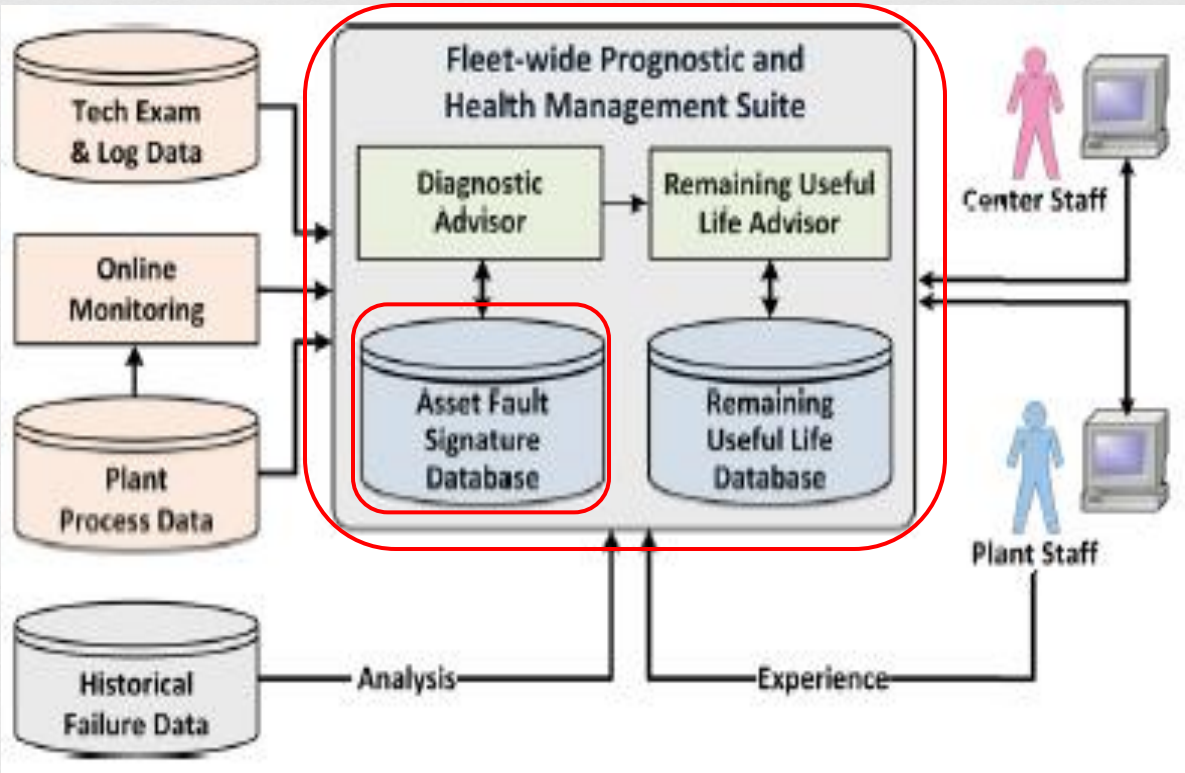
NDE Effectiveness

Grade predictive technologies according to their performance in detecting associated faults [6]

