Cycle time analysis of automation system using PLC and HMI based Scara Robot

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ABSTRACT

This article discusses about the design of palletizing machine automation system using SCARA robot based on PLC and HMI. The purpose of this design is to be able to perform programming on the SCARA Robot using a Programmable Logic Controller (PLC), design an interface design for the control system and monitor the system response using a Human Machine Interface (HMI). And test the functional performance of the SCARA T3 robot. The design is supported by Siemens S7-1200 PLC device and Siemens KTP-700 Basic PN HMI. A series of programming processes and making system interfaces are carried out using Epson RC + 7.0 and TIA Portal software. The results of the test can be concluded the design of the palletizing machine automation system can run well at 80% high speed with a 100% success percentage and 0% error percentage.

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1. INTRODUCTION

The Cyber Physical Production System, or CPPS is the fourth industrial revolution that is now under progress and is drastically altering how various industries function [1]. With the use of cutting-edge technologies like the Internet of Things, artificial intelligence, robotics, human-machine interaction, and 3D printing, this system combines the actual and virtual worlds [2]-[3]. Companies must successfully apply these five elements if they want to compete in the Indonesian manufacturing era. One of the applications of the industrial revolution 4.0 in the manufacturing sector is the use of industrial robots [4]-[5]. Robots function to help human work, including in the industrial field [6].With various forms and functions, robots can complete various tasks, including in the production process. In this research, the focus will be given to the SCARA robot, which is a type of arm robot that is often used in industry.

SCARA robots, or Selective Compliant Articulated Robot Arm, have simple movements and are very suitable for assembly tasks as well as moving goods from one location to another [7]-[8][9]. The use of SCARA robots requires a deep understanding of robotics concepts in order to be programmed properly, ranging from basic to advanced level applications. The operator controlling and programming the robot must prepare an algorithm based on the workflow to be performed [10]. One of the applications of the SCARA robot is in palletizing systems, which is an automated system for placing products or goods onto pallets [11]. The palletizing process is very important in logistics and distribution, especially in the manufacturing industry. The use of SCARA robots in palletizing systems can improve the efficiency and quality of the production process thanks to the speed, accuracy, and flexibility offered [12].

In the context of industrial automation, the use of Programmable Logic Controller (PLC) and Human Machine Interface (HMI) is very important [13]. PLC serves as the brain of the automation system, which can be programmed to control various hardware such as motors, sensors, and actuators [14]. With a PLC, the palletizing process can be optimized to reduce downtime [15]. On the other hand, HMI allows operators to interact with the system more effectively, monitor machine performance, and make necessary settings without intensive training. It is anticipated that the palletizing machine automation system's integration of the SCARA robot with PLC and HMI will offer a practical way to raise worker safety and quality. In addition to increasing productivity, this technology makes the workplace safer by lowering the amount of human intervention in high-risk tasks. As a result, in the context of industry 4.0, the study and development of palletizing machine automation systems utilizing SCARA robots based on PLC and HMI becomes extremely pertinent.

2. METHOD

This research aims to design and implement a palletizing machine automation system using a PLC-based SCARA robot and HMI. In order to achieve these objectives, this research method includes several main interrelated stages, namely system design, hardware design, software design, and system testing. Each stage is designed specifically and in detail to ensure that the system can function properly in accordance with the research objectives. Figure 1 show the block diagram of proposed system.

