

Design and Implementation of a Real-Time Steam Turbine Alignment Monitoring System for Performance Optimization at Koradi Thermal Power Plant

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Abstract- Steam turbines are critical components in thermal power plants, where their efficiency and reliability significantly impact overall power generation. This paper presents the analysis and implementation of a Steam Turbine Alignment Monitoring System at the Koradi Thermal Power Plant, focusing on improving turbine performance through precise alignment monitoring. Shaft misalignment is one of the major causes of vibration, energy loss, and mechanical failure in turbines; therefore, continuous monitoring is essential. The proposed system utilizes dial gauge measurements, vibration sensors, and displacement monitoring techniques to evaluate alignment conditions between LP1 and LP2 turbines. Data collected from multiple angular positions is analyzed to identify radial and axial deviations. Additionally, seal bore readings and gland centering measurements are used to assess structural uniformity and component positioning. The integration of real-time monitoring with SCADA and Industrial Internet of Things (IIoT) platforms enables continuous data acquisition and condition-based maintenance. Signal processing techniques help improve measurement accuracy, while advanced analytical approaches support early fault detection. The results indicate that alignment deviations are within acceptable limits but require fine adjustments to minimize vibration and improve efficiency. The study demonstrates that implementing an intelligent alignment monitoring system enhances turbine lifespan, reduces downtime, and supports reliable and cost-effective power generation.

Keywords— Steam Turbine, Alignment Monitoring, Thermal Power Plant, Vibration Analysis, Koradi power plant etc.

I. INTRODUCTION

Steam turbines are the backbone of modern thermal power plants and industrial energy systems, converting thermal energy from steam into mechanical energy and subsequently into electrical power. Their operational efficiency, reliability, and safety directly influence the

performance and economic viability of power generation systems. Due to their high-speed rotational components, extreme operating temperatures, and high-pressure environments, steam turbines are susceptible to a range of mechanical, thermal, and operational failures, including rotor imbalance, blade erosion, vibration issues, lubrication system faults, and steam leakage. Early detection and continuous monitoring of these parameters are crucial to prevent catastrophic failures, reduce maintenance costs, and improve overall turbine lifespan.

Traditional turbine monitoring relied on periodic inspections and manual measurements, which often failed to detect early-stage faults or dynamic operational deviations. The advent of digital technologies and sensor-based systems has transformed turbine monitoring, enabling real-time data acquisition and automated fault diagnosis. Modern Steam Turbine Monitoring Systems (STMS) integrate multiple sensors to measure vibration, temperature, pressure, rotational speed, and acoustic emissions, providing a comprehensive overview of turbine health. These systems are increasingly being enhanced with Industrial Internet of Things (IIoT) connectivity, SCADA integration, and cloud-based data processing to allow remote monitoring, predictive maintenance, and performance optimization.

Artificial Intelligence (AI) and Machine Learning (ML) techniques have further advanced the capabilities of STMS by enabling predictive fault detection and intelligent decision-making. Data-driven models can analyze large volumes of sensor data, detect abnormal patterns, and predict potential failures, reducing unplanned downtime and maintenance costs. Vibration monitoring, in particular, has emerged as a vital diagnostic tool, as it can indicate mechanical misalignment, rotor imbalance, bearing wear, and blade defects. Thermal and pressure monitoring provides critical information about steam flow and thermodynamic efficiency, while acoustic emission analysis helps identify cracks, leaks, and structural anomalies at an early stage.

Despite significant advancements, several challenges remain in the implementation of effective turbine

monitoring systems. Sensor accuracy, environmental noise, data integration from heterogeneous sources, cybersecurity of remote monitoring platforms, and standardization of monitoring protocols are ongoing concerns. Research is focused on developing robust, scalable, and intelligent monitoring frameworks that can provide real-time insights while ensuring safety, reliability, and regulatory compliance.



