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AI-Based Industrial Equipment Monitoring & Predictive Maintenance

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***Abstract*— In recent industrial environments, unexpected equipment failure causes production loss and increases maintenance cost. Normally, PLC-based systems are used only for monitoring and control, and faults are identified only after failure occurs. To overcome this limitation, this project focuses on predicting equipment failure in advance using cloud-based analytics.**

In this work, an AI-based industrial equipment monitoring and predictive maintenance system is developed using a Mitsubishi Q13UDEHCPU PLC and the ThingSpeak cloud platform. The system uses two sensors, namely a water tank level switch sensor and a motor temperature sensor, to monitor the operating condition of industrial equipment. Sensor data is collected by the PLC and transmitted to the cloud through an Ethernet-based IoT gateway. The collected data is analyzed in the cloud to identify abnormal patterns related to sensor failure and motor overheating.

The proposed system helps in detecting water tank level switch malfunction and motor temperature abnormalities before actual breakdown occurs. By providing early warning alerts, the system supports timely maintenance, reduces downtime, and improves overall system reliability. This project demonstrates that effective predictive maintenance can be achieved using a simple hardware setup combined with intelligent cloud-based analysis.

***Keywords*-- Industrial Internet of things, PLC, Think speak Cloud platform**

I. INTRODUCTION

In modern industrial systems, automation plays a major role in improving productivity and efficiency. Most industries depend on machines such as motors, pumps, and water handling systems for continuous operation. To control and monitor these machines, Programmable Logic Controllers (PLCs) are widely used because of their reliability and real- time performance. However, traditional PLC-based systems mainly focus on control and basic monitoring and are not capable of predicting equipment failure in advance.

In many industries, equipment faults such as sensor malfunction or motor overheating are detected only after the failure occurs. This reactive maintenance approach leads to unexpected downtime, production loss, increased maintenance cost, and reduced equipment life.

Therefore, there is a strong need for a system that can continuously monitor equipment condition and also predict possible failures before they happen.

With the development of Industrial Internet of Things (IIoT) and cloud computing, it has become possible to collect industrial data remotely and analyze it intelligently. By combining PLC-based data acquisition with cloud-based analytics and Artificial Intelligence (AI), predictive maintenance can be implemented effectively. AI techniques help in identifying abnormal patterns from historical and real-time data, enabling early fault detection.

In this work, an AI-based industrial equipment failure monitoring and predictive maintenance system is proposed using a Mitsubishi Q13UDEHCPU PLC and the ThingSpeak cloud platform. The system uses a water tank level switch sensor and a motor temperature sensor to monitor equipment operating conditions. [1]Sensor data collected by the PLC is transmitted to the cloud through an Ethernet-based IoT gateway, where it is analyzed to detect abnormal behavior. The proposed system aims to reduce unplanned downtime, improve maintenance efficiency, and enhance overall system reliability with a simple and cost-effective approach.

II. LITERATURE REVIEW

An Several research works have been carried out in the area of industrial equipment monitoring and predictive maintenance using PLC, IoT, and Artificial Intelligence techniques. Traditional industrial monitoring systems mainly rely on PLCs to control and monitor machines based on predefined threshold values. These systems are effective for real-time control but fail to provide early warning about equipment failure.

Many researchers have proposed IoT-based monitoring systems where sensor data is collected and transmitted to cloud platforms for remote monitoring. In such systems, [2]multiple sensors such as temperature, vibration, and current sensors are used to monitor machine health. While these systems improve visibility and remote access, most of them focus only on condition monitoring and not on failure prediction.

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Recent studies have introduced AI and machine learning techniques for predictive maintenance. These approaches use historical sensor data to train models that can identify abnormal patterns and predict future failures. Techniques such as neural networks, support vector machines, and statistical trend analysis have been widely used. Although these methods show good accuracy, they often require large datasets, complex hardware setups, and high computational resources, making them less suitable for low-cost industrial applications.

Some research works have integrated PLC systems with cloud platforms using Ethernet or IoT gateways. These systems demonstrate the feasibility of sending real-time industrial data to the cloud for analysis. However, many existing implementations use complex architectures with multiple sensors and expensive hardware, which increases system cost and implementation difficulty.

From the literature, it is observed that there is a need for a simple, cost-effective, and reliable predictive maintenance system that combines PLC-based data acquisition with cloud-based intelligent analysis. The proposed work addresses this gap by using a minimal number of sensors along with a Mitsubishi Q13UDEHCPU PLC and the ThingSpeak cloud platform to achieve effective predictive maintenance with reduced complexity.

