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PLC PROGRAM OPTIMIZATION ON MODULAR PRODUCTION SYSTEM DISTRIBUTION AND PICK & PLACE STATION

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ABSTRACT

Automation is becoming increasingly prevalent in industries, as it is a highly beneficial technology that increases production rates. A control system is an integral part of automation, which helps organize and process instructions or commands. A Modular Production System (MPS) is a unit consisting of different stations that simulate the design of a production system on a small scale before it is implemented in reality. MPS operations are controlled using a PLC that has been programmed using the ladder diagram, which is a commonly used programming language in PLC programming. The PLC program makes the MPS work autonomously, leading to increased work efficiency. This research focuses on optimizing PLC programs for MPS, particularly distribution and pick & place stations, resulting in improved cycle time efficiency and MPS work accuracy. Out of the three programs created, program 3 is the most efficient, with a 100% accuracy level and a cycle time of 11.276 seconds.

Keywords: *Optimization; Modular Production System; PLC; Ladder Diagram*

1. Introduction

In this modern era, industry automation development is rapidly accelerating. This is also supported by the Industrial Revolution 4.0, which gives manufacturing companies new challenges to create automation, system integration, data management, and everything becomes more efficient to meet consumer demand. [1] Industrial processes are becoming more complex because customer and market requirements change quickly [2]. Therefore, many industry players need automation designs to be applied to their industries. The development of automation is in line with the development of control systems. Control systems have a role as a link between humans and technological systems [3].

A modular Production System or MPS is a station unit used to simulate the design of a production system on a small scale before it is realized in an actual situation. In other words, MPS is a miniaturized industrial automation process consisting of various standardized components used to simulate product processing [4]. MPS can simulate that production is always consistent, flexible, and high quality [5]. Generally, MPS is implemented using a PLC as a control system that runs programs as needed to maintain safety and sequence the system [6]. MPS is composed of several actuators such as cylinders, motors, or suction cups generated by vacuum generators, also equipped with control components such as push buttons and sensors, all of which will be controlled using PLC [7].

PLC is a control system that is widely used in the industrial world. The PLC has much reliability, such as easy to program and apply, more uncomplicated system troubleshooting, relatively lower power consumption, and simpler and faster system modification [8]. The working principle of the PLC is simply that it receives an input signal which is then processed and ends with an output command [9]. PLC must be programmed first to be able to run a system. Programming commonly used is ladder diagrams because ladder diagrams have convenience or advantages in troubleshooting [10].

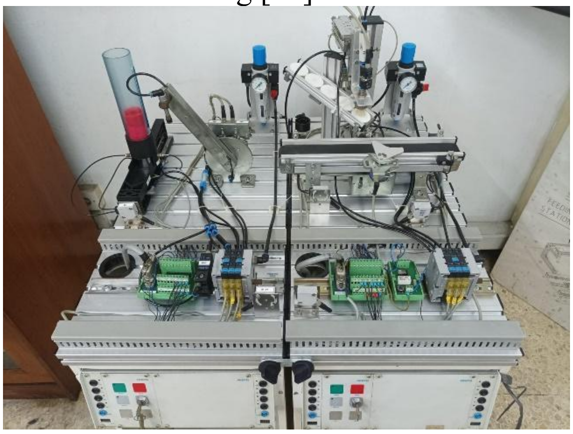

Figure 1. MPS distribution and pick & place station

A distribution Station is one type of MPS in the form of a workpiece supply distribution station. The Distribution Station has the purpose of removing the workpiece from the storage area and moving the workpiece to the next process place through the transfer module. The Transfer Module has a vacuum and rotary cylinder to move the workpiece. Pick & Place Station is a type of MPS in the form of a workpiece picking station. The Pick & Place Station aims to assemble workpieces with its components above the conveyor module. The conveyor module is used to move the workpiece to be assembled, which is equipped with a separator as the device that stops the workpiece rate from being assembled.

2. Methodology

This research used the development and experiment method to produce a more efficient output for MPS. This research is expected to create a better MPS production system.

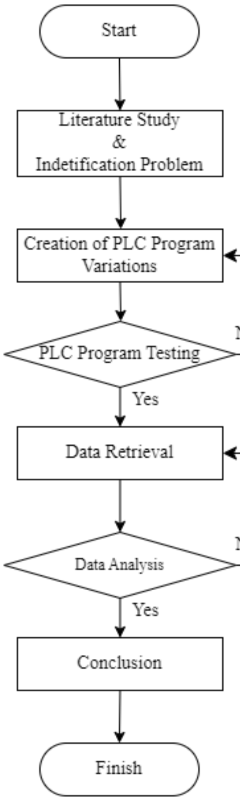

Figure 2. Research flowchart

In this research, three PLC programs for MPS will be made. Then testing will be carried out on each program to ensure program performance. Data collection is carried out for each program with variable cycle time and MPS work accuracy. From the data obtained, analysis will be carried out and determine which program is the most efficient for cycle time and accuracy for the MPS work process.