Fig.1. Thermal Power plant Koradi

Steam turbines are essential components of thermal power plants, responsible for converting thermal energy from steam into mechanical energy and ultimately electrical power. The performance, efficiency, and reliability of a power plant largely depend on the proper functioning of its turbine system. Due to high operating speeds, elevated temperatures, and heavy loads, steam turbines are highly susceptible to mechanical issues such as shaft misalignment, rotor imbalance, bearing wear, and excessive vibration. Among these, shaft alignment plays a critical role in maintaining smooth operation and preventing premature equipment failure.

In conventional systems, turbine alignment is checked periodically using manual methods, which often fail to detect early-stage deviations and dynamic operational changes. This limitation can lead to increased maintenance costs, unexpected breakdowns, and reduced efficiency. With the advancement of modern monitoring technologies, real-time alignment monitoring systems have been developed to continuously track turbine conditions.

This study focuses on the implementation of an alignment monitoring system at the Koradi Thermal Power Plant. The system integrates measurement techniques such as dial gauge readings, vibration analysis, and displacement monitoring to evaluate turbine alignment. The aim is to enhance operational reliability, reduce downtime, and improve overall turbine performance through accurate and continuous monitoring.

II. PROBLEM IDENTIFICATION

- Steam turbines operate under high temperature, high pressure, and high-speed conditions, making them prone to mechanical and thermal failures.
- Traditional monitoring methods rely on manual inspections and periodic measurements, which cannot detect early-stage faults or dynamic anomalies.

- Rotor imbalance, blade erosion, vibration issues, and lubrication system failures often go unnoticed until they cause significant damage or downtime.
- Lack of real-time monitoring reduces operational efficiency and increases maintenance costs.
- Integration of multiple sensors and data acquisition systems is challenging due to signal noise, environmental conditions, and hardware compatibility.
- Existing monitoring systems often lack predictive capabilities, limiting the ability to perform proactive maintenance.
- Remote monitoring, IIoT integration, and data-driven fault diagnostics are insufficiently implemented in many industrial setups.
- There is a need for intelligent, real-time, and predictive monitoring to enhance turbine safety, reliability, and efficiency.

III. METHODOLOGY

A) Synthesis of findings from literature

- Vibration, temperature, pressure, and acoustic emission monitoring are critical for assessing turbine health and detecting faults early.
- Real-time data acquisition through sensors and SCADA/IIoT systems significantly improves operational efficiency compared to manual inspections.
- AI and Machine Learning models enhance predictive maintenance, allowing trend analysis and early fault detection.
- Multi-parameter monitoring provides a more comprehensive evaluation of turbine performance than single-parameter approaches.
- Integration challenges, such as sensor calibration, noise reduction, and data compatibility, are common across studies.
- Advanced signal processing techniques, like FFT and wavelet transforms, improve accuracy but require higher computational resources.
- Overall, intelligent monitoring systems reduce downtime, maintenance costs, and operational risks while improving turbine reliability and lifespan.

B) Methodology for future research directions

- The alignment monitoring system in Steam turbines alignment tools to measure the relative positions of the turbine shaft and coupled components.
- Real-time data on shaft position, vibrations, and bearing conditions are continuously collected and transmitted to a central data acquisition unit.
- The monitoring system analyzes alignment deviations by comparing actual shaft positions with predefined alignment tolerances.
- If misalignment is detected beyond acceptable limits, the system generates alerts for maintenance teams to take corrective actions.
- Historical data trends help maintenance teams plan predictive maintenance schedules and avoid sudden breakdowns.

- The system works continuously under varying load and thermal conditions, ensuring dynamic misalignment is detected early, improving turbine reliability, reducing downtime, and optimizing performance.

