Design and Implementation of a Secure Real-Time Remote Plant Monitoring System Using PLC and Industrial IoT Framework

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Abstract: *Industrial processes can now be monitored and controlled in real time with increased efficiency, scalability, and security thanks to the quick development of Industrial Internet of Things (IIoT) technologies. The design and implementation of a secure real-time remote plant monitoring system utilising Programmable Logic Controllers (PLCs), Node-RED, Node-RED Dashboard, ZeroTier virtual networking, and the InfluxDB time-series database are presented in this paper. The system combines cloud-enabled visualisation, secure remote access, and industrial field devices. Node-RED serves as middleware for data collection, processing, and communication, while PLCs are used for real-time control. Time-series data is stored in InfluxDB, and real-time visualisation is offered by Node-RED Dashboard. Peer-to-peer networking across geographically dispersed systems is made secure by ZeroTier. The suggested system exhibits secure data transmission, low latency, and high reliability, making it appropriate for Industry 4.0 applications.*

Keywords: IIoT, PLC, Node-RED, InfluxDB, ZeroTier, Remote Monitoring, SCADA, Industry 4.0

I. INTRODUCTION

From conventional SCADA systems to IIoT-based smart monitoring platforms, industrial automation has changed over time. Contemporary industries need:

- Monitoring in real time
- Accessibility from a distance
- Safe communication
- Architecture that is scalable

Because of their deterministic and dependable control capabilities, PLCs continue to be the foundation of industrial control systems. Nevertheless, sophisticated analytics and remote monitoring capabilities are absent from conventional PLC systems.

PLCs and cloud systems can communicate seamlessly thanks to integration with IIoT platforms like Node-RED. Modbus, MQTT, and OPC UA are examples of industrial protocols that Node-RED can handle as a middleware layer. This study suggests a real-time, scalable, and secure monitoring system that combines:

- PLC (control layer)
- Node-RED (middleware)
- InfluxDB (storage of data)
- Node-RED Dashboard (visual aid)
- Secure networking, or ZeroTier

II. SYSTEM ARCHITECTURE

Overall Architecture

The system follows a layered IIoT architecture:

- Field Layer – Sensors, actuators, PLC
- Control Layer – PLC executes control logic
- Middleware Layer – Node-RED processes and routes data
- Network Layer – ZeroTier secure communication
- Application Layer – Dashboard visualization
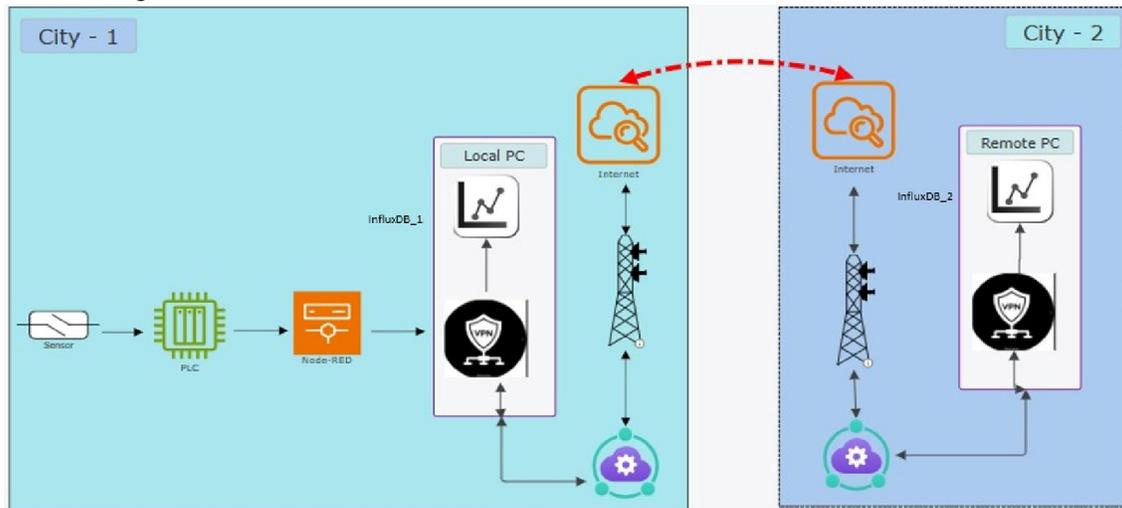- Data Layer – InfluxDB storage

