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Analysis of Scara Robot program design using PLC for material handling automation system

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ABSTRACT

Industrial automation is increasingly developing in improving efficiency and productivity, one of which is the use of SCARA (Selective Compliant Articulated Robot Arm) robots. This research discusses the design and testing of SCARA robot programs for material handling automation systems based on Programmable Logic Controller (PLC). Testing is done using software and hardware, including function block diagrams, and implementation of the SCARA robot program. The test results show that the designed automation system can function optimally, with integration between the robot, conveyor, and sensors running efficiently. In addition, the robot program is able to execute commands with high accuracy, including automatic material removal. This success confirms that the system design can be applied to improve efficiency in industrial production processes.

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1. INTRODUCTION

The development of the times at this time occurs very rapidly. Technology and knowledge are developing more and more in various industries. Modern manufacturing industries are increasingly dependent on automation technology to improve efficiency, productivity, and consistency of production output [1]-[3]. One of the key elements in industrial automation is the use of robots that are capable of performing complex tasks with high precision. To control robots, a reliable control system is needed and can be integrated with various other hardware and software [4], Automation in the industrial world is also often referred to as industrial automation is one of the realizations of technological developments which is an alternative to obtaining a fast, accurate, effective and efficient work system [5].

Robot is an automation system that functions to assist humans in doing a job [6], Robot consists of a combined series of equipment that is given a program and can be reprogrammed [7], and has many functions that are usually created to move goods. One type of robot that is developing is the SCARA (Selective Compliant Articulated Robot Arm) robot, the SCARA Robot is a robot arm consisting of 4 axes and can mimic human hand movements [8],[9]. In addition to robots, PLC (Programable Logic Control) is an industrial control equipment that can regulate sequential processes as needed [10], Several programming methods commonly used by PLCs include ladder diagrams which are derivatives of conventional relays making it easier to apply PLCs as industrial controls and function blocks are graphical programming languages that combine functions in the form of logic such as AND, OR, NOT to produce outputs using lines and signs to represent variables in a more graphical format [11]-[13].

One of the applications of systems that use robots and PLC in material handling automation systems. Material handling is the process of moving, controlling and protecting materials in a production system [14], one of which the application of automation technology in material transfer has great potential to revolutionize manual systems with fully automated processes. The material transfer automation system is designed to minimize dependence on humans and the time required in the manual process, besides that an automated system can do a job repeatedly, does not require rest time, and is easily programmed according to human wishes [15]. According to research [16] material handling equipment is an important chart in the industrial world in the production process, where in the production process the product needs to be moved from one point to another using a conveyor as a product mover.

2. METHOD

The method used in this research is the design of the SCARA Robot program for PLC based material handling automation systems. Program testing is done using software and hardware. The tested program includes, first testing the function block diagram program, second testing the scara robot program. Testing was carried out at Universitas Negeri Padang.

Figure 1 shows the flowchart of the system work starting from the push start button is pressed then the PLC will process the input signal and then the PLC signal is sent to the robot to turn on the robot power, after that when the HMI start is pressed, the robot will move to the home position, then move to the coordinate point position 1 and the solenoid is active to pick up the workpiece, after that the robot moves to position 2 to place the workpiece and the solenoid turns off. When the workpiece has been placed on the conveyor, the photoelectric sensor 1 will detect the workpiece then the signal goes to the PLC and then the PLC is processed. After that the PLC will send an output signal to the conveyor so that the conveyor will turn on. When photoelectric sensor 2 detects the workpiece, the PLC will process and send an off signal to the conveyor.

