



# International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

*(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)*



**Impact Factor: 9.935**

**Volume 15, Issue 8, August 2026**

# (IIoT)-Based Smart Industrial Energy and Machine Monitoring System

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**ABSTRACT:** The rapid growth of industrial automation has increased the need for efficient energy management and continuous monitoring of industrial machines. This paper proposes an **Industrial Internet of Things (IIoT)-based smart industrial energy and machine monitoring system** for real-time collection, analysis, and visualization of industrial parameters. The proposed system uses sensors and smart measuring devices to monitor electrical energy consumption, voltage, current, power, temperature, vibration, and machine operating conditions. The collected data is transmitted through an IIoT communication network to a centralized cloud or edge platform, where it can be analyzed and displayed through a user-friendly monitoring interface. The system enables real-time identification of abnormal machine conditions, excessive energy consumption, equipment faults, and potential maintenance requirements. By applying data analytics and threshold-based alerts, the proposed approach supports predictive maintenance, reduces machine downtime, improves energy efficiency, and enhances overall industrial productivity. The system provides a scalable and cost-effective solution for smart factories by integrating energy monitoring and machine-condition monitoring into a single IIoT framework. The proposed methodology demonstrates the potential of IIoT technology to improve operational efficiency, reduce energy wastage, and support data-driven decision-making in modern industrial environments.

**KEYWORDS:** Industrial Internet of Things (IIoT), Smart Industry, Energy Monitoring, Machine Monitoring, Predictive Maintenance, Energy Efficiency, IoT Sensors, Smart Factory.

## I. INTRODUCTION

The rapid development of industrial automation and digital technologies has transformed traditional manufacturing systems into intelligent and interconnected environments. Modern industries operate a large number of electrical machines, motors, pumps, compressors, and other equipment that consume significant amounts of energy. Efficient energy utilization and reliable machine operation are therefore essential for improving productivity, reducing operational costs, and maintaining sustainable industrial processes. Conventional monitoring methods generally depend on manual inspection and periodic measurements, which may not provide continuous information about energy consumption or machine health.

The **Industrial Internet of Things (IIoT)** provides an effective approach for addressing these limitations by connecting industrial equipment, sensors, communication networks, and data-processing platforms. IIoT enables real-time acquisition and exchange of machine and energy-related data through connected sensing devices. Parameters such as voltage, current, power, energy consumption, temperature, vibration, and machine operating status can be continuously measured and transmitted to a centralized monitoring system. This enables industries to obtain accurate information about equipment performance and energy usage without relying solely on manual observation.

Energy monitoring is an important component of smart industrial management. Excessive or abnormal energy consumption can indicate inefficient operation, equipment degradation, overload conditions, or possible faults. Continuous monitoring allows such conditions to be detected at an early stage, helping industries reduce unnecessary energy consumption and improve overall energy efficiency. Similarly, monitoring machine parameters such as temperature and vibration can provide useful information about the condition of industrial equipment and support predictive maintenance strategies.



The proposed **IIoT-based Smart Industrial Energy and Machine Monitoring System** integrates energy monitoring and machine-condition monitoring into a common platform. Sensors and measurement modules collect real-time data from industrial machines, while a microcontroller or edge device processes and communicates the acquired information through an IIoT network. The collected data can be stored on a cloud or local server and displayed through a web-based or mobile monitoring interface. The system can also generate alerts when measured parameters exceed predefined limits, allowing operators to respond quickly to abnormal operating conditions.

The major objective of the proposed system is to provide a low-cost, scalable, and real-time solution for monitoring industrial energy consumption and machine health. By combining IIoT connectivity with data monitoring and analysis, the system can help reduce machine downtime, identify abnormal operating conditions, minimize energy wastage, and improve maintenance planning. Furthermore, the collected historical data can support data-driven decision-making and future implementation of advanced analytics and predictive maintenance techniques.

Thus, the integration of IIoT with industrial energy and machine monitoring represents an important step toward the development of **smart factories and Industry 4.0 systems**. The proposed approach aims to improve energy efficiency, equipment reliability, operational safety, and overall industrial productivity through continuous monitoring and intelligent utilization of industrial data.

