

Implementation of IoT-based SCADA in MPS Processing Station Integrated with CtrlX Automation

Gun Gun Maulana*, Ridwan Mada, Ismail Rokhim, Hendy Rudiansyah, and Muhammad Giri Suhada
Politeknik Manufaktur Bandung
Jl. Kanayakan no. 21 Bandung, 40135
*e-mail: gungun@polman-bandung.ac.id

Abstract—The increasing complexity of industrial automation technology today requires industries to upgrade their existing systems, such as IoT-based SCADA, which allows for real-time production monitoring from anywhere. However, to achieve this, a system is needed that does not affect or halt the production process and does not require replacing the existing system during the upgrade process. Therefore, a system that can adapt to the existing one is necessary. This research aims to implement an IoT-based SCADA system in an existing plant by integrating the system with ctrlX Automation to address this issue. The implementation is carried out in several stages. The first stage involves integrating the plant controlled by the Omron CP1L PLC with ctrlX Automation. The second stage is creating tags for the SCADA system using tools installed on ctrlX Automation. The third stage involves developing the user interface. The fourth stage is the remote access communication process for the IoT system using the OpenVPN Cloud tool. The test results show that the integration between the Omron CP1L PLC and ctrlX Automation was successful, with a 100% tag retrieval rate from the Omron CP1L PLC, and the data could be visualized. The user interface can be accessed, and remote access can be performed on different networks and locations using the OpenVPN Cloud tool. During testing, the average data transfer write-read delay with one address/tag during remote access was 61.3ms, and for the write-read test with three addresses simultaneously, the average was 78.1ms. Based on these results, the data transfer process using ctrlX Automation integrated with the Omron CP1L PLC can be categorized as very good.

Keywords: *ctrlx automation, internet of things, mps processing station, node-red, plc*

I. INTRODUCTION

Currently, industrial automation technology continues to evolve. The field of industrial automation, which previously involved stand-alone systems, now requires integrated systems [1]. Most existing systems in the industry are controlled using PLCs (Programmable Logic Controllers). Each system/machine uses a single PLC. To support the production process, multiple machines controlled by several PLCs are needed. However, industries often use various brands of PLCs. Communicating between different brands of PLCs poses a challenge due to differences in programming capacity, communication systems, control, and monitoring [2], as well as the higher costs associated with replacement and development [3]. To upgrade the existing system, a solution is needed that does not affect or halt production processes and does not require replacing the current system during the upgrade process. Therefore, a system that can adapt to the existing system is necessary.

As production machinery becomes more complex, a system is needed to monitor the machines in operation. To meet this need, SCADA (Supervisory Control and Data

Acquisition) is applied to the machinery used. The use of SCADA systems has increased due to the rising level of industrial process automation [4]. In SCADA systems, data from controllers, in this case PLCs, is collected by the system integrated with SCADA.

When the location of plants is far from the control and monitoring site, a system is needed that can store data from each plant in an internet-based database, enhancing user mobility to access plant data [5]. If PLCs are integrated, data exchange to the database using IoT-based SCADA connected via the internet and directly to the cloud is very feasible. This improves data storage efficiency in terms of scalability, cost, and other factors [6]. This aligns with the development of SCADA architecture, which is currently in its fourth generation, IoT-based SCADA [7], [8]. The concept of IoT-based SCADA combines the traditional SCADA system, which was initially accessible only via local servers, with IoT concepts that allow data transfer to database servers through the cloud.

By integrating IoT and SCADA technologies, it enables direct data acquisition through sensors connected to ctrlX Core edge devices. Data to a web-based or cloud-based SCADA interface to be explained and displayed in

Received 2 Dec 2024; Revised 2 April 2025; Accepted 8 May 2025

Copyright © 2025 by Jurnal Rekayasa Elektrika, published by Universitas Syiah Kuala. This is an open-access article distributed under the Creative Commons Attribution 4.0 International License (<https://creativecommons.org/licenses/by-sa/4.0/>)

real-time. The advantages of this approach are that it can improve operational efficiency, predictive maintenance, and visibility into the production process. This study also covers several aspects, such as device connectivity, industrial protocol configuration, such as OPC UA and MQTT, to UI development for monitoring. In addition, this study will highlight the advantages of ctrlX as an open automation platform that supports transmission with third-party devices and software, and makes it easier to develop IoT-based industrial applications. Many studies have been conducted on SCADA systems with PLC as the main controller and IoT-based. This is because PLCs cannot directly connect to or be applied to IoT systems, which must connect to the internet for data transfer [9], [10]. These studies use additional devices as intermediaries to connect PLC SCADA to IoT servers.