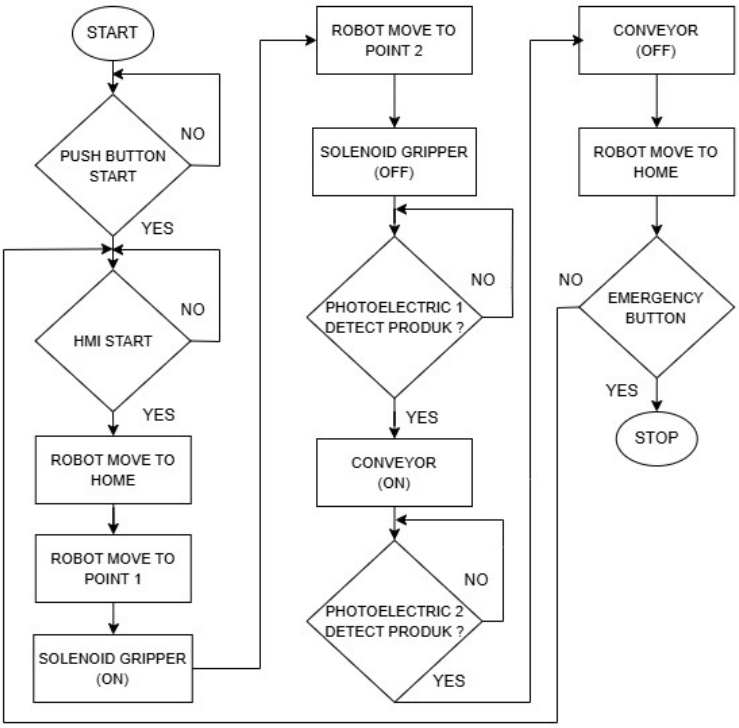


Figure 1. Flowchart System

3. RESULTS AND DISCUSSION

In After testing the data program through software and hadrware, the results of the tests that have been carried out are presented in the form of tables and simulations. The following is the system result data after testing, including:

3.1. PLC Program Testing Using Function Block Diagram Language

Figure 2 shows the simulation results of testing the program when the push button start with address %I0.0 is pressed, it will activate the output address %Q2.0 using the set command (S) which serves to turn on the robot motor. This shows that the system uses the set method, where the motor will remain active after the button is pressed without having to hold the button continuously.

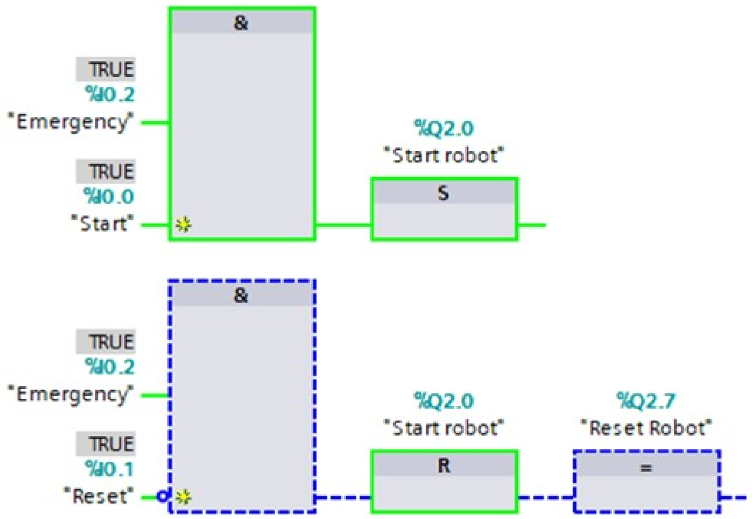


Figure 2. Conditions Button Start Active and Activate the Robot

Figure 3 displays the condition when the reset push button with the address %I0.1 is FALSE then the system will disable the %Q2.0 output with the reset command (R) and the robot motor stops. FALSE is used NOT logic because the reset button uses NC contacts where the input is 1 then the output will be 0, and if the input is 0 then the output will be 1.