Methodology

Architecture

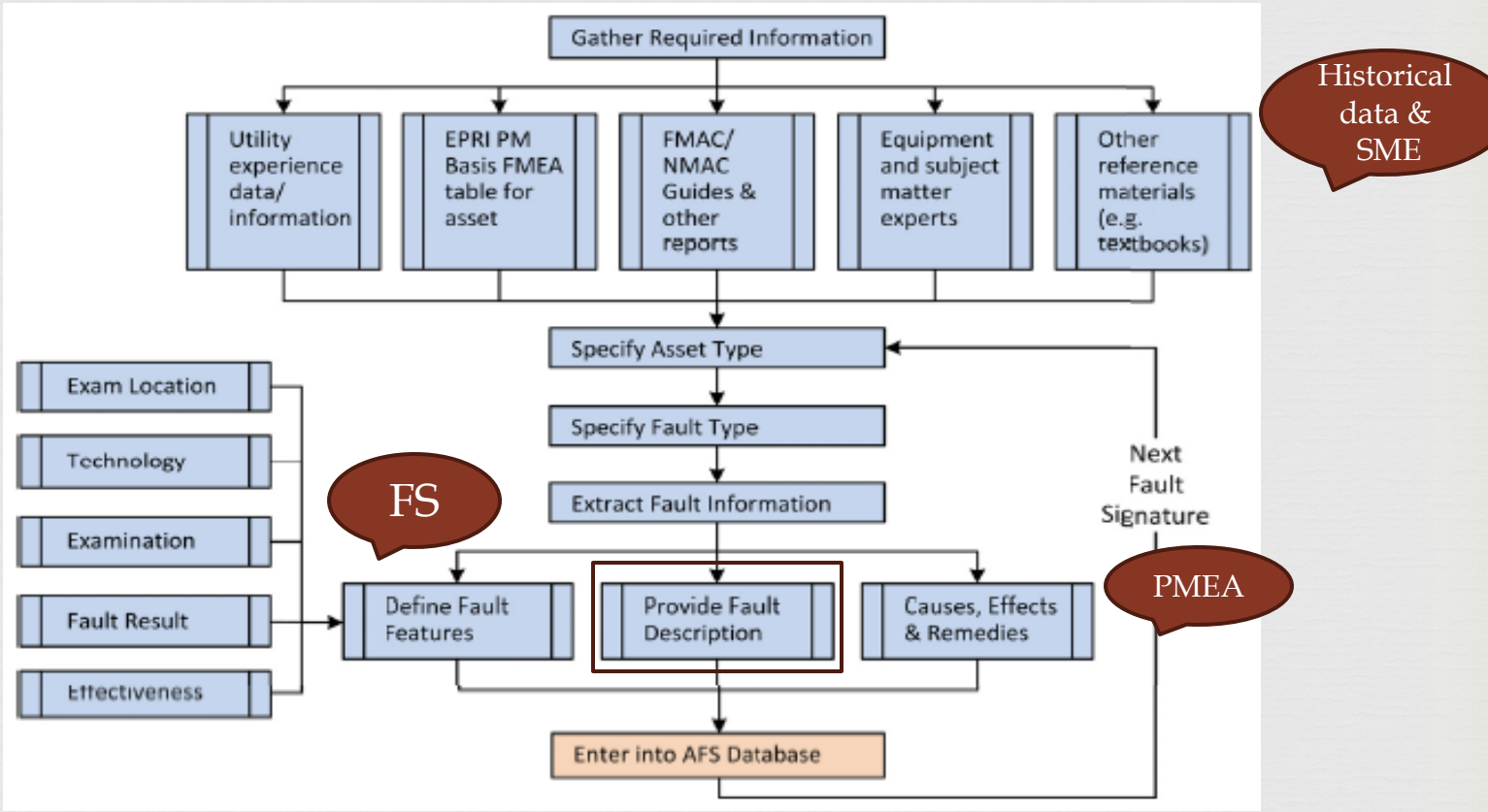
- Functional Architecture of the EPRI FW-PHM Software Suite [1]



Methodology

3.0 Detailed design

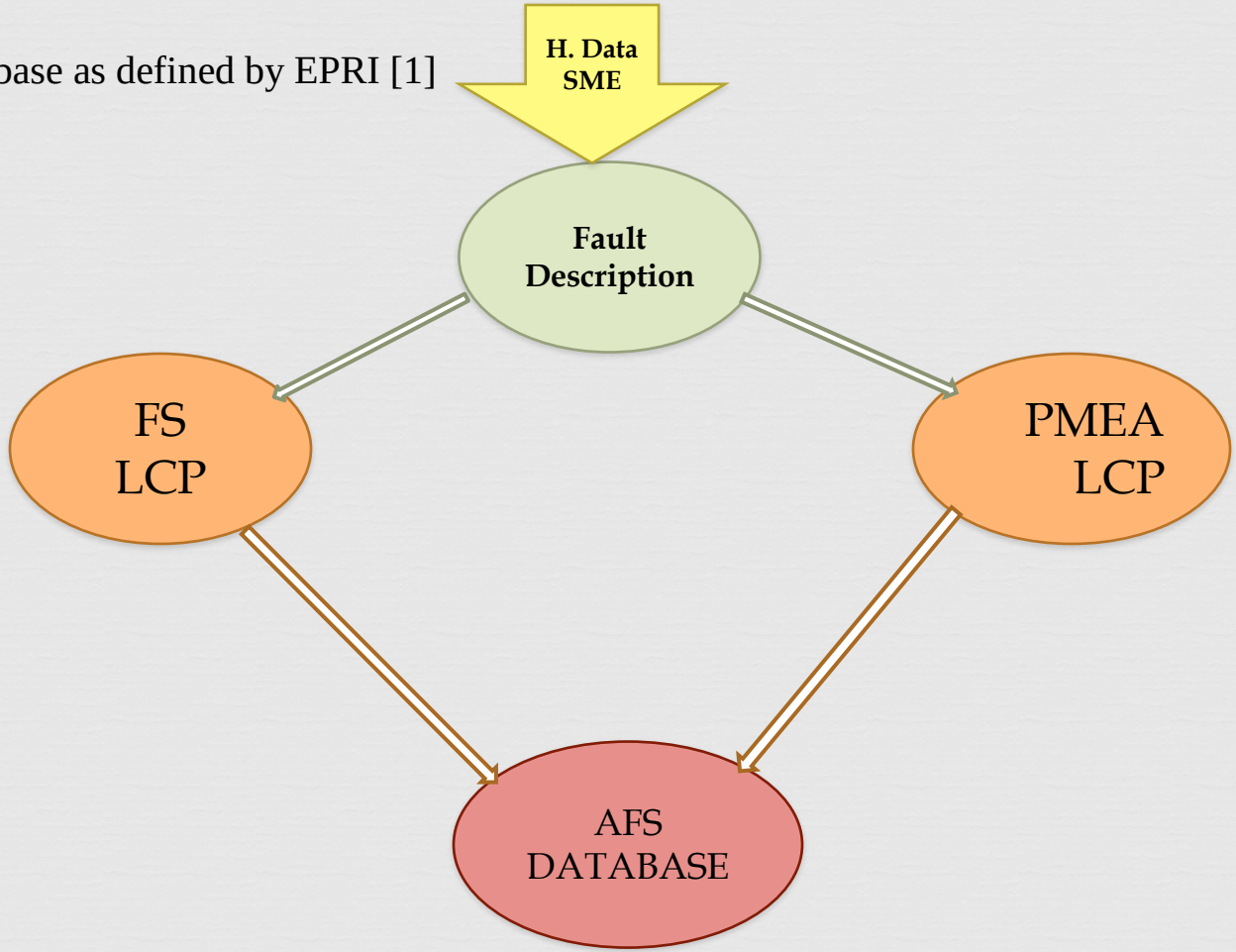
- AFS development as defined by EPRI [1]



