The SCADA system using PLC and HMI to improve the effectiveness and efficiency of production processes

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Abstract. One of the problems in the industry is waste. There are 7 wastes, namely excessive production, inventory, defect/damage, transfer/transportation, movement, waiting time and excessive processes are things that absorb and waste resources, expenses, and additional time but don’t provide any added value in the activity, and therefore this research is fundamental to create an effective and efficient production process. The purpose of this research is to find out how much effectiveness and efficiency can be achieved by a SCADA system using PLC and HMI on industrial machines. This research uses a comparative method between a conventional control system with a SCADA system using PLC and HMI to get cost and time savings results. The results obtained in this study are SCADA systems using PLC and HMI can reduce production from 1.1% to 0.3%, increase productivity 6, 1%, saving production time from 396 minutes to 352 minutes and reduce costs from 6, 71%. The conclusion obtained in this research SCADA system using PLC and HMI can improve the effectiveness and efficiency in the production process in industries.

1. Introduction
There are so many problems in the industrial world, one of them is the waste. It’s called 7 waste because it consists of 7 categories of waste [1], including excessive production of products that are ready to sell or products that are still in the process stage; inventory waste, occurs due to accumulation of finished products, semi-finished products and raw materials that require storage and additional employees to control and to document; defects or damage waste, occurs due to poor quality of production resultso that needs extra repair costs and labor costs; transportation waste due to poor layout of production areas and machines that requires activities to move goods from one process to the next process; movement waste, due to movements of machines or employees that don’t provide added value; waiting time waste, due to the machines or workers don’t do work because of waiting for status, orders, engine damage or lack of materials, so that the production process is hampered; the process wastes, because to produce a product requires reprocessing or repairs such as a repeat inspection process.

Therefore this research is vital to create an effective and efficient production process. The purpose of this research is to find out how much effectiveness and efficiency can be achieved by the SCADA system using PLC and HMI on industrial machines. This research uses a comparative method between a conventional manual control system based on physical buttons and relays with the SCADA system using PLC and HMI.
2. System presentations
The SCADA system in this research shown in figure 1. SCADA (Supervisory Control and Data Acquisition) is a computer-based monitoring and control system that is used for data controlling, monitoring and data acquisition [2-5] of a process such as manufacturing production processes, electricity generation and so on. The SCADA system has four functions: data acquisition, network communication, data presentation, data control and monitoring. The SCADA has four main supporting components, namely:

1. Input and output devices are connected directly to the PLC which is used as a data acquisition tool to find out the current conditions on the running system, such as temperature sensors, air pressure sensors, count sensors, etc.
2. RTUs (Remote Telemetry Units) are computers, in this case is a PLC (programmable logic controller) which functions to collect data from sensors and send it to a SCADA master or HMI. RTUs convert analog/digital signals provided by sensors into signals that can be sent to the SCADA Master according to the protocol used.
3. SCADA Master / Human Machine Interface (HMI), that connects users directly with the system to be able to carry out data controlling, monitoring and data acquisition.
4. Communication network, which connects SCADA Masters with RTUs either through RS232 network.

Figure 1. Block diagram of SCADA systems. Figure 2. Wiring diagram of input-output PLC.

Figure 2 shows a PLC (programmable logic controller) LS Master K120s with wiring input-output. PLC (Programmable Logic Controller) is an electronic computer that is easy to use (user-friendly) which has control function for various types and levels of difficulty. PLC (Programmable Logic Controller) is a computer specifically designed to control process or machine. This controlled process can be in the form of variable regulation continuously as in servo systems or only involves two-state control (On/Off) but is done repeatedly as we commonly find in a drilling machine, conveyor system and so on.
Definition of PLC (Programmable Logic Controller) is an electronic system that is operated digitally and designed for use in an industrial environment, this system uses programmable memory to internally store instructions that implement specific functions such as logic, sequence, timing, enumeration and arithmetic operations to control machines or processes through digital I/O (Input / Output) modules or analog [6-7].

Based on the name, the PLC concept is:

1. Programmable; shows the ability in terms of memory to store programs that have been made that are easily changed in function or usefulness.
2. Logic; shows the ability to process inputs in arithmetic and logic that is to do operations such as comparing, summing, multiplying, dividing, reducing, negation, AND, OR and so on.
3. Controller; shows the ability to control and manage the process to produce the desired output.

This PLC is designed to replace a sequential relay circuit in a control system. Besides being programmable, this tool can also be controlled and operated by people who don’t have knowledge in the field of computer operation specifically. PLC has a programming language that is easy to understand and can be operated if the program that has been created using software that is in accordance with the type of PLC used has been entered.

