Raspberry Pi based SCADA system using Codesys for workshop facilities

S C Abadi*, M Eriyadi, D Usman, Y M Hamdani and A Suryadi

Electrical Engineering Department, Politeknik Enjinering Indorama, Jatiluhur 41152, Purwakarta, Indonesia

*sarosa.castrena@pei.ac.id

Abstract. This study aims to create a prototype of the SCADA system used to control the lighting source facilities and a fan-based Raspberry Pi in the workshop of the Electrical Engineering Study Program of Politeknik Enjinering Indorama. This system consists of Raspberry Pi Model B, UL 2803 Driver, switch module, relay module, lamp, and fan. Raspberry Pi as a controller or mini PLC programmed using CodeSys software with the ladder logic diagram programming. The System control process can also be done through the HMI display (Human Machine Interface), HMI display is designed using Codesys Web Visualization feature so the system can be controlled through a PC or mobile web browser while connected to the campus intranet network. The results showed the prototype SCADA system that was built was able to control sources for lighting and fans both locally and remotely through a mobile or PC in real-time with an average control time of 200 ms.

1. Introduction
Politeknik Enjinering Indorama has a workshop building as a place for practicum activities is required to provide comfortable environment around the workshop [1], therefore the workshop should be supported by good facilities such as lighting and HVAC (Heating, ventilation and air conditioning) [2-3]. Workshop facilities such as lighting and fans in the workshop are still running conventionally and there is still a need for manpower in control, the problem that frequently occurs is that students and lab staff forget to turn off the facility after the practical activities are finished.

Based on these problems the authors intend to build a SCADA system to control sources of lighting and fans based on Raspberry pi. SCADA (Supervisory Control and Data Acquisition) is one of the automation technologies that can perform supervision, control and data acquisition of a control system consisting of subsystems and processes [4]. There are various SCADA applications for a system, one of which is a Raspberry pi based SCADA system as in the study of Mrs. Asha john [5]. That study discusses an alternative programmable logic controller (PLC) [5-6] device where Raspberry Pi has replaced PLC, Raspberry Pi is used as a soft PLC for automation of a small 11 KV substation [5]. Raspberry Pi based SCADA systems that have been implemented are mostly raspberry pi used as a server or MTU [7] and also as a PLC [5-7].

In this study prototype system designed utilizing Raspberry Pi as a soft PLC [5] programmed using CodeSys [5,8] software with ladder logic diagram [9-10], which is programming language using symbols to declare logic functions such as a relay, timer, counter and many other instructions [9-10]. The system can be controlled through the HMI (Human Machine Interface) display from Codesys, so it
can be controlled anywhere while connected to the network [5, 11]. This study is expected to provide efficiencies in the use of resources in the workshop so that it can be used in the later analysis and hopefully this research can become media learning about the programming of Raspberry Pi using the Diagram ladder as well as an added value to the world of research in Indonesia.

2. Research method
Figure 1 shows a block diagram of a system, structured to facilitate an understanding of the functions and works principle of the system. Each block has its function, so that when combined multiple blocks of diagrams will be obtained the result of a working system that works gradually with more complex functions [12].

![Figure 1. Block diagram of system.](image)

The Hardware design of the SCADA system Prototype consists of the following components:

- Raspberry Pi is a single-board computer (SBC) that has a size like an ATM card and supports LINUX as its main operating system [13]. Raspberry Pi is used as a mini PLC that controls and monitors lamp lighting and fan.
- Module relay 8 channel as a magnetic switch that can be controlled by Raspberry Pi to disconnect and connect the power source to the lamp and the fan.
- Switch as input that can control light equipment and fan on location directly.
- ULN2803 as a driver with the output current for each channel of 500mA to control the relay [14-15].
- Lamps and fans as a controlled device.