Architecture Diagram

Fig. 1 BLOCK DIAGRAM

III. SYSTEM COMPONENTS

Programmable Logic Controller (PLC)

- Performs real-time control of plant processes
- Interfaces with sensors and actuators
- Communicates using Modbus TCP/RTU

PLCs ensure deterministic operation and are essential for industrial safety-critical systems.

Node-RED (Middleware Layer)

Node-RED is a flow-based development tool used for:

- Data acquisition from PLC
- Protocol conversion (Modbus → MQTT/HTTP)
- Data processing and filtering
- Integration with databases

Its graphical interface simplifies system development and maintenance.

Node-RED Dashboard (Visualization)

Provides real-time monitoring UI

Displays:

Temperature, pressure, flow

Machine status

Alerts and alarms

Dashboards are accessible via web browser.

InfluxDB (Database Layer)

InfluxDB is a time-series database used for:

- Storing sensor data
- Handling high-frequency data streams
- Supporting analytics and historical trends

It enables efficient querying of time-based industrial data.

ZeroTier (Secure Networking)

ZeroTier provides:

- Virtual private network (VPN)
- End-to-end encrypted communication
- Secure remote access without port forwarding

This ensures secure communication between:

- Remote user
- Node-RED server
- PLC network

IV. SYSTEM IMPLEMENTATION

PLC Programming

Ladder logic is used in the PLC's programming to carry out real-time industrial control tasks. Through input modules, the software reads sensor inputs like temperature, pressure, and flow rate. Logical instructions are used to process these values, which are kept in internal memory registers. The PLC triggers outputs like motors, relays, or alarms based on predetermined control conditions. For industrial automation systems that demand high precision and dependability, the scan cycle guarantees continuous monitoring and deterministic control. Modbus registers are properly mapped and addressed in order to facilitate communication with other systems.

Modbus Communication Setup

To facilitate communication between the PLC and the Node-RED platform, the Modbus RTU or TCP protocol is used. Node-RED functions as a client requesting data, and the PLC functions as a Modbus server, exposing its internal registers. IP address, port number, and register mapping are examples of communication parameters that are set up. Standardised, dependable, and effective data transfer is guaranteed by this protocol. In industrial settings, error handling techniques like timeout and retry logic are used to improve communication resilience.

Node-RED Flow Development

Node-RED is a visual programming interface that uses connected nodes to create flows. Data is read from the PLC at predetermined intervals using Modbus nodes. Debug nodes help monitor system behaviour during development, while function nodes handle data processing. Node-RED's modular design makes it simple to add more devices and integrate it with cloud services. The flow-based approach is ideal for industrial IoT applications that need flexibility and scalability because it simplifies complex system design and shortens development time.

Data Processing and Transformation

The PLC's raw data must be transformed into useful engineering units because it is frequently in integer or encoded format. Scaling, normalisation, and filtering are carried out by Node-RED function nodes. For instance, calibration formulas are used to transform raw sensor values into temperature or pressure units. Techniques for data validation eliminate noise and inaccurate readings. This processing guarantees the accuracy, dependability, and suitability of the data stored in the database and displayed to users for analysis and decision-making.

InfluxDB Integration

As a high-performance time-series database built for managing constant data streams, InfluxDB is integrated. Node-RED uses dedicated nodes to send processed data to InfluxDB, where each data point is recorded with a measurement tag and timestamp. Historical data can be efficiently queried and retrieved thanks to this structure. Long-term monitoring and analysis are made possible by InfluxDB's support for down sampling and retention policies, which aid in effective storage management.

