# IOT-Based Industrial Equipment Monitoring System

**Haripriya S[1], Abishek S[2], Ajeshkumar M[2], Keerthivasan S[2], Thuvarakesh P[2]**

**[1]Assistant Professor, IT, Hindusthan Institute of Technology, Coimbatore**

**[2]Student, Fourth year IT, Hindusthan Institute of Technology, Coimbatore**

**DOI: https://doi.org/10.51583/IJLTEMAS.2026.150300059**

**Received: 27 March 2026; Accepted: 01 April 2026; Published: 13 April 2026**

## ABSTRACT

Industrial machinery is highly susceptible to faults such as oil leakage, overheating, excessive vibration, and abnormal current consumption, which may lead to equipment damage, production loss, or safety hazards. This paper presents an IoT-based industrial monitoring and protection system that continuously observes machine health parameters including vibration direction, temperature, oil leakage, and motor current consumption.

The system uses a MEMS accelerometer to detect vibration intensity and direction, along with temperature sensors, oil leakage sensors, and current sensors to monitor critical operational conditions. When abnormal conditions are detected, the system automatically stops the motor using a motor driver and activates a buzzer for immediate alert.

Additionally, all sensor data and total current usage are transmitted to an IoT platform for real-time monitoring and notifications. This system enhances equipment safety, reduces downtime, improves operational efficiency, and supports predictive maintenance in modern industrial environments.

**Keywords:** IOT, Industrial Monitoring, MEMS Sensor, Fault Detection, Predictive Maintenance, Smart Industry

## INTRODUCTION

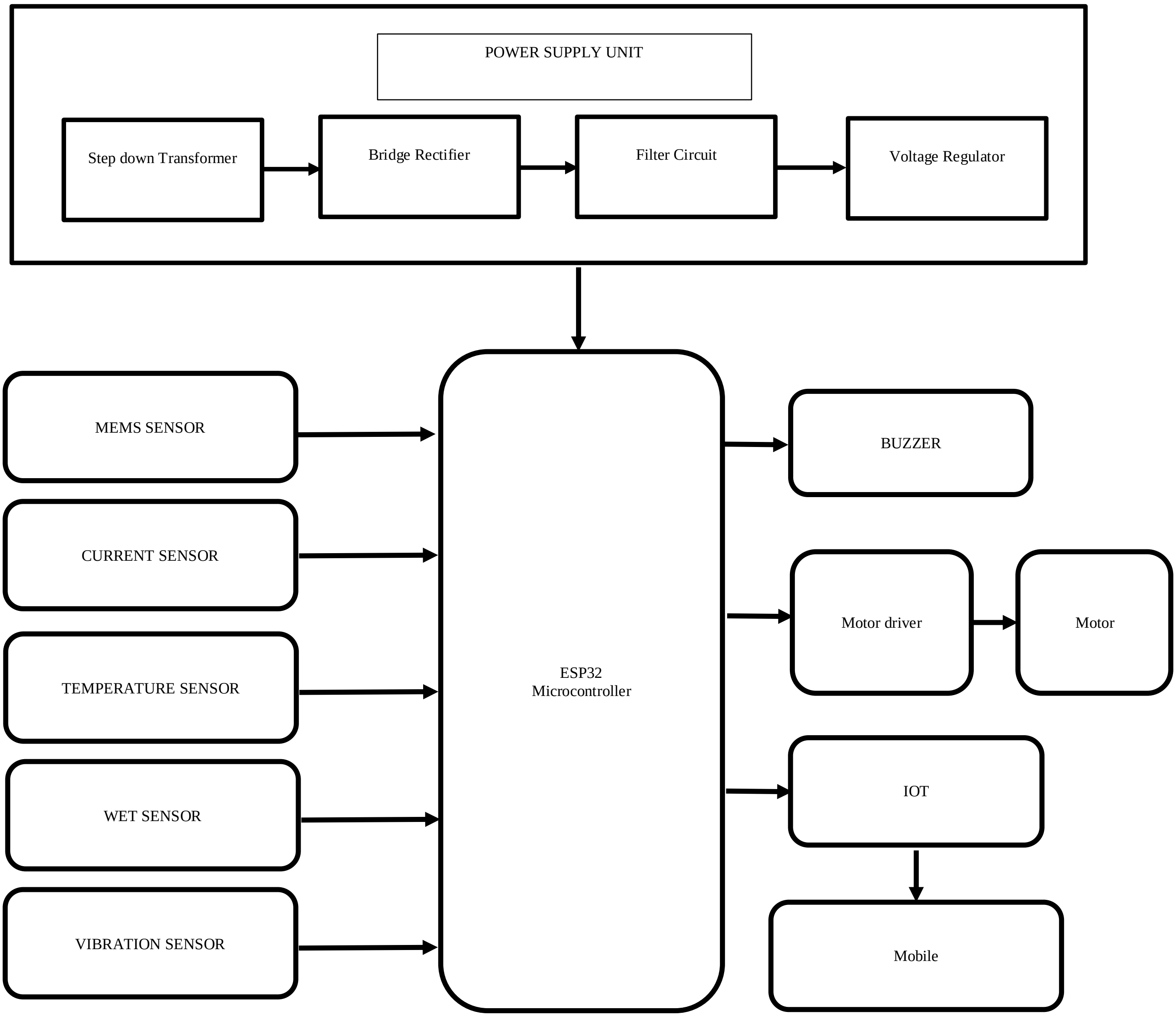
The rapid expansion of Industry 4.0 paradigms has fundamentally transformed expectations for industrial equipment management. Modern manufacturing facilities, petrochemical plants, and power generation stations operate under increasing pressure to maximize machine uptime, reduce operational expenditure, and ensure worker safety — often simultaneously.