## **II. LITERATURE SURVEY**

The Industrial Internet of Things (IIoT) has emerged as a key technology for developing smart and connected industrial environments. It enables the integration of sensors, industrial machines, embedded controllers, communication networks, cloud platforms, and data analytics. Recent research has demonstrated that IIoT-based monitoring can provide continuous information about machine health and energy consumption, thereby improving operational efficiency, reducing downtime, and supporting intelligent maintenance decisions.

### **A. IIOT FOR INDUSTRIAL MONITORING**

Early industrial monitoring systems primarily relied on manual inspection and conventional wired control systems. These approaches provided limited real-time information and often required significant human intervention. With the development of IoT and IIoT technologies, sensors can now be installed directly on industrial equipment to continuously collect operating parameters. Microcontrollers and edge devices process the sensor data and transmit it through communication networks to monitoring platforms. This approach enables remote supervision and improves the visibility of industrial operations.

### **B. ENERGY MONITORING IN INDUSTRIAL SYSTEMS**

Industrial energy consumption has been widely investigated because inefficient use of electrical energy directly affects production costs. Several researchers have proposed IoT-based energy monitoring systems using current transformers, voltage sensors, smart energy meters, and power-measurement modules. These systems measure parameters such as voltage, current, active power, power factor, and accumulated energy. The measured values are transmitted to a monitoring platform where operators can observe real-time consumption and historical trends. Such systems help identify energy-intensive machines and abnormal consumption patterns and can support energy conservation strategies.

### **C. MACHINE CONDITION MONITORING**

Machine-condition monitoring is another important research area in IIoT. Industrial machines can experience failures because of excessive vibration, overheating, mechanical wear, electrical faults, misalignment, and overload. Researchers have therefore investigated the use of vibration, temperature, current, speed, and proximity sensors for continuous machine monitoring. Vibration-based monitoring is particularly useful for identifying mechanical abnormalities, while temperature and current measurements can provide information about thermal and electrical conditions. Continuous monitoring enables faults to be identified earlier and reduces dependence on periodic inspection.

### **D. PREDICTIVE MAINTENANCE**

Conventional corrective maintenance can result in unexpected machine failures and production downtime. Predictive maintenance attempts to overcome this limitation by using real-time sensor data and historical operating information to estimate equipment health. IIoT platforms can collect large quantities of machine data and apply statistical analysis,

anomaly detection, or machine-learning techniques to identify abnormal behavior. Research in this area indicates that predictive maintenance can improve equipment availability, reduce maintenance costs, and increase machine lifetime.

#### E. CLOUD-BASED INDUSTRIAL MONITORING

Cloud computing has been widely integrated with IIoT systems to provide centralized data storage and remote monitoring. Sensor data collected from industrial machines can be uploaded to cloud servers and accessed through web or mobile applications. Cloud platforms also provide data visualization and analytics capabilities. However, cloud-dependent systems may experience communication delays and increased bandwidth requirements when large quantities of industrial data are continuously transmitted.

#### F. EDGE COMPUTING IN IIOT

To overcome some limitations of cloud-based monitoring, recent research has introduced edge computing into industrial IoT architectures. In edge-based systems, data processing is performed near the source of data, such as an industrial gateway or microcontroller. This reduces communication latency and allows rapid detection of abnormal machine conditions. Edge computing is particularly useful for industrial applications where immediate response is important. A combined edge-cloud architecture can provide local real-time monitoring while using cloud platforms for long-term storage and advanced analytics.

#### G. COMMUNICATION TECHNOLOGIES

Different communication technologies have been studied for IIoT applications depending on industrial requirements. Wi-Fi and Ethernet provide high data rates and are suitable for many factory environments, whereas Zigbee and other low-power wireless technologies can be useful for sensor networks. LoRa-based communication is suitable for applications requiring long-range, low-power data transmission. Industrial systems may also use established industrial communication protocols to improve interoperability between sensors, controllers, and monitoring platforms.

A significant portion of existing research addresses either energy monitoring or machine-condition monitoring independently. Energy-monitoring systems primarily focus on electrical parameters, whereas machine-monitoring systems concentrate on parameters such as vibration and temperature. An integrated approach can provide a more complete view of industrial performance by correlating energy consumption with machine operating conditions. For example, an increase in power consumption combined with increased vibration or temperature may indicate an abnormal operating condition.

