Omron PLC-Based Automated Goods Packaging System Design

Marsal Nasution, Zuraida Tharo, Parlin Siagian

Abstract

This research aims to design and test Omron's PLC-based automated goods packaging system in the product packaging process. The system combines PLC technology, industrial robots, and sensors to improve efficiency and accuracy in packaging. The test was conducted in two modes, namely manual mode and automatic mode, with a focus on the filling process, bottle cap placement, and bottle cap sealing. The test results showed that in manual mode, the system can pack one bottle in a row, while in automatic mode, the system can pack three bottles efficiently with an efficiency of up to 99.99%. In addition, tests on the actuator and sensor show that all components are in good working order, and the system can detect the position of the bottle as well as control the milk flow with precision. The use of Omron's PLC as a control center provides ease of programming and improves system reliability. Overall, the study shows that Omron's PLC-based automated packaging system is effective in increasing productivity and reducing reliance on manual labor, with the potential to be applied in large-scale packaging industries.

Keywords: Automatic Packaging System, Omron PLC, Industrial Automation, Actuator, System Efficiency.

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Introduction

Modern Industrial Fiber is currently experiencing very rapid development, along with the adoption of advanced technology in various aspects of operations. One of the sectors that has made significant progress is the packaging and sorting process, which is now increasingly turning to automation. The use of technology in packaging not only aims to minimize the risk of product contamination, but also provides protection for products from physical damage, as well as supports product marketing and branding efforts more effectively. In addition, automation in packaging allows for increased efficiency, both in terms of time and cost, and provides greater flexibility in responding to changes in design and evolving product characteristics [1].

Along with these advancements, the need for automated packaging systems that can increase productivity and reduce reliance on human labor is becoming more urgent. One potential solution in this regard is the application of industrial robots equipped with integrated vision technology. By relying on this technology, the packaging process can be carried out with a higher level of precision, efficiency, and accuracy. In addition, industrial robots are able to adapt to different types of products that require different handling, providing greater flexibility in automation applications. [2].

One of the technologies that has proven effective in controlling industrial automation is the Programmable Logic Controller (PLC. PLC is a control system that is widely used in the industrial world, replacing the relay circuit in conventional control systems. The system works by receiving input signals from various sensors attached to the machine, processing that information, and generating output signals that correspond to pre-programmed programs. The main advantage of PLCs, when compared to conventional control systems, lies in their ability to handle complex and repetitive processes with a very high level of reliability, as well as the ability to be integrated with a variety of other industrial devices, such as industrial robots. [3].

The use of PLC in automated goods packaging systems is a very ideal choice, especially for packaging processes that demand speed, precision, and efficiency. PLC can control production machines more effectively, ensuring that the entire packaging process runs smoothly, in accordance with established quality standards, and meets the increasingly stringent demands of the industry related to quality, time, and cost. [4].

In this context, this study aims to design and develop an automated goods packaging system based on Omron's PLC. This system is expected to provide a more effective and efficient solution in the packaging process, by utilizing the advantages of PLC technology to control the automatic machines involved in the packaging of goods. Thus, this research is expected to make a significant contribution to the development of automated packaging systems that not only increase productivity, but also reduce reliance on manual labor in industry, making them more adaptive, efficient, and sustainable. [5].

Literature Review

1. Automated Packaging in Industry

Automatic packaging is one of the important innovations in the modern industrial world. This process focuses not only on speed and efficiency, but also on improving product quality. Several studies show that automation in packaging can reduce the likelihood of human error, improve product consistency, and optimize resource utilization. One significant example of implementation is the use of industrial robots in production lines, which have proven effective in addressing various manual packaging challenges, such as product speed and variety (Tan, 2020.

2. PLC Technology in Industrial Automation

Programmable Logic Controllers (PLCs) have become an essential component in industrial automation, replacing conventional relay-based controls. PLCs allow for more flexible and efficient control of machines and processes. PLCs work by monitoring and regulating inputs automatically, and can be programmed to control different types of industrial devices. According to several studies, such as those conducted by Kumar & Singh (2021), the use of PLCs in the manufacturing industry can reduce downtime, improve system reliability, and minimize operational errors. In addition, PLCs can be integrated with a variety of sensors and other devices, allowing the automation process to run optimally.