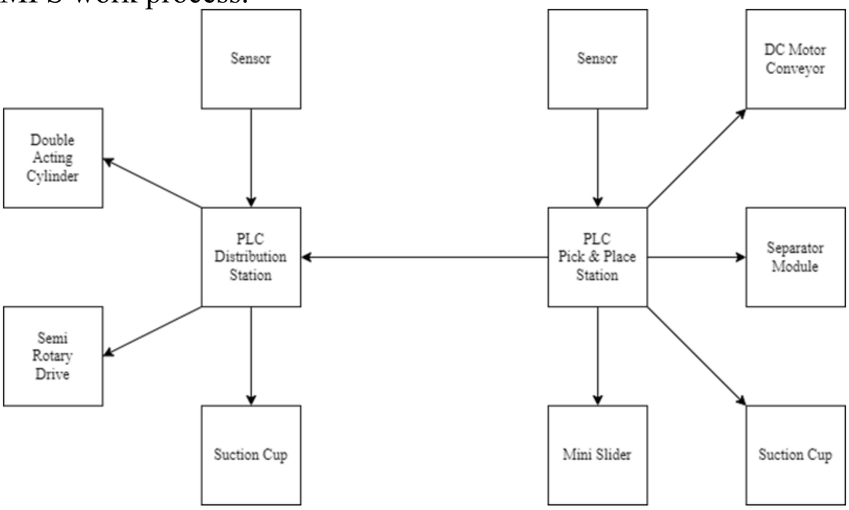

Figure 3. The schematic architecture of the MPS controller with PLC

PLC programming will use the ladder diagram programming language. PLC will be programmed to be able to control and run MPS automatically and also to be able to communicate with other MPS. The control distributes workpieces from the distribution station to the pick & place station. Where PLCs will communicate with each other to run a predetermined system cycle.

PLC will connect input from existing buttons and sensors at the Distribution Station. Then the input signal will be forwarded to actuators such as double acting cylinder, semi-rotary drive, and suction cup to be processed into output.

While at the Pick & Place Station, PLC will connect input from existing buttons and sensors. Then the input signal will be forwarded to actuators such as DC Motor Conveyor, Separator Module, Suction Cup, and Mini Slider to be processed into output.

3. Result and Discussion

After programming three times on the MPS distribution and pick & place stations, several results and analyses of the program on MPS work. For Program 1 at the distribution station, sometimes the double-acting cylinder moves late or does not move, resulting in the workpiece being processed late. The sequence program is less than optimal, where the pick and vacuum process is carried out without a holder on the workpiece, which can result in the pick position of the workpiece being moved to be less precise. At the Pick & Place Station, sometimes, when the optical sensor detects the workpiece, the workpiece becomes pushed towards the opposite conveyor due to the active separator. This event can cause inaccuracy in the pick & place process and fail the work process. So the results of the accuracy value for program 1 are as follows:

Table 1. Accuracy process program 1

Experiment	Accuracy Process	
	Distribution	Pick & Place
1	OK	OK
2	OK	Not OK
3	Not OK	OK
4	OK	OK
5	OK	OK
Total Fail	1	1

After experimenting with program 1, the accuracy results were obtained with one failure at the distribution station and one time at the pick & place station. So that if a percentage of the accuracy value for program one is obtained by:

$$Accuracy\ (\%) = \frac{Experiment\ success}{Total\ experiment} \times 100\% = \frac{8}{10} \times 100\% = 80\% \quad \text{................(1)}$$

Then for Program 2, a sequence change is made to the distribution station program. The double-acting cylinder will move backward when the vacuum sensor has turned on. This program is done so that the double-acting cylinder holds the workpiece so that the pick position does not change. So that when doing pick and vacuum, the position of the workpiece will be precise. Changes to the pick & place station separator will be in the stop position when optical sensors 1 and 3 are on. In program 1, the separator will be active when optical sensor 2 is on. This event is done to avoid the occurrence of workpieces being pushed in the opposite direction of the conveyor due to the active separator. So the results of the accuracy value for program 2 are as follows:

Tabel 2. Accuracy process program 2

Experiment	Accuracy Process	
	Distribution	Pick & Place
1	OK	OK
2	OK	OK
3	Not OK	OK
4	OK	OK
5	OK	OK
Total Fail	1	0

