iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** III **Month of publication:** March 2026

DOI: https://doi.org/10.22214/ijraset.2026.77956

www.ijraset.com

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

Cloud Based CNC Monitoring System

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Abstract: ***Computer Numerical Control (CNC) machines are widely used in modern manufacturing industries because they provide high precision and consistent production quality. However, many CNC machines are still monitored manually or through limited local systems, which makes it difficult to identify faults at an early stage. This project presents a Cloud Based CNC Monitoring System that allows real-time monitoring of important machine parameters such as temperature and current. In this system, sensors are connected to an ESP32 microcontroller to collect machine condition data. The collected data is transmitted to the cloud platform using the MQTT communication protocol through Wi-Fi. AWS IoT Core is used to receive and process the data, while visualization dashboards such as Grafana or AWS QuickSight display the machine parameters. The system enables operators to monitor the machine remotely and identify abnormal conditions quickly. This approach improves machine reliability, reduces downtime, and supports modern smart manufacturing practices.***

I. INTRODUCTION

A. Background Information of the Study

Computer Numerical Control (CNC) machines are widely used in modern manufacturing industries for producing components with high precision and accuracy. These machines operate through programmed instructions that control the movement of tools and workpieces. CNC technology has significantly improved productivity, reduced human effort, and ensured consistent product quality in various industrial sectors such as automotive, aerospace, electronics, and metal fabrication. Because of their importance in production processes, the continuous monitoring of CNC machine conditions is essential to maintain efficiency and avoid unexpected machine failures.

CNC machines operate under different mechanical and electrical conditions, which may affect their performance over time. Important parameters such as temperature, electrical current, vibration, and load conditions play a significant role in determining the health of the machine. If these parameters exceed their normal limits, it may lead to machine malfunction, tool wear, or damage to machine components. In many industries, machine monitoring is still performed manually or through basic control systems that provide limited information. This approach makes it difficult to detect faults in the early stages and may result in production downtime and increased maintenance costs.

With the rapid development of Internet of Things (IoT) technology, industries are now adopting smart monitoring systems that allow real-time observation of machine conditions. IoT systems use sensors to collect data from machines and transmit the information to centralized platforms for storage and analysis. These technologies enable engineers and operators to monitor machine performance remotely and respond quickly when abnormal conditions occur. The integration of IoT with cloud computing further enhances the capability of monitoring systems by providing scalable data storage, advanced analytics, and remote accessibility.

Cloud computing platforms provide powerful tools for storing large amounts of machine data and analyzing them efficiently. Data collected from sensors can be transmitted through wireless communication protocols such as MQTT and stored in cloud environments like Amazon Web Services (AWS). Cloud-based monitoring systems allow industries to visualize machine performance through dashboards and graphs. These systems also support predictive maintenance strategies by identifying patterns in machine behavior before a failure occurs.

The adoption of cloud-based monitoring technologies has become an important step toward implementing Industry 4.0 in manufacturing environments. Industry 4.0 focuses on the use of digital technologies, automation, and data exchange to improve manufacturing efficiency and productivity. Through continuous monitoring and data analysis, industries can reduce machine downtime, improve operational efficiency, and extend the lifespan of equipment.

In this project, a cloud-based CNC monitoring system is developed to observe important machine parameters such as temperature and electrical current in real time. Sensors are connected to an ESP32 microcontroller that collects data from the machine and sends it to a cloud platform using Wi-Fi communication. The cloud platform stores the data and displays it on monitoring dashboards so that operators can easily observe machine conditions. This system helps in identifying abnormal machine behavior and enables timely maintenance actions.