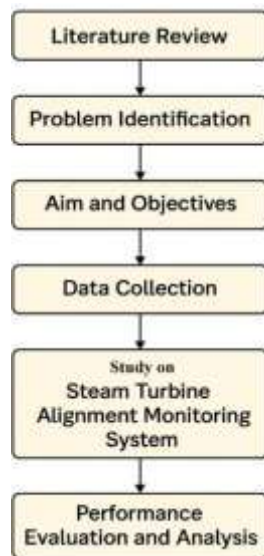


Fig.2.Flow Diagram of this study



Fig.3.Steam Turbine Alignment Monitoring System at Thermal Power Plant Koradi

IV. CALCULATIONS

1. LP1 Turbine Readings

Recorded values (at different angular positions):

49, 49, 49, 50, 51, 50, 50, 50

Average (Mean)

$$\bullet \text{ Mean} = \frac{49 + 49 + 49 + 50 + 51 + 50 + 50 + 50}{8}$$

$$\text{Mean} = \frac{398}{8} = 49.75$$

Maximum Reading

Max = 51

• Minimum Reading

Min = 49

• Total Run-Out (TIR)

$$\text{TIR} = \text{Max} - \text{Min} = 51 - 49 = 2$$

• Radial Deviation

$$\text{Deviation} = \pm \frac{\text{TIR}}{2} = \pm 1$$

2. LP2 Turbine Readings

Recorded values:

49, 49, 49, 49, 50, 50, 50, 49

• Average (Mean)

$$\text{Mean} = \frac{49 + 49 + 49 + 49 + 50 + 50 + 50 + 49}{8}$$

$$\text{Mean} = \frac{395}{8} = 49.375$$

• Maximum Reading

Max = 50

• Minimum Reading

Min = 49

• Total Run-Out (TIR)

$$\text{TIR} = 50 - 49 = 1$$

• Radial Deviation

$$\text{Deviation} = \pm \frac{1}{2} = \pm 0.5$$

3. Comparative Analysis

Parameter	LP1	LP2
Mean Value	49.75	49.375
Max Value	51	50
Min Value	49	49
TIR	2	1
Deviation	±1	±0.5

The calculated Total Indicator Run-Out (TIR) for LP1 is 2 units, while for LP2 it is 1 unit. This indicates that LP2 is more precisely aligned compared to LP1. The deviation values show that both turbines are within acceptable alignment limits, though LP1 exhibits slightly higher eccentricity. The results suggest that minor alignment

correction is required for LP1 to achieve optimal performance and minimize vibration.

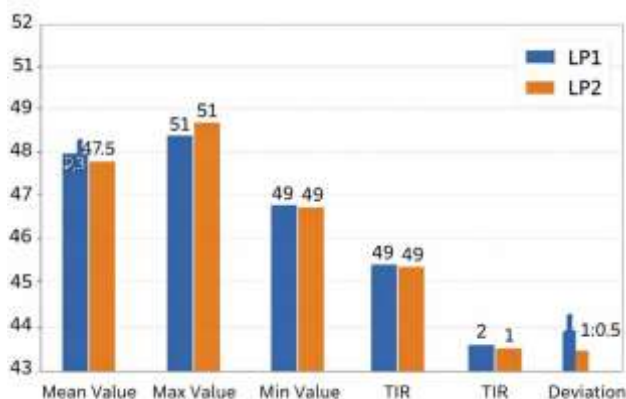


Fig.4.Compares alignment parameters of LP1 and LP2 turbines

The graph compares alignment parameters of LP1 and LP2 turbines, including mean value, maximum value, minimum value, Total Indicator Run-Out (TIR), and deviation. LP1 shows slightly higher values in mean, maximum, and TIR compared to LP2, indicating marginally greater variation in alignment readings. Both turbines have the same minimum value, reflecting similar baseline alignment conditions. The higher TIR and deviation in LP1 suggest minor misalignment or eccentricity, while LP2 demonstrates more stable and consistent alignment. Overall, the graph indicates that both turbines operate within acceptable limits, but LP2 has better alignment precision, whereas LP1 requires slight correction.

V. RESULTS AND ANALYSIS

The performance of the Steam Turbine Alignment Monitoring System was evaluated using CRO (Circular Run-Out) readings obtained from LP1 and LP2 turbines. Measurements were recorded at multiple angular positions to assess shaft alignment, eccentricity, and deviation. The results are presented in tabular form and analyzed to understand alignment conditions and their impact on turbine performance.