With the development of current industrial automation technology, PLC architecture is also evolving. Now, PLC architecture includes connections that can link to modems and routers, enabling internet access. This supports critical tasks requiring wireless communication [11] and can meet the needs for building IoT systems. One PLC brand that has developed such capabilities is ctrlX Automation from Bosch Rexroth [12]. Moreover, ctrlX Automation can be tailored to specific needs, supporting various programming languages and development environments, allowing users to adapt and simplify system configuration [13]. Therefore, this research is necessary for subsequent industrial implementation, reducing costs when upgrading systems to IoT.

II. METHOD

In this implementation, the Software Development Life Cycle (SDLC) Waterfall method is used, which consists of Requirement Analysis, System Design, Implementation, Integration, and Testing.

A. Requirement Analysis

In this stage, an analysis is conducted to determine the requirements for the development process in terms of both function and system. The requirements for this study are as follows:

1. Hardware

The hardware requirements are detailed as follows:

- MPS Processing Station, serving as the research object plant and controlled using the Omron CP1L-M40DR-A PLC.
- CP1W-CIF41 Communication Module, providing FINS communication protocol for the Omron PLC.
- CtrlX Automation, an industrial PLC used as a gateway for upgrading to an IoT system and controlling the PLC I/O for teaching aid.

2. Software

- CX-Programmer, for creating control programs on the Omron PLC.
- CtrlX Works, for configuring the ctrlX Automation as

a PLC.

- Node-RED, as a gateway for integrating the two controllers and for monitoring the interface.
- InfluxDB, for storing data that needs to be saved (database).

B. Design System

System Design is conducted to create an overview of the system and applications to be developed [14].

1. MPS Processing Station

Modular Production System (MPS) is a miniature industrial automation process that consists of various standardized components and is used to simulate the product processing process [15]. Processing Station is one of the modular parts of the MPS Station Plant. The system used in the Processing Station only uses sensors and actuators that are electrically powered.

Based on Figure 1, there are several functions of this station, namely testing, drilling, and clamping. The rotary table at the station rotates with the help of a motor and an inductive sensor that is used to determine whether the table has rotated or not and the presence of workpieces. The process flow diagram of the MPS Processing Station is shown in Figure 2.

Based on Figure 2, the process begins when the initial position is met, which is when the workpiece is in the initial position marked by the active Part_AV sensor. If the starting position is met, the process will begin by pressing the Start button. Then, the rotary table will rotate 60° clockwise and deliver the workpiece to the next process, which is the workpiece checking process. Checking the workpiece is done by activating the clamp cylinder. The cylinder will check if the workpiece is already in the checking position indicated by the capacitive proximity sensor in the active checking position. After the checking process is complete, the rotary table will return to rotate 60° to deliver the workpiece to the next process, namely the workpiece drilling process. After the drilling process is complete, the rotary table rotates 60° to deliver the workpiece to the last process to be forwarded to the storage area, which is pushed using a magnetic motor.

2. System Overview

The system consists of two PLCs from different brands, namely Omron PLC and ctrlX PLC from Bosch Rexroth.

