# IoT-Based Smart Vibration Monitoring and Predictive Maintenance System for Motor–Pump Applications

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## Abstract

The reliability of electric motor–pump systems is critical in industrial and municipal applications, particularly in water supply systems where failures lead to significant economic losses, service interruptions, and resource wastage. Vibration is one of the primary indicators of mechanical and hydraulic faults such as misalignment, imbalance, bearing defects, and cavitation. This paper proposes a low-cost IoT-based condition monitoring system for real-time detection and prevention of motor–pump faults. The system integrates multiple sensors, including vibration sensors mounted at the motor drive end, non-drive end, and pump casing, along with a current sensor and water level sensor. These sensors are interfaced with a Node MCU ESP8266 microcontroller, which enables wireless data transmission to a cloud-based platform for monitoring and analysis.

The proposed system employs intelligent decision logic to correlate vibration, current, and water level parameters for accurate fault identification, such as dry running, cavitation, mechanical looseness, and overload conditions. The system also provides automated control through relay-based switching and real-time alerts via a mobile application, such as the Blynk IoT App. The total implementation cost is less than ₹2000, making it highly suitable for low-resource environments like municipal water systems and small-scale industries. The proposed solution enhances equipment reliability, reduces maintenance costs, and prevents unexpected failures, thereby contributing to efficient and sustainable operation.

## 2.Keywords

IoT-based monitoring, Motor vibration analysis, Predictive maintenance, Water pump system, NodeMCU ESP8266, Vibration sensors, Cavitation detection, Smart water management, Low-cost automation, Condition monitoring

## 1 Introduction

Electric motor–pump systems form the backbone of industrial processes and municipal infrastructure, particularly in water supply, irrigation, and wastewater management systems. In regions such as Vasai-Virar, these systems operate continuously under varying load and environmental conditions, making them highly susceptible to mechanical and operational faults. Among the various indicators of machine health, vibration is one of the most reliable and widely used parameters for condition monitoring of rotating machinery.

Excessive vibration in motor–pump systems is primarily caused by factors such as misalignment, rotor imbalance, bearing defects, looseness, and hydraulic issues like cavitation. If not detected at an early stage, these issues can lead to severe damage, increased energy consumption, unplanned downtime, and significant financial losses. Traditional maintenance practices in many municipal and small-scale industrial setups are largely reactive, where faults are addressed only after failure occurs. This approach not only increases operational costs but also affects service reliability and resource efficiency.

With the advancement of sensing technologies and wireless communication, Internet of Things (IoT)-based monitoring systems have emerged as an effective solution for predictive maintenance. These systems enable continuous monitoring of machine parameters, real-time data analysis, and early fault detection. However, most existing industrial solutions are expensive and complex, limiting their adoption in low-budget environments.

To address this gap, this work proposes a low-cost, IoT-based condition monitoring system for motor–pump applications. The system integrates multiple sensors, including vibration sensors placed at critical locations (motor drive end, non-drive end, and pump casing), along with electrical and hydraulic parameters such as current and water level. These sensors are interfaced with a compact microcontroller, the NodeMCU ESP8266, which enables real-time data acquisition and wireless transmission to a cloud-based platform for monitoring and analysis.

The proposed system not only measures vibration but also implements intelligent decision logic by correlating multiple parameters to identify specific fault conditions such as dry running, cavitation, overload, and mechanical defects. Additionally, it incorporates automated control and alert mechanisms through mobile-based applications like the Blynk IoT App, ensuring timely intervention and improved system reliability.

The main objective of this study is to develop an economical, scalable, and efficient monitoring solution that can be easily deployed in municipal water systems and small industries. By enabling predictive maintenance and reducing unexpected failures, the proposed system contributes to improved operational efficiency, cost savings, and sustainable resource management.

