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Performance Analysis of an IoT and Scada-Based Oil Tank Filling Monitoring System Using Omron PLC at PT Pertamina Patra Niaga Meulaboh

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Article Info

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ABSTRACT

The monitoring and control system in the oil tank filling process plays a crucial role in ensuring efficiency, safety, and accuracy in fuel distribution. This study aims to analyze the implementation of an IoT and SCADA-based monitoring system for oil tank filling using an Omron PLC at PT Pertamina Patra Niaga Meulaboh. The system integrates an Omron Programmable Logic Controller (PLC) as the main control unit, level sensors for real-time tank capacity detection, as well as IoT and Supervisory Control and Data Acquisition (SCADA) for remote monitoring. The research methodology includes system design, implementation, and testing, focusing on data communication reliability, sensor accuracy, and tank filling efficiency. The test results show that the system can monitor oil levels with an accuracy of ±0.5%, and improve operational efficiency by reducing filling errors by up to 20% compared to conventional methods. The implementation of IoT allows operators to access real-time filling data through a web-based dashboard, while SCADA provides more structured control over the filling process. The findings of this study conclude that the integration of IoT and SCADA in a PLC-based tank filling system significantly enhances efficiency, accuracy, and safety in oil filling operations. This technology holds great potential for broader application in the oil and gas industry to improve the effectiveness of fuel distribution systems.

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INTRODUCTION

In the oil and gas industry, the efficiency and reliability of oil tank filling systems are critical aspects of daily operations. PT Pertamina Patra Niaga Meulaboh, as a company engaged in the distribution and storage of fuel, requires an accurate and real-time monitoring system to ensure optimal filling processes while minimizing the risks of loss and leakage. Supervisory Control and Data Acquisition (SCADA) and the Internet of Things (IoT) have been widely adopted in industrial automation systems to enhance operational efficiency and safety. By utilizing an Omron Programmable Logic Controller (PLC), the monitoring system can be further developed to ensure precise tank filling, monitor liquid volume levels, and automatically control valves and pumps.

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However, challenges in implementing this system include the integration of SCADA and IoT technologies with existing infrastructure, as well as the reliability of data communication in industrial environments. Therefore, an in-depth analysis is needed to evaluate the effectiveness of an IoT and SCADA-based monitoring system in the oil tank filling process at PT Pertamina Patra Niaga Meulaboh, in order to enhance operational efficiency, safety, and accuracy. This study aims to analyze the extent to which the integration of SCADA and IoT systems based on Omron PLC can improve the monitoring and control of oil tank filling, as well as to identify the technical obstacles that may arise during the implementation of this system.

Literature Review

Sensor

A sensor is an electronic component used to convert a certain quantity into another quantity. A sensor is a type of transducer used to convert magnetic, light, heat, chemical, mechanical, and other quantities into voltage or electric current. This sensor functions to detect a quantity when measuring or controlling.

Proximity sensoror proximity switch is a detector that works based on the distance of the object to the sensor. The characteristic of this sensor is to detect objects at a fairly close distance, ranging from one millimeter to several centimeters only according to the type of sensor used. This Proximity Switch has a working voltage of between 6-36 VDC and there are also those that use a voltage of 100-200 VAC. At present, almost every industrial machine has used this type of sensor, because in addition to being practical, this sensor is a sensor that is resistant to impacts and shocks.

Figure 1. Proximity Sensor

Proximity Switchconsists of 2 types:

a. ProximityCapacitive (Capacitive Proximity Sensor).
   ProximityCapacitive will detect all objects within its sensing range, both metal and non-metal, based on the principle that all types of materials can be capacitor plates (can store charges). Capacitive Proximity measures the change in capacitance of a capacitor's electric field caused by an object approaching it. Capacitive proximity can detect both metal and non-metal objects.
b. ProximityInductive (Inductive ProximitySensor).
   ProximityInductive functions to detect iron or metal objects. Even though it is blocked by non-metallic objects, the sensor will still be able to detect objects as long as it is

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within the sensing distance or tolerance range. If the sensor detects metal in its sensing area, the sensor output condition will change its value.

The sensor is a sensor that functions to detect the height of a flow at a certain point, either at a low, medium or peak level. The types of level sensors vary according to the application of the material being detected, such as closed containers such as tanks, silos, or changing heights such as lakes, rivers and seas. The level switch sensor is included in one type of level sensor. This sensor performs normal switching, when the liquid comes into contact with the sensor, the switch will be pressed and will connect the NO / NC leg with a voltage of 24 VDC or 220 VAC, then the signal is forwarded to the controller such as PLC (Programmable Logic Control).