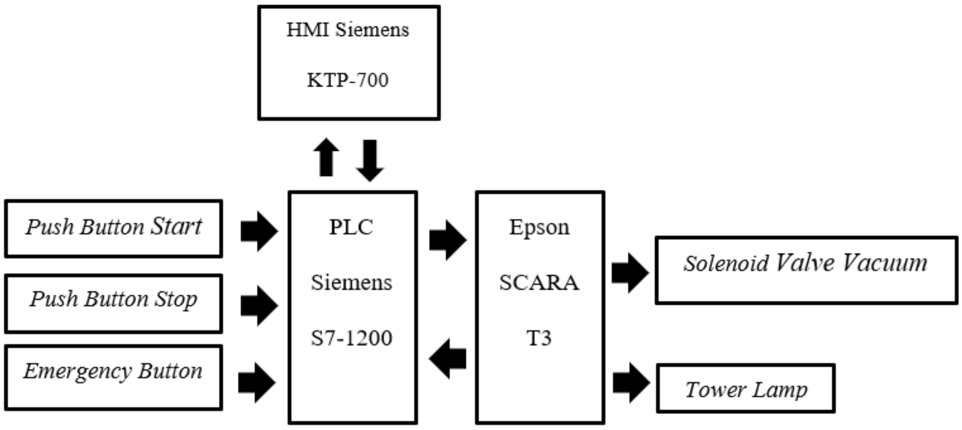

Figure 1. System Block Diagram

The initial step of system design involves creating a block diagram that shows how the different parts of the system interact with one another. A Siemens S7-1200 PLC controller processes inputs such push-button start, push-button stop, and emergency button, which are among the system's primary components. Furthermore, the Siemens KTP-700 HMI interface facilitates human contact, and the PLC provides instructions that operate outputs like solenoid valves and tower lighting. The primary actuator for the palletizing process is the SCARA Epson T3 robot, and all parts are integrated to guarantee the system can operate effectively and automatically.

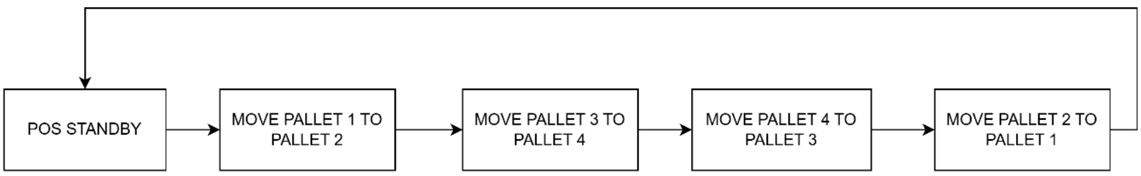

Figure 2. Working Principle of the Tool

Furthermore, the working principle of the tool is explained by emphasizing that the tool performs the palletizing process automatically and repetitively until the system is stopped. The SCARA robot starts from the standby position, then moves the workpiece from pallet 1 to pallet 2, continues to pallet 3 and pallet 4, before reassembling the objects from pallet 4 to pallet 3, and from pallet 2 to pallet 1. The process repeats until the system is stopped via the stop or emergency button. The working principle of the device and a sketch of the palletizing machine system are shown in Figure 2 and Figure 3, which provide a visual representation of the work sequence of the robot in the system.

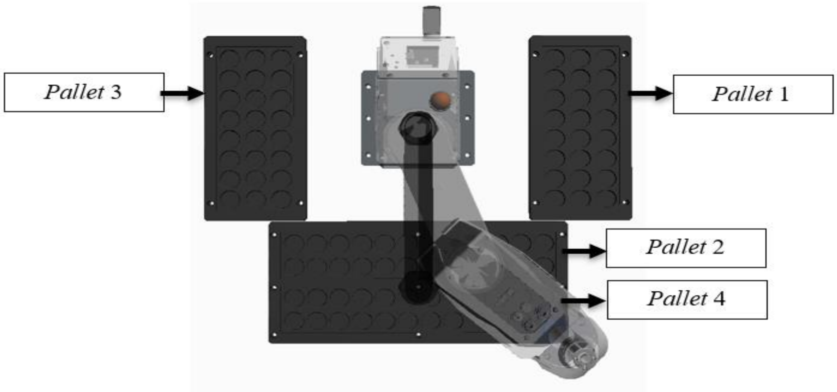

Figure 3. Sketch of the Palletizing Machine

To make it easier to understand the workflow of the system, a system flowchart is used to visualize complex processes to be simpler and more structured. The flowchart includes the main steps, starting from system initialization, palletizing process, to system termination. The palletizing system flowchart is shown in Figure 4, which shows how each step is interconnected and contributes to the overall functioning of the system. Following the stages of this research not only designs an efficient palletizing machine automation system, but also ensures that each component and process functions harmoniously to achieve the desired goal.