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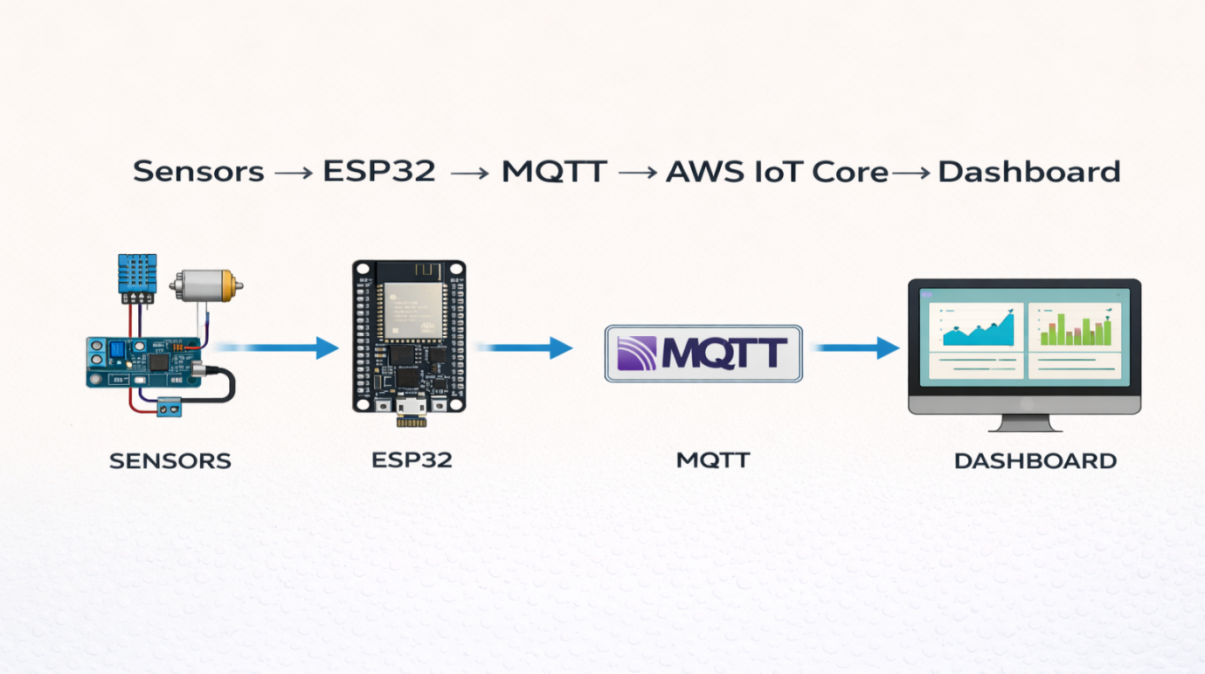
By implementing this monitoring system, industries can improve machine reliability and reduce maintenance costs. The proposed system demonstrates how IoT and cloud technologies can be integrated to develop a smart monitoring solution for CNC machines. Such systems contribute to modern manufacturing practices by providing better control over machine operations and supporting data-driven decision making.

II. METHODOLOGY

1) The monitoring system is designed using IoT technology and cloud computing.
2) Sensors such as the DHT11 temperature sensor and ACS712 current sensor are used to measure machine parameters.
3) The sensors are connected to an ESP32 microcontroller which acts as the main controller of the system.
4) The ESP32 reads the sensor data and processes it before sending it to the cloud.
5) Data transmission is carried out using the MQTT communication protocol through Wi-Fi.
6) AWS IoT Core is used to receive and process the sensor data in the cloud environment.
7) The collected data is stored and displayed using monitoring dashboards such as Grafana or AWS QuickSight.



III. SYSTEM COMPONENTS

The main components used in the cloud-based CNC monitoring system include:

1) ESP32 Microcontroller
2) Temperature Sensor (DHT11)
3) Current Sensor (ACS712)
4) DC Motor (used for CNC spindle simulation)
5) Relay Module
6) Power Supply Unit
7) AWS IoT Cloud Platform

These components work together to collect machine data, process it, and transmit it to the cloud platform for monitoring.

IV. LITERATURE SURVEY

Further research has also focused on the application of wireless sensor networks for monitoring industrial machines. Wireless sensors allow the collection of machine data without complex wiring systems, which makes installation easier and more flexible in industrial environments. Researchers have shown that wireless monitoring systems can effectively collect data such as temperature, vibration, and motor current, which are important indicators of machine health.

Another study investigated the use of cloud platforms for storing and analyzing machine data collected from IoT devices. The researchers explained that cloud computing provides scalable storage and high processing capability for handling large volumes of industrial data. By analyzing this data, industries can identify patterns in machine behavior and take preventive maintenance actions before serious failures occur.

Some researchers have also explored predictive maintenance techniques using IoT data. Predictive maintenance involves analyzing machine parameters continuously in order to predict potential faults before they occur. Machine learning algorithms and data analysis tools are often used to evaluate sensor data and detect unusual patterns. These methods help industries reduce maintenance costs and improve machine reliability.

In addition, several studies have highlighted the importance of real-time monitoring dashboards for industrial machines. Visualization tools such as Grafana, Power BI, and cloud-based dashboards allow operators to easily understand machine performance through graphical representations. These dashboards display parameters such as temperature, current consumption, and machine operating status in real time, which helps engineers quickly identify abnormal conditions.

Recent developments in Industry 4.0 technologies have further encouraged the integration of IoT, cloud computing, and data analytics in manufacturing systems. Smart factories are now adopting intelligent monitoring systems that connect machines, sensors, and cloud platforms into a unified network. This integration improves operational efficiency, enables remote monitoring, and supports data-driven decision making in industrial environments.

Overall, the literature indicates that IoT and cloud-based monitoring systems play a significant role in improving machine performance, reducing downtime, and supporting advanced maintenance strategies in modern manufacturing industries.