#### I. RESEARCH GAP

From the existing literature, it can be observed that IIoT provides significant advantages for real-time industrial monitoring, energy management, and predictive maintenance. However, several challenges remain, including system cost, scalability, sensor integration, communication reliability, data security, and the need for real-time processing. In addition, many existing systems are designed for a specific parameter or machine rather than providing a unified platform for both energy and machine monitoring.

Therefore, there is a need for a **low-cost, scalable, and integrated IIoT-based smart industrial monitoring system** capable of measuring electrical energy parameters and machine-health parameters simultaneously. The proposed system addresses this requirement by combining sensor-based data acquisition, IIoT communication, real-time monitoring, data visualization, and abnormal-condition alerts. Such an integrated system can contribute to improved energy efficiency, reduced machine downtime, better maintenance planning, and enhanced industrial productivity.

#### J. SUMMARY OF LITERATURE SURVEY

The literature indicates that IIoT technologies have significantly improved the capabilities of industrial monitoring systems. Energy monitoring enables industries to understand and optimize electrical consumption, while machine-condition monitoring helps detect faults and prevent unexpected failures. Cloud and edge computing further enhance data processing and remote accessibility. However, the integration of these capabilities into a single, economical, and easily scalable system remains an important area for further development. The proposed work focuses on addressing this requirement through an IIoT-based platform for simultaneous **industrial energy and machine monitoring**.

### III. DISCUSSION

The proposed **IIoT-Based Smart Industrial Energy and Machine Monitoring System** provides an integrated approach for monitoring both electrical energy consumption and machine operating conditions. Unlike conventional industrial monitoring methods, which generally depend on manual inspection or separate measurement systems, the proposed system continuously collects data from multiple sensors and makes the information available through a centralized monitoring platform.

#### A. ENERGY MONITORING

Continuous measurement of voltage, current, power, power factor, and energy consumption enables the operator to understand the electrical performance of individual machines. Abnormal increases in power consumption may indicate machine overload, inefficient operation, or developing faults. Therefore, real-time energy monitoring can help identify energy wastage and support better energy-management decisions.

#### B. MACHINE MONITORING

Machine parameters such as temperature, vibration, current, and operating status provide useful information about equipment health. Continuous monitoring makes it possible to identify abnormal conditions before they develop into major failures. For example, increased temperature or vibration can indicate mechanical stress, bearing problems, misalignment, or excessive loading. This capability can reduce unexpected machine downtime and improve equipment reliability.

#### C. IIOT-BASED DATA COMMUNICATION

The use of IIoT connectivity allows the collected sensor data to be transmitted to an edge device, server, or cloud platform. The data can then be displayed through a web-based or mobile dashboard. This provides operators with real-time access to machine and energy information and allows monitoring from a remote location. The architecture can also be expanded by adding additional machines and sensors without significantly changing the basic monitoring concept.

#### D. FAULT DETECTION AND ALERTS

An important advantage of the proposed system is the ability to establish threshold values for monitored parameters. When a parameter exceeds its predefined safe range, the system can generate an alert. This allows the operator to take corrective action at an early stage. Combining energy measurements with machine-condition parameters can provide more useful information than monitoring either parameter independently.

#### E. ENERGY EFFICIENCY AND PREDICTIVE MAINTENANCE

The integration of energy and machine monitoring can contribute to both energy efficiency and predictive maintenance. Historical energy data can be analyzed to identify machines with unusually high consumption, while machine-condition data can be used to identify deterioration trends. This combined information can help industries schedule maintenance according to actual equipment condition rather than relying only on fixed maintenance intervals.

#### F. ADVANTAGES AND LIMITATIONS

The major advantages of the proposed approach include **real-time monitoring, reduced manual inspection, early fault detection, energy-consumption analysis, remote accessibility, and improved maintenance planning**. However, practical implementation also involves challenges such as sensor accuracy, communication failures, cybersecurity, data storage, network dependency, and the initial installation cost. Proper sensor calibration and secure communication are therefore important for reliable operation.