After experimenting with program 2, the accuracy results were obtained with one failure at the distribution station. So that if a percentage of the accuracy value for program two is obtained by:

$$Accuracy\ (\%) = \frac{Experiment\ success}{Total\ experiment} \times 100\% = \frac{9}{10} \times 100\% = 90\% \ \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

In the program three distribution station, the timer for the workpiece blow is changed to 2 seconds which was originally 1 second. This changes is done to improve the precision of the workpiece drop position on the conveyor. When the timer is used for 1 second, there can be inaccuracy in the position of the workpiece so that the workpiece may fall off the conveyor and cannot be processed. At the pick & place station, the timer to stop the conveyor and the timer to remove the workpiece vacuum was changed to 1 second, which was originally 2 seconds. These changes is done to reduce cycle time without reducing the accuracy of the work process. So the results of the accuracy value for program 3 are as follows:

Table 3. Accuracy process program 3

Experiment	Accuracy Process	
	Distribution	Pick & Place
1	OK	OK
2	OK	OK
3	OK	OK
4	OK	OK
5	OK	OK
Total Fail	0	0

After experimenting with program 3, the accuracy results were obtained with no failures at the distribution and pick & place stations. So that if a percentage of the accuracy value for program three is made, it is obtained by:

$$Accuracy\ (\%) = \frac{Experiment\ success}{Total\ experiment} \times 100\% = \frac{10}{10} \times 100\% = 100\% \ \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

After programming three times at the MPS distribution station and pick & place station and testing the program, several MPS work cycle time results were obtained.

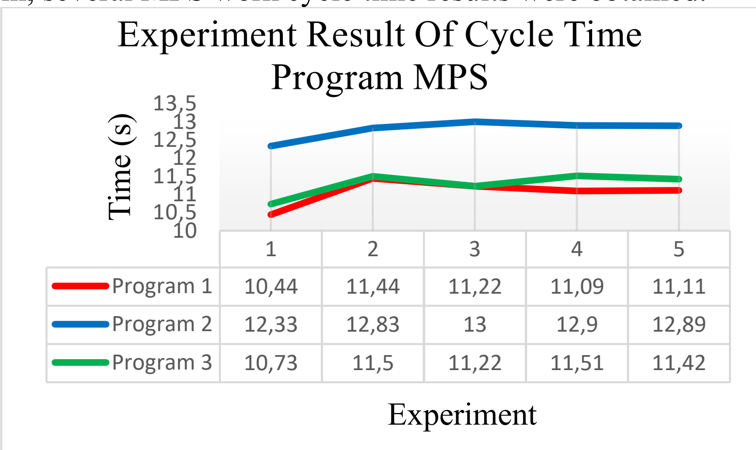

Figure 4. The experiment result of the cycle time program MPS

From the experiments that have been carried out, the average cycle time value for program one is obtained as follows:

$$\underline{X} = \frac{\Sigma\ cycle\ time}{5\ experiments} = \frac{55{,}3\ sec}{5} = 11{,}06\ sec \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

From the experiments that have been carried out, the average cycle time value for program two is obtained as follows:

$$\underline{X} = \frac{\Sigma\ cycle\ time}{5\ experiments} = \frac{63{,}95\ sec}{5} = 12{,}79\ sec \quad (5)$$

From the experiments that have been carried out, the average cycle time value for program three is obtained as follows:

$$\underline{X} = \frac{\Sigma\ cycle\ time}{5\ experiments} = \frac{56{,}38\ sec}{5} = 11{,}276\ sec \quad (6)$$

From the experimental data obtained, a program analysis of the accuracy and cycle time for the work process can be made as follows.

Table 4. Program analysis

Program	Parameter	
	Accuracy	Total Cycle Time
1	80%	11,06 s
2	90%	12,79 s
3	100%	11,276 s

Program 1 has the fastest total cycle time of 11.06 seconds, but the accuracy value is only 80%. With an accuracy value of 80%, it impacts the MPS work process, which will fail more often. So, program 1 becomes less efficient in the accuracy of the work process even though the required cycle time is fast.

Program 2 has the longest total cycle time of 12.79 seconds, but its accuracy value is greater than program 1, which is 90%. Although the accuracy value is 90%, program 2 is still less efficient because the cycle time required is longer.

Program 3 has a total cycle time between program one and program 2 of 11.276 seconds with an accuracy value of 100%. This makes Program 3 the most efficient. Where the cycle time required is not too long, and the accuracy value obtained is 100%.

4. Conclusions

Based on the three programs created, the most effective program is Program 3, with a total cycle time of 11.276 seconds and 100% accuracy. This is because the total cycle time of program 3 is between the total cycle time of programs 1 and 2 and has a higher accuracy than programs 1 and 2. So, application in MPS will be with a fairly fast cycle time, and 100% accuracy will improve the work process of MPS.

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