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IOT Based Machine Vibration Monitoring and Predictive Maintenance System

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***Abstract*— The IoT-Based Machine Vibration Monitoring and Predictive Maintenance System is developed to continuously monitor the health and operating condition of industrial machines in real time. The system uses a vibration sensor along with temperature and current sensors to collect important machine parameters during operation. An ESP32 development board receives and processes the sensor data to identify abnormal conditions such as excessive vibration, imbalance, misalignment, bearing wear, overheating, and overloading. The monitored data can be displayed on an I2C LCD and transmitted through IoT connectivity to a software or cloud-based dashboard for remote monitoring, visualization, and alert generation. Historical data can also be analyzed to observe machine health trends and plan maintenance before major failures occur. The proposed system helps reduce unexpected breakdowns, machine downtime, maintenance costs, and production losses while improving the reliability and efficiency of industrial machinery.**

Keywords: IoT, Machine Vibration Monitoring, ESP32, Predictive Maintenance, Vibration Sensor, Condition Monitoring, Fault Detection, Industrial Automation.

I. INTRODUCTION

Industrial machinery is widely used in manufacturing plants, production units, power systems, pumping stations, and automated industries. Most rotating machines such as motors, pumps, fans, and compressors produce a certain level of vibration during normal operation. However, when mechanical components start developing faults, the vibration pattern may change significantly. Problems such as imbalance, misalignment, bearing wear, looseness, and excessive loading can increase vibration and affect machine performance. If these conditions are not detected at an early stage, they may lead to sudden machine failure, production losses, and increased maintenance costs.

Traditional maintenance methods generally depend on manual inspection and scheduled servicing. In such systems, machines are inspected at particular time intervals, which may not provide continuous information about their actual operating condition. A fault can develop between two inspection periods and may remain unnoticed until it becomes serious. Unexpected breakdowns can cause long machine downtime and may also damage other components. Therefore, continuous condition monitoring is required to identify abnormal machine behavior before it develops into a major failure.

The IoT-Based Machine Vibration Monitoring and Predictive Maintenance System provides a solution for continuous monitoring of machine health. The proposed system uses a vibration sensor to measure mechanical vibrations produced by the motor. In addition, temperature and current sensors are used to monitor the thermal and electrical conditions of the machine. These sensors provide real-time information about machine operation, while the ESP32 development board collects and processes the sensor signals. The system can analyze vibration parameters and compare them with predefined limits to identify abnormal operating conditions.

IoT technology makes the system more useful by allowing the collected machine data to be transmitted to a remote monitoring dashboard. Operators can observe vibration, temperature, and current values in real time and analyze changes in machine performance through graphs and historical trends. When any monitored parameter exceeds its safe threshold, the system can generate an alert to inform the operator about a possible machine fault. Important

parameters can also be displayed locally using an I2C LCD, providing direct access to the machine status.

The main purpose of the proposed system is to support predictive maintenance by using real-time and historical machine data. Continuous monitoring helps identify gradual changes in machine behavior and provides an opportunity to perform maintenance before a major breakdown occurs. This approach can reduce unexpected failures, machine downtime, repair expenses, and production losses while improving the reliability, efficiency, and service life of industrial machinery.

II. AIMS & OBJECTIVES

Aim:

To develop an IoT-based machine vibration monitoring and predictive maintenance system that continuously monitors vibration, temperature, and current parameters of industrial machinery, detects abnormal operating conditions at an early stage, and provides real-time monitoring and alerts to reduce unexpected machine failures and downtime.

Objectives:

- To continuously measure the vibration, temperature, and current of the machine in real time using suitable sensors.
- To detect abnormal machine conditions such as imbalance, misalignment, bearing wear, overheating, and overloading before they result in major equipment failure.
- To use the ESP32 development board for collecting, processing, and analyzing sensor data to determine the operating condition of the machine.
- To transmit machine parameters through IoT connectivity to a monitoring dashboard for remote visualization and real-time status monitoring.
- To generate automatic alerts whenever vibration, temperature, or current values exceed predefined safe limits.
- To maintain and analyze historical machine data and vibration trends so that maintenance can be planned in advance, reducing downtime, repair costs, and unexpected breakdowns.

III. LITERATURE SURVEY

The literature on machine vibration monitoring and predictive maintenance shows a shift from manual and scheduled maintenance toward continuous, sensor-based and data-driven monitoring. Vibration is considered an important indicator of rotating-machine health because changes in vibration patterns can reveal developing mechanical faults. Recent research also combines IoT, embedded controllers, signal processing, and intelligent data analysis to improve early fault detection and maintenance planning.