#### G. OVERALL DISCUSSION

Overall, the proposed IIoT-based system demonstrates how industrial energy management and machine-condition monitoring can be integrated into a single smart monitoring platform. The combination of sensing, communication, data visualization, and alert generation can improve industrial decision-making and reduce unnecessary energy consumption and machine downtime. Future improvements can include **machine-learning-based fault prediction, advanced energy analytics, edge computing, digital twins, and automated maintenance recommendations**. Such developments can further improve the scalability and intelligence of the system and support the transition toward Industry 4.0 and smart-factory environments.

#### **IV. METHODOLOGY**

The proposed **IIoT-Based Smart Industrial Energy and Machine Monitoring System** is designed to provide continuous, real-time monitoring of industrial energy consumption and machine operating conditions. The methodology consists of sensing, data acquisition, communication, processing, storage, visualization, and alert generation stages.

##### **A. SYSTEM ARCHITECTURE**

The proposed system consists of five major layers:

Sensing Layer

Data Acquisition and Processing Layer

IIoT Communication Layer

Cloud/Database Layer

Monitoring and Alert Layer

Industrial machines are equipped with suitable sensors to collect electrical and physical parameters. The acquired data is processed by a microcontroller or edge device and transmitted to a monitoring platform through an IIoT communication network.

##### **B. SENSING LAYER**

The sensing layer collects real-time information from industrial equipment. Current and voltage sensors are used to measure electrical parameters, while temperature and vibration sensors are used to monitor machine health. Depending on the application, additional sensors such as speed, proximity, or humidity sensors can also be incorporated.

The main parameters considered are:

- Voltage
- Current
- Power
- Energy consumption
- Power factor
- Temperature
- Vibration
- Machine operating status

The sensors are selected according to the operating range, required accuracy, response time, and environmental conditions of the industrial equipment.

##### **C. DATA ACQUISITION**

The outputs from the sensors are connected to a microcontroller or industrial edge device. The controller periodically samples the sensor signals and converts them into digital data. Appropriate signal-conditioning and calibration techniques are applied to improve measurement accuracy.

The acquired data is then organized into suitable data packets containing parameters such as sensor value, machine identification, and time stamp. This allows the system to maintain a historical record of machine operation and energy consumption.

##### **D. ENERGY MEASUREMENT**

Electrical energy consumption is determined by measuring the voltage and current associated with the machine. The system calculates relevant electrical parameters and continuously records energy usage. The collected information can be used to compare the energy consumption of different machines and identify unusual increases in consumption.

This information helps operators identify inefficient operating conditions, overload situations, and machines that require inspection or maintenance.

##### **E. MACHINE CONDITION MONITORING**

Machine-health parameters are monitored continuously using temperature, vibration, current, and other appropriate sensors. The sensor readings are compared with predefined operating limits. If the measured value exceeds the specified threshold, the system identifies the condition as abnormal.

For example, an increase in vibration may indicate mechanical imbalance or bearing deterioration, while an increase in temperature may indicate overheating or excessive load. Continuous monitoring allows these conditions to be detected at an early stage.

#### **F. IIOT COMMUNICATION**

After local processing, the data is transmitted through an IIoT communication network. Depending on the industrial environment and system requirements, communication can be implemented using Wi-Fi, Ethernet, LoRa, Zigbee, or other suitable industrial communication technologies.

The communication layer provides connectivity between the machine-level sensors and the monitoring server. Reliable communication is essential for maintaining continuous monitoring and minimizing data loss.

#### **G. CLOUD AND DATABASE PROCESSING**

The received sensor data is stored in a local or cloud-based database. The database maintains historical information about machine operating conditions and energy consumption. This historical data can be used to analyze trends, compare machine performance, and support predictive maintenance.

A cloud-based architecture also enables authorized users to access the monitoring system remotely through an internet-connected device.

#### **H. MONITORING DASHBOARD**

A web-based or mobile dashboard is developed to display real-time information in an understandable format. Important parameters such as voltage, current, power, energy consumption, temperature, and vibration can be displayed using numerical indicators, graphs, and status indicators.

The dashboard can provide separate views for individual machines, allowing operators to quickly identify machines operating outside their normal conditions.