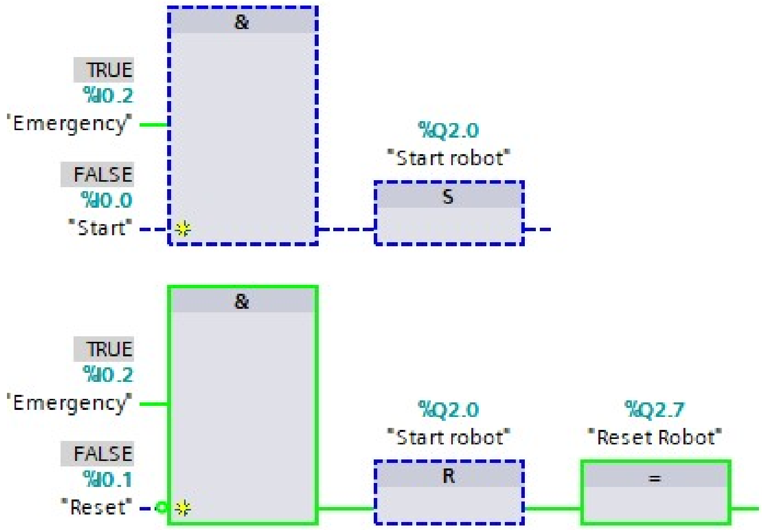


Figure 3. Conditions Button Reset Active and Deactivatesthe Robot

Figure 4 shows the condition when the robot start and emergency programs are active and start hmi with memory bit address %M0.0 is activated, then output %Q.3.5 will also be active and the system executes the robot movement command according to the program that has been made. This activation shows that the memory bit serves as the main trigger in the control system and ensures that the robot only moves when the initial conditions are met. Figure 5 shows the condition when the robot start and emergency programs are active and stop hmi with memory bit address %M2.0 is activated, then output %Q.2.4 will also be active and the program executes the robot movement command to stop.Figure 6 shows the condition when the robot start program and emergency program are active and the Home hmi with memory bit address %M0.1 is activated, the output %Q.3.0 will also be active and the program commands the robot to move to the home position that has been created in the teaching robot.