This tool works based on existing inputs and depends on circumstances at a particular time which will then ON or OFF the outputs. (1) indicates that the expected situation is fulfilled while (0) means that the expected condition is not fulfilled. PLC can also be applied to control systems that have a lot of output. Table 1 shows a list of input-output PLC.

| Address  | Description                  | Input          | Address  | Description                  |
|----------|-------------------------------|----------------|----------|-------------------------------|
| P0000    | Switch start/stop             | P40 Relay 1: conveyor A |
| P0001    | Emergency switch              | P41 Relay 2: conveyor B |
| P0002    | Photoelectric sensor 1        | P42 Relay 3: circulating fan |
| P0003    | Photoelectric sensor 2        | P43 Relay 4: blower |
| P0004    | Pressure sensor OUT 1         | P44 Relay 5: heater |
| P0005    | Pressure sensor OUT 2         | P45 Relay 6: spray disc A |
| P0006    | Thermocontrol EV 1            | P46 Relay 7: spray disc B |
| P0007    | Thermocontrol EV 2            | P47 Relay 8: start lamp |
| P0000    | Thermocontrol EV 2            | P48 Relay 9: indicator lamp (low temperature) and buzzer |
|          |                               | P49 Relay 10: indicator lamp Operate temperature |
| P4A      |                               | P410 Relay 11: indicator lamp low Air |
| P4B      |                               | P412 Relay 12: indicator lamp normal Air |
Figure 3 shows the PLC program created for this SCADA system.

![Program of PLC](image)

**Figure 3.** Program of PLC.

Figure 4 shows the power wiring of SCADA systems, the power circuit works by activating the MCB to the ON position so that the voltage goes into the circuit through a fuse. Turn the power switch to ON so that the zero relays (R0) will be active and R0 contacts change from NO (Normally Open) to NC (Normally Close) so that the voltage enters and activates PLC (Programmable Logic Controller), PSU (Power Supply Unit), TC (Thermocontrol), and power indicator lights. Step to turn off the circuit by turning the power switch to OFF and deactivate the MCB to OFF so that all equipment returns to OFF.
The HMI (Human Machine Interface) is to make visualization of technology or system in real terms so that the HMI design can be adjusted to facilitate physical work [8-9]. The HMI aims to increase the interaction between the machine and the operator through the computer screen, touch screen and HMI micropanel display and meet user needs for system information. HMI in the manufacturing industry is a Graphic User Interface (GUI) display on a computer screen that will be faced by machine operators and users who need machine working data. In the HMI, there are various kinds of visualizations for monitoring and machine data that are connected online and in real time. HMI will provide the description of machine condition in the form of a production machine map that can be seen which part of the machine is working. In HMI there’s also a machine controller visualization in the form of buttons, sliders and so on that can be used to control the machine as it should. Furthermore, the HMI also displays an alarm in case of danger in the system. HMI also displays machine work summary data including graphically.

By using online and real-time systems on the HMI can be obtained a system that can be controlled and monitored as soon as events occur. With the system integrated HMI, all events can be observed from the monitor screen and can control the system immediately through a computer monitor. So that this system can save time and employee to monitor and control each production workstation. Changes online can include adding tags to HMIs, controllers, editing logic on the program and controlling the OS process. An online and real-time system in HMI requires the connection between computer, control system and production machine. Under these conditions, simultaneous information can be transferred from sensors and actuators to the controller and from the controller to the computer, namely to the HMI and database. Likewise in the opposite direction. The real-time system is a system

![Diagram of equipment connections](image)

**Figure 4.** Power wiring of SCADA systems and devices.

**Table 2.** List equipment of power wiring.

| Equipment | Description       |
|-----------|-------------------|
| PLC       | Programmable logic controller |
| PSU       | Power supply unit |
| TC        | Thermocontrol     |
| LP        | Indicator Lamp    |
| S1        | Count sensor 1    |
| S2        | Count sensor 2    |
| P         | Pressure sensor   |
| CNV (M)   | Motor conveyor    |
|           | Heater            |
|           | Buzzer            |
|           | Circulation fan   |
|           | Blower            |
that provides information on a situation, where the information displayed on the receiving side matches the side observed in both times in circumstances. Figure 5 and 6 shows HMI displays.