Central to meeting these demands is the ability to monitor the health of critical rotating equipment such as induction motors, pumps, compressors, and conveyor drives in real time, and to respond automatically when operational parameters deviate from safe limits [1].

Industrial motors are among the most failure-prone components in manufacturing environments. Studies indicate that bearing failures account for approximately 40% of motor faults, followed by stator winding failures (38%), rotor bar defects (10%), and shaft/coupling issues (12%) [4].

These failure modes manifest progressively through characteristic signatures in vibration spectra, temperature profiles, current waveforms, and lubrication conditions. Early detection of these signatures — before damage propagates to catastrophic failure — is the foundational objective of condition-based monitoring (CBM) and predictive maintenance (PdM) frameworks.

**Block Diagram**



The proposed system architecture is organized into four functional tiers as illustrated in Fig. 1. The sensing tier comprises the ADXL345 MEMS accelerometer, DS18B20 temperature sensor, resistive oil leakage sensor, and ACS712 current sensor, each interfaced to the ESP32 microcontroller via appropriate digital or analog channels. The processing tier implements threshold-based fault inference, hysteresis filtering, and cumulative energy computation entirely on the ESP32 edge node. The actuation tier consists of the L298N dual H-bridge motor driver circuit, which receives PWM enable signals from the ESP32 to control motor operation, and a BC547-driven 5V buzzer for local audible alerting. The communication tier leverages the ESP32's integrated Wi-Fi module to transmit structured JSON telemetry packets to the ThingSpeak IoT cloud platform via MQTT. A 16×2 LCD display provides a local human-machine interface for real-time parameter readout and fault status indication.

## METHODOLOGY

### System Design:

The system is designed using a modular approach. It includes sensors, an ESP32 microcontroller, a motor driver, and an IoT platform. Each module performs a specific function and is integrated to achieve reliable monitoring and control. The design ensures scalability and flexibility for future enhancements.

**Data Acquisition:**

The system collects real-time data from various sensors. The MEMS accelerometer detects vibration intensity and direction. Temperature sensors measure machine heat levels. Oil leakage sensors identify leaks, while current sensors monitor power consumption. Continuous data acquisition ensures accurate monitoring.

**Data Processing:**

The ESP32 processes all sensor data and compares it with predefined threshold values. The system filters noise and ensures reliable readings. This step is critical for accurate fault detection and decision-making.

