

IoT Based Predictive Maintenance System for Spot Welding Machine

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Abstract: Predictive maintenance is a vital task in the present industrial settings, which aims at retaining the reliability of equipment for reducing downtime and overall operational cost. This project presents an IoT-based Predictive Maintenance System for Spot Welding Machines that will focus on real-time monitoring of critical machine parameters using embedded systems and integrating them with the cloud. At the heart of the system is the STM32 microcontroller, which is used as the main data acquisition device. It receives the critical parameters such as the flow rate of the cooling water, the water temperature, and electrical parameters like voltage and current variations during the welding processes. These parameters are vital indicators of the health of the machine and can be used to predict possible failures or inefficiencies. The ESP32 microcontroller is used for wireless communication to enable remote monitoring and data analysis. It transmits the sensed data to a cloud server, which is then made available on a user-friendly web interface in real time. The website presents visual information, historical trends, and alerts to help maintenance personnel make intelligent decisions. The system constantly monitors these parameters for any anomalies, such as decreased cooling efficiency, overheating, or abnormal power consumption, all of which are precursors to machine wear or failure. This allows for proactive maintenance, which prolongs the life of a spot welding machine by enhancing production quality and minimizing sudden downtimes.

Keywords: Predictive maintenance, IoT, Spot Welding Machine, Real time monitoring, Industrial automation

I. INTRODUCTION

In the industrially competitive environment of today, reliability and performance are the two most critical factors of machinery. Traditional maintenance strategies, such as reactive and preventive maintenance, are no longer adequate to guarantee maximum uptime and cost efficiency. These conventional methods often lead to unnecessary maintenance, unexpected breakdowns, and increased operational costs. To overcome these limitations, industries are increasingly adopting Predictive Maintenance—an advanced approach that utilizes real-time sensor data and analytics to predict potential equipment failures before they occur. This work presents the design and implementation of an IoT-based Predictive Maintenance System for a spot welding machine. The proposed system is intended to enhance the reliability and operational efficiency of industrial welding equipment by continuously monitoring critical parameters such as temperature, current, voltage, and coolant flow rate. These parameters serve as key indicators of machine health, enabling early fault detection and better decision-making. The integration of IoT technology provides the capability to collect, transmit, and analyze real-time data remotely. The system employs an STM32 microcontroller as the central unit to process sensor data, which is then transmitted via the ESP32 Wi-Fi module to a cloud-based platform (Google Sheet) for data storage and visualization. The proposed system also includes intelligent alert mechanisms and automated safety responses. When any monitored parameter exceeds its predefined threshold, the system instantly triggers a buzzer alarm and displays a warning message on the LCD screen. Additionally, the automatic stoppage of machine operation under unsafe conditions prevents potential damage and ensures operator safety. Once the parameters return to normal, regular functioning is automatically resumed. Implementation of this predictive



maintenance system will offer cost-effective maintenance management strategies, laying the foundation for the realization of Industry 4.0, characterized by smart production through connected systems and real-time analytics, thus improving efficiency and sustainability in operations.

II. LITERATURE REVIEW

In this study, the electric resistance spot welding process was applied to cold rolled sheet used in automotive industry for body construction. Resistance spot welding parameter such as, electrode form, electrode material, and electrode force were stayed constant. This experiment uses different welding time and welding current to identify the optimum welding parameters for maximum joint strength. By using 1, 2, and 3 kA welding current and 4, 6, and 8 cycles welding times 0.8 mm. sheets were spot welded to prepare samples. These spot-welded joints were tested with uniaxial tensile test in laboratory to identify shear strength from spot-welded joint. This experiment is not only to identify shear load from the result of uniaxial tensile test but also to observe the size of weld nugget. Weld nugget can detect the quality of spot-welded joint with its size to prevent the expulsion and get the acceptable nugget diameter in that process. This experiment shows the optimum welding parameters that can be used in the automotive application especially in body construction. [1]

Industry 4.0 introduces significant challenges in optimizing maintenance processes to enhance operational efficiency and minimize downtime. Traditional maintenance approaches, such as reactive and preventive maintenance, are often inefficient and costly. This study proposes an lot-driven predictive maintenance architecture to address these challenges, leveraging real-time data from lot sensors, cloud computing, and machine learning algorithms. The focus of the research is on developing a predictive maintenance framework for industrial equipment, using data collected from milling machines to predict potential failures. Machine learning algorithms, including Logistic Regression, Random Forest, and Decision Trees, were applied to sensor data to identify anomalies and forecast equipment failures. The results show that the proposed system. significantly reduces downtime by up to 50% and maintenance costs by 25%, while optimizing maintenance schedules for better resource allocation.[2]