Methodology

4.0 Implementation

- AFS Database as defined by EPRI [1]



Result

Table 1 PMEA for LCP

Item	Degradation	Causes	Effects	Remedies	Time to Failure (month)	Criticality
Radial Bearing	Wear	Vibration, Design	Low efficiency	Use adequate Lubricant	36	Critical
	Fatigue/age	Design, Vibration	Excessive Vibration	Lubricate Bearings	34	Critical
Mechanical Seal	Wear	Vibration	Low efficiency	Replace seal	38	Critical
Impeller	Rubbing with casing	Design, Operation	Vibration	Lubricate Thrust Bearing	20	Critical
	Wear	Operation, Impeller lift	Low efficiency	Change Impeller	84	Minor
Shaft	Cracked	Design, Misalignment	Low efficiency, Vortexing	Replace Shaft	43	Minor
	Wear	Corrosion, Vibration	Low efficiency, Abnormal noise	Replace Shaft and Seal	105	Minor
Coupling	Cracked	Corrosion, Vibration	Low efficiency, Abnormal noise	Replace Coupling	60	Minor
Casing	Vanes fatigue	Design, Vibration	Reduced flow rate	Change Casing	127	Minor
	Wear	Corrosion	Crack	Change casing	144	Minor

Result

Table 1 Cont. PMEA for LCP

Item	Degradation	Causes	Effects	Remedies	Average Failure %	Criticality
Thrust Bearing	Wear	Excessive vibration	High Bearing Temperature	Change Bearing	42	Critical
	Failure	Insufficient lubrication	Corrosion	Use adequate Lubricant		
Stator	Winding insulation degradation	Persistent overload	Motor overheating	Change Insulation of Lamination	33	Critical
	Lamination insulation degradation	Normal deterioration	Motor short circuit	Change Insulation of lamination		
	Loose bracing & blocking	Normal deterioration	Motor vibration and noise	Tighten/replace block		
Rotor	Failed Rotor Shorting Rings	Excessive vibration	Motor shutdown	Change rotor shorting rings	9	Minor
	Loose Lamination	Insufficient lubrication	Low motor efficiency	Change lamination		
Others					16	Minor

Result

Table 2 Fault signatures for LCP

Component	Fault	NDE and Location	Fault Feature	Effectiveness
Radial Bearing	Wear	Vibration analysis: Measure loading & vibration	High Loading & Vibration	High
	Fatigue or age	Vibration analysis: Measure Bearing housing vibration	High Bearing housing vibration	High
Mechanical Seal	Wear	Ultrasonic analysis: Measure Oil level	Low Oil level	Low
Impeller	Rubbing with casing	Vibration analysis, Ultrasonic analysis: Measure Impeller vibration & ultrasonic level	High Impeller vibration & Ultrasonic level	High
	Wear	Vibration analysis: Measure Pump head & flow rate	Low Pump head & Flow rate	High
Shaft	Cracked	Vibration analysis, Ultrasonic analysis: Measure Shaft vibration & ultrasonic	High Vibration & Ultrasonic level	High
	Wear	Vibration analysis, Ultrasonic analysis: Measure Shaft vibration & ultrasonic	High Vibration & Ultrasonic level	High
Coupling	Cracked	Vibration analysis, Ultrasonic analysis: Measure Coupling vibration & ultrasonic level	High Vibration & Ultrasonic level	High
Casing	Vanes fatigue/Wear	Vibration & Ultrasonic analysis, Performance Trending: Measure Casing vibration & performance	High Vibration Level, and reduced Performance	Medium