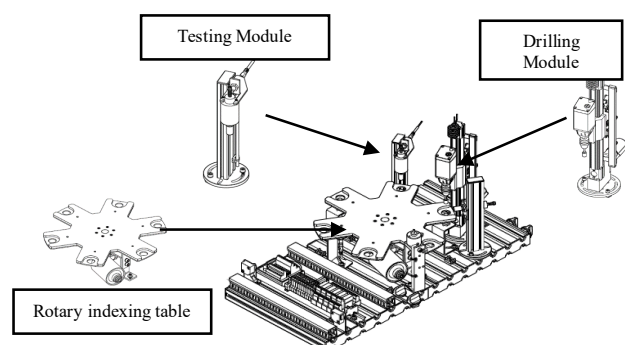


Figure 1. MPS processing station

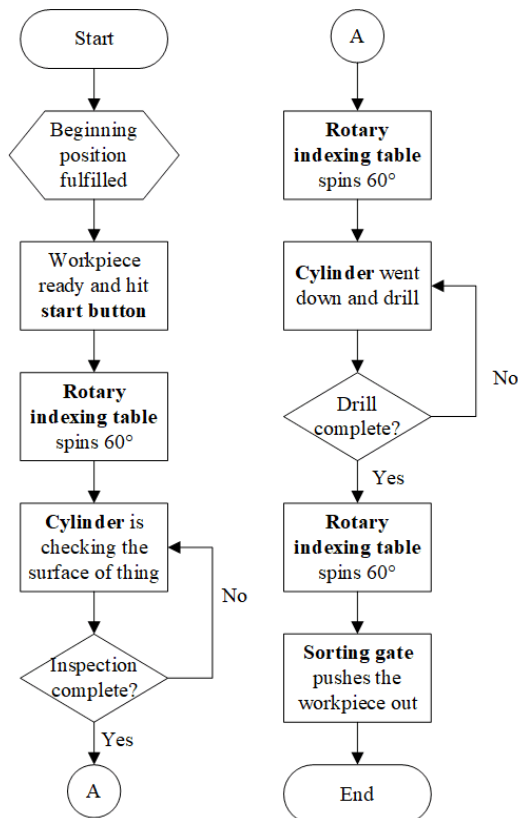


Figure 2. Flowchart process of MPS processing station

The Omron PLC is the PLC used in the field device, the MPS Processing Station. In this research, the two PLCs will be integrated so that they can communicate with each other. CtrlX PLC will be used on the teaching aid with I/O connected to the buttons and lights on the teaching aid. These two controllers will communicate with each other. For example, one of the buttons on the ctrlX PLC teaching aid can be used as a start button to activate the initial sequence on the MPS Processing Station, and vice versa, the button on the MPS Processing Station can activate the light indicator connected to the teaching aid.

An overview of the system designed in this study is depicted in Figure 3. Based on the figure, the system consists of two PLCs from different brands, namely Omron PLC and ctrlX PLC from Bosch Rexroth. Omron PLC is the PLC used in the field device, the MPS Processing Station. In this study, the two PLCs will be integrated to communicate with each other. CtrlX PLC will be used on the teaching aid with I/O connected to the buttons and lights on the teaching aid. These two controllers will communicate with each other. For example, one of the buttons on the ctrlX PLC teaching aid can be used as a start button to activate the initial sequence on the MPS Processing Station, and vice versa, the button on the MPS Processing Station can activate the light indicator connected to the teaching aid.

All the main hardware used, such as controllers (PLC Omron and ctrlX Core) and router modems as access points, are connected to the Switch Hub using an Ethernet cable. In order for communication to be carried out, it is necessary to set the IP address class on each hardware

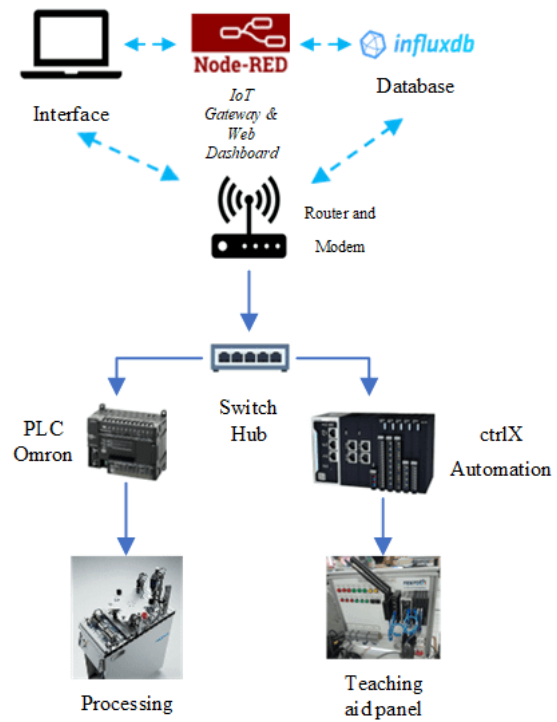


Figure 3. System overview

used.

Both controllers were integrated using Node-RED. This is because Node-RED provides a gateway for the integration process with many industrial communication protocols. In this implementation, the Omron PLC will be connected to Node-RED using the Omron FINS (Factory Interface Network Service) communication protocol, while the ctrlX Core uses the ctrlX Automation palette. Then, data acquisition and data processing are performed at Node-RED.