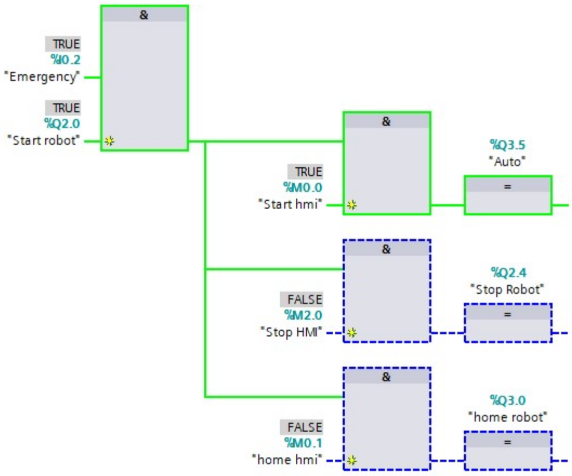


Figure 4. Condition Output Auto Active

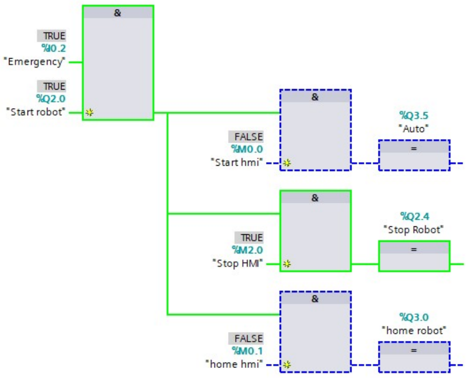


Figure 5. Condition Output Stop Robot Active

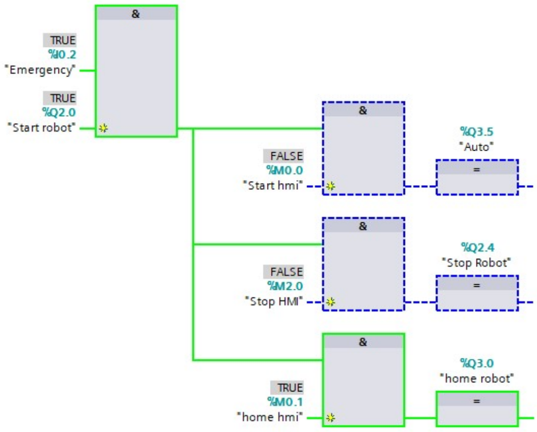


Figure 6. Condition Output Home Robot Active

Figure 7 shows the program instructing the conveyor to start operating to move product when photoelectric sensor 1 with address %I1.4 detects the presence of an object. When the object is detected, the sensor will activate and activate the timer for 0.2 seconds before finally turning on the conveyor. The use of the timer functions as a delay to ensure that the object is actually detected before the conveyor is activated. After the 0.2 second delay is complete, the timer will activate the conveyor output with address %Q5.2 using the set coil. The use of a set coil in the program indicates that the conveyor will remain active even if the sensor no longer detects objects, so it does not require continuous detection of objects to keep the conveyor running.

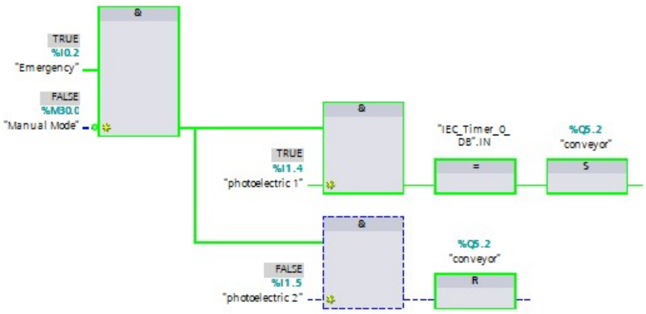


Figure 7. Condition Photoelectric 1 and Set Conveyor Active

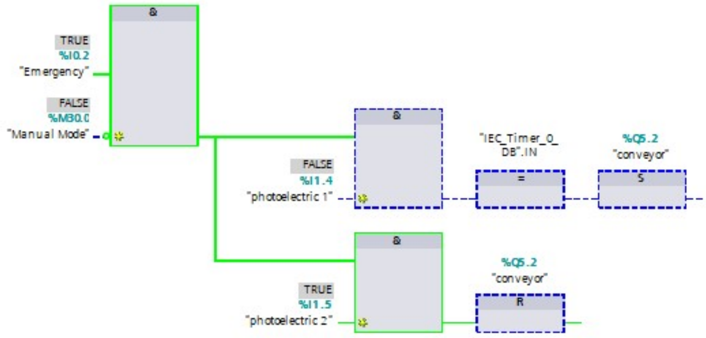


Figure 8. Condition Photoelectric 2 and Reset Conveyor Active

Figure 8 shows when photoelectric sensor 2 with address %I1.5 detects an object, the sensor will activate and give a signal to disable the conveyor output with address %Q5.2 using the reset coil (R) command.