The rise of Internet of Things (IoT) in industrial environments has made Predictive Maintenance (Pdm) a cornerstone for achieving operation efficiency and equipment reliability. By transitioning from reactive to Condition-Based Maintenance (CBM) helps extend equipment lifespan by addressing faults before failure. It involves deploying multiple sensors on industrial equipment to monitor critical parameters such as temperature, vibration and transmitting the data to the cloud for predictive analysis using advanced Machine Learning (ML) models. Our primary goals are to reduce maintenance cost, improve operational efficiency and minimize unplanned downtime of industrial components. Additionally, it addresses challenges such as data security, sensor compatibility, and scalability to enhance processing efficiency. These advancements position lot-Pdm as a key enabler of Industry 4.0 smart. [3]

This paper generally bring in a smart system that predicts when industrial motors need maintenance using machine learning. Traditional maintenance methods, like waiting for something to disrupt or following a set schedule, can lead to unexpected downtime and higher repair costs. This research explores a predictive approach that influences real-time data from vibration, current, and temperature sensors installed on motors. The data is analyzed by smart computer programs to find unusual patterns and guess when equipment might break, so repairs can be done before any problems happen. Predictive maintenance systems commonly use machine learning algorithms to forecast equipment failures. When comparing the algorithms, the Random Forest (RF) algorithm often demonstrates the highest accuracy in predicting motor failures. A data-driven approach to predictive maintenance can significantly reduce downtime and lower maintenance costs by enabling more efficient scheduling and better-informed decisions. By combining Industrial Internet of Things (IoT) technologies, MQTT messaging, and machine learning, industrial motor maintenance can be improved, which aligns with the goals of Industry 4.0 for sustainable. Predictive maintenance helps to reduce maintenance cost.[4]

Implementation of lot-based equipment monitoring systems has transformed industrial automation by allowing real-time data collection, predictive maintenance, and optimization of performance. This paper demonstrates the design of an IoT-Based Equipment Effectiveness Monitoring System utilizing Raspberry Pi as a central gateway. The suggested system utilizes various industrial sensors to monitor major parameters like machine uptime, temperature, and vibration



in real time. Data is processed locally through the Raspberry Pi and relayed to a cloud dashboard for visualization and analysis. By computing Overall Equipment Effectiveness (OEE), the system determines performance bottlenecks and improves transparency of operation. The design guarantees cost-effectiveness, scalability, and flexibility of integration with existing industrial installations. This paper is focused on assisting industries to shift toward smart manufacturing with minimum infrastructure redesign and laying down the groundwork for additional research on intelligent factory monitoring systems.[5]

This study examines the predictive maintenance of industrial equipment. Through a Google form, we gathered various viewpoints from experts in the disciplines of Machine Learning (ML), the Internet of Things (IoT), and Information Technology. We learned from this survey that if we don't take any protective steps to maintain industrial equipment, a lot of rubbish will be produced, which will further contribute to pollution and several other issues, including a lack of equipment and many others. This study examines the predictive maintenance of industrial equipment. Through a Google form, we gathered various viewpoints from experts in the disciplines of machine learning, the Internet of Things, and Information Technology. We learned from this survey that if we don't take any proactive steps to maintain industrial equipment, a lot of rubbish will be produced, which will further contribute to pollution and several other issues, including a lack of equipment and many others. IoT is widely used, and devices are prevalent across numerous industries. To ensure the best operation of machinery and processes, industrial lot makes use of lot devices and sensors to monitor machines and environments. One Industrial IoT technology that has gained interest recently is predictive maintenance, which tracks the health of equipment to predict the likely failure of components. Massive volumes of data are gathered, handled, and finally analyzed using Machine Learning algorithms to enable effective Predictive Maintenance. [6]

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This paper studies the real-time monitoring and fault early warning algorithm of substation equipment based on Internet of Things (IoT) technology, aiming at improving the stability and security of power system. Aiming at the problems of low efficiency and warning in traditional substation equipment condition: monitoring methods, this paper designs and implements an efficient and accurate real-time monitoring and fault early warning system. The system adopts layered architecture, including sensing layer, transmission layer, processing layer and application layer[8]

III. METHODOLOGY

The proposed IoT-based predictive maintenance system for the spot welding machine is designed through a structured methodology integrating sensing, processing, communication, and cloud monitoring.