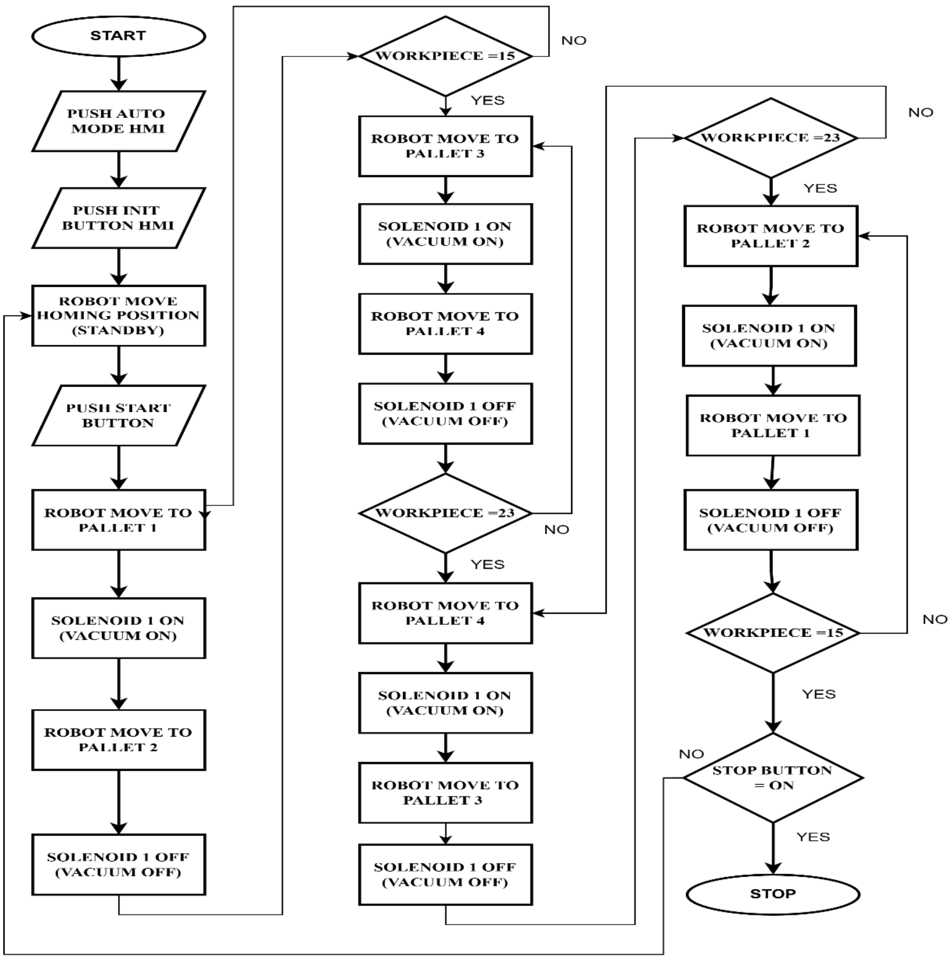

Figure 4. System Flowchart

3. RESULTS AND DISCUSSION

InSCARA robot function testing was conducted to evaluate the robot's performance in carrying out the palletizing process. The speed of the robot was chosen based on consideration of the weight of the workpiece and the robot's space. If the speed was slow, it can affect production efficiency, while speed was high, it can affect accuracy and precision. Tests were conducted with three speed variations: 60%, 80%, and 100%. Each test was conducted five times to obtain the average time and success rate.

At 60% speed, the average time taken for one palletizing cycle was 300,4408 seconds or 5,07 minutes, with a 100% success rate. The test data is shown in Table 1. At this speed, the palletizing process on the palletizing machine system shows success up to 100 % success rate, but at this speed it produces a very long cycle time, so it is not recommended as the default speed to be used on the palletizing machine.

Table 1. Speed Testing Results 60%

Experiment	Cycle Time (s)	Success Rate (%)
1	300,448	100
2	300,440	100
3	300,466	100
4	300,414	100
5	300,436	100
Averages	300,4408	100

At 80% speed, the average time taken for one palletizing cycle was 289.112 seconds or 4.81 minutes, with a 100% success rate. The test data is shown in Table 2. At this speed, the palletizing process on the palletizing machine system shows success up to 100 % success rate, and at this speed produces a faster cycle time than the speed of 60%. Making this speed is recommended and set as the default speed of the palletizing machine system with the best accuracy.

Table 2. Speed Testing Results 80%

Experiment	Cycle Time (s)	Success Rate (%)
1	289,092	100
2	289,142	100
3	289,112	100
4	289,092	100
5	289,122	100
Averages	289,112	100

At 100% speed, the average time taken for one palletizing cycle was 281,3084 seconds or 4,68 minutes, with a 92% success rate. The test data is shown in Table 3. At this speed, it shows faster cycle time results than the previous one, but has a success rate that continues to decrease in each experiment. At this speed, the robot produces very high vibrations, so that the workpiece is detached from the vacuum suction cup which results in the palletizing process cannot be successfully carried out. It shown in figure 5.