## 2 Financial and Social Losses Study

The failure of motor–pump systems due to excessive vibration and associated mechanical faults has significant economic as well as social consequences, especially in critical infrastructure such as water supply systems. In many developing regions and urban local bodies like Vasai-Virar, where water distribution relies heavily on electrically driven pumps, even minor faults can escalate into major operational disruptions if not addressed in time.

### 2.1 Financial Losses

Motor vibration is a key precursor to faults such as bearing failure, misalignment, imbalance, and cavitation. These issues lead to:

- Increased maintenance costs: Frequent repair or replacement of bearings, shafts, and impellers
- Unplanned downtime: Interruption in industrial processes and water supply operations
- Energy inefficiency: Vibrating machines consume more power due to mechanical losses
- Equipment damage: Severe faults may lead to complete motor or pump failure

Globally, industrial losses due to machine failures—including vibration-related faults—are estimated to reach hundreds of billions of dollars annually. In the Indian context, such losses are estimated in the range of ₹50,000 crore to ₹1.5 lakh crore per year, considering the scale of manufacturing, infrastructure, and utility services.

In municipal water systems, the financial burden includes not only repair costs but also electricity wastage, water loss, and emergency maintenance expenses. A single pump failure can result in repair costs ranging from ₹10,000 to ₹50,000, along with additional indirect losses due to service disruption.

### 2.2 Social Losses

Beyond financial implications, motor–pump failures also lead to serious social challenges, particularly in public utility systems:

- Water supply disruption: Affects daily life, sanitation, and public health
- Inequitable distribution: Some areas may receive less or no water during failures
- Increased dependency on alternative sources: Tankers or bottled water, increasing household expenses

- Public dissatisfaction: Reduced trust in municipal services

In rapidly growing urban areas, the reliability of water infrastructure is directly linked to quality of life and urban sustainability. Frequent breakdowns not only inconvenience residents but can also lead to hygiene issues and increased risk of waterborne diseases.

2.3Need for Preventive Solutions

The analysis of financial and social losses clearly indicates that reactive maintenance approaches are insufficient. There is a strong need for:

- Early fault detection
- Continuous monitoring of critical parameters
- Low-cost and scalable solutions

The proposed IoT-based monitoring system using NodeMCU ESP8266 addresses these challenges by enabling real-time condition monitoring and preventive maintenance. By minimizing failures and ensuring timely intervention, such systems can significantly reduce both economic losses and social disruptions.

The combined financial and social impact of motor–pump failures highlights the importance of adopting intelligent monitoring systems. A cost-effective, IoT-enabled solution not only improves equipment reliability but also enhances service delivery and public welfare, making it highly relevant for modern infrastructure systems.

## 3 Probable Solutions

The analysis of financial and social losses highlights the urgent need for effective, practical, and scalable solutions to mitigate motor–pump failures caused by excessive vibration and related faults. The following probable solutions are identified based on industrial practices, technological advancements, and field-level constraints in municipal and small-scale systems

3.1Mechanical and Operational Improvements

The first level of solution focuses on addressing the root causes of vibration through proper installation and maintenance practices:

- Shaft Alignment: Ensuring accurate alignment between motor and pump shafts reduces stress on bearings and couplings.
- Dynamic Balancing: Periodic balancing of rotors and impellers minimizes vibration due to uneven mass distribution.
- Bearing Maintenance: Regular lubrication and timely replacement prevent excessive vibration and overheating.
- Foundation Strengthening: Proper mounting, tightening of bolts, and use of anti-vibration pads reduce structural looseness.

Cavitation Prevention: Maintaining adequate suction conditions and avoiding air entry in pipelines helps eliminate hydraulic vibration.

These measures are essential but rely heavily on manual inspection and periodic maintenance, which may not always be reliable in practice.

3.2Conventional Monitoring Techniques

Traditional monitoring methods include:

- Handheld vibration meters
- Periodic inspection schedules
- Manual logging of operational parameters

While these methods are useful, they are time-consuming, less accurate, and reactive in nature, often detecting faults only after they have progressed significantly.