**Fault Detection:**

When sensor values exceed predefined limits, the system identifies abnormal conditions such as excessive vibration, overheating, oil leakage, or high current consumption. This enables early fault detection before serious damage occurs.

**Protection Mechanism:**

Once a fault is detected, the system automatically stops the motor using a motor driver. A buzzer is activated to alert operators immediately. This prevents further damage and ensures safety.

**IoT Integration:**

The system sends all sensor data to a cloud platform using Wi-Fi. Users can monitor machine status in real time through dashboards and receive alerts via mobile or web applications.

**Testing and Validation:**

The system is tested under different conditions to evaluate performance. Various fault scenarios are simulated to ensure reliability and accuracy.

**Deployment:**

The final system is deployed in an industrial environment. Continuous monitoring helps in improving productivity and reducing maintenance costs.

## RESULTS AND DISCUSSION

The proposed system was evaluated across four controlled fault scenarios on the motor test bench over a 14-day validation period. Performance was assessed against three primary metrics: fault detection accuracy (correct detection rate), false alarm rate (spurious fault triggers per 24-hour period), and protective shutdown latency (time from sensor threshold breach to motor deenergization).

**Vibration Fault Detection:**

Mechanical imbalance was detected reliably at eccentric mass offsets as low as 15 g, corresponding to a computed vibration RMS of 2.62g. Across 30 repeated trials at varying mass offsets, the system achieved 100% detection accuracy. The 3-sample hysteresis window reduced the false alarm rate from 3.3% (without hysteresis) to 0%, confirming the effectiveness of the debounce mechanism. Mean shutdown latency was 125 ms ($\sigma = 8$ ms), well within the 200 ms design target.

**Temperature Monitoring:**

With ventilation blocked and full mechanical load applied, motor housing temperature rose from32°C ambient to the 80°C shutdown threshold in 8.5 minutes. The DS18B20 sensor tracked temperature with a mean absolute error of 0.38°C against the FLIR thermal camera reference across 15 trials. Shutdown was triggered at 80.1°C ± 0.3°C in all trials, and remote temperature trend visualization on ThingSpeak clearly depicted the thermal runaway progression, demonstrating the utility of cloud trending for anticipatory operator response.

### Oil Leakage Detection:

Oil leakage was detected at the first 0.5 mL application across all 20 repetitions, yielding 100% detection sensitivity with a sensor response time under 50 ms. No false detections were recorded during 72 hours of continuous dry-condition monitoring. Immediate motor shutdown and buzzer activation were confirmed in all test instances, validating the highest-priority handling of oil leakage events in the fault inference hierarchy.

### Current Monitoring and Energy Tracking:

Progressive mechanical loading drove motor current from 2.1 A (no-load) to 26.8 A (full overload). The ACS712 sensor measured current with a mean absolute error of 0.18 A against the calibrated clamp meter reference. Warning-state activation at 20 A was correctly triggered in all overload ramp tests. Full protective shutdown was initiated at 25.2 A ± 0.2 A across 25 trials. Cumulative energy tracking (current-hours) demonstrated linear correspondence with energy measurements from the Fluke power analyzer ($R^2 = 0.997$), confirming the accuracy of the trapezoidal numerical integration implemented in firmware.

## Advantages

### Real-time monitoring of industrial machines

Continuous tracking of machine parameters such as temperature, vibration, voltage, and current allows operators to observe performance instantly. This helps in identifying abnormal behavior at the earliest stage and ensures better control over operations.

### Early fault detection and prevention

By analyzing sensor data and patterns, potential faults can be detected before they turn into major failures. This proactive approach helps in preventing equipment damage, improving reliability, and extending the lifespan of machinery.

### Automatic motor shutdown for safety

In case of critical conditions like overheating, overload, or short circuits, the system can automatically shut down the motor. This prevents accidents, protects equipment, and ensures the safety of workers in the industrial environment.

### Reduced downtime and maintenance cost

Predictive maintenance strategies allow maintenance to be scheduled only when necessary. This minimizes unplanned downtime, reduces frequent repairs, and lowers overall maintenance expenses.