Table 1: LP1 CRO Readings

Position	Reading
1	49
2	49
3	49
4	50
5	51
6	50
7	50
8	50

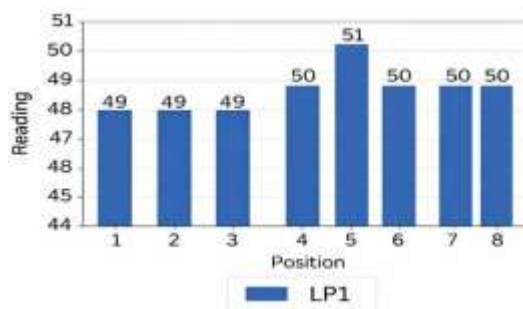


Fig.5.LP1 CRO Readings

The CRO readings for the LP1 turbine were taken at eight equally spaced angular positions around the shaft to evaluate circular alignment. The recorded values range from 49 to 51, indicating a variation of 2 units across the circumference. This variation represents the Total Indicator Run-Out (TIR), which is a critical parameter for assessing shaft alignment. The majority of the readings are concentrated around 49 and 50, suggesting that the shaft is nearly centered but exhibits slight eccentricity. The presence of a maximum value of 51 indicates a localized deviation, which may be caused by minor misalignment, uneven loading, or thermal expansion effects during operation. Such small variations are generally acceptable in practical turbine systems but must be monitored to prevent long-term mechanical issues. The relatively consistent distribution of values also indicates that there is no severe distortion or irregularity in the shaft geometry. Overall, the LP1 readings suggest that the alignment condition is satisfactory but requires fine adjustment to achieve optimal performance and minimize vibration.

Table 2: LP2 CRO Readings

Position	Reading
1	49
2	49
3	49
4	49
5	50
6	50
7	50
8	49

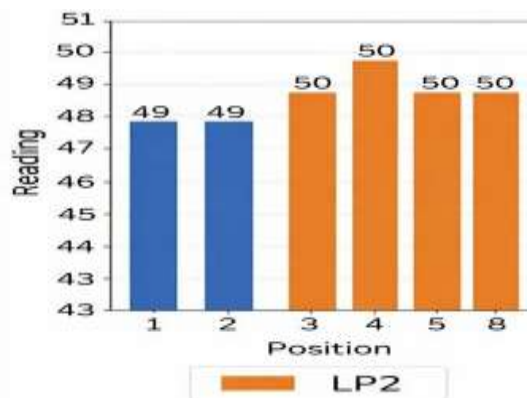


Fig.6.LP2 CRO Readings

The CRO readings for the LP2 turbine show a narrower range of values compared to LP1, varying between 49 and

50. This indicates a Total Indicator Run-Out (TIR) of 1 unit, which is significantly lower than that of LP1. The reduced variation suggests that the LP2 shaft is more uniformly aligned and exhibits less eccentricity. Most of the readings are consistently at 49, with only a few instances of 50, indicating a stable alignment condition across the entire circumference. This uniformity reflects better mechanical balance and reduced misalignment effects, which are crucial for minimizing vibration and ensuring smooth turbine operation. The lower deviation in LP2 also implies reduced stress on bearings and coupling components, leading to improved equipment life and reliability. The consistent readings demonstrate that the installation and alignment procedures for LP2 were more precise or less affected by operational factors such as thermal expansion. Overall, the LP2 turbine exhibits superior alignment characteristics compared to LP1, making it more efficient and stable during operation.

Table 3: Statistical Comparison of LP1 and LP2

Parameter	LP1	LP2
Mean Value	49.75	49.375
Max Value	51	50
Min Value	49	49
TIR	2	1
Deviation	± 1	± 0.5