Figure 2. Switch Level Sensor

Programmable Logic Controller (PLC)

Programmable Logic Controller(PLC) is basically a computer that is specifically designed to control a process or machine. The controlled process can be in the form of continuous variable regulation such as in servo systems or only involves two-state control (On/Off) but is carried out repeatedly as we commonly encounter in drilling machines, conveyor systems, and so on. (Iwan Setiawan, 2006)

The working principle of a PLC is that first the PLC will read the input signal from the input components such as sensors, push buttons, limit switches, magnetic switches and so on, then the PLC will read the control program that has been stored in the PLC memory such as the ladder diagram (LD) program. This control program functions to change input instructions into output instructions. Output equipment can be a switch that turns on the indicator light, a relay that drives the motor or other equipment that can be driven by the output signal from the PLC. PLC hardware is basically composed of the following four main components: Processor, Input/Output Module Power supply, and Memory. Functionally, the interaction between the four components of the PLC can be illustrated in Figure 4. PLC will not operate if there is no power supply. The power supply functions to change the input voltage from PLN (220 VAC) to the electrical voltage required by the PLC (24 VDC).

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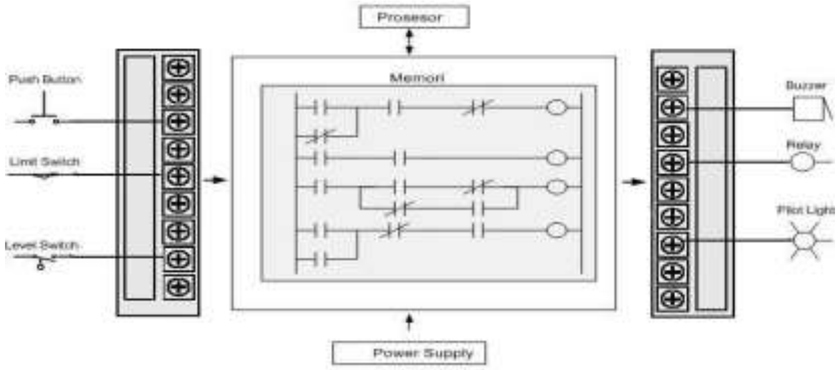

Figure 3. Interaction of PLC System Components

Ladder Diagram Programming Language

In general, PLC programming languages can be divided into several languages such as LDR (Ladder Diagram), STL (Statement List) or BASIC (Beginners' Programming Language). All-purpose Symbolic Instruction Code). PLC pneumatic drilling four holes equipment teaching aid uses ladder diagram as its programming language.

This type of ladder diagram language is a series of schematics that are shaped like a ladder, where there are two main vertical lines that indicate the power line and there is a series of symbols arranged horizontally. Each instruction on the ladder diagram is expressed in a symbol that is similar to an electrical circuit. In using instructions, it should always be followed by filling in the reference number or address above it. Contact and coil instructions are standard components for doing this programming. Contacts are input devices that can be set for external switches, flags, and timer functions. Contact instructions can be set to two states, normally open or normally closed. The coil instruction is an output device that can be set to control motors, solenoids, flags and other actuator processes.

The manufacture of this four holes pneumatic drilling PLC practical tool uses a PLC made by OMRON with the CP1E - E 20 DR - A unit model. The CP1E PLC is a type of PLC designed for easy applications.

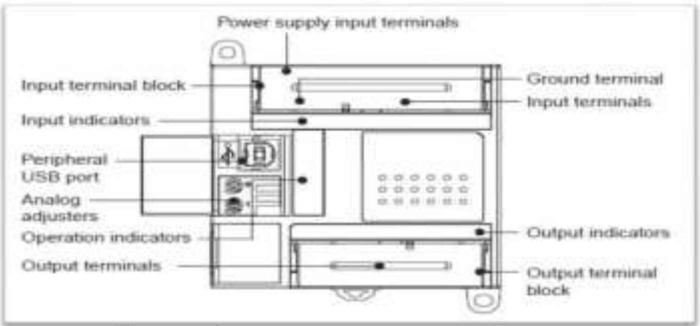

Figure 4. Omron CP1E PLC Schematic

CX-Programmer

CX-Programmer is a software used to program PLC (Programmable Logic Controller) especially Omron brand (Drs. Slamet Wibawanto, 2014). This program operates under Windows system, therefore this software is quite familiar among Windows users. Omron PLC can be programmed using CX-Programmer application by compiling ladder diagram containing instructions and addresses that will be used in PLC later (Tiar Kusuma Dewi, 2014). CX-Programmer can also be used for online PLC monitoring to monitor system performance via serial cable.