V. RESULTS AND DISCUSSION

The developed monitoring system was tested using a DC motor to simulate the operation of a CNC machine spindle. The temperature and current sensors successfully collected machine condition data during operation. The sensors were able to provide continuous readings while the motor was running under different operating conditions.

The ESP32 microcontroller processed the sensor readings and transmitted them to the AWS IoT cloud platform using the MQTT protocol. The cloud platform received the data and displayed it on a monitoring dashboard. This allowed the machine parameters to be observed remotely through an internet connection.

The dashboard showed real-time graphs representing temperature and current values. When the motor operated continuously, the temperature gradually increased. Similarly, when mechanical load was applied to the motor, the current consumption also increased. These changes were recorded by the sensors and reflected immediately on the monitoring dashboard.

The system response time was observed to be satisfactory during the experiment. Data from the sensors was transmitted to the cloud platform within a few seconds, which made real-time monitoring possible. The graphical representation of the data helped in understanding the variation of machine parameters during operation.

During testing, the monitoring system was also able to identify abnormal operating conditions. For example, when the motor operated for a long period without interruption, the temperature values increased beyond the normal range. This condition can indicate overheating, which may lead to damage if not detected early. The monitoring system helped in identifying such conditions quickly.

The current sensor readings also provided useful information about the load conditions of the motor. When additional mechanical resistance was applied to the motor shaft, the current consumption increased. This behavior is similar to what occurs in real CNC machines when cutting forces increase during machining operations.

The collected data can also be stored in the cloud platform for future analysis. Historical data helps engineers analyze machine performance over a longer period of time. By studying this data, industries can identify trends and perform predictive maintenance before machine failure occurs.

Overall, the experimental results demonstrate that the developed system is capable of monitoring machine parameters effectively. The combination of sensors, microcontroller, and cloud platform provides a reliable solution for real-time machine monitoring. The system can help improve machine safety, reduce unexpected downtime, and support better maintenance planning in industrial environments.

VI. WORKING PRINCIPLE

The working principle of the proposed system is based on the continuous collection of machine data, processing of the collected information, and transmission of the data to a cloud platform for monitoring.

Sensors are used to measure important machine parameters such as temperature and electrical current. These parameters help in understanding the operating condition of the machine and identifying any unusual changes in performance.

The temperature sensor and current sensor are connected to the ESP32 microcontroller, which acts as the main control unit of the system. The sensors continuously collect data from the machine while it is operating. The ESP32 reads the sensor values at regular time intervals and converts the analog signals into digital data that can be processed by the system.

After collecting the data, the ESP32 microcontroller processes the readings and prepares them for transmission. The processed data is then sent to the AWS IoT cloud platform through a wireless network using the MQTT communication protocol. Wi-Fi connectivity allows the system to transmit data over the internet without the need for complex wiring.

Once the data reaches the cloud platform, it is received and stored for further analysis. The cloud platform organizes the data and displays it through a monitoring dashboard. The dashboard provides graphical representations of parameters such as temperature and current consumption. These graphs allow operators and engineers to observe machine performance easily and understand how the machine behaves during different operating conditions.

The monitoring dashboard updates the information continuously as new data is received from the sensors. This real-time visualization helps operators monitor the machine remotely from any location with internet access. By observing the trends in the graphs, it becomes possible to identify whether the machine is operating under normal or abnormal conditions.

If the system detects unusual values, such as excessive temperature or abnormal current consumption, it can generate alerts to notify the operator. Early detection of such conditions helps prevent possible damage to machine components and reduces the chances of unexpected breakdowns.

The stored data can also be used for future analysis and maintenance planning. Engineers can review the historical data to study machine performance over time and identify patterns that indicate wear or potential faults. In this way, the system supports predictive maintenance and improves the overall reliability of industrial machines.

Overall, the working principle involves sensor-based data acquisition, microcontroller-based processing, wireless communication, and cloud-based monitoring. This combination enables continuous supervision of machine conditions and helps industries maintain safe and efficient machine operation.

VII. CONCLUSION

The Cloud Based CNC Monitoring System developed in this study demonstrates the practical application of Internet of Things (IoT) technology and cloud computing in industrial machine monitoring. The system is capable of collecting important machine parameters such as temperature and electrical current through sensors and transmitting the collected data to a cloud platform for real-time observation. This approach provides a more efficient way of monitoring machine performance compared to traditional manual monitoring methods.

The monitoring dashboard plays an important role in presenting the collected data in a clear and understandable form. By displaying parameters such as temperature and current in graphical format, operators and engineers can easily observe the operating condition of the machine. The real-time visualization of machine data helps in identifying unusual variations and abnormal operating conditions at an early stage.

Another advantage of the developed system is the ability to perform remote monitoring. Since the data is stored in the cloud platform, machine conditions can be accessed from any location with an internet connection. This feature reduces the need for constant physical inspection of machines and allows engineers to supervise machine performance more efficiently.

The monitoring system also contributes to improving machine reliability and reducing unexpected downtime. By continuously tracking machine parameters, the system can help detect possible faults before they lead to serious machine failure. Early fault detection enables timely maintenance actions and helps industries avoid costly production interruptions.

In addition, the integration of sensors, microcontrollers, and cloud technology supports the concept of smart manufacturing and Industry 4.0. The use of digital monitoring systems allows industries to collect valuable operational data that can be used for performance analysis and maintenance planning.

Overall, the proposed Cloud Based CNC Monitoring System provides a practical and cost-effective solution for monitoring industrial machines. The system enhances machine safety, improves operational efficiency, and supports modern manufacturing practices through real-time data monitoring and analysis.

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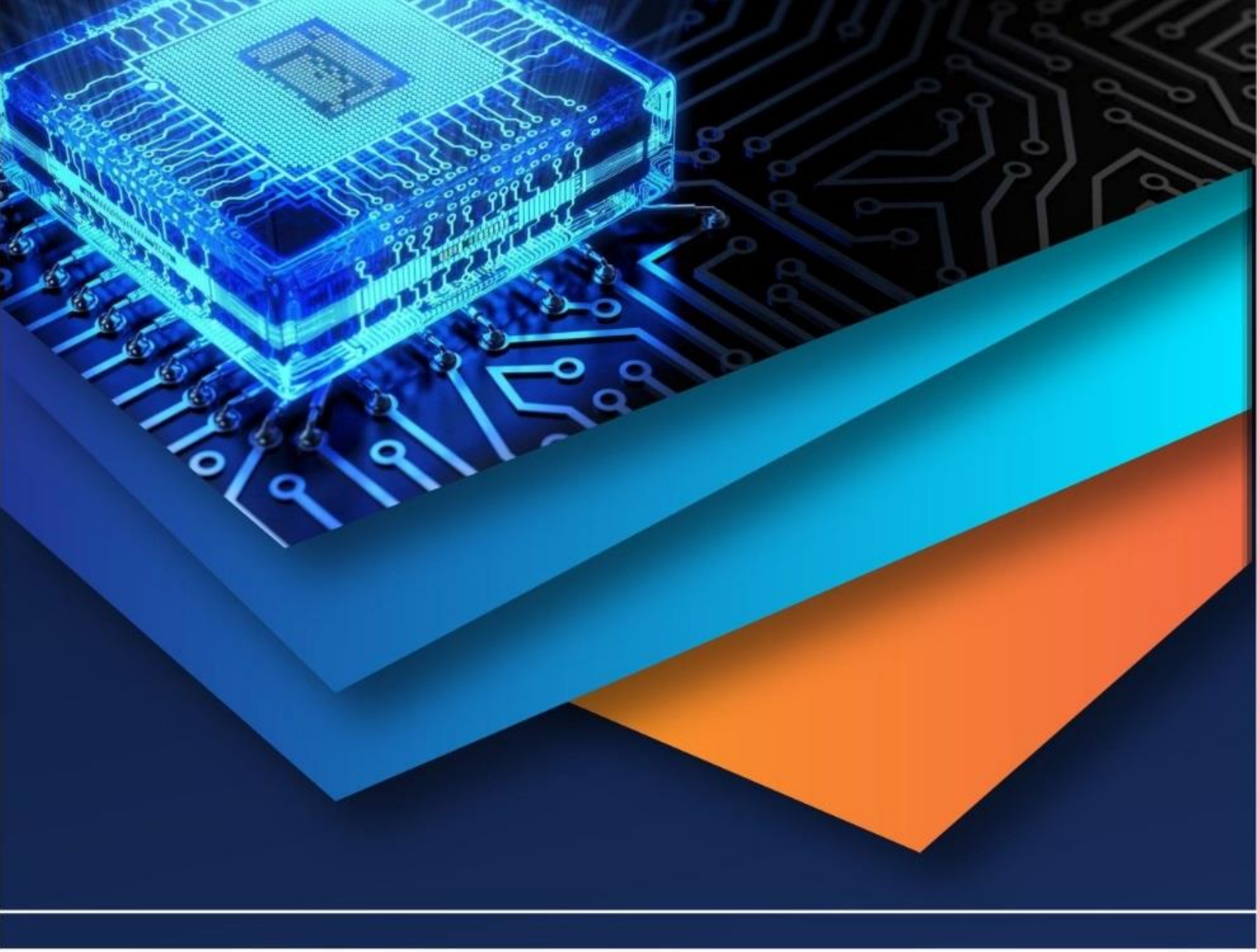

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