Then, all the data that has been acquired will be sent to the database. The database used in this research is InfluxDB, which is an open-source database platform. The process of sending data from Node-RED to InfluxDB uses the InfluxDB palette. Then, the data contained in the database will be retrieved again with Node-RED to be displayed on the Node-RED dashboard. If depicted, the data transmission flow is shown in Figure 4.

3. System Testing Design

The design of system testing in this study is carried out by conducting several tests. The tests that will be carried out are as follows:

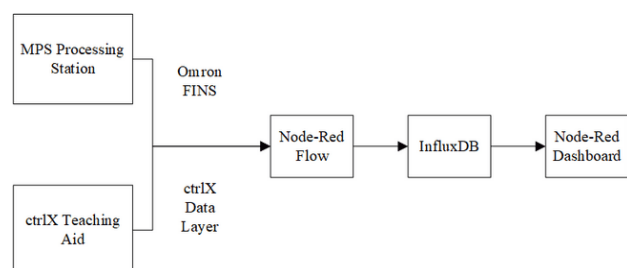


Figure 4. Data communication flow

a. Overall Hardware Testing of the System

This test is done by creating a special ladder program to test all I/O from each controller. Then, checking is done by activating each I/O and ensuring that the hardware runs according to the function created. This test aims to ensure that all hardware on the I/O connected to each controller can perform its function properly.

b. Testing Communication between Hardware

Before communication testing, the hardware used is connected first to the Switch-Hub which will function as an Access Point. Then, it is done on each hardware to equalize the class on the IP Address so that all hardware can exchange data with each other. After all the setup and configuration on the hardware, testing is carried out.

This test is carried out using the communication protocol carried out on each controller. The MPS Processing Station uses the FINS communication protocol and the ctrlX Automation uses the EtheCAT communication protocol on the Bus Coupler to read the I/O on the Teaching Aid that is connected and controlled by ctrlX CORE.

c. System Testing System wide Data Integration

In this test, send-request experiments were carried out between controllers or PLCs using the communication protocol of each PLC. Then, the measurement of the time required or data transfer delay by each controller for the process of sending-request data to the monitoring system is also carried out. Testing is conducted by recording the timestamp when issuing a write data command and the timestamp when the data is read back in Node-RED. The difference between the two timestamps represents the data transfer delay. Tests were conducted with three types of connections to ctrlX CORE, namely by direct connection using an ethernet cable, wireless connection using a router,

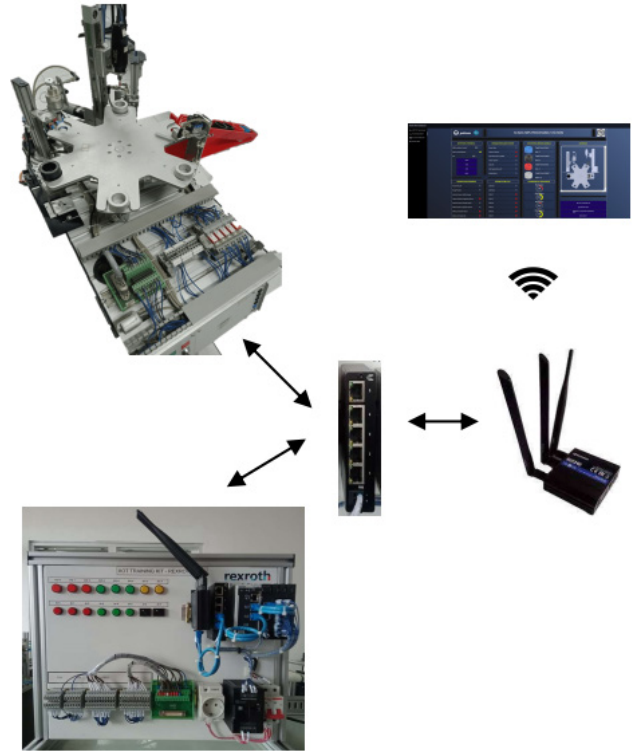


Figure 6. Implementation of hardware using star network topology

and using the remote access method using the OpenVPN Cloud tool installed on ctrlX CORE and the user's laptop. All tests were carried out using the flow on Node-RED.

III. RESULTS AND DISCUSSION

A. System Implementation

According to Figure 5, all devices are connected using a star network topology, namely by connecting all the main hardware used such as, controllers (Omron PLC and ctrlX Core) and router modems as Access Points connected to the Switch Hub using an ethernet cable. In order for communication to be carried out, it is necessary to set the IP address class on each hardware used. Once implemented, the functions created will be displayed on the interface. The implemented network topology is shown in Figure 6.