Dashboard Development (Node-RED Dashboard)

The Node-RED Dashboard module is used to develop an interactive and user-friendly graphical interface to display different plant parameters. Different types of widgets can be used to display charts, gauges, switches, and indicators. The dashboard can be viewed by opening a web browser. This allows users to view the system remotely. Alert and notification features can also be used to display any abnormalities. The dashboard design is such that it is easy to understand the situation. This allows users to make informed decisions.

Secure Network Configuration (ZeroTier)

ZeroTier provides a secure virtual private network that connects all the components of the system. It provides a virtual local area network that is connected to the internet. This enables remote devices to communicate as if they are connected to the local area network. All the information being sent is encrypted to ensure that it is secure. This helps to eliminate the need for port forwarding, thus protecting the system from online threats.

System Testing and Validation

The complete system is tested to ensure it works under real-time operating conditions. This includes performance and reliability tests. The tests ensure the system's performance in terms of communication latency, data accuracy, system response time, and fault tolerance. The integration between the PLC, Node-RED, InfluxDB, and dashboard is also tested. The stress tests ensure the system's performance in handling high data loads. The tests show that the system can operate stably, securely communicate, and monitor in real time.

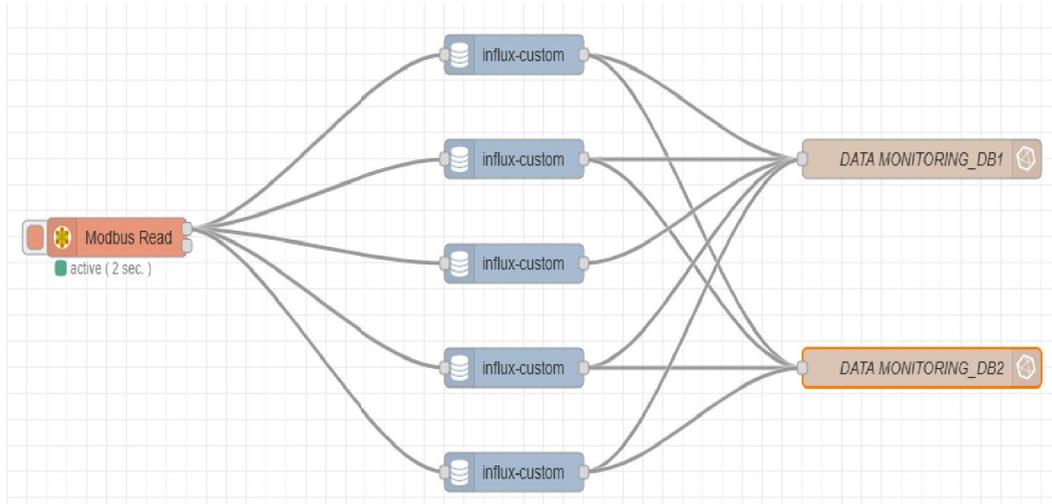## V. RESULTS AND DISCUSSION

Performance

Fig. 2 Node-RED Flow for Real-Time Data Acquisition and store to InfluxDB
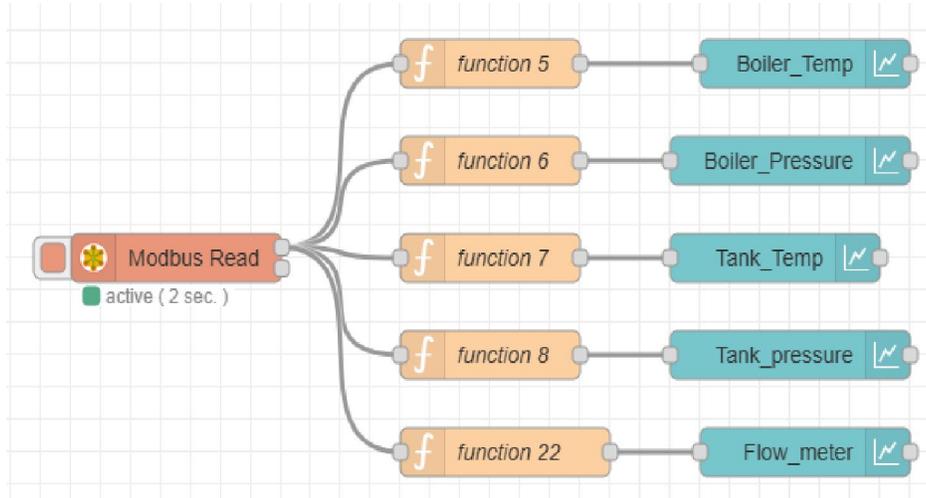