Table 1. List of Shortcuts in CX-Programmer

Icon	Keyboard	Function
Selection Mode	D	Make a selection
New Contact	C	Enter contact NO.
Contact	/	Entering NC contacts
New Contact OR	W	Enter NO (OR) contact
New Closed Contact OR	X	Inserting NC (OR) contacts
New Vertical	Ctrl+Down	Inserting a vertical line
New Horizontal	Ctrl+Right	Inserting a horizontal line
New Coil	O	Inserting coil / output
New Closed Coil	Q	Inserting coil / output (closed)
New Instruction	I	Entering commands/functions

Basic PLC programming instructions with CX-Programmer software Ladder diagram is one way to program PLC and is the easiest way compared to others. Ladder diagram instructions are symbolized using instruction symbols. PLC/PC Omron CPM2A-20CDRS-A has 20 I/Os, namely 12 inputs and 8 outputs with the following addresses:

Input: from 0.00 to 0.11
Output : from 10.00 to 10.07

Addressing on a PLC ladder diagram is very important because the address given to each contact will affect the sequence or way the program works, so users must know the input output addresses of a PLC that will be programmed.

METHOD OF RESEARCH

In this study, the method used includes several stages to ensure systematic and accurate analysis. This research is an experimental and analytical research, where the IoT, SCADA, and Omron PLC based oil tank filling monitoring system will be tested and its performance analyzed based on the operational data obtained. The data collected in this study were obtained through the following methods:

a. Literature Study: Collecting references from journals, books, and related sources regarding SCADA, IoT, and Omron PLC in industrial monitoring systems.
b. Direct Observation: Conducting observations on the oil tank filling system at PT Pertamina Patra Niaga Meulaboh to understand the actual conditions and the current system.
c. Experiments and Simulations:
    1. Developing and testing a SCADA and IoT based monitoring system using Omron PLC in oil tank filling.
    2. Conduct simulations or limited implementations to observe system effectiveness and constraints.

d. Interview and Discussion: Conduct interviews with technicians, operators, and related experts to gain insight into the implementation and challenges of this system.

Once the data is obtained, analysis is carried out using the following steps:

1. System Performance Analysis
   Measuring sensor accuracy and the effectiveness of Omron PLC in controlling the oil tank filling process. Evaluate the reliability of data communication between sensors, PLC, SCADA, and IoT in monitoring systems.
2. Efficiency and Security Analysis
   Assess how much this system can optimize operational efficiency compared to conventional systems. Identifying potential operational and security risks in the application of SCADA and IoT to oil tank filling.
3. Constraint Analysis and Solutions
   Identify technical and non-technical constraints in system implementation. Develop recommendations for system optimization and improvement.

As part of this research, a monitoring system will be designed and tested with the following steps:

a. Hardware and software selection used, such as oil level sensors, Omron PLCs, SCADA systems, and IoT connectivity.
b. System integration and testing to ensure data communication runs smoothly.
c. Evaluation of trial results to see system performance in operational scenarios.
d. Compare research results with previous studies and industry standards.
e. Analyze system effectiveness by comparing efficiency, accuracy, and security parameters before and after implementation.

Through this research method, it is expected to obtain a comprehensive analysis of the effectiveness, challenges, and benefits of the IoT and SCADA monitoring system based on Omron PLC in the oil tank filling process at PT Pertamina Patra Niaga Meulaboh.

RESULT

Result Production Process

To run the production process, the PLC program, SCADA PLC control panel must be in ON or live condition. When the button or instruction on the SCADA is executed, the SCADA will send the electrical signal and command the equipment on the control panel. As the final result of the command, external equipment such as chain motors, elevator motors, indicator lights, and others will work ON or OFF. The following is a brief explanation.