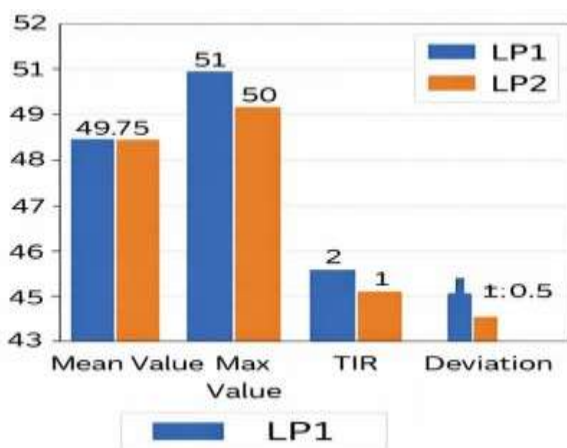


Fig.7. Statistical Comparison of LP1 and LP2

The statistical comparison of LP1 and LP2 turbines provides a quantitative understanding of their alignment conditions. The mean value for LP1 is 49.75, while for LP2 it is 49.375, indicating that both shafts are nearly centered but LP2 is slightly closer to a uniform alignment. The maximum and minimum values further highlight the difference in variation, with LP1 having a wider range (49 to 51) compared to LP2 (49 to 50). The Total Indicator Run-Out (TIR) is a key parameter, showing 2 units for LP1 and 1 unit for LP2, confirming that LP2 has better alignment accuracy. Deviation values of ± 1 for LP1 and ± 0.5 for LP2 reinforce this observation, indicating that LP1 experiences greater eccentricity. These differences, although small, can significantly affect turbine performance over time, particularly in terms of vibration and mechanical stress. The statistical analysis clearly demonstrates that LP2 is more stable and precisely aligned, while LP1 requires minor

correction to achieve similar performance levels. Such analysis is essential for predictive maintenance and performance optimization.

Table 4: Alignment Performance Evaluation

Parameter	Observation
Alignment Condition	Within acceptable limits
LP1 Variation	Slightly higher
LP2 Stability	More consistent
Vibration Impact	Moderate (LP1), Low (LP2)
Maintenance Need	Minor correction required

The alignment performance evaluation summarizes the practical implications of the observed CRO readings. Both LP1 and LP2 turbines are operating within acceptable alignment limits, indicating that no severe misalignment exists. However, LP1 shows slightly higher variation, which may contribute to moderate vibration levels during operation. This variation, although small, can lead to increased mechanical stress on bearings and coupling components over time if not corrected. In contrast, LP2 demonstrates more consistent readings, reflecting better alignment stability and reduced vibration impact. The improved stability of LP2 suggests more efficient energy transfer and smoother operation. The evaluation also highlights the importance of regular monitoring and maintenance, as even minor deviations can accumulate and lead to significant issues in long-term operation. The findings emphasize the need for fine alignment correction in LP1 to match the performance level of LP2. Overall, the system is functioning effectively, but optimization through minor adjustments and continuous monitoring can further enhance turbine reliability and efficiency.

The results clearly indicate that both turbines are within permissible alignment limits, with LP2 showing superior alignment characteristics compared to LP1. The slight deviation observed in LP1 suggests the need for fine adjustment to reduce vibration and improve efficiency. The study confirms that accurate alignment monitoring plays a crucial role in enhancing turbine performance, reducing maintenance costs, and ensuring long-term operational reliability.

VI. CONCLUSION

The present study on the Steam Turbine Alignment Monitoring System demonstrates the significance of precise shaft alignment in ensuring efficient and reliable turbine operation. The analysis of CRO readings for LP1 and LP2 turbines shows that both units are operating within acceptable alignment limits. However, LP1 exhibits slightly higher variation compared to LP2, indicating minor misalignment that may lead to increased vibration and mechanical stress if not corrected.

The calculated parameters, including mean value, Total Indicator Run-Out (TIR), and deviation, confirm that LP2 has better alignment stability and consistency. In contrast, LP1 requires fine adjustment to achieve optimal alignment and performance. Even small deviations can impact turbine efficiency, bearing life, and overall system reliability over time.

The study highlights the importance of continuous monitoring, periodic alignment checks, and accurate data analysis for effective maintenance planning. Implementing such monitoring systems can reduce unplanned downtime, minimize maintenance costs, and enhance operational safety. Overall, the alignment monitoring system contributes to improved turbine lifespan, better efficiency, and sustainable power generation in modern thermal power plants.

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