1. **Vibration-Based Fault Detection:** Vibration analysis is widely used for monitoring rotating machinery. Different vibration characteristics can help identify faults such as imbalance, misalignment, looseness, and bearing deterioration. Time-domain and frequency-domain techniques are commonly used to extract useful information from vibration signals.
2. **Sensor-Based Condition Monitoring:** Research has highlighted the importance of accelerometers and other vibration sensors for collecting machine-health information. MEMS-based sensors are particularly useful because they are compact, economical, and suitable for integration with embedded monitoring systems. Temperature and current measurements can also complement vibration data and provide additional information about machine operating conditions.
3. **IoT-Based Machine Monitoring:** IoT technology has enabled machine parameters to be collected continuously and transmitted to remote monitoring platforms. Such systems allow operators to

observe machine conditions in real time, monitor historical trends, and receive alerts when abnormal operating conditions are detected.

4. **ESP32 and Edge Processing:** Low-cost IoT architectures using ESP32 and MEMS sensors have demonstrated the feasibility of performing vibration monitoring close to the machine. Basic signal-processing techniques such as RMS and FFT can be used to extract useful vibration features, while local processing can reduce the need to continuously transmit raw sensor data.
5. **Predictive Maintenance:** Predictive maintenance uses continuously collected machine data to identify degradation before complete equipment failure. Research indicates that combining condition monitoring with data analysis, IoT, and machine-learning techniques can support better maintenance scheduling, reduce unplanned downtime, and improve equipment availability.
6. **Integrated and Intelligent Monitoring:** Recent developments are moving toward integrated systems that combine IoT, vibration sensing, signal processing, machine learning, edge computing, and cloud-based analysis. These approaches provide more comprehensive machine-health information, although challenges remain in sensor calibration, changing operating conditions, data quality, and selecting suitable diagnostic techniques.

Research Gap:

From the existing literature, advanced predictive-maintenance systems can involve complex algorithms, specialized sensors, or expensive industrial equipment. There is therefore scope for a simple, low-cost and practical IoT-based system that combines vibration, temperature, and current monitoring with ESP32 processing, real-time visualization, threshold-based alerts, and historical data analysis. The proposed system addresses this requirement by integrating these functions into a single monitoring platform.

IV. METHODOLOGY

The proposed IoT-Based Machine Vibration Monitoring and Predictive Maintenance System follows a sensor-based condition-monitoring methodology in which the machine is continuously observed through vibration, temperature, and current parameters. The system consists of a 12V DC motor, vibration sensor, temperature sensor, current sensor, ESP32 development board, motor driver, I2C LCD, power supply, and supporting electronic components. The sensors collect real-time information from the operating motor, while the ESP32 acts as the main control and processing unit. The collected data is processed to determine the health condition of the machine and is compared with predefined threshold values. The system can then communicate the processed information through IoT connectivity to a monitoring dashboard, where real-time values and historical trends can be observed. If abnormal vibration, temperature, or current is detected, an alert is generated to indicate a possible machine fault. Historical data is further used to observe changes in machine behavior and support predictive maintenance.

Working

1. **Power Supply and Initialization:** The system receives power through the DC power supply and voltage-regulation circuit. The ESP32, sensors, LCD, motor driver, and other components are initialized before monitoring begins.
2. **Motor Operation:** The 12V DC motor is operated through the motor driver. During normal operation, the motor produces a characteristic level of vibration, temperature, and current consumption.
3. **Sensor Data Collection:** The vibration sensor continuously detects mechanical vibrations from the motor. The temperature sensor measures the motor temperature, while the current

sensor measures the electrical current drawn by the motor.

4. **Data Acquisition by ESP32:** The outputs of all sensors are provided to the ESP32 development board. The ESP32 periodically reads the sensor values and processes the collected information to obtain meaningful machine-condition parameters.
5. **Vibration Analysis:** The vibration readings can be processed using parameters such as RMS, peak value, and peak-to-peak value. These values help determine whether the vibration level is within the normal operating range.
6. **Condition and Fault Detection:** The processed vibration, temperature, and current values are compared with predefined threshold limits. Excessive vibration may indicate imbalance, misalignment, looseness, or bearing wear, while abnormal temperature or current may indicate overheating or excessive loading.
7. **Local Display:** The measured parameters and machine status can be displayed on the I2C LCD. This allows the operator to observe the condition of the motor directly without requiring a separate monitoring device.
8. **IoT Data Transmission:** The ESP32 uses its built-in wireless connectivity to transmit the processed sensor data to an IoT or software-based monitoring dashboard. The dashboard can display real-time readings and machine-condition information.
9. **Alert Generation:** When any monitored parameter exceeds its predefined safe limit, the system generates an automated warning or alert. This informs the operator that the machine should be inspected or maintenance action should be considered.
10. **Historical Analysis and Predictive Maintenance:** Sensor data can be stored over time to create historical machine-health records. By observing trends in vibration, temperature, and current, gradual deterioration can be identified and maintenance can be scheduled before a major machine failure occurs. This helps reduce unexpected breakdowns, downtime, maintenance costs, and production losses.