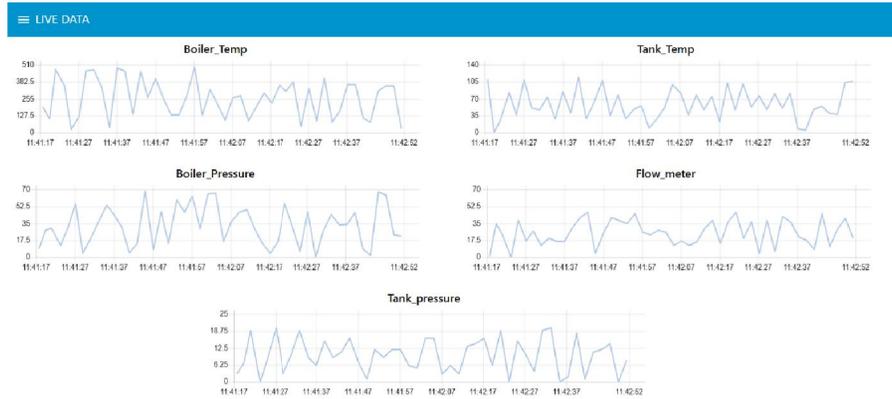Fig. 3 Node-RED Flow for Real-Time Data Acquisition
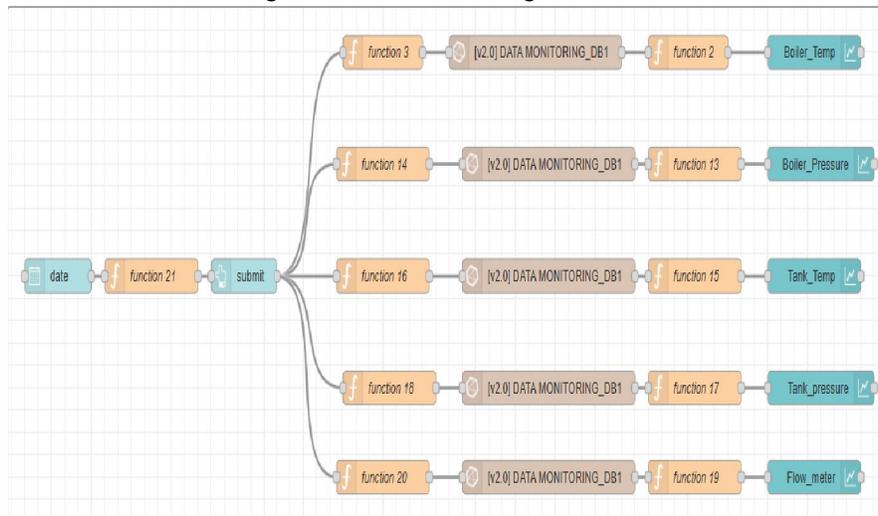
Fig. 4 Real-Time Monitoring Dashboard

