RESOLVING INTERMITTENT VIBRATION SPIKES ON STEAM TURBINES

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Contents

• Background
• Machine description
• Data analysis
• Initial Analysis & Recommendations
• Machine Inspection results
• Subsequent Mechanical Failure Analysis
• Conclusions
• Lessons Learned
Background

- Six Fresh Cooling Water Pumps:
  - 4 Steam Turbines and 2 Motor driven pumps
  - Critical pumps in LNG production
- Intermittent vibration spikes - Proactive detection on three steam turbines using expert systems
- The condition deteriorated and sporadic steam turbine trip.
- Plant vulnerable to production loss

Schematic Diagram of Fresh Cooling Water System
Turbine Type: Back pressure (5 stage)
Bearings: Tilting pad
Seals: Mechanical Labyrinth
Coupling: Diaphragm
Power: 3840KW
Speed: 3602 RPM
Data Analysis

- Increasing Vibration Trend & High vibration Trip
- No correlation with the process parameters

Overall Vibration vs. Process data

- Green plot – Vibration
- Black, White, Red & Blue plots – Process parameters
Abnormal Behavior – Significant Phase Angle Change During Steady State (All Over 360°)

Data Analysis Cont’d..

Polar Plot – 1X Amplitude & Phase Angle
Data Analysis Cont’d..

Direct Orbit Review During Vibration Excursion

Flat Orbit & Truncated Time Waveform due to Rub
Significant change in the Orbit Shape & Amplitude (Change in Balance Condition Due to Thermal Bow)

Direct Orbit Overlay – Comparison of Low & High Vibration Amplitudes

Orange plot – when vibration is at minimum
Blue plot – when vibration is at maximum

Turbine NDE

Turbine DE

Direct Orbit Becomes circular when the vibration is at maximum
Thermal Bow Effect of Rub

Data Analysis Cont’d..

High Spot

Rubbing Spot

Effective Unbalance

A New High Spot and Rubbing Location

Increased 1X Orbit

Heavy Spot

1X Orbit

1X Orbit

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Data Analysis Cont’d..

Vibration Trend and Polar Plot – Reviewed for 2nd Steam Turbine

Similar Behavior - Intermittent vibration
Amplitude & Change in Phase Angle
Data Analysis Cont’d..

Vibration Trend and Polar Plot – Reviewed for 3rd Steam Turbine

Similar Behavior But Less Severity - Intermittent vibration Amplitude & Change in Phase Angle
Initial Analysis & Recommendations:

Expert Analysts at site concluded the Rubbing Issue is most likely due to

- Carbonized oil buildup in the oil deflector / seal area.

Recommended Action Items:

- Inspect oil/steam seal areas for rubbing marks due to deposit built-up / carbonized oil.
Machine Inspection Results
Oil Seal Area at Non Drive End Bearing of 1st Turbine

Rubbing Marks at the seal area due to oil carbonization is evidenced.
No abnormalities noticed on the Rotor internal components.
Machine Inspection Results Cont’d..

Oil Seal Area at Non Drive End Bearing of 2^{nd} & 3^{rd} Turbine

- Oil Carbonization deposits and Rubbing Marks at the seal area
- Based on the inspection results of 1^{st} Turbine, no internal checks carried out for the 2^{nd} & 3^{rd} Machines
Subsequent Mechanical Failure Analysis

- Oil leak and migration to steam end
  - Design issue
  - Sealing Air pressure low
    - Breather clogging
    - LO Supply Pressure high
    - Outside Operating condition
  - Ejector poor performance
    - Gland fins clearance high

- Heavy Steam Leak from steam gland
  - Carbonization
Conclusions

Primary Causes:
- Low seal air pressure - Oil leakage, migration at steam gland

Contributed Causes:
- Breather clogging - Oil leakage due to vapor accumulation and high lube oil pressure inside the bearing housing
- Design issues
  - Back pressure on the common return header - Wrong elevation of breather on the Gearbox drain line
  - Oil shelter in close vicinity to the steam gland

Action Items:
- Installed Pressure Gauge
- Breather cleaning task - Equipment Strategy.
- Modify the Breather elevation
Lessons Learned

- Reduced Maintenance Cost and Down Time
  - Prognostic approach on the issues and accurate analysis through experts helped early detection of machine malfunctions.
  - Findings on one steam turbine assisted to minimize the maintenance activities on other two steam turbines.
  - Presence of online diagnostic system helped to plan the machine shutdown for the maintenance without impact on the production.

- Design issues – A lesson for future projects.
  - Absence of seal air pressure monitoring
  - Close vicinity of oil seal and steam gland
  - Wrong elevation of breather location on the Gearbox