B. Testing of SCADA Control

Figure 7 is the interface that is used to control the plant. There are several buttons and controls used. The “HMI for Button Control” switch is used to initiate the control from the interface. The “Auto/Manual” switch is used to select the running mode of the plant. The “Start” button is used to start the sequential process on the plant when it meets the initial conditions. The “Stop” button is used if the user wants to stop the process or pause the plant while running. The “Emergency” button is used to stop the process when a problem occurs in the plant. The “Reset” button is used to return the plant to its initial state and indicates

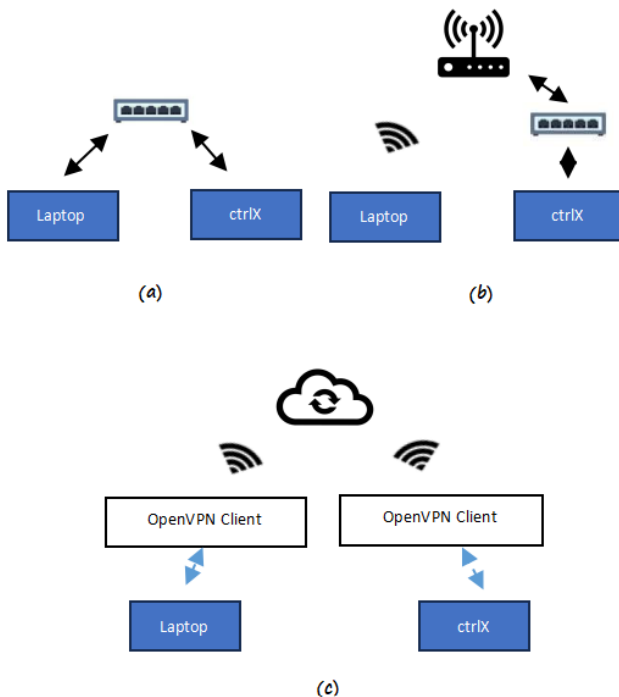


Figure 5. (a) Ethernet connection, (b) Wireless connection, (c) Remote access connection

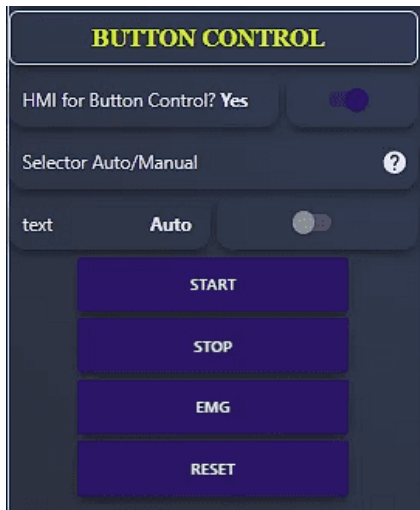


Figure 7. Control button interface

the process can be carried out again. If the “Reset” button is not pressed after an emergency, the process cannot be restarted.

C. Monitoring Test on Node-Red Dashboard

1. Monitoring On MPS Processing Station Page

On the monitoring page of the SCADA on the plant, there are led indicators that display the status of all I/O on the plant such as sensors and actuators. Then, the monitoring page also displays a movement animation of the plant whose movements are adjusted to the real conditions on the plant.

Furthermore, the monitoring page displays the sorting

results of the processed workpieces. The sorting process is carried out using two parameters, namely the material and color of the workpiece. The number of workpieces from the sorting results will also be displayed on this page. After that, there is a gauge that displays the percentage progress of the target number of workpiece processes.

2. Workpiece Process Data Page

On this page, some features display details about the process carried out at the station. Then, it displays the number of workpieces that have entered the process at the MPS Processing Station. In this implementation, there are two types of sorting performed, namely sorting workpieces based on material, metal or non-metal, and sorting based on workpiece color. Then, workpiece sorting is also done based on the color of the workpiece.

Figure 8 shows user input to determine the target process. Then, the system will calculate progress based on the process carried out by the station. After the progress of each object is calculated, there is also the progress of the entire workpiece, which is calculated based on the progress of each workpiece.

Then, on this page, a graph is also displayed about the workpiece sorting process based on the parameters used, namely sorting based on metal or non-metal materials, shown with a pie chart based on the percentage of the number of metal workpieces and non-metal workpieces. Then, for sorting workpieces based on color, it is shown with a block diagram derived from data on the number of workpieces processed.