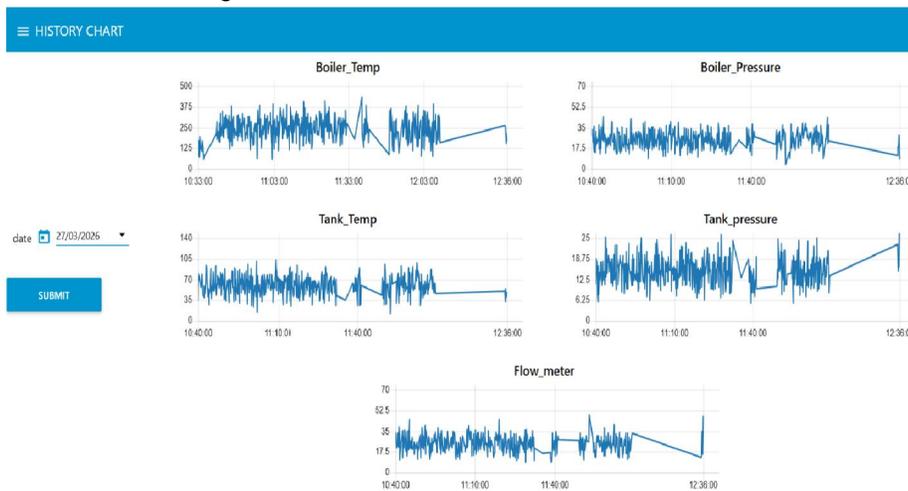Fig. 5 Node-RED Flow for Historical Data Retrieval

Fig. 6. Historical Data Visualization Dashboard

The above figures show the real-time implementation of the proposed system of industrial monitoring using Node-RED and PLC integration. From the Node-RED flow shown above, it is evident that the system can acquire data successfully from the PLC. This is because the function nodes are able to process the values of the sensors connected to the system, such as the temperature and pressure of the boilers.

Moreover, the visualization of the system using the Node-RED dashboard shown above is a confirmation of the fact that the system can monitor the parameters of the system in real-time using the visualization of the parameters of the system in a graphical format. Parameters such as temperature and pressure are monitored in real-time, and the system can display the parameters of the system instantly.

In conclusion, the results of the proposed system of industrial monitoring are a confirmation of the fact that the system can efficiently monitor the parameters of the system in real-time and can integrate the parameters of the system with the use of the Internet of Things technology and PLCs efficiently.

Advantages

The proposed system has a number of advantages compared to the traditional systems. The system is cost-effective, as it utilizes open-source tools like Node-RED and InfluxDB. The system is scalable, which means more devices can be added with ease. The system also allows for safe access remotely, which increases the security of the system. The system also allows real-time visualization, which increases efficiency. The system is also easy to maintain, which means it is suitable for a modern industrial environment.

Comparison with Traditional SCADA

The rapid development of Industrial Internet of Things technologies has allowed modern monitoring systems to be developed that have overcome the limitations of traditional systems. In order to assess the effectiveness of the proposed system, it is necessary to compare the performance, cost, and flexibility of the system with traditional SCADA-based monitoring systems.

Feature	Traditional SCADA	Proposed System
Cost	High	Low
Flexibility	Limited	High
Remote Access	Complex	Easy (ZeroTier)
Data Storage	Limited	Advanced (InfluxDB)

VI. CONCLUSION

The proposed secure real-time remote plant monitoring system effectively combines the advantages of PLC-based control systems with those of Industrial IoT technologies to provide an efficient, scalable, and cost-effective solution. The use of PLC, Node-RED, InfluxDB, and ZeroTier ensures that the system effectively acquires data, visualizes it in real-time, and remotely monitors it. Compared to other SCADA systems, this solution offers greater flexibility and lower costs. The solution's strong performance makes it highly suitable for use in modern industrial automation and monitoring.

FUTURE WORK

- Edge Computing Integration
- AI-Based Predictive Maintenance
- Cloud Integration
- Mobile Application Development
- Advanced Cybersecurity Mechanisms
- Integration with SCADA Systems
- Energy Monitoring and Optimization

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