Result

Table 2 Cont.: Fault signatures for LCP

Component	Fault	NDE and Location	Fault Feature	Effectiveness
Thrust Bearing	Wear	Vibration analysis, Ultrasonic analysis: Measure bearing housing vibration, ultrasonic level, & lube oil contamination	High Vibration, Ultrasonic, & contamination level	High
	Failure	Vibration analysis, Ultrasonic analysis: Measure Bearing housing vibration, Ultrasonic level	High Vibration & Ultrasonic level	High
Stator	Winding insulation degradation	Infrared-thermography, Motor current signature analysis, Motor circuit analysis: Measure Winding temperature	High Winding Temperature	Low
	Lamination insulation degradation	Infrared-thermography, Motor current signature analysis, Motor circuit analysis: Measure Stator insulation	High Core Temperature	Low
	Loose bracing & blocking	Scheduled restoration	High Core Temperature	Low
Rotor	Failed rotor band/shorting rings	Infrared-thermography, Motor current signature: Measure Circuit resistance	High Circuit Resistance	Medium
	Loose Lamination	Infrared-Thermography, Motor current signature Analysis: Measure Winding temperature	High Winding Temperature	Medium

Result

- **Discussion of Result**

✓ Pump failures within a 36 months were classified as Critical

while below 36 months were considered Minor

✓ The pump driver failures below 10% were classified as Minor, while above 10% were classified Critical.

- For optimization, Critical Failures with associated High NDE effectiveness is recommended for predictive OLM.

Result

- **Recommendation**

Table 3: Optimized FS for OLM of LCP

Item	Fault	NDE and Location	Fault Feature
Radial Bearing	Wear	Vibration analysis: Measure loading & vibration	High Loading & Vibration
	Fatigue	Vibration analysis: Measure Bearing housing vibration	High Bearing housing vibration
Impeller	Rubbing with Casing	Vibration analysis, Ultrasonic analysis: Measure Impeller vibration & ultrasonic level	High Impeller vibration & Ultrasonic level
Thrust Bearing	Wear	Vibration analysis, Ultrasonic analysis: Measure bearing housing vibration, ultrasonic level, & lube oil contamination	High Vibration, Ultrasonic, & contamination level
	Failure	Vibration analysis, Ultrasonic analysis: Measure Bearing housing vibration, Ultrasonic level	High Vibration & Ultrasonic level

Conclusion

- FS of LCP for OLM has been developed
- The FS Database for LCP were established using EPRI guidelines
- Cost-Benefit Analysis for OLM implementation of LCP in NPP is proposed.

REFERENCES

[1] V. Argawal, J. Lybeck, T.Pham, R.Rusaw, R. Bickford, Online Monitoring of Plant Assets in the Nuclear Industry, Annual Conference of the Prognostic and Heath Management Society, 2013.

[2] J.Coble, P. Ramuhalli, J.Bond, J.Hines, B. Ipadhyaya, A Review of Prognostics and Health Management Applications in Nuclear Power Plants, Centre for Non-destructive Evaluation Publications, Iowa State University, 2015.

[3] E. O.Ohaga, Y.K Lee, J.C. Jung, Systems Engineering approach to Reliability Centred Maintenance of Containment Spray Pump, Kepco International Nuclear Graduate School, 2013.

[4] Plant Support Engineering: Large Vertical Pump End-of-Expected-Life Report. EPRI, Palo Alto, CA: 2009. 1019154

[5] K.M. Siddiqui, K. Sahay, V.K. Giri, Health Monitoring and Fault Diagnosis in Induction Motor, Vol. 3, Issue 1, January 2014

[6] D. M. Kitch, J. S. Schlonski, P. J. Sowatskey, W. V. Cesarski, Aging and Service Wear of Auxiliary Feedwater Pumps for PWR Nuclear Plants, Volume 2 Oak Ridge National Laboratory, 1988.

[7] EPRI, Improving Maintenance Effectiveness, An Evaluation of Plant Preventive and Predictive Maintenance Activities.

러분의 관심에 감사드립니다

Thank you for your attention