III. PROPOSED METHODOLOGY

The proposed methodology describes the step-by-step process used to design and implement the AI-based industrial equipment failure monitoring and predictive maintenance system. The main objective of this methodology is to collect real-time sensor data using a PLC, transmit the data to a cloud platform, and analyze it to predict equipment failure before actual breakdown occurs.

Initially, the water tank level switch sensor and motor temperature sensor are installed at appropriate locations to monitor the operational condition of the industrial equipment. The water tank level switch provides digital input signals indicating the water level status, while the motor temperature sensor provides continuous analog temperature data. These sensors are connected to the Mitsubishi Q13UDEHCPU PLC.

The PLC continuously reads sensor data and stores the values in internal data registers. In addition to data acquisition, the PLC performs basic control operations such as motor ON and OFF based on predefined conditions[3]. The collected sensor data is prepared for transmission without performing any complex analysis at the PLC level, ensuring reliable real-time operation.

To enable remote monitoring and analysis, the PLC is connected to an RS232/RS485 to WiFi/Ethernet (B) IoT gateway using the built-in Ethernet port of the Q13UDEHCPU. Industrial communication protocols such as MC protocol or Modbus TCP are used to transfer sensor data from the PLC to the gateway. The gateway acts as an interface between the industrial environment and the cloud platform.

The IoT gateway forwards the PLC data to the ThingSpeak cloud platform using HTTP communication and a secure API key. The cloud platform stores the incoming data and displays it in graphical form for real-time monitoring. MATLAB-based analytics available in ThingSpeak are used to analyze historical and real-time sensor data.

AI-based analysis is applied in the cloud to identify abnormal patterns related to equipment behavior. In the case of the water tank level switch, inconsistencies between motor runtime and level switch response are detected as potential sensor failure. For the motor temperature sensor, continuous or abnormal temperature rise beyond normal operating conditions is identified as a potential overheating fault[4]. When such abnormal conditions are detected, the system generates early warning alerts to support predictive maintenance.

Through this methodology, the proposed system enables intelligent monitoring and early fault prediction using a simple hardware setup, thereby reducing unplanned downtime and improving overall equipment reliability.

IV. BLOCKDIAGRAM

The block diagram of the proposed system consists of sensors, a PLC unit, an IoT gateway, a cloud platform, and an AI-based analytics module[5]. Each block plays a specific role in monitoring industrial equipment and predicting possible failures.

The water tank level switch sensor and motor temperature sensor are used as input devices. The water tank level switch provides digital signals indicating the water level status, while the motor temperature sensor provides continuous analog temperature values. These sensors continuously monitor the operating condition of the industrial system.

The sensor outputs are connected to the **Mitsubishi Q13UDEHCPU PLC**. The PLC acts as the central control unit of the system. It reads the sensor data in real time, performs basic control operations such as motor ON and OFF, and stores the sensor values in internal data registers.

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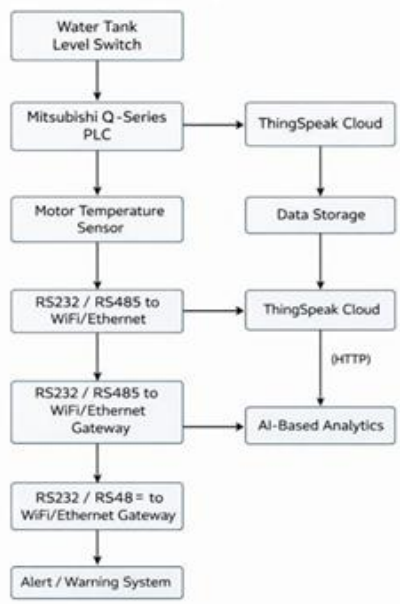


Figure 1: Block diagram of the industrial predictive maintenance system.

The PLC ensures reliable and continuous operation in the industrial environment.

To enable remote monitoring and analysis, the PLC is connected to an RS232/RS485 to WiFi/Ethernet (B) IoT gateway[6] using the built-in Ethernet port of the Q13UDEHCPU. The gateway communicates with the PLC using industrial communication protocols such as MC protocol or Modbus TCP. It collects sensor data from the PLC and converts it into a format suitable for cloud transmission.