The system architecture consists of four main layers: (1) Sensing Layer, where temperature, current, voltage, and coolant flow sensors continuously monitor machine parameters; (2) Processing Layer, employing an STM32 microcontroller for data acquisition, threshold comparison, and control logic; (3) Communication Layer, using an ESP32 Wi-Fi module to transmit data wirelessly; and (4) Cloud Layer, where data is logged to Google Sheets for visualization and analysis.

An intelligent alert mechanism triggers a buzzer and LCD warning when abnormal conditions are detected, while a relay control ensures automatic shutdown during critical states to prevent damage. Once parameters return to normal, operation resumes automatically.



The system enables real-time condition monitoring, early fault detection, and automated safety control, ensuring improved equipment reliability, reduced downtime, and cost-effective maintenance aligned with Industry 4.0 objectives.

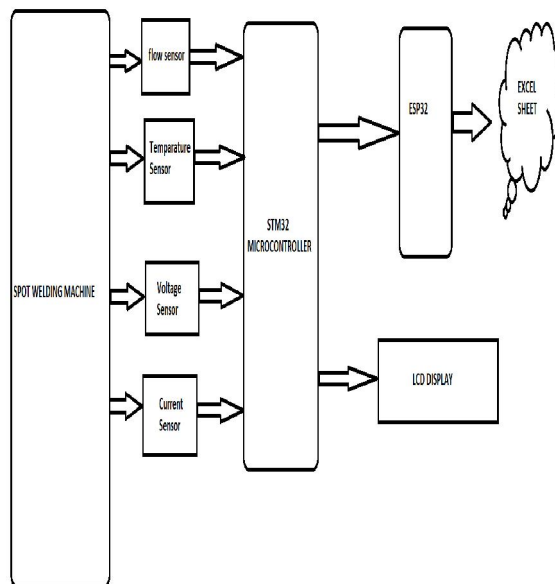


Fig. 1 Block Diagram

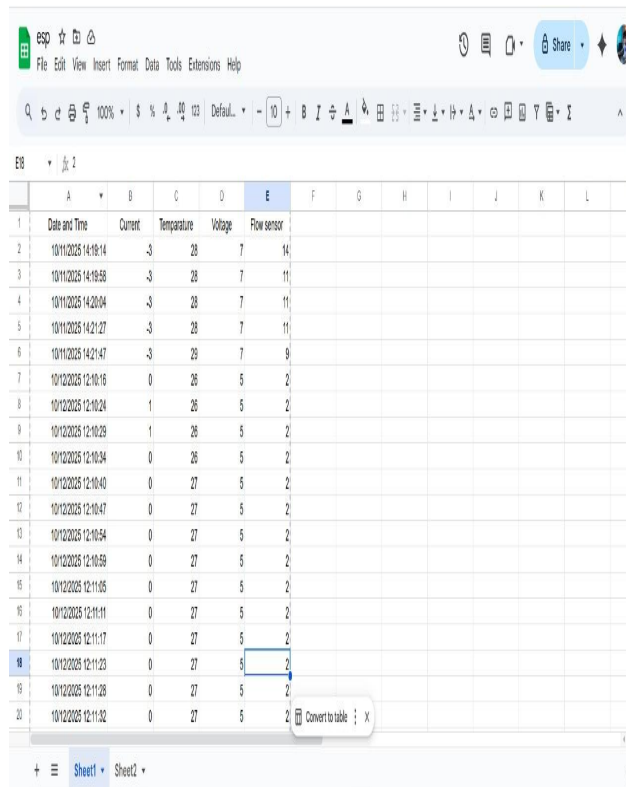
IV. RESULTS

This fig. shows the successful implementation of an IoT-based Predictive Maintenance System for a Spot Welding Machine, capable of wirelessly monitoring key operating parameters in real time. The system transmits live data including current, temperature, voltage, and coolant flow rate from the STM32 microcontroller through the ESP32 Wi-Fi module to a Google Sheet for cloud-based logging and analysis.

From the recorded data, it is observed that the temperature of the welding system remains within the range of 26°C to 29°C, indicating stable thermal conditions during operation. The current readings fluctuate between -3 A and +1 A, representing variations in the welding process or standby states. The voltage values are mostly steady around 5-7 V, showing consistent electrical input. The flow sensor data ranges between 2 and 14 pulses, confirming proper coolant circulation throughout the operation.