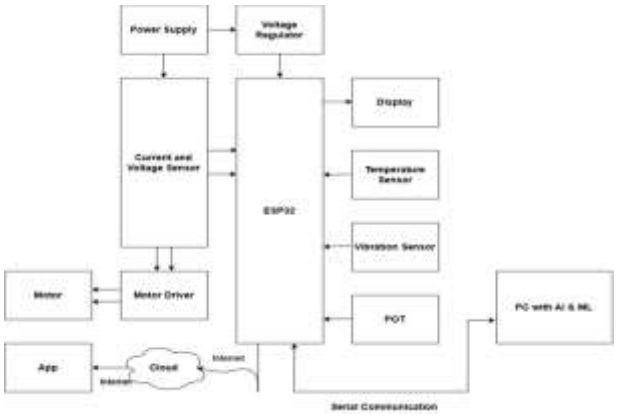


Figure 1: Block Diagram of the proposed system

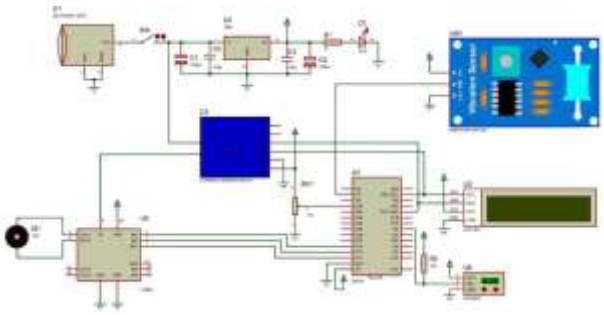


Figure 2: Block Diagram of the proposed system

V. RESULTS

The proposed IoT-Based Machine Vibration Monitoring and Predictive Maintenance System successfully provides continuous monitoring of the machine's vibration, temperature, and current parameters. The ESP32 collects and processes sensor data and helps identify abnormal operating conditions by comparing the measured values with predefined limits. The I2C LCD provides local monitoring, while IoT connectivity enables remote visualization of machine parameters and alerts. The system can identify conditions such as excessive vibration, overheating, and abnormal current consumption, while historical data helps observe machine-health trends. Thus, the system provides an effective and low-cost approach for real-time machine condition monitoring and early fault detection.

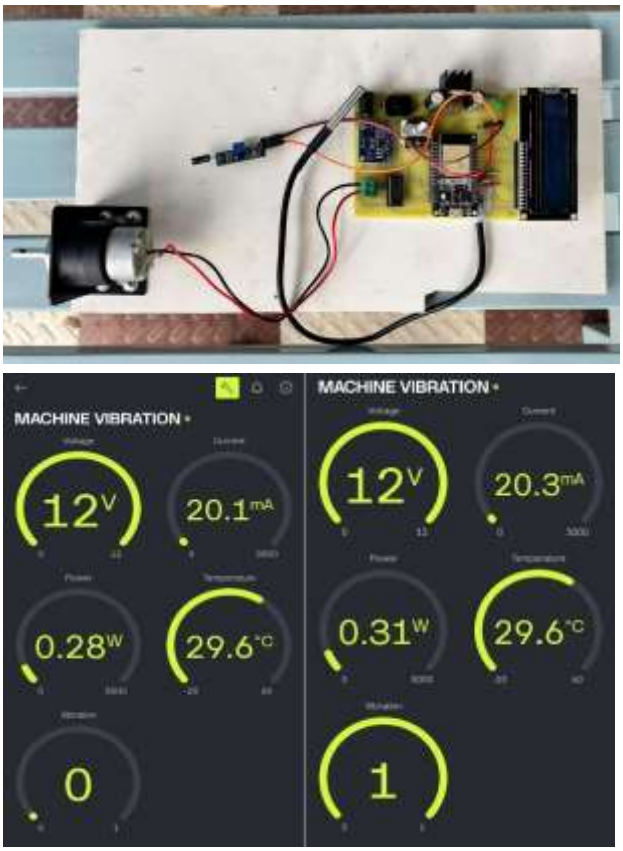


Figure 3: Hardware Model of the Proposed System

VI. CONCLUSION

The proposed system demonstrates that IoT and sensor-based monitoring can be effectively used for predictive maintenance of industrial machinery. Continuous monitoring of vibration along with temperature and current helps detect developing faults at an early stage and reduces dependence on manual inspection. Real-time alerts and historical data analysis allow maintenance personnel to take timely action before serious machine failure occurs. Overall, the system can help reduce unexpected breakdowns, machine downtime, maintenance costs, and production losses, while improving the reliability and operational efficiency of industrial machines.

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