Figure 5. Workpiece Detaches From Vacuum Suction Cup

Table 3. Speed Test Results 100%

Experiment	Cycle Time (s)	Success Rate (%)
1	281,352	97
2	281,298	94
3	281,294	89
4	281,346	89
5	281,252	89
Averages	281,3084	92

The result of the system in moving workpieces using the palletizing system can be seen in Figure 6 and Figure 7, which show the position of workpieces on pallets 1, 2, 3, and 4.

Figure 6. Workpiece on Pallet 1 and 2

Figure 7. Workpiece on Pallet 3 and 4

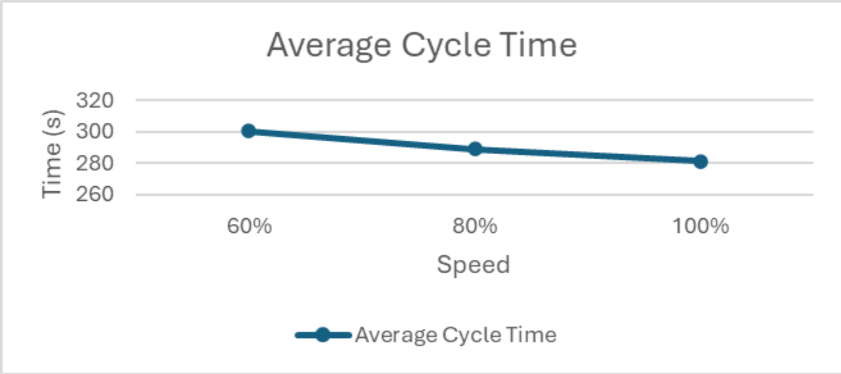

Figure 8. Cycle Time Testing Graph

Figure 8 is a graph of the average cycle time test results from 60% to 100% speed and the recommended speed for use in this system is 80 percent speed with a success rate of up to 100 percent. From the results of the experiments that have been carried out, the 80% speed was chosen based on the results of the accuracy and precision of the palletizing process on the palletizing machine.

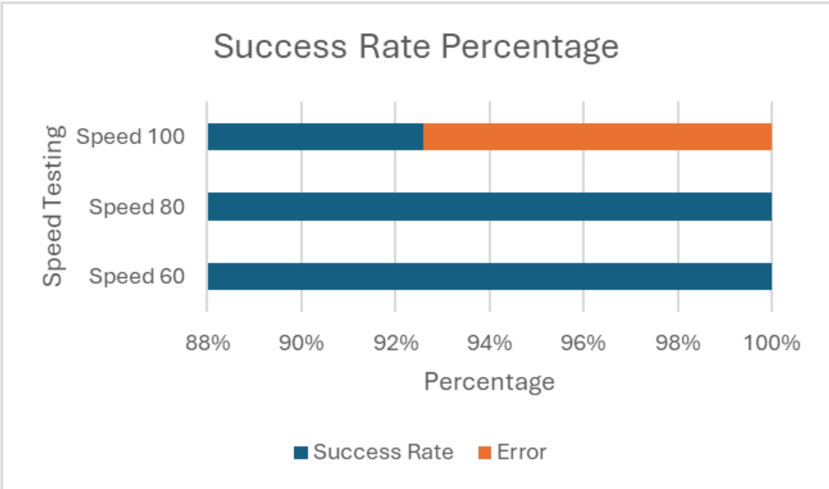

Figure 9. Success Rate Graph

Figure 9 shows a graph of the success rate of the palletizing process carried out by the palletizing machine using a PLC and HMI-based robot, the graph shows that at speed of 60 percent, the robot has a success percentage of 100 percent, but has a low cycle time, when experimenting using a speed of 80 percent, the robot has a success rate of up to 100 percent, so this speed was chosen as the default speed of the system, while the speed of 100 percent has a success rate of 92 percent, due to the vibrations produced by the robot making the workpiece detached from the vacuum suction cup

4. CONCLUSION

The design of the palletizing machine automation system using a PLC and HMI-based SCARA robot has successfully met its goals, according to the results of the tests and discussions that have taken place. This is because the SCARA T3 robot has proven to be an effective palletizing medium, the programming has been successfully executed, and the system is functioning in accordance with the program that was designed. Through the Human Machine Interface (HMI), the created interface design enables control and monitoring of the system reaction. According to the test findings, the system operates best at 80% speed, at which point the success rate rises to 100%. Efficiency gains and the incorporation of new technology, including sophisticated sensors to improve precision, are among the development potential.

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