3.3Advanced Industrial Solutions

Industries with higher budgets adopt:

- Online vibration monitoring systems
- SCADA-based supervision
- PLC-controlled automation systems

These solutions provide high accuracy and continuous monitoring but are expensive and complex, making them unsuitable for small industries and municipal applications.

3.4IoT-Based Smart Monitoring (Proposed Solution)

To bridge the gap between cost and performance, an IoT-based condition monitoring system is proposed as the most feasible solution. The system uses low-cost sensors and a microcontroller such as the Node MCU ESP8266 to enable real-time monitoring and control.

Key Features:

- Continuous measurement of vibration at critical points (motor DE, NDE, and pump casing)
- Monitoring of electrical (current) and hydraulic (water level) parameters
- Wireless data transmission to cloud platforms
- Real-time visualization using mobile applications like the Blynk IoT App
- Automated alerts and relay-based motor control.

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### 3.5 Intelligent Fault Diagnosis

A significant improvement over conventional systems is the use of multi-parameter decision logic, where different sensor inputs are correlated to identify specific faults:

- High vibration + low water level → Dry run condition
- High vibration (pump side) → Cavitation
- High vibration + high current → Mechanical fault (misalignment/bearing issue)
- Tank full → Automatic motor shutdown (overflow prevention)

This approach enhances the accuracy and reliability of fault detection, reducing false alarms.

### 3.6 Advantages of the Proposed Approach

- **Low Cost:** Implementation under ₹2000
- **Scalability:** Can be deployed across multiple pump systems
- **Real-Time Monitoring:** Enables immediate response to faults
- **Energy Efficiency:** Reduces unnecessary power consumption
- **Ease of Implementation:** Suitable for existing infrastructure.

Among the various solutions, the IoT-based monitoring system offers the best balance between cost, performance, and scalability. By integrating sensing, communication, and intelligent decision-making, it provides a comprehensive solution for minimizing vibration-related failures and improving the overall reliability of motor pump systems.

## 4 Proposed System

This work proposes a low-cost, IoT-based smart monitoring and control system for motor–pump applications, specifically designed for municipal water systems and small-scale industries. The system integrates vibration, electrical, and hydraulic parameters to provide real-time condition monitoring, fault diagnosis, and automatic control.

### 4.1 System Overview

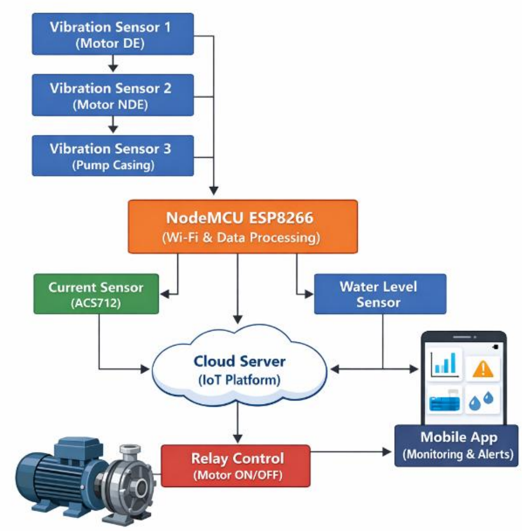
The proposed system continuously monitors the health of the motor–pump unit using:

Three vibration sensors mounted at:

- Motor Drive End (DE)
- Motor Non-Drive End (NDE)
- Pump casing
- Current sensor to monitor electrical load
- Water level sensor to detect tank status

All sensor data is processed by the Node MCU ESP8266, which transmits data to a cloud platform for visualization and analysis. The system also includes a relay control unit for automatic switching of the motor based on predefined conditions.