In this system, Raspberry Pi as Mini PLC will transmit the output signal to the relay module based on the input signal from the user through the Web interface or from the switch directly. In this system, there are eight input switches and eight output channels, each input function to set one output channel. To clarify the system workflow, we can see the system flowchart as shown in Figure 2. The system flowchart begins with initializing the GPIO on the Raspberry Pi then after the initialization process finishes the Raspberry Pi as a PLC ready to receive the input of data control either hardware or software. First, the program will check the data control that goes to the output channel 1 up to the last output channel then check the status of the last each output whether it is on or off if the status of the last output on then the program will check if the control instruction from the input is off then the output is set off and if there is no control instruction the program returns to the input read process otherwise if the status is last output off then the program will check if the input control instruction is on then the output in Set on and if there is no control instruction the program returns to the input read process. The output control algorithm for each channel is the same as the flowchart for each typical output.
Raspberry Pi as a soft PLC programmed with ladder diagram programming using CodeSys software version 3.5 [5,8], in this system the HMI display is designed using Web visualization features from the Codesys version 3.5 as shown by Figure 3 and Figure 4.
There is a GPIO (general purpose input and output) setting on the Raspberry Pi to be adjusted to the variable used in the ladder program and HMI [16]. The following table 1 shows the list of I/O address list PLC, Raspberry Pi, and HMI on the system.

**Table 1. I/O address list.**

| No | I/O                        | PLC      | GPIO  | HMI          |
|----|----------------------------|----------|-------|--------------|
| 1  | Push Button On/Off Lamp 1 | %IX2.3   | GPIO 19 | HMI_Lstart  |
| 2  | Push Button On/Off Lamp 2 | %IX2.4   | GPIO 20 | HMI_L2start |
| 3  | Push Button On/Off Lamp 3 | %IX2.5   | GPIO 21 | HMI_L3start |
| 4  | Push Button On/Off Lamp 4 | %IX2.6   | GPIO 22 | HMI_L4start |
| 5  | Push Button On/Off Fan 1  | %IX2.7   | GPIO 23 | HMI_Fstart  |
| 6  | Push Button On/Off Fan 2  | %IX3.0   | GPIO 24 | HMI_F1start |
| 7  | Push Button On/Off Fan 3  | %IX3.1   | GPIO 25 | HMI_F2start |
| 8  | Push Button On/Off Fan 4  | %IX3.2   | GPIO 26 | HMI_F4start |
| 9  | Lamp 1 Status             | %QX0.4   | GPIO 4  | L1           |
| 10 | Lamp 2 Status             | %QX0.5   | GPIO 5  | L2           |
| 11 | Lamp 3 Status             | %QX0.6   | GPIO 6  | L3           |
| 12 | Lamp 4 Status             | %QX1.4   | GPIO 12 | L4           |
| 13 | Fan 1 Status              | %QX1.5   | GPIO 13 | F1           |
| 14 | Fan 2 Status              | %QX2.0   | GPIO 16 | F2           |
| 15 | Fan 3 Status              | %QX2.1   | GPIO 17 | F3           |
| 16 | Fan 4 Status              | %QX2.2   | GPIO 18 | F4           |

3. Result and discussion

The test results indicated that the system can work properly in controlling the lamps and the fan in real-time. System testing consists of hardware and software testing, hardware testing is to test the input circuit, controllers and output circuit. Software testing includes HMI display testing through a web browser. The following Figure 5 shows system test results.
Figure 5. System testing.

Testing the software started by accessing the address http://192.168.100.12:8080/webvisu.htm then testing control and monitoring the status of lamps and fans through the HMI display. The process of control and monitoring by phone or PC works properly and in real-time, following the table of test results of the system. This test measures the success of the function and delivery time as used in previous client server research [17].

Table 2. System test results.

| No | I/O       | ON   | OFF  | Time |
|----|-----------|------|------|------|
| 1  | Lamp 1 Status | Success | Success | 200ms |
| 2  | Lamp 2 Status | Success | Success | 200ms |
| 3  | Lamp 3 Status | Success | Success | 200ms |
| 4  | Lamp 4 Status | Success | Success | 200ms |
| 5  | Fan 1 Status  | Success | Success | 200ms |
| 6  | Fan 2 Status  | Success | Success | 200ms |
| 7  | Fan 3 Status  | Success | Success | 200ms |
| 8  | Fan 4 Status  | Success | Success | 200ms |

4. Conclusion

SCADA system with ladder programming and web-based HMI display design using Codesys succeeded to perform process control and monitoring of light facilities and fans. The process of control and monitoring through the web-based HMI (Human Machine Interfaces) display can be accessed through mobile and PC with an average control time of 200ms. Uln2803IC is very important to use on this system, uln 2803 used to amplify the TTL signal from GPIO raspberry pi to drive the 8 channel relay module. The study is expected to be a low-cost system that can be applied in Politeknik Enjinering Indorama workshops and can be used as a learning medium for students in the future.

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