D. Integration Testing Between PLCs



Figure 8. Monitoring page interface

In this test, it was proven that integration or information exchange between PLCs that have different communication protocols can be done by ctrlX. Integration is done by utilizing the Node-RED installed in ctrlX CORE because it can cover all needs with existing features. In this test, one of the buttons connected to the ctrlX I/O can perform the same function as the “Start” button on the MPS Processing Station controlled by the Omron CP1L PLC. Vice versa, the “Reset” button on the MPS Processing Station is used to activate one of the LED indicators connected to the ctrlX I/O.

After testing, the control carried out between PLCs was successful, with the need to adjust the type of data sent and received by the two PLCs.

E. Testing Data Transfer Delay

In this test, communication from the PLC to the Node-RED interface accessed via ctrlX was tested. Just like the data transfer measurement time intersection test above. This test is done by recording the timestamp when writing to the Omron PLC w address. Then, reading the status at the same address with an injecting 0.05s and recording the timestamp when the status at the address changes and the difference between the two timestamps is the data transfer delay.

In this test, three different connections were used, namely ethernet, wireless, and remote access with two types of tests, namely testing with write-read one data and multiple data. For testing with remote access, the OpenVPN tool was used. Testing by remote access is done by using a mobile hotspot internet connection on the modem connected to the ctrlX CORE and Polman Wi-Fi internet connection on the computer that does remote access. The data transfer delay test node is shown in Figure 9 and Figure 10.

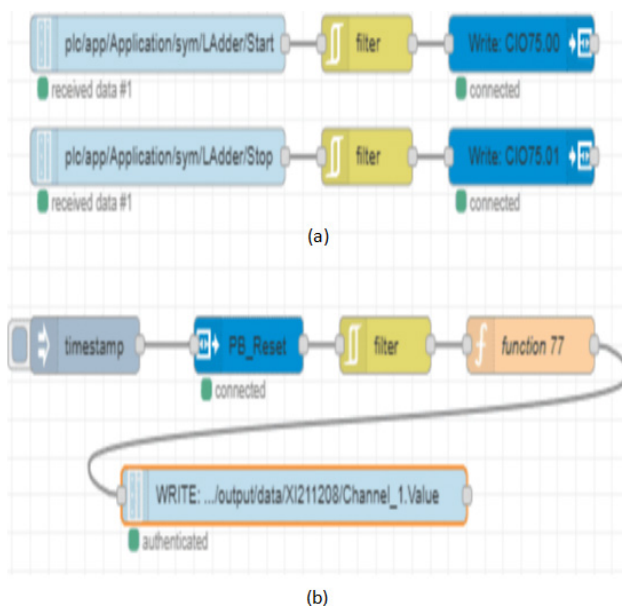


Figure 9. PLCs integration testing nodes, (a) ctrlX PLC - Omron PLC (b) Omron PLC - ctrlX PLC