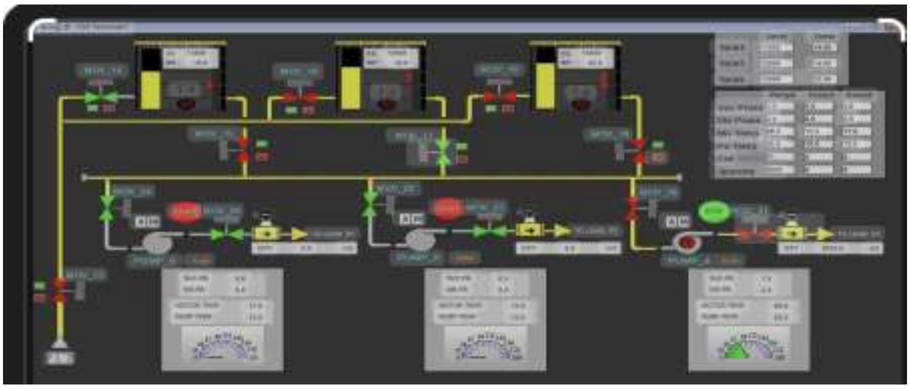

Figure 5. SCADA System Control Test

In designing this SCADA system, the author created 2 control systems, namely MANUAL mode and AUTO mode.

Manual Mode

This mode is used for manual line operation, without having to follow the sequence as per the company's production SOP.

1. On the SCADA screen, Click the selector switch on manual mode.
2. On the control panel, also direct the selector switch to manual mode. So that the manual override indicator light on the scada screen and control panel lights up.
3. To run the elevator from the SCADA screen, click the elevator button then the machine will run and the indicator signal will be ON.
4. To run the elevator from the control panel, click the elevator button then the machine will run and the indicator signal on the panel will be ON.
5. To run the conveyor from the SCADA screen, click the conveyor button then the machine will run and the indicator signal will be ON.
6. To run the conveyor from the control panel, click the conveyor button then the machine will run and the indicator signal on the panel will be ON.
7. In manual mode, the high level and low level indicator signals on the storage bin will work according to their respective functions.
   a. When the raw material is fully filled in the bin, the high level indicator will be ON.
   b. When the raw material in the bin is empty, the low level indicator will be ON.

Auto Mode

This mode is used for automatic line operation, without having to control from the control panel and also the SCADA screen. Users only need to monitor on the SCADA screen.

1. On the SCADA screen and control panel, direct the selector switch to AUTO mode. Then the indicator lights on the SCADA and control panel will be ON.
2. The entire machine will be able to run under the following conditions:
   a. When the storage bin is empty, the Low level indicator signal will be ON. The truck carrying raw materials will be directed to the Intake machine pouring.
   b. When the raw material is poured into the Intake, the proximity sensor installed on the intake hopper will read and the intake indicator light will turn ON.

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c. When the intake sensor is ON, the elevator and conveyor machines will run simultaneously. Users can find out the condition of the running machine by looking at the ON machine indicator signal on the screen. SCADA.
d. After the raw material filling process, the storage bin condition will be full. This can be seen when the High level sensor is ON.
e. When the high level indicator signal is active, the conveyor and elevator machines will be OFF after the next 60 seconds. This is intended to using up the remaining raw materials on the delivery machine line.

Figure 6. PLC Installation on SCADA System

In this section, the author will write about how PLC works in controlling the production system that has been designed.

1. The PLC will respond to read, write, and ON/OFF commands from SCADA.
2. As a result of the SCADA command, the computer screen will display *"feedback"*(feedback) such as color changing indications on conveyors, elevators, sensor readings, etc.
3. For example, a conveyor motor, when the conveyor is instructed from SCADA to turn ON, SCADA will send digital data to the PLC that the conveyor will turn ON.Then the CPU on the PLC will command the output of the PLC module to send 24 vdc electricity, which will then move the relay for the conveyor. When the conveyor is ON, the auxiliary contact NO (normally open) on the relay will send a digital signal to the PLC that the conveyor is ON. This data will be immediately forwarded to SCADA, so that the conveyor display on the SCADA screen will change color from the OFF position to the ON position.

Ladder Diagram Program Testing

After installing and programming the PLC, it is necessary to test it so that it can be known whether the program and I/O installation that has been made can work properly and correctly. Ladder diagram programming is made using Cx-programmer software.