These results demonstrate that the designed system effectively captures and transmits real-time data to the cloud, ensuring continuous monitoring and early fault detection. The observed parameter trends verify the system's reliability, data accuracy, and ability to detect any deviation from normal operating conditions, which are crucial for predictive maintenance and machine safety.





	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Date and Time	Current	Temperature	Voltage	Flow sensor								
2	10/11/2025 14:18:14	-3	28	7	14								
3	10/11/2025 14:18:58	-3	28	7	11								
4	10/11/2025 14:20:04	-3	28	7	11								
5	10/11/2025 14:21:27	-3	28	7	11								
6	10/11/2025 14:21:47	-3	29	7	9								
7	10/12/2025 12:10:16	0	26	5	2								
8	10/12/2025 12:10:24	1	26	5	2								
9	10/12/2025 12:10:29	1	26	5	2								
10	10/12/2025 12:10:34	0	26	5	2								
11	10/12/2025 12:10:40	0	27	5	2								
12	10/12/2025 12:10:47	0	27	5	2								
13	10/12/2025 12:10:54	0	27	5	2								
14	10/12/2025 12:10:59	0	27	5	2								
15	10/12/2025 12:11:05	0	27	5	2								
16	10/12/2025 12:11:11	0	27	5	2								
17	10/12/2025 12:11:17	0	27	5	2								
18	10/12/2025 12:11:23	0	27	5	2								
19	10/12/2025 12:11:28	0	27	5	2								
20	10/12/2025 12:11:32	0	27	5	2								

Fig. 2 shows the result

V. DISCUSSION

The implementation of the proposed IoT-based Predictive Maintenance System for Spot Welding Machine demonstrates how embedded sensing, wireless communication, and cloud technologies can be effectively integrated to achieve real-time condition monitoring and fault prevention in industrial environments. Unlike traditional maintenance strategies that rely on periodic inspection or post-failure repair, this system provides continuous monitoring of critical parameters such as temperature, current, voltage, and coolant flow rate, enabling timely detection of abnormal conditions before major failures occur.

The results indicate that the system reliably measures and transmits sensor data through the ESP32 Wi-Fi module to a cloud-based Google Sheet, ensuring remote accessibility and real-time data visualization. The readings show stable performance under normal operating conditions, with clear variations captured during parameter fluctuations, validating the accuracy and responsiveness of the system. The integration of a buzzer, LCD display, and automatic cutoff control further enhances safety by providing immediate alerts and protecting the machine from potential damage. Compared to conventional wired or manual monitoring methods, the wireless IoT-based approach significantly reduces human intervention and downtime, while improving maintenance efficiency and data accuracy. The system's low-cost design and modular architecture make it easily adaptable for other industrial machines, promoting scalability in smart manufacturing environments.

However, certain limitations were observed. The Wi-Fi range may be restricted in large factory floors or high-EMI zones, and sensor drift or noise interference could affect long-term accuracy without proper calibration. Future enhancements could include the integration of edge-based machine learning algorithms for predictive fault analysis, LoRa or MQTT-based communication for extended range, and cloud dashboards with graphical analytics for better visualization.



Overall, the discussion confirms that the developed system provides a cost-effective, reliable, and scalable solution for industrial predictive maintenance. It successfully bridges the gap between conventional maintenance and modern Industry 4.0 smart monitoring systems, offering improved equipment reliability, reduced downtime, and enhanced operational safety in manufacturing processes.

VI. CONCLUSIONS

Wildlife monitoring is important for effective protection, sustainable use and scientific management of wildlife resources. Although there is currently a lot of work on building real sensor systems, very few attempts have been made to deploy them in the field and then maintain and develop them. The study of the animals through this system or their conservation. Proposed system is the best possible way to keep track of the animal's location and their health 24 hours-a-day. Proposed new system can find the animal over large, dense forest areas with the help of a Node MCU. It also gives a live update of their health through the temperature and pulse sensors.

The app in the mobile phones of forest officers will allow them to keep track of the wildlife from anywhere and at all times. The notification system will alert them immediately. if anything is wrong with the species ,the caretaker can reach the exact location immediately. Proposed system does not require any human attention as this is a completely self independent and automated system.

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BIOGRAPHIES



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