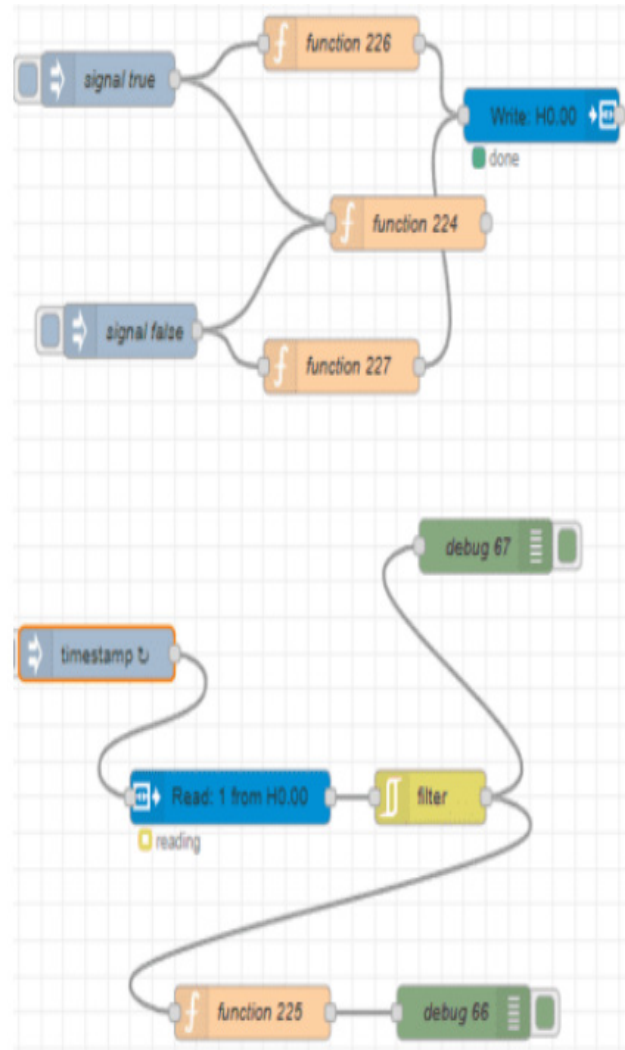


Figure 10. Data transfer delay testing node

After testing, the results are shown in Table I. Based on the data in Table 1, the smallest average delay in the FINS communication protocol on the Omron PLC is shown when using a connection with an Ethernet cable with an average write-read data delay time of 50 ms. Then, based on the

Table 1. Delay testing with one address

Test to-	Delay (ms)		
	Remote	Wireless	Ethernet
1	55	64	49
2	40	59	70
3	52	70	48
4	110	50	57
5	45	40	36
6	66	46	36
7	39	56	37
8	100	97	65
9	57	79	53
10	49	37	49
Average	61,3	59,8	50

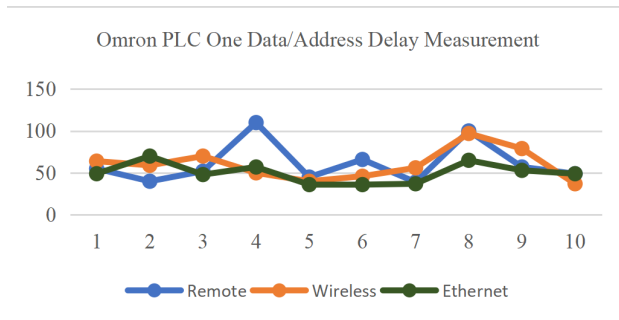


Figure 11. Data transfer delay at Omron PLC

graph in Figure 11, the data transfer delay in the test using an Ethernet cable connection produces a more stable delay and a smaller time compared to the other two connections. This is because the connection using an Ethernet cable transmits data directly without interference, in contrast to the other two connections, which have interference during the data transmission process.

Then, testing with write-read data at multiple addresses was also carried out. In this test, three PLC addresses were used. During the test, write-read was performed on all three PLC addresses simultaneously. Based on the data shown in Table 2, the lowest average delay is still when using a connection with an Ethernet cable, with an average time of 60 ms. However, there is a difference in average delay when performing write-read with one data, with a time difference of 10 ms on an Ethernet cable connection, 11 ms on a wireless connection, and 16.8 ms when using remote access. Based on these differences, it can be concluded that the more data used, the more likely the data transfer delay is to continue to increase in the FINS communication protocol implemented on Node-RED.

To determine the category of data transfer delay, standardization by Telecommunications and Internet Protocol Harmonization Over Network (TIPHON) [16] is used. The categories are shown in Table 3. From Table 3 data obtained and the category of the delay, namely 50 ms - 61.3 ms for one address and 60 ms - 78.1 ms for multiple address on the Omron PLC with the Omron FINS

Table 2. Delay testing with multiple addresses

Test to-	Delay (ms)		
	Remote	Wireless	Ethernet
1	93	65	55
2	133	49	46
3	64	65	63
4	57	45	76
5	81	55	85
6	79	46	67
7	75	111	52
8	77	133	55
9	58	61	50
10	64	78	51
Average	78,1	70,8	60

Table 3. Delay category based on tiphon standardization

Category	Delay Value	Index
Very Good	<150 ms	4
Good	150 ms – 300 ms	3
Moderate	300 ms – 450 ms	2
Bad	>450ms	1

communication protocol. When categorized, it is in the Very Good category for Omron PLCs.

IV. CONCLUSION

Integration experiments between Omron PLCs and ctrlX Automation using compatible communication protocols were successfully implemented using the FINS communication protocol on Omron PLCs communicated to the RED Node on ctrlX CORE. The implementation of a real-time SCADA monitoring system at the MPS Processing Station using ctrlX Automation as a gateway to the IoT system and data communication center was successfully implemented on the Node-RED Dashboard. The implementation of IoT-based SCADA at the MPS Processing Station using a connection or built-in system from ctrlX Automation was successfully implemented and can already be done remote monitoring and control using the Cloud-based OpenVPN tool with a fairly low average write-read data transfer delay, which is 50 ms - 78.1 ms for Omron PLCs. When categorized, it is in the Very Good category for Omron PLCs.