#### **I. ALERT AND FAULT DETECTION**

Threshold-based fault detection is implemented to identify abnormal operating conditions. When a measured parameter exceeds its predefined limit, the system generates an alert. The alert may be displayed on the dashboard and, depending on implementation, transmitted through notification services.

This feature enables operators to respond quickly to abnormal conditions and can help reduce machine downtime and prevent serious equipment damage.

#### **J. DATA ANALYSIS**

The collected data is analyzed to identify trends in energy consumption and machine performance. Normal operating ranges are established for each machine, and deviations from these ranges are monitored. Historical data can also be used to identify gradual changes in machine behaviour.

In future implementations, machine-learning algorithms can be integrated to improve anomaly detection and predictive maintenance.

#### **K. SYSTEM TESTING**

The developed system is tested under different machine operating conditions. Sensor measurements are compared with reference instruments to verify accuracy. The communication system is tested for data transmission reliability, while the dashboard is evaluated for real-time data display and alert generation.

The overall performance of the system can be evaluated using parameters such as:

- Sensor measurement accuracy
- Data transmission reliability
- Response time
- Fault-detection capability
- Energy-monitoring accuracy
- System scalability
- Monitoring availability



#### L. OVERALL METHODOLOGY

The complete methodology can be summarized as:

Industrial Machine → Sensors → Microcontroller/Edge Device → Data Processing → IIoT Communication → Cloud/Database → Monitoring Dashboard → Fault Alert and Analysis

The proposed methodology provides an integrated framework for monitoring both **industrial energy consumption and machine health**. By combining real-time sensing, IIoT communication, data storage, visualization, and abnormal-condition detection, the system supports energy efficiency, predictive maintenance, reduced downtime, and improved industrial productivity.

#### V. CONCLUSION

The **IIoT-Based Smart Industrial Energy and Machine Monitoring System** provides an effective and intelligent solution for real-time monitoring of industrial equipment and energy consumption. The proposed system integrates sensors, embedded controllers, communication technologies, data processing, and a monitoring platform to continuously collect and analyze important industrial parameters.

By monitoring **voltage, current, power, energy consumption, temperature, vibration, and machine operating status**, the system enables early identification of abnormal operating conditions. Real-time energy monitoring helps industries identify excessive energy consumption and improve energy efficiency, while machine-condition monitoring supports timely maintenance and reduces unexpected equipment failures.

The integration of IIoT technology also provides remote access to machine data and enables operators to receive alerts when monitored parameters exceed predefined limits. This can reduce manual inspection, minimize machine downtime, improve equipment reliability, and support data-driven industrial decision-making.

Overall, the proposed system demonstrates the potential of IIoT to integrate **energy management and machine-condition monitoring** into a single smart industrial platform. The approach is scalable and can be extended to multiple machines and additional sensors. Future work can focus on incorporating **machine-learning algorithms, predictive analytics, edge computing, digital twins, advanced fault diagnosis, and cybersecurity mechanisms** to further improve system intelligence, reliability, and scalability. Thus, the proposed system can contribute significantly to the development of **smart factories, energy-efficient industries, and Industry 4.0-based manufacturing environments**.

#### VI. ACKNOWLEDGMENT

We would like to express our sincere gratitude to all those who supported and guided us in completing the project titled **"IIoT-Based Smart Industrial Energy and Machine Monitoring."**

First and foremost, we are deeply thankful to our **project guide as Mr. Y D Mahajan and faculty members** for their valuable guidance, continuous encouragement, technical suggestions, and constructive feedback throughout the development of this project. Their knowledge and support were essential in completing the work successfully.

We also express our gratitude to the **Head of the Institute as Prof. P T Kadave Sir, Head of the Department as Prof. S B Pawar Sir and the management of our institution** for providing the necessary facilities, laboratory resources, and academic environment required for this project.

We would like to thank our **department staff and laboratory technicians** for their assistance with hardware components, sensors, measurement equipment, and technical resources used during the implementation and testing of the IIoT-based monitoring system.

We are also grateful to our **friends and classmates** for their valuable suggestions, cooperation, and encouragement during the different stages of the project.

Finally, we would like to thank our **parents and family members** for their continuous moral support, motivation, and encouragement throughout our academic work.



We sincerely acknowledge the contribution of everyone who directly or indirectly helped us in successfully completing this project.

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