The processed data is then transmitted to the ThingSpeak cloud platform using HTTP communication. ThingSpeak stores the data and displays it in graphical form, allowing real-time visualization of temperature and water level status. The cloud platform also maintains historical data for further analysis.

The **AI-based analytics module**, implemented using MATLAB tools in ThingSpeak, analyzes both real-time and historical data. It identifies abnormal patterns such as level switch malfunction and motor temperature rise. When abnormal behavior is detected, the system generates early warning alerts, enabling predictive maintenance and preventing unexpected equipment failure.

Thus, the block diagram clearly shows the integration of PLC-based data acquisition with cloud-based AI analytics to achieve intelligent industrial equipment monitoring and predictive maintenance.

V. Result & Discussion

The proposed AI-based industrial equipment failure monitoring system was implemented and tested using a Mitsubishi Q-Series PLC, a water tank level switch sensor, and a motor temperature sensor. The primary objective of the system was to evaluate its ability to monitor real-time parameters, visualize data on the cloud platform, and predict equipment failure at an early stage.

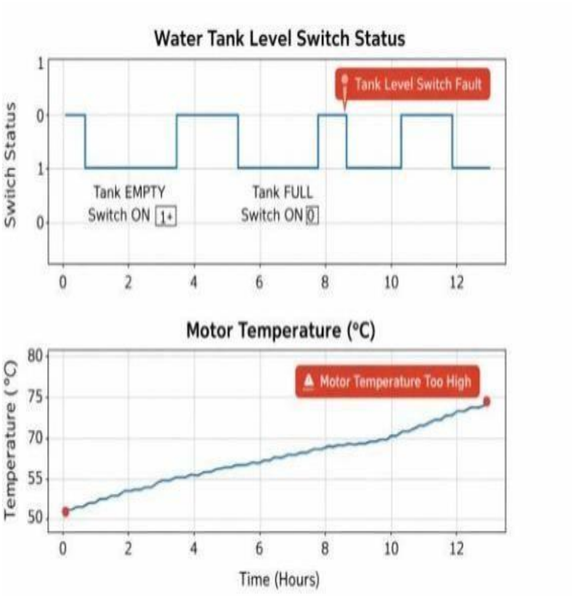
During normal operating conditions, the water tank level switch sensor showed periodic ON and OFF transitions corresponding to the filling and emptying of the tank. This behavior was clearly visualized on the ThingSpeak cloud dashboard as a time-based digital graph. The motor temperature sensor exhibited a gradual increase in temperature during motor operation and stabilized within the normal operating range of 40°C to 70°C. These results confirmed proper sensor operation and reliable data transmission from the PLC to the cloud through the IoT gateway.

When abnormal conditions were introduced, the system effectively identified fault scenarios. In the case of the water tank level switch, the sensor value remained constant for an extended period despite motor operation[7]. This abnormal pattern was detected by the AI-based analytics module, which classified the condition as a potential level switch failure. The fault was visually evident in the graph, where the digital signal failed to toggle over time.

Similarly, motor overheating conditions were simulated by increasing the motor load. The temperature graph showed a continuous upward trend crossing the predefined safe threshold. Instead of relying only on a fixed threshold, [8] the AI module analyzed the temperature trend and predicted an overheating fault before a critical condition occurred. An alert was generated on the cloud dashboard, indicating the need for preventive maintenance.

The combined visualization of water level switch status and motor temperature provided better insight into the system behavior. By correlating both parameters, the system was able to differentiate between normal operational delays and actual fault conditions. This multi-parameter analysis improved fault prediction accuracy and reduced false alarms

Overall, the experimental results demonstrate that the proposed system successfully integrates PLC-based data acquisition with cloud-based AI analytics. The system enables real-time monitoring, early fault detection, and predictive maintenance using minimal hardware components. The results confirm that even with only two sensors, effective predictive maintenance can be achieved, making the system suitable for low-cost industrial applications.



VI. Conclusion

This project successfully demonstrates an AI-based industrial predictive maintenance system using a PLC and IoT platform. Real-time sensor data such as temperature and vibration are continuously monitored through the PLC and transmitted to the cloud for analysis.

The integrated AI model effectively identifies abnormal operating conditions and generates early alerts, thereby reducing unexpected equipment failures. The proposed system improves equipment reliability, maintenance efficiency, and operational safety, making it suitable for Industry 4.0–based smart industrial applications.

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