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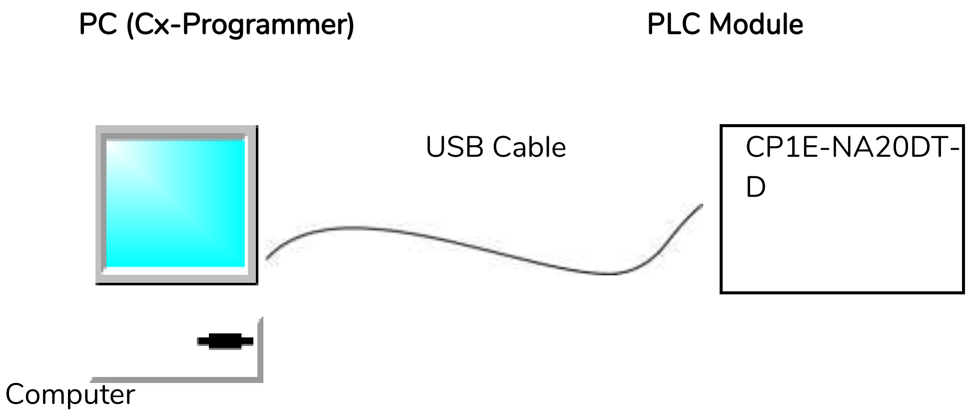

Figure 7. Block Diagram of Communication Between PLC and PC

Testing is done by monitoring and executing according to the working conditions of the plant, namely automatic testing. When conducting plant testing and monitoring and execution, namely by opening the cx-programmer software.

a. To run the auto program, the selector switch must be turned ON in the auto position. This can be seen in the ladder diagram that the author has made. When the input *0.00*(auto button) is active or has a value of 1, then the automatic mode on the system will run. This can be seen in the output W90.02 (AUTO_MODE) has been active or has a value of 1.

Figure 8. Ladder Diagram Auto Mode

b. The conveyor and elevator machines are not ON yet, because the intake sensor is still OFF, this is because the raw material has not been poured into the intake. It can be seen in the ladder diagram, input *0.03*still has a value of 0.

Figure 9. Ladder Diagram of Intake Sensor

c. Next, the truck pours the raw material into the intake. Then the sensor will be ON and 30 seconds later the conveyor and elevator machines will run. This can be seen in the ladder diagram below.

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Figure 10. Ladder Diagram of ON Conveyor Machine

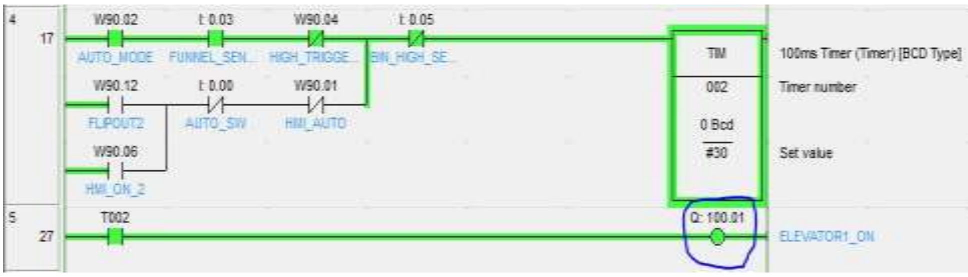

Figure 11. Ladder Diagram of Elevator Machine ON

d. After carrying out the process of filling raw materials into the silo, the condition of the silo will change. This can be seen from the sensor reading.low levelhas been ON. In this position, the conveyor and elevator are still in the run position.

Figure 12. Ladder Diagram Low Level ON

e. When the raw material is fully filled in the silo with the high level indicator ON, the conveyor and elevator machines will be OFF. This condition can be seen in the ladder diagram that the author has made.

Figure 13. Ladder Diagram High Level ON

Scada Testing Based Oil Tank Filling.

The research results obtained are the final results of the realization of the tool (unit) and the reading results of the SCADA system.

Final result of tool realization (unit)

The final results of the tools created in this study include software and hardware. The combination of these two devices forms a SCADA system. The following is a picture of the software and hardware of the realization of the designed tool.