3. Integration of Industrial Robots with PLC

The integration between industrial robots and PLC systems is becoming a growing trend in the manufacturing industry. Industrial robots are equipped with advanced sensors and an integrated vision system that allows them to recognize objects and adjust the packaging process according to the characteristics of the product. This combination allows for greater flexibility in handling different types of products that have different sizes and shapes. A study by Lee et al. (2022) posited that the integration of industrial robots with PLCs in packaging lines can significantly increase productivity, especially in the packaging of products that require high precision and packaging in large quantities.

4. Use of Omron PLC in Packaging Automation

Omron PLC is one of the brands of PLCs that are often used in industrial control systems. The advantage of Omron PLCs lies in its ability to offer efficient and flexible control solutions in a wide range of industrial applications, including automated packaging systems. Omron PLCs are equipped with a variety of input-output modules that can be adapted to the needs of the system, and have communication capabilities that allow integration with other devices, such as robots and sensors. In the context of automated packaging, Omron PLCs enable highly efficient machine control, as well as provide ease in system programming and maintenance (Hansen & Liu, 2021.

3. Research Method

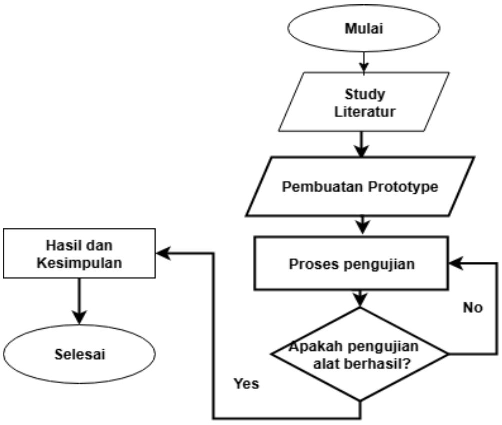

Figure 1. Research Flow

Research Flow

1) Literature Studies
   The research began by examining the theory of automated packaging, PLC technology, and the application of industrial robots in packaging systems. The literature collected includes books, journals, scientific articles, and relevant online resources to understand the basics of automation systems and their components, in particular the Omron PLCs used for system control.
2) Determination of Parameters and Assumptions
   At this stage, the research determines the components to be used in the system, such as Omron's PLCs, sensors, and industrial robots. In addition, important parameters such as

packaging speed, product type, and packaging are also set so that the system can function properly and according to production needs.

3) Automatic Packaging System Design
   The design phase involves the creation of a design of Omron's PLC-based automated packaging system, which includes the creation of flowcharts and block diagrams to illustrate the relationships between components. In addition, the PLC program will be structured to regulate all packaging processes, from motor control, sensors, to industrial robots used to handle products.
4) Prototype Development and Implementation
   Once the design is complete, the next step is to assemble the physical system by bringing together all the components such as Omron's PLC, robots, and sensors. The program that has been created will be implemented into the PLC to ensure that all components can work automatically according to the predetermined design.
5) System Performance Testing and Evaluation
   The assembled system is then tested with different types of products to ensure that the packaging process runs efficiently and accurately. During testing, the system's performance will be evaluated, including packaging time, product accuracy, and the degree of reliance on human labor.
6) Analysis of Test Results
   The results of automatic packaging will be compared with manual packaging systems in terms of time, cost, and product quality. In addition, issues that arise during testing, such as packaging errors or glitches in the system, will be analyzed for further improvement.

7) Conclusions and Recommendations
   After evaluation, the study will draw conclusions regarding the effectiveness of Omron's PLC-based automated packaging system. In addition, recommendations will be provided for further development of the system, as well as its application in industries that require automated packaging processes to improve efficiency and reduce reliance on manual labor.

Results

4.1 Tool design

Programmable Logic Controller (PLC) is a control system designed specifically for industrial applications, thanks to its reliability and ease of operation. The main advantage of PLCs lies in their hardware and software capabilities that have been adapted to meet the operational needs of industrial environments, which require high standards and precision. In general, a PLC consists of several main components, including inputs, outputs, and other elements that are interconnected in a system block diagram.

