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Automatic Control of Bottle Contents and Separation of Empty Bottles in Packaging Process Using Programmable Logic Controller Siemens S7-1200

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ABSTRACT

Filling liquid into bottles with the same volume is an important part of product packaging. All packaged bottles must be filled per a product's provisions. A device is needed to control the contents of the bottles from a certain distance or from outside the bottles by moving on the conveyor track. So that the bottles can be automatically filling the same volume continues to the packaging process. To be able to control the contents of the bottle automatically and properly may need a tool and a control program. This research was carried out to be able to control the contents of transparent bottles, using a Siemens S7-1200 PLC, so that a system for controlling bottle contents quickly and precisely, which helps the production process run smoothly. The main components used in this research were the Siemens S7-1200 Programmable Logic Controller, Omron E3S-DB sensor, and pneumatic cylinder. The result showed the Control Module Program 1 successfully detected empty bottles and rejected them properly. Control module program 2 successfully moves the pneumatic cylinder to move the cylinder continuously until the stop button was pressed. Tthe module 3 programs succeeded in moving the cylinder, which was limited to only 10 repeated movements until it stopped.

KEYWORDS: *Siemens S7-1200 PLC, E3S-DB Sensor, Empty Bottle, Control Program, Pneumatic Cylinder.*

1.0 INTRODUCTION

Filling liquid into bottles with the same volume is a very important part of the packaging process for a beverage product or other product. All packaged bottles must be filled per a product's provisions. There are no empty bottles that are more or less than the desired conditions [1]. Unequal bottle volumes can be caused by improper positioning of the bottles on the conveyor, due to defective bottles or damaged liquid volume control devices entering the bottles. If the bottle is not filled and remains in the packaging box, then the packaged product will not be sold or there will be complaints from consumers, so the company will suffer losses, starting from losses in the production process, to the marketing process and ultimately all of the company's products [2].

The process of filling liquid into bottles and the entire packaging process must be carried out automatically, so that the production process can be carried out quickly and precisely for large-scale production, and labor can be saved and profits will be greater. For large-scale production processes that require a fast packaging process, human power will no longer be able to control the contents of the bottles and will also require large costs for human power resulting in production process costs increasing and profits decreasing [3]-[4].

To control the contents of the bottles so that they are the same or by the provisions, a device is needed that can control the contents of the bottles from a certain distance or from outside the bottles that are moving on the conveyor track so that bottles that are not filled can be separated automatically from bottles that are already filled. the same volume continues to the packaging process. To be able to control the contents of the bottle automatically and well, you need a tool and a control program [5]-[6]-[7].

The control device must be able to read empty bottles and full bottles quickly and immediately carry out the process of separating empty bottles from the conveyor line and filling bottles into the packaging box [8]-[9]. To meet these needs, research was carried out with process design and program creation that was applied to obtain a control device for separating empty bottles from the conveyor line in the packaging process that worked quickly and precisely [10]-[11]-

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[12]. This paper aims to develop an automatic control of bottle contents and separation of empty bottles in packaging process using programmable logic controller siemens s7-1200. This research is hoped to support the large, medium, and small industries in the production process, save costs, and be able to carry out production processes on a large scale. In the world of education, it will help students and lecturers improve basic knowledge and application of industrial product control processes in research [13]-[14].

2.0 RESEARCH METHOD

2.1 Materials and Equipment

The materials used as objects to be detected to be separated in packaging are PET bottles and glass bottles containing colored liquids that are full and not full. The components or spare parts used and arranged into one unit of auxiliary tools and main detection tools are shown in Figures 1-4. The compressor is used as a source of compressed air with a working pressure of 5 bars to move the pneumatic cylinder. In Figure 1 shows the tube compressor with a pressure of 9 bars. The Shut Off Valve was used to open the flow of pressurized air from the compressor to the pneumatic cylinder and the valve opening can be adjusted according to the movement that will be carried out on the pneumatic cylinder. In Figure 2 shows the Shut Off Valve of Pneumatic used in this research.

Figure 1: Tube compressor with a pressure of 9 bars


Figure 2: Shut Off Valve of Pneumatic

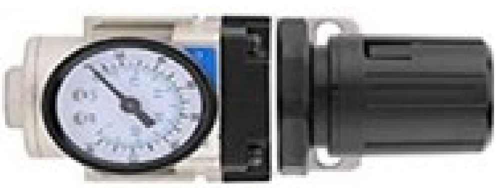
Figure 3: Pneumatic air pressure regulator

Then, the regulator was used to regulate the air pressure that will press the pneumatic cylinder (Figure 3). The electromagnetic solenoid valve can be controlled by opening the valve with a voltage of 24VDC via a Programmable Logic Controller (PLC). It can be seen in Figure 4.


Figure 4: Solenoid Valve

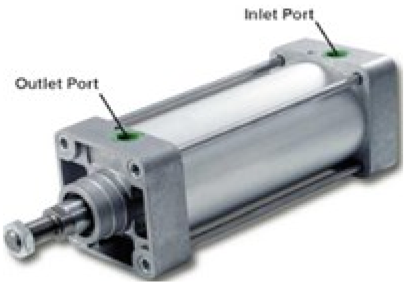

Figure 5: Pneumatic Cylinder


Figure 6: E3S-DB sensor used to detect bottles

A pneumatic cylinder with a plunger is used to push bottles that are not full according to packaging standards out of the conveyor line. So that only bottles that enter the packaging were bottles that were full or according to packaging standards. The movement of the pneumatic cylinder plunger pushes the bottle based on air pressure from the compressor, which pushes the piston in the cylinder and was regulated through a valve and regulator. Therefore, the air pressure entering the cylinder was set at 5 bars to push the bottle according to general operational pressure.

The equipment used for object sensors that is capable of detecting transparent objects is the E3S-DB sensor as shown in Figure 2. The E3S-DB sensor is the most reliable sensor for all types of transparent objects such as PET bottles, glass bottles, or transparent trays. Using the E3S-DB sensor will make it easier to make settings quickly and determine optimal thresholds. So with the E3S-DB sensor, detecting empty and filled bottles according to the desired bottle content standards in packaging will be done easily and quickly.

To automatically adjust the plunger to push the bottle based

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on information from the E3S-DB sensor, a Siemens Simatic S7-1200 programmable logic controller was used. In Figure 7 can be seen the Programmable Logic Controller (PLC) Siemens Simatic S7-1200, which used in this research. This PLC works with a 24 VDC power supply with 15 inputs and 10 outputs. The input works with 24 V DC and the output is relay type.

To control the input, 2 inputs are connected and for the output logic, 3 relay coