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## Abstract

The manufacturing industry plays a crucial role in the global economy, requiring continuous improvements in efficiency and productivity. Digital transformation through Supervisory Control and Data Acquisition (SCADA) systems has enabled better monitoring and control of production processes. However, recent industrial challenges demand more advanced solutions, particularly through the integration of Industrial Internet of Things (IIoT) technologies. This research proposes a web-based SCADA-IIoT production monitoring system for stamping machines that supports real-time machine monitoring, reliable communication, and automated abnormal event notifications. The system architecture integrates sensors for monitoring critical production parameters, SCADA software for visualization and control, and a web-based interface for remote monitoring. System security and communication reliability are ensured through appropriate protocol implementation. A case study conducted in a manufacturing environment evaluates the performance of the proposed system. Experimental results show that the system achieves a data integrity level of 98.99% during monitoring operations. The system is also capable of storing machine condition history and operational activities with a storage capacity of 604,800 data points and an average storage delay of 45.50 ms. Additionally, an error notification feature integrated with the Telegram messaging platform provides automated alerts with an average message latency of 445.99 ms. The proposed system demonstrates the potential of SCADA-IIoT integration to enhance production monitoring, improve decision-making accuracy, and increase operational efficiency in manufacturing environments.

## Keywords:

SCADA, IIOT, production monitoring system, stamping machine

## 1 Introduction

Modern manufacturing industries require effective production monitoring systems to maintain machine performance and operational efficiency. In stamping machine operations, real-time monitoring of machine conditions and production parameters is essential to ensure stable production processes and prevent unexpected downtime. Supervisory Control and Data Acquisition (SCADA) systems have been widely used to monitor and control industrial processes [1][2]. Digital transformation has been a major catalyst in this effort, and SCADA systems have become an essential platform for monitoring and controlling production processes in modern manufacturing environments. To address current monitoring challenges, this study integrates SCADA and Industrial Internet of Things (IIoT) technologies to enhance production monitoring capabilities in stamping machines [2], [3], [4], [5], [6].

In the context of the manufacturing industry, the need for more sophisticated and responsive production monitoring is becoming increasingly urgent. Challenges such as increasing product variety, stringent quality requirements, and global competition emphasize

the importance of a system that provides comprehensive insights across the entire production chain. It may have limitations in deep real-time data integration and adaptability to rapid change.

Previous research has developed a production monitoring system using the Overall Equipment Effectiveness (OEE) method to evaluate stamping machine performance. The study focused on analyzing machine efficiency through availability, performance, and quality indicators. However, the system was primarily designed for performance evaluation and did not fully integrate real-time monitoring capabilities using SCADA and Industrial IIoT technologies. Therefore, this research extends the previous work by integrating SCADA and IIoT technologies to enable real-time production monitoring, machine condition tracking, and automatic notification systems[2], [4], [7], [8]. However, many existing studies tend to focus on specific aspects such as energy efficiency or quality monitoring, without integrating all components required for comprehensive production monitoring. without combining all the elements that may be necessary for holistic production monitoring. Data integration limitations and system complexity are major obstacles that need to be overcome. Some studies tend to focus on specific aspects without considering the overall integration of the entire production chain. Previous studies may not have fully addressed the complexity of integrating data from various sources, especially in the context of dynamic changes in the production process. Some solutions may be less responsive to sudden changes in production conditions, which can limit adaptability in dynamic environments.

This research offers a holistic solution by integrating SCADA and IIoT to gain a deep, real-time understanding of production conditions. This solution includes developing a system that integrates data from the entire production chain, from raw materials to finished products, and utilizes connected production sensors to monitor production parameters in real time by providing accurate visibility into machine and production environment conditions [9], [10], [11], [12], [13]. In addition, an adaptive SCADA user interface is developed to allow operators to easily interpret production data and respond quickly to abnormal conditions. The system also supports more efficient management of energy and production resources through the implementation of an integrated SCADA-IIoT framework, which can contribute to reducing operational costs.

By combining these solutions, his research aims to develop a production monitoring system that provides a comprehensive understanding of production conditions from multiple perspectives, enabling more informed decision-making, as well as ensuring rapid adaptation to industry dynamics and overcoming data integration limitations by providing a more flexible framework that can be tailored to the specific needs of the company [14], [15], [16], [17]. Furthermore, the system is designed to optimize the utilization of energy and production resources, supporting sustainability principles in manufacturing operations. Thus, this research provides a foundation for implementing an SCADA-IIoT-based production monitoring system to improve efficiency and productivity in stamping machine operations within modern manufacturing industries [1], [18], [19].

## 2 Research methodology

### 2.1 Research overview

Fig. 1 illustrates the architecture of the proposed monitoring system. Various sensors installed on the stamping machine collect operational data such as pressure, temperature, energy consumption, and mechanical strain. These sensors are connected to Arduino Nano microcontrollers that function as slave nodes for data acquisition. The collected data are then transmitted to the Raspberry Pi 3, which acts as the master controller for system coordination and communication. The Raspberry Pi sends the data through a LAN network to the server, where the information is stored in a database.

## 2.2 System flow

Fig. 2 illustrates the flow of the SCADA-based Production Monitoring System. The process begins when the user enters the login page and enters their credentials. If the login is successful, the user is directed to the main dashboard, where they can monitor

production data. From the dashboard, users can select other pages to input data such as OEE values, material prices, available stock, power consumption, temperature, and cylinder pressure. This data is then stored in the system as production records. Once finished, the user can log out to end the session, and the process is complete.

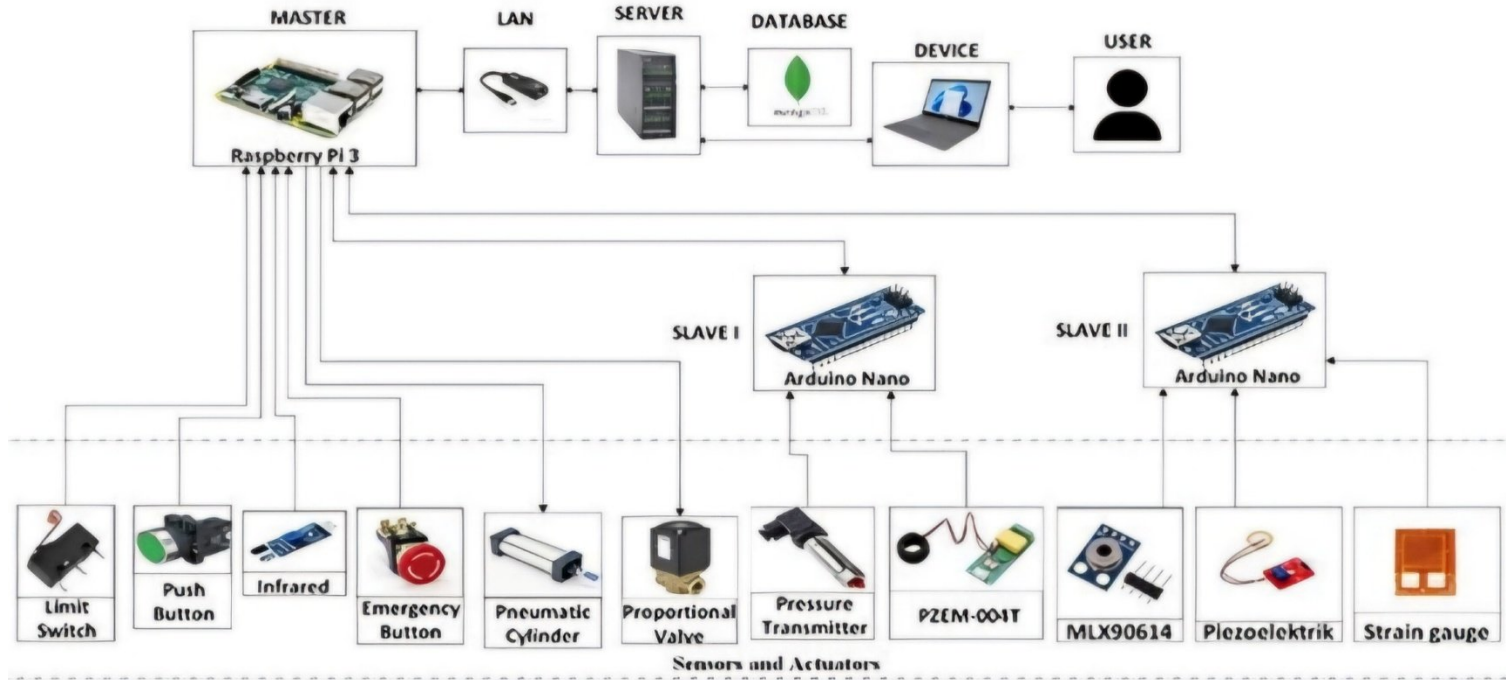


Fig. 1. Overview of the system

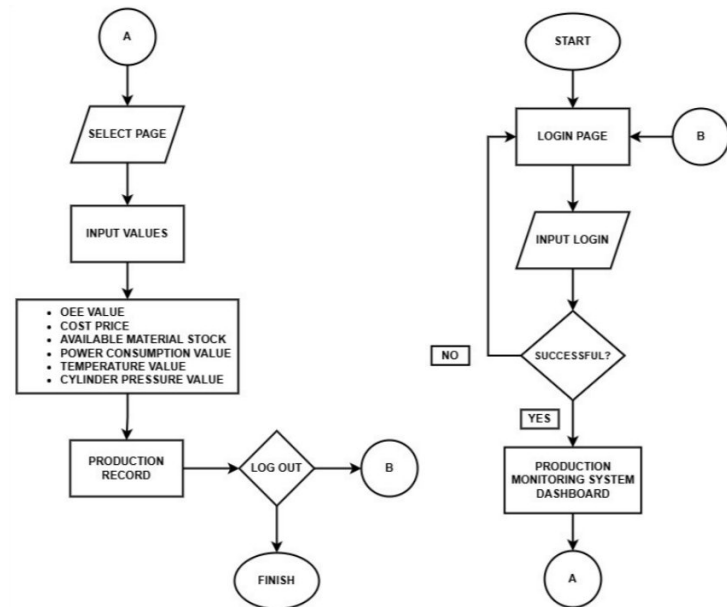


Fig. 2. System flowchart

## 2.3 Research stages

- **Literature study:** Study literature related to SCADA, production monitoring systems, and production efficiency; identify previous research to understand the framework.
- **System design formulation:** Determine the objectives of the production monitoring system and design the SCADA system architecture, including the selection of sensors and hardware.
- **SCADA software development:** Developing SCADA software according to the design; ensuring integration with production equipment and sensors.
- **Sensor integration and real-time monitoring:** Integrating sensors to measure critical parameters; ensuring real-time access to monitoring data.
- **System testing and validation:** Conducting system trials in a simulated environment to verify functionality and performance; comparing monitoring results with conventional methods.

- **Implementation in production environment:** Implementing the SCADA system in a real production environment without disrupting ongoing operations.
- **Continuous monitoring and evaluation:** Monitoring system performance post-implementation; evaluating efficiency and productivity after implementation.
- **Data analysis and improvement:** Analyzing data from the SCADA system; compiling improvement recommendations based on the analysis.
- **Final report compilation:** Compiling a final research report that includes methodology, findings, conclusions, and recommendations for future research.

## 3 Results and discussion

### 3.1 System implementation results

The implementation of the system in this study is divided into two parts, namely hardware implementation and SCADA software implementation for monitoring the production process. Fig. 3 shows the hardware implementation using a main cylinder above the material mold, with temperature and infrared sensors attached to the aluminum profile to detect the cylinder temperature and the presence of the workpiece.

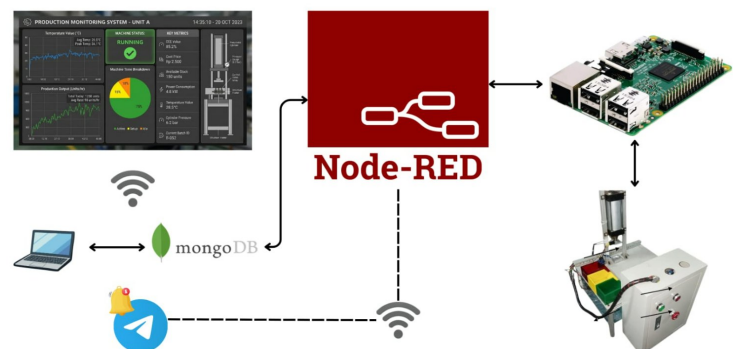


Fig. 3. System implementation

Vibration sensors are located under the mold to monitor vibrations on the plate. An insulated steel plate supports the cylinder and its pressure, with a frame made of aluminum profiles. A proportional

valve is also installed on the plate to regulate the air flow into the machine.

Then, the software implementation was carried out using software created in the form of a complete SCADA interface using NodeRED Dashboard on the SCADA system, a MongoDB database as internal storage, and an alarm notification system that would be sent via telegram to users who had access.

a. Hardware implementation

Fig. 4 shows the side view of the press machine used in the production process. The main components of the machine include the press frame, pneumatic cylinder, die set, and the sensor installation points used for monitoring machine operation. These components enable the system to measure parameters such as machine position, pressure, and operational status during the stamping process.



Fig. 4. Side view of the press machine

b. Software implementation

1) Home page

Fig. 5 shows the Home page of the monitoring dashboard, which displays temperature, vibration, and strain sensor data using intuitive needle gauge visualizations. The interface is designed to provide a clear overview of machine conditions in real time.

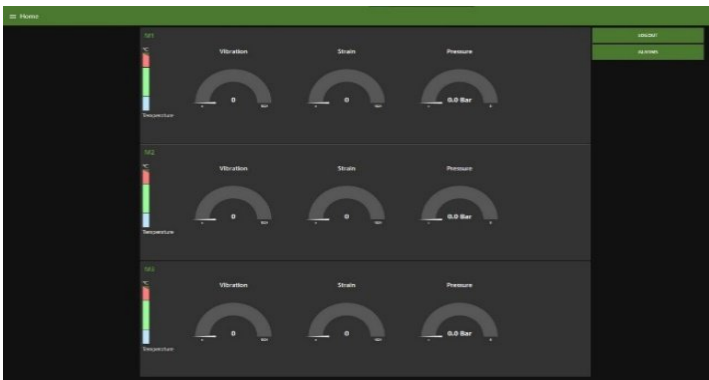


Fig. 5. Home page interface

2) Management page

Fig. 6 shows the Management page containing charts for Availability, Performance, Quality, and OEE. This page can only be accessed by users with management and administrator access rights. This page is modular and can display data from multiple machines.

The needle visualization shows machine efficiency with green (high efficiency), yellow (decreasing), and red (very low) colors. The OEE percentage represents the overall efficiency of the machine, allowing management to quickly view the performance of multiple machines.



Fig. 6. Management page

3) Page M1

Fig. 7 shows the M1 page containing temperature, voltage, vibration, machine operating time, machine status, processed object count, and machine performance visualization data, all presented on a single screen without the need to navigate between pages. The time graph makes it easy for users to monitor the last hour of data to respond to the current situation.



Fig. 7. Page M1

3.2 Testing data communication between Raspberry Pi and SCADA server

To obtain a more representative evaluation of communication reliability between the Raspberry Pi and the SCADA server, the data integrity test was extended to several days. Data transmission was performed every second using the HTTP protocol over a LAN network. The ideal data amount represents the expected number of data points based on the testing duration, while the actual data amount represents the data successfully received by the SCADA server. The results of data communication integrity testing between the Raspberry Pi and the SCADA server can be seen in Table 1.

The results show that the system maintains stable communication performance over multiple days, with an average data integrity of around 99% and data loss below 1.1%. This indicates that the proposed SCADA-IIoT system is reliable for real-time production monitoring. This result is in line with previous studies on IoT-based monitoring systems, which typically report data integrity levels in the range of 95%–99% and data loss below 5% under industrial communication conditions.

Table 1. Results of data communication integrity testing between the Raspberry Pi and the SCADA server

Testing duration (s)	Ideal data amount	Actual data amount	Data loss	Data integrity (%)	Data integrity
22-Jun-24	26.488	26.488	26.22	268	98.99
23-Jun-24	28.12	28.12	27.812	308	98.90
24-Jun-24	27.54	27.54	27.276	264	99.04
25-Jun-24	25.96	25.96	25.704	256	99.01
26-Jun-24	27.3	27.3	27.045	255	99.07
Average	—	—	—	—	99.00

Furthermore, the integration of SCADA and IIoT technologies has been shown to improve data accuracy and system responsiveness, with latency generally maintained below 500 ms for real-time applications, enabling effective monitoring and decision-making processes in Industry 4.0 environments [20], [21]. Compared to these studies, the proposed system demonstrates slightly higher reliability, indicating that the implemented communication architecture is effective for continuous industrial data transmission.

Fig. 8 shows the communication latency test graph during eight hours of testing. The highest latency reached 774ms, the lowest was 13ms, with a median of 32ms and an average of 45.50ms. With data collection every 1 second (1000ms), the highest latency of 774ms leaves 226ms to process and send the next data.