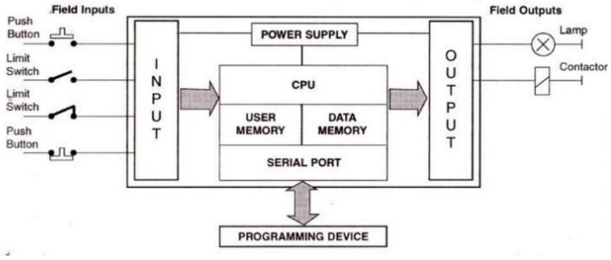

Figure 2. PLC Block Diagram

The CPU on a PLC serves as the main regulator in running all the processes that occur in the PLC system. The three main components that make up a PLC CPU are the processor, memory, and power supply. The processor is in charge of executing instructions and processing the data received from the inputs, then producing the output according to the programmed program. Memory serves to store temporary data, such as running programs as well as input-output data, allowing the PLC system to run smoothly without interruption. Meanwhile, the power supply provides the power needed to operate the entire PLC system, ensuring smooth and stable performance. Effective interaction between these three components is very important to maintain the reliability and smooth operation of the PLC system. In general, PLC operation is quite simple, where the external equipment used as input or output is connected to the input and output modules on the PLC. This external equipment can be in the form of sensors such as limit switches, push buttons, solenoid motors, and others.

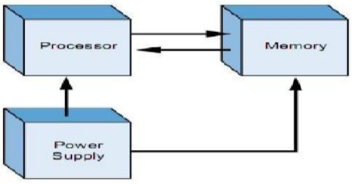

Figure 3. CPU Block Diagram on PLC

4.2 Sensor Testing

The proximity switch on the plant filling and capping bottle functions as a position sensor to detect the location of the bottle. The float sensor is used as a level sensor to detect the volume of liquid in the filling tank, while the limit switch is used to calculate the number of bottles in automatic mode. Table 1. shows the test results of the sensors used in the system. The proximity switch detects bottles that have an average voltage of 7,465V, which indicates that this sensor is operating with an active low nature. The float sensor, when detecting the volume of water in a full filling tank, produces a voltage of 0.01V. Meanwhile, the limit switch detects bottles with a voltage value of 0.02V.

Table 1. Sensor Test Results

Sensors	**Voltage (V)**	**PLC Indicator**
	Active	Digit
Proximity Sensor 1	6,61	23,8
Proximity Sensor 2	8,32	24,1
Limit Switch 1	0,02	23,6
Float Sensor	0,01	24,0

From the test results, it can be seen that these sensors operate with an active low nature, which is in accordance with the wiring design of the COM PLC, where the COM pin is connected to the VCC (+24VDC. This ensures that the input system functions properly according to the original design.

4.3 Actuator Testing

Actuator testing is done to ensure that the actuator is functioning properly, using two different types of voltages which are 12V and 24V. The output voltage generated by the CP1E PLC output is 24VDC. This test aims to verify whether the actuator is performing as intended, which is done by checking the voltage value delivered to the actuator. In addition, tests were also carried out on OMRON LY2N series relay coils, which will be controlled by the output from the PLC. The test results on the relay coil showed that the measured average voltage was 23.77V.

Table 2. Actuator Test Results

Actuator	**Voltage (V)**	**Actuator Conditions**
	Active	Idle
Motor Power Window	23,89	11,89
Selonoid Valve 2/2	23,67	11,69
Motor DC	24,03	11,84
Pump	23,78	11,82
Selonoid Valve 5/2 (1)	23,87	11,59
Selonoid Valve 5/2 (2)	23,83	11,65

Selonoid Valve 5/2 (3)	23,6	23,7
Selonoid Valve 5/2 (4)	23,5	23,3

4.4 Testing the Filling Process with On/Off Control and Without On/Off Control

The testing process is carried out to compare the filling system with and without on/off controls. In uncontrolled testing, the milk in the filling tank will continue to flow until there is no milk left. Seven data were taken during the test, which showed variances in the volume of filled bottles according to the height of the milk surface.

Table 3. Uncontrolled Filling Test Results

Milk Surface Height (cm)	Filled Bottle Volume (ml)	Set Point Bottle Volume (ml)
6	100	100
7	95	100
9,5	88	100
11	85	100
13	80	100
19	75	100
24	50	100

From the results of the test above, it can be seen that in the first data, the volume of milk in the bottle is in accordance with the set point, which is 100 ml. However, after repeated testing, the volume of milk filled in the bottle decreased. The most significant decrease in milk volume occurs when the milk surface height reaches 24 cm from the height of the tank.