![Figure 5. HMI display page 2-5.](image)

![Figure 6. HMI display page 6-9.](image)

The work process of SCADA system using PLC and HMI starting from the control section provides input to the PLC process section that will process it according to the program that has been made and then forwarded to the output module to activate the relay junction. If the relay is active, the relay contact used to supply voltage of 220 VAC toward the load that requires a voltage of 220 VAC and if the relay is inactive, it must be checked on the PLC input and output modules. Line painting model consists of various equipment as a display of the system. The readings result of the thermocouple and photoelectric sensors provide feedback to the process as part of the control. The following is the input and output path of each switch and keypad that is processed by the PLC:

- The start switch will send the input signal to the PLC which is then processed according to the program that has been entered into the PLC. If the PLC gives outputs, the R8 will be active so that the start indicator light turns on and if the light doesn’t turn on, it must be checked to start from the PLC input-output section of the relay and its indicator light.

- The F1 keypad screen 2, 3, 4, 5, 6, 7 and 8 gives the input signal to the PLC which is then processed according to the program that has been entered into the PLC. If the PLC gives outputs, the relay will be active so that the loads will be active and if the loads are inactive, it must be checked to start from the PLC input-output section of the relay and the load part.

- The F2 keypad screen 2, 3, 4, 5, 6, 7 and 8 gives the input signal to the PLC which is then processed according to the program that has been entered into the PLC which means that if the keypad is pressed, it will stop work rather than those loads.

- The F1 and F2 Keypad screen 9 only to reset the counter count. The status of the load and counter is displayed digitally by the HMI.
Figure 7. Communication network.

Figure 7 shows a communication network. The XGT panel that contains the program to be able to communicate with the PLC can be connected by using the RS232 serial port and cable and programs that have been created in the editor panel can be uploaded or downloaded by using the RS232 serial port and cable, the configuration of the cable arrangement has adjusted to figure 5.

3. Results and discussion

Based on the system representation in the previous section, the circuit models is realized and tested with the previous arrangement given in figure 1. Procedures of SCADA systems is Data Acquisition (Sensor): Obtain data from the equipment in the field to find out the real-time condition of the running processes, for example: the condition of the device on/off, the value of motor speed, temperature, pressure, counter, etc. Network Communication (Remote Telemetry Units): Data communication between sensors with RTU/PLC and RTU/PLC with SCADA master/HMI. In this case, RTU has an important role to bridge between sensors and SCADA network, RTU converts the sensor/relay input signal into the corresponding protocol format and sends it to the SCADA master. Data Presentation (HMI): The SCADA system can present the data needed by the user in the desired format. Control System (HMI): Control of the ongoing process can be carried in full through HMI, automatically or manually. Table 3 shows the comparison between a conventional control system with the SCADA system.

| Process          | Conventional system                                      | SCADA system                                  |
|------------------|----------------------------------------------------------|------------------------------------------------|
| Data acquisition | To obtain data have to look directly at the position where the measuring instruments | All can be done in one screen (HMI) easily and quickly |
| Data presentation| Data collection and Data input is done manually on the computer, data presentation take a long time |                                             |
| Control and Monitoring | Control and monitoring is done directly on the machine |                                           |
| Troubleshooting  | Problem analysis is done by checking one by one on the equipment | With an alarm system |
|                  | Count sensor 1                                            |                                              |
Figure 8. Results of comparison between a conventional system with SCADA system; (a) the total value of the rejected product; (b) productivity of conventional and SCADA system; (c) the length of time of production; (d) the cost of producing conventional systems and SCADA systems.

Figure 8 shows the results of comparison between a conventional system and a SCADA system in the pie chart (a) shows the total value of the rejected product that is produced from the production process for a conventional system of total rejection 1.1% and the SCADA system producing a better total rejection of 0.3%. In the bar graph (b) the SCADA system has higher productivity than the conventional system which is a productivity increase of 6.1%. In the bar graph (c) shows the length of time the SCADA system is able to do work faster than conventional systems. In the bar graph (d) shows the cost of producing conventional systems and SCADA systems compared to the predetermined standard costs SCADA system costs more economically 6.71% compared to conventional systems.

4. Conclusion

The process of designing and manufacturing SCADA systems based on PLC (Programmable Logic Controller) and HMI (Human Machine Interface) consists of two designs, namely hardware and software, for hardware consisting of PLC input/output design, power and power circuits for software comprising of a ladder diagram PLC and make an appearance on the HMI. After testing the system, the whole system can work properly, operators can more easily control, monitor and retrieve the data needed, easier to maintain and solve problems that occur, the use of HMI (human machine interface) makes installation wiring more simple, that it can be concluded that the results obtained in this research are two benefits, the first SCADA system can improve the effectiveness of the production process with operational ease. The second SCADA systems can increase efficiency by saving the cost and time used in the production process.

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