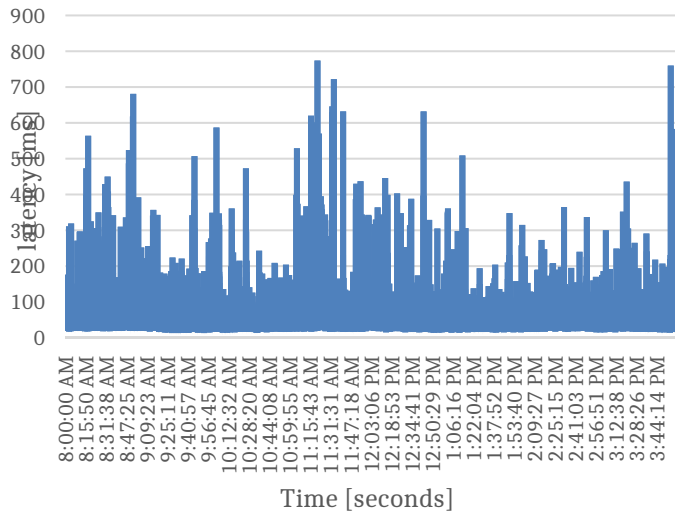


Fig. 8. Latency test results for the connection between the Raspberry Pi and the SCADA server

Latency exceeding 500ms consecutively can cause untimely data delivery, so data loss in the integrity test is likely caused by high latency, not communication protocol failure. An integrity test is likely caused by high latency rather than communication protocol failure. This finding is consistent with previous studies, where IIoT-based monitoring systems typically maintain average latency below 100 ms under normal conditions, while latency spikes above 500 ms may lead to transmission delays and temporary data loss in real-time systems [22]. Furthermore, prior research highlights that network-induced latency, rather than protocol limitations, is a common factor affecting data reliability in IIoT-based communication systems.

### 3.3 Data communication between SCADA server and Telegram server

The SCADA server notification system sends messages to the Telegram server, which are then forwarded to users. Communication latency testing between the SCADA server and the Telegram server was conducted on July 18, 2024, for 1000 seconds, from 09:00 to 09:16, using the Telkomsel Mobile Network. A total of 100 data points were sent to record the delivery time from the SCADA server to the Telegram server until a response was received from the Telegram server.

Fig. 9 shows that out of 100 data points, the average communication latency is 445.99 ms, with a maximum value of 1172 ms, a minimum value of 378 ms, and a median of 424.5 ms. The maximum latency of 1172 ms is considered an anomaly, and without this data point, the maximum value becomes 604 ms.

The experimental results demonstrate that the proposed monitoring system is capable of supporting real-time monitoring of the stamping machine. The average communication latency of 445.99 ms indicates that the system can transmit monitoring data within an acceptable time range for industrial monitoring applications. This finding is consistent with previous studies, where IIoT-based monitoring systems typically operate with latency below 500 ms to ensure effective real-time data transmission and system

responsiveness [20]. Furthermore, prior research indicates that such latency performance is sufficient to support timely decision-making and improve control over production processes, as commonly required in Industry 4.0 environments.

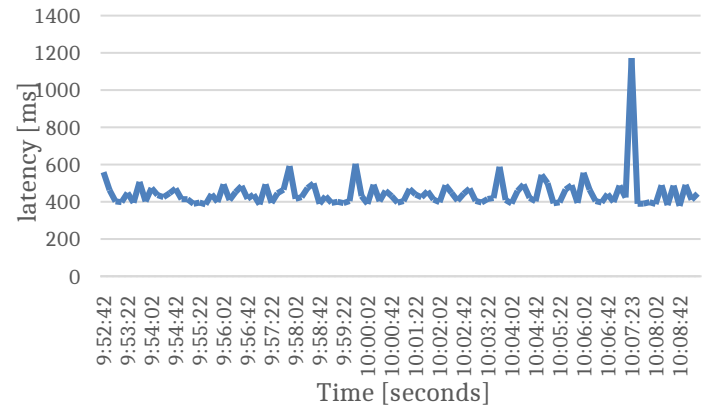


Fig. 9. Latency test results of the connection between the SCADA server and the Telegram server

## 4 Conclusion

Based on the design, implementation, and testing conducted in this study, the proposed web-based SCADA system is capable of monitoring and controlling the production process with a data integrity level of 98.99%. The system is also able to calculate the effectiveness of the press machine prototype and store historical data related to machine conditions and operational activities with a storage capacity of 604,800 data points and an average storage delay of 45.50 ms. In addition, the system provides an error indicator feature integrated with the Telegram messaging application, which is capable of sending notifications with an average latency of 445.99 ms. These results indicate that the proposed SCADA-IIoT monitoring system can effectively support real-time production monitoring and improve operational awareness in stamping machine operations.

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