Table 4. Testing Results of Filling with Control

Milk Surface Height (cm)	Filled Bottle Volume (ml)	Set Point Bottle Volume (ml)
6	100	100
6	100	100
6	100	100
6	100	100
6	100	100
6	100	100
6	100	100

In a controlled filling system, the filling results show good stability. Each time the experiment was carried out, the volume of milk filled in the bottle remained stable at 100 ml. This shows that with control, the milk surface height is kept stable at 6 cm from the maximum height of the filling tank, so that there are no errors in filling the milk volume.

4.5 Manual Mode Overall System Testing

The system will operate in manual mode if the operator does not select automatic mode. In manual mode, the system processes only one bottle at a time. The process starts with filling, followed by bottle closure and sealing of the bottle cap. Each of these steps is done manually, so the operator controls every process for each bottle processed.

Figure 4. Bottles Detected at Filling stations.

In Figure 5, the bottle at the filling station is detected by a proximity switch marked in red. Once the bottle is detected, the conveyor will automatically stop at the filling station position. Once the bottle stops right in place, the selonoid valve will activate and drain the milk into the bottle.

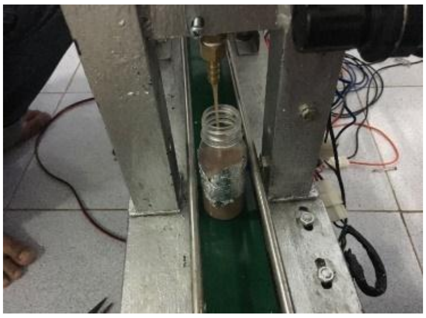

Figure 5. The bottle is being filled.

After the milk filling process is completed, the bottle will be transported by conveyor to the bottle cap laying part. Eventually, the bottle will go through the sealing process of the bottle cap, as seen in Figure 6.

Figure 6. Bottles Detected on Capping Stations.

For 5 experiments carried out using manual mode, the process starting from filling to the final stage of capping was carried out sequentially. Based on this experiment, the percentage of overall system performance in manual mode can be calculated.

6. Overall System Testing in Automatic Mode

Testing in **automatic mode** is carried out using **3 bottles** that are tested in turn, and cannot be done simultaneously. The test covers the entire process, from the **filling process**, **to the sealing of the bottle cap**, as seen in **Table 5**.

Table 5. System Test Results in Auto Mode

Filling Process (300 ml)	Bottle cap placement (3 tests)	Bottle Cap Sealing (3 tests)
300 ml	3	3
300 ml	3	3
300 ml	3	3
300 ml	3	3
300 ml	3	3

To find out **the efficiency of the plant** in **automatic mode**, we can calculate it using the following equation:

$$Ef = \left(\frac{V \times (B1 + B2)}{3}\right) \times 100$$

Where:

a) Ef = Plant efficiency at 1 iteration (%)
b) V = Volume of milk filled by 3 bottles (ml)
c) B1 = Variable value of plant success in bottle cap placement (0-3)
d) B2 = Variable value of plant success in sealing bottle caps (0-3)

From this calculation, **Ef** (Plant efficiency) is obtained as stated in **Table 6**.

Table 6. Plant Efficiency Yield (Ef) in Auto Mode

Iteration	Ef (Plant Efficiency) (%)
1	99,99 %
2	99,99 %
3	99,99 %
4	99,99 %
5	99,99 %
Average	99,99 %

From the calculations, the efficiency of the plant in automatic mode showed a value of 99.99% in each iteration, which indicates that the system operates very efficiently in executing the entire process.

Conclusion

Based on the test results of Omron's PLC-based automated packaging system, it can be concluded that this system works very efficiently and reliably, both in manual and automatic modes. In manual mode, the system is able to carry out the packaging process of one bottle at a time in order, starting from the filling process, placing the bottle cap, to sealing the bottle cap properly. Meanwhile, in automatic mode, the system is capable of packing three bottles in turn with very high efficiency, reaching 99.99% on each iteration, indicating that the system can operate very well automatically without any significant errors. The process of filling milk in bottles has also proven to be stable, both with on/off and no control controls, with the volume of milk remaining in accordance with the targeted set point. In addition, tests on the actuators and sensors show that all devices are functioning properly, ensuring the overall reliability of the system. The use of Omron's PLC as a control center provides ease of programming and ensures reliability in setting up automated processes. Overall, this automated packaging system is reliable to improve efficiency in the production process, and the recommendation for further development is to test this system in more complex industrial environments, as well as to consider improving the monitoring features and integration of the system for more optimal results.

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