### 4.2 Block Diagram of the Proposed System




The proposed IoT-based motor–pump monitoring system operates by continuously sensing, processing, transmitting, and controlling various operational parameters of the motor–pump unit. The system begins with three vibration sensors mounted at critical locations: the motor drive end (DE), motor non-drive end (NDE), and pump casing. These sensors continuously monitor vibration levels to detect faults such as misalignment, imbalance, bearing defects, and cavitation. Along with vibration monitoring, a current sensor measures the electrical current consumed by the motor, while a water level sensor monitors the tank condition to prevent dry running and overflow.

All sensor outputs are connected to the Node MCU ESP8266, which acts as the central processing and communication unit. The controller collects real-time sensor data, converts it into digital form, and compares the values with predefined threshold conditions. Based on intelligent decision logic, the system identifies abnormal operating conditions such as excessive vibration, overload, low water level, or overflow.

The processed data is transmitted wirelessly through Wi-Fi to a cloud-based IoT platform, where it can be visualized and monitored remotely using the Blynk IoT App. The mobile interface displays real-time vibration levels, motor current, water level status, and system alerts. Whenever fault conditions are detected, the system immediately sends notifications to the user and activates the relay control unit to automatically switch the motor ON or OFF as required. This integrated operation enables real-time monitoring, predictive maintenance, fault prevention, and efficient management of motor–pump systems.

## 5 Results and Discussion

The proposed IoT-based motor–pump monitoring system was developed and tested under simulated and practical operating conditions. The objective was to evaluate the system's ability to detect faults, generate alerts, and prevent failures using multi-parameter sensing.

### 5.1 Observed Results

- **Normal Condition**
- Vibration levels remained within acceptable limits
- Current consumption was stable
- Motor operated smoothly without abnormal noise

**Fault Simulation Results**

- **Misalignment / Mechanical Fault**
- Increased vibration at motor DE & NDE
- Slight rise in current
- System generated alert indicating mechanical issue
- **Cavitation Condition (Pump Side)**
- High vibration detected at pump casing
- Water level normal
- System correctly identified hydraulic fault and issued warning
- **Dry Run Condition**
- Water level low
- Current reduced
- Vibration fluctuating
- System automatically stopped the motor
- **Overflow Condition**
- Tank reached maximum level
- System successfully switched OFF the motor

### 5.2 Comparative Insight

| **Parameter** | **Conventional System** | **Proposed System** |
|---|---|---|
| Monitoring | Periodic | Continuous |
| Cost | High | Very Low |
| Fault Detection | Late | Early |
| Automation | Limited | Fully Automated |
| Accessibility | On-site only | Remote (IoT-based) |

## 6 Conclusion

This work presents a low-cost, IoT-based condition monitoring and control system for motor–pump applications, addressing the critical issue of vibration-induced failures in industrial and municipal environments. By integrating vibration sensors at the motor drive end, non-drive end, and pump casing along with current and water level sensing, the system provides a comprehensive multi-parameter monitoring approach**.**

The use of the Node MCU ESP8266 enables real-time data acquisition and wireless communication, while the Blynk IoT App offers an intuitive platform for visualization, alerts, and remote control. The implementation demonstrates that combining mechanical, electrical, and hydraulic parameters significantly improves **the** accuracy of fault detection compared to conventional single-parameter systems.

Experimental results confirm that the system can effectively identify conditions such as misalignment, cavitation, dry running, and overflow, and take timely actions through automated control mechanisms. The total implementation cost of less than ₹2000 makes the solution highly suitable for large-scale deployment in resource-constrained environments, including municipal water systems and small industries.

Overall, the proposed system enhances equipment reliability, reduces maintenance costs, minimizes downtime, and prevents resource wastage, thereby contributing to efficient and sustainable operation. The study also highlights the potential of IoT-based solutions in transforming traditional maintenance practices into predictive and intelligent systems.

## 7 Future Scope

- Integration of machine learning algorithms for advanced fault prediction
- Development of a dedicated web dashboard for centralized monitoring
- Expansion to multi-pump and smart city infrastructure systems
- Use of industrial-grade sensors for higher accuracy and robustness

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