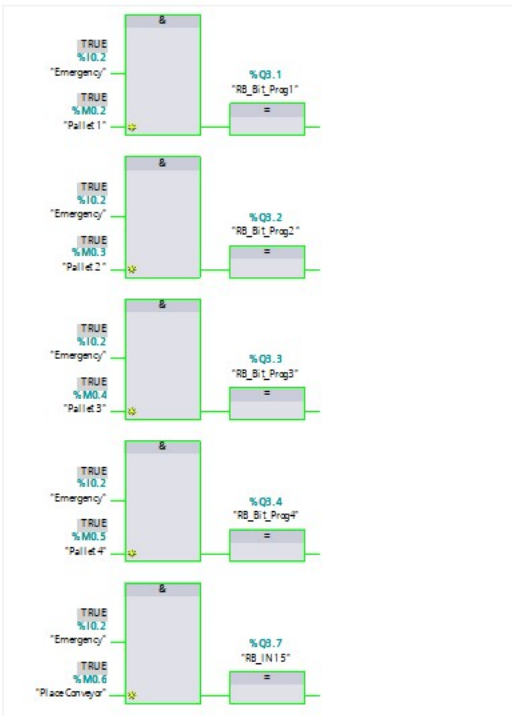


Figure 9. Simulation of Robot Movement According to Pallet

Figure 9 shows that each pallet is controlled using memory bits from %M0.2 to %M0.6, which determine the movement of the robot to the pallet position. If emergency is active and one of the pallet bits is activated, then the corresponding output will be activated to control the robot or conveyor. The first pallet is controlled by %M0.2, and if it is active, then the system will activate %Q3.1, which sends a signal to the SCARA robot to execute the command that has been programmed in RB_Bit_Prog1. The second pallet is controlled by %M0.3, which activates %Q3.2 when conditions are met, allowing the robot to execute the task associated with the second pallet. This process continues for the third and fourth pallet, which are controlled by %M0.4 and %M0.5 respectively, with outputs %Q3.3 and %Q3.4 commanding the SCARA robot to move to the corresponding pallet position. In addition to pallets, there is also a special condition controlled by %M0.6, referred to as “Place Conveyor”. If this bit is active at the same time as the emergency condition, the system will activate %Q3.7, which controls RBIN15 to activate the conveyor.

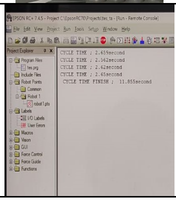
3.2. SCARA Robot Program Testing

This test focuses on evaluating the function of the program implemented on the SCARA robot. Table 1 displays each program instruction, such as system initialization, movement to a specific position, object removal, and object placement, tested to ensure that the control logic runs according to the program that has been created. At the System Initialization instruction, success indicates that the robot is ready to begin operation. The initialization stage is very important because it is the command to start the program. Furthermore, the instruction If Sw(RB_IN_Action_Start) = On Then is the activation of the robot motor as an input signal and gives an indication that the robot is ready to run. The next step, Call Homing to ensure that the robot is in an accurate initial position (homing) before starting the operation cycle. The instruction Call PALLET_POINT 1 to Call PALLET_POINT 4 shows the success of the robot in moving products one by one from the pallet to the conveyor.

In the Print “CYCLE TIME FINISH” step, the system records the operational cycle time from start to finish. This data is very useful for system efficiency analysis. For example, the cycle time can be used to stop the robot performance under operational conditions. The analysis of the SCARA robot program testing reveals that the control logic implemented functions correctly and aligns with the intended operational flow. Overall, the test results confirm that the SCARA robot’s program logic operates reliably and is capable of performing the expected tasks with precision.

Table 1. Testing the Robot Program Instructions

No	Program Instructions	Test Results	Information
1	System initialization		System ready to start
2	If Sw(RB_IN_Action_Start) = On The		Motor starts and ready to run
3	Call Homing		Robot moves to Homing position
4	Call PALLET_POINT 1		Robot moves product 1 from pallet to conveyor
5	Call PALLET_POINT 2		Robot moves product 2 from pallet to conveyor

6	Call PALLET_POINT 3		Robot moves product 3 from pallet to conveyor
7	Call PALLET_POINT 4		Robot moves product 4 from pallet to conveyor
8	Print " CYCLE TIME FINISH”		The program displays the program cycle time from start to stop

4. CONCLUSION

Based on the test results and discussion of the SCARA robot-based material handling automation system, PLC, and HMI that have been discussed, it can be concluded that PLC program testing using Function Block Diagram (FBD) at TIA Portal shows that the robot automation system for material handling functions according to the program that has been made. The use of AND, OR, and NOT logic gates in the program language facilitates understanding in making programs. Control of automatic, manual robot movements to pallet points and logic-based conveyors has been successfully programmed so that the robot can be run through program commands from the PLC. SCARA robot program testing is able to carry out all program instructions according to the program and teaching that has been made, such as system initialization, movement to a certain position, object removal, and object placement.

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