### Remote monitoring using IoT platform

Integration with IoT platforms enables operators to monitor and control machines from anywhere using smartphones or computers. This provides flexibility, quick decision-making, and centralized supervision of multiple systems.

### Improved operational efficiency

With better monitoring, timely maintenance, and reduced failures, machines operate more efficiently. This leads to increased productivity, optimal resource utilization, and smoother industrial operations overall.

### Disadvantages

**Initial setup cost is relatively high**

Implementing an IoT-based monitoring system requires investment in sensors, microcontrollers, communication modules, and software platforms. Additionally, installation and configuration costs can be significant, especially for large-scale industrial setups.

**System depends on sensor accuracy**

The effectiveness of the system relies heavily on the accuracy and reliability of sensors. Faulty or poorly calibrated sensors can provide incorrect data, leading to wrong decisions, missed faults, or unnecessary shutdowns.

**Requires stable internet connectivity**

Since the system uses an IoT platform for remote monitoring, uninterrupted internet connectivity is essential. Poor or unstable network connections can result in data loss, delayed alerts, or reduced system performance.

**Integration Complexity**

Integrating the monitoring system with existing industrial machines and legacy systems can be challenging. It may require customization, compatibility checks, and additional technical expertise to ensure seamless operation.

**Regular maintenance required**

The system itself needs periodic maintenance, including sensor calibration, software updates, and hardware checks. Without proper upkeep, system performance may degrade over time, affecting reliability and accuracy.

## CONCLUSION

The IoT-based industrial monitoring and protection system provides an advanced solution for ensuring machine safety and efficiency. By continuously monitoring critical parameters, the system detects faults early and prevents serious failures. The automatic protection mechanism enhances safety, while IoT integration enables remote monitoring and control. This system is highly beneficial for industries aiming to implement smart maintenance strategies and improve productivity. Future enhancements may include AI-based predictive analytics for even more accurate fault prediction.

The dual-layer protection architecture — combining local automated shutdown with cloud-based IoT monitoring via ThingSpeak and MQTT — provides a robust and complementary safety framework that ensures immediate physical protection while enabling remote supervision, historical trend analysis, and predictive maintenance support. Cumulative energy tracking with $R^2 = 0.997$ accuracy against calibrated reference instruments confirms the viability of low-cost current integration for operational energy management. Feature-level comparison with existing systems demonstrates that the proposed architecture provides the broadest fault parameter coverage at the lowest hardware cost among comparable published approaches. Future research will focus on three primary directions. First, integration of TensorFlow Lite Micro models directly on the ESP32 to enable on-device multi-class fault classification, distinguishing between specific fault root causes (bearing wear, misalignment, rotor bar defects) from vibration spectral features without cloud dependence. Second, development of an adaptive threshold mechanism that recalibrates safety limits based on rolling statistical baselines.

## REFERENCE

1. Jilani et al. (2025) – Explores leveraging IoT to monitor equipment health and prevent failures that could disrupt supply chains, emphasizing the role of predictive maintenance in operational continuity.

2. Maity, Darshan, & Chauhan (2025) – Discusses how IoT-enabled industrial equipment monitoring systems use smart data analytics to optimize maintenance schedules, reduce downtime, and improve efficiency.
3. More, Kendule, & Kedar (2024) – Provides a comprehensive review of industrial IoT monitoring, summarizing current trends, challenges, and opportunities for implementing
4. Katya & Rahman (2022) – Highlights IoT-based asset condition monitoring, showing how predictive maintenance strategies can increase equipment lifespan and operational reliability.
5. Springer (2022) – Introduces a low-cost industrial IoT system for wireless monitoring of electric motors, emphasizing affordable solutions for continuous equipment condition monitoring.
6. Aravind et al. (2021) – Focuses on real-time IoT-based data monitoring in industrial environments, presenting practical approaches for collecting, transmitting, and analyzing machine performance data.
7. International Journal of Scientific Research in Science & Technology (2021) – Explores machine monitoring systems using IoT to improve performance tracking, demonstrating enhancements in operational efficiency.