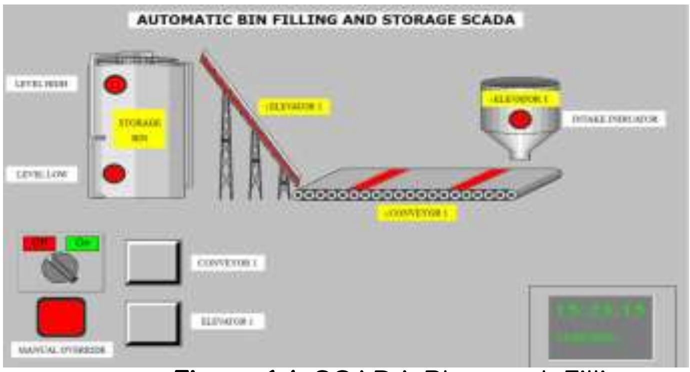

Figure 14. SCADA Plant tank Filling

The plant page is a display to see the process/simulation of the raw material filling plant into the silo/storage bin. On this page, users can monitor and control events in the ongoing plant. The animations drawn are monitoring the storage bin level, intake sensor, and running the conveyor and elevator machines used. On this page, the design of the monitoring must be made as similar as possible to the actual plant so that what happens to the plant can be seen in real time on the monitor screen.

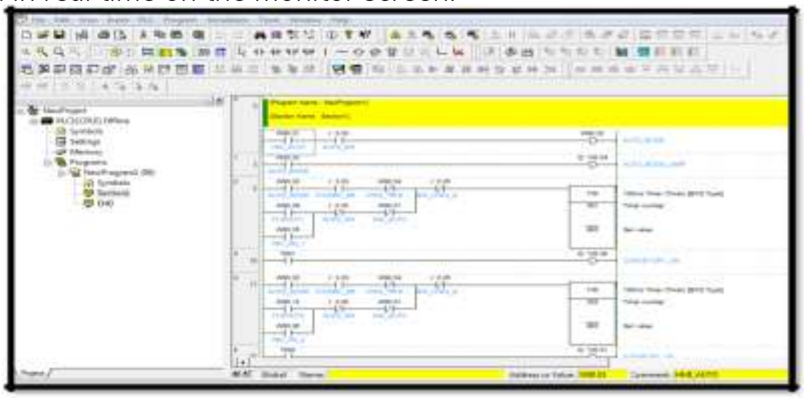

Figure 15. PLC Ladder Diagram Using CX-Programmer Software.

Based on the block diagram above, the analysis is carried out by running the plant from SCADA and looking at the response on the PLC and the path on the integrated plant.

SCADA System Design Analysis

The SCADA system in this study uses an Omron CP1E-NA20DT-D PLC whose ladder diagram is programmed using Omron's own product software, namely Cx-Programmer. While to create the SCADA software, the author also uses Omron's product software, namely Cx-Supervisor. The control circuit on the input/output wiring of this tool design uses a voltage of 24vdc, this is because the type of PLC that the author uses has an I/O type in the form of a transistor. To connect to a 220 Vac output such as elevator and conveyor signs, the author connects a 24 vdc relay and installs a 220 vac coomon on each output line used.

When conducting a running test, the SCADA function is clearly visible in the supervisory process and the controlling process. The supervisory process aims to find out the entire system process directly (online and real time) through the SCADA display screen. While the controlling process aims to control the processes that occur in the plant in real time from a distance. In this study, the control process is realized by creating manual/automatic and start/stop buttons on the SCADA plant. This button functions to control the process of filling raw materials in the storage bin directly.

The SCADA system in this study uses a digital proximity sensor that is used as an intake, high level, and low level sensor. This sensor is used as an input that will send a signal to the PLC. The PLC functions as an RTU (Remote Terminal Unit) that will send a control signal to the equipment that controlled, taking data from the equipment, and sending the data to the MTU (Master Terminal Unit) or computer. The computer (SCADA software) functions as an MTU (Master Terminal Unit) which displays the system conditions to the operator via the SCADA screen in real time and can send control signals to the plant.

CONCLUSION

Based on the results of the analysis, it can be concluded that the integration of IoT and SCADA technologies with OMRON PLC in the oil tank filling process significantly enhances system performance in terms of efficiency, accuracy, and operational safety. The system successfully provides real-time monitoring of tank levels with an accuracy margin of approximately ±0.5%, and reduces filling errors by up to 20% compared to conventional methods. The use of IoT allows remote data access through a web-based dashboard, enabling operators to monitor and respond to filling activities more effectively. Meanwhile, SCADA offers a structured and centralized control interface, improving system responsiveness and decision-making in critical operations. Despite some challenges in data communication and system integration, the overall performance shows that the implementation is both feasible and beneficial. Therefore, this system can serve as a scalable and modern solution for fuel distribution monitoring, with high potential for broader application in the oil and gas industry.

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