REFERENCE

- [1] M. Yusuf and A. Rohman, "Pengendalian kecepatan motor induksi 3 fasa menggunakan PLC omron CP1E dengan kontrol proposional," *Jurnal Ecotipe (Electronic, Control, Telecommunication, Information, and Power Engineering)*, vol. 7, no. 2, pp. 92–98, 2020.
- [2] M. Georgiev, D. Gospodinova, and A. Georgieva, "PLC based monitoring of energy system of a family house," in *Proc. Electrical Engineering Faculty Conference (BulEF)*, 2020, pp. 1–6.
- [3] I. D. Pranowo, Y. B. T. Bagastama, and T. A. F. Wibisono, "Communication between PLC different vendors using OPC server improved with application device," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 18, no. 3, pp. 1491, 2020.
- [4] S. Nazir, S. Patel, and D. Patel, "Assessing and augmenting SCADA cyber security: A survey of techniques," *Comput Secur*, vol. 70, pp. 436–454, 2017.
- [5] R. Priyatna, F. M. S. Nursuwars, and A. Andang, "Model sistem otomatis water treatment plant menggunakan PLC berbasis wireless," *Journal of Energy and Electrical Engineering*, vol. 2, no. 2, 2021.
- [6] A. Gavlas, J. Zwierzyna, and J. Koziorek, "Possibilities of transfer process data from PLC to cloud platforms based on IoT," *IFAC-PapersOnLine*, vol. 51, no. 6, pp. 156–161, 2018.
- [7] L. O. Aghenta and M. T. Iqbal, "Development of an IoT based open source SCADA system for PV system monitoring," in *Proc. 2019 IEEE Canadian Conference of Electrical and Computer Engineering (CCECE)*, 2019, pp. 1–4.

- [8] G. Yadav and K. Paul, "Architecture and security of SCADA systems: A review," *International Journal of Critical Infrastructure Protection*, vol. 34, pp. 100433, 2021.
- [9] S. W. Jadmiko, D. N. Suharno, and S. K. Nugraha, "Aplikasi internet of things (IoT) untuk pemantauan simulator plant berbasis PLC – web server," *SEMNASTERA*, vol. 2, pp. 28–33, 2020.
- [10] S. C. Abadi, N. W. Nugraha, I. A. Dhimyati, and A. H. Sumarso, "Penerapan human machine interface berbasis augmented reality pada sistem scada modular production system," *Elkomika: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika*, vol. 11, no. 2, pp. 285, 2023.
- [11] M. Dharmadhikari, N. P. Closepet, S. Deka, and S. Ajith Kumar, "Automated product quality testing using IoT," *International Research Journal of Engineering and Technology*, vol. 8, no. 6, pp. 4451-4457, 2021.
- [12] Bosch Rexroth, "Ctrlx automation - PLC." Accessed: Aug. 18, 2024. [online]. Available: <https://developer.community.boschrexroth.com/t5/store-and-how-to/ctrlx-automation-plc/ba-p/13298>
- [13] N. Jankala, "Condition monitoring concept of the hydraulic power unit," Aalto University, 2024. Accessed: Aug. 18, 2024. [Online]. Available: <https://aaltodoc.aalto.fi/items/7e18db0e-881a-4527-a93f-87c942005453>
- [14] Z. Ramdani and I. Ikrimach, "Implementasi internet of things pada aplikasi monitoring mesin penggilingan padi berbasis android," *JUKI : Jurnal Komputer dan Informatika*, vol. 6, no. 1, pp. 55–63, 2024.
- [15] E. M. Sartika, T. R. Sarjono, and K. Christian, "Modular production system control using supervisory control theory method," *Journal of Physics: Conference Series*, vol. 1858, no. 1, pp. 012095, 2021.
- [16] A. N. Yaqin and G. Gunawan, "Optimalisasi jaringan internet dengan teknik simple queue menggunakan metode PCQ pada high traffic network," in *Proc. Prosiding Seminar Sosial Politik, Bisnis, Akuntansi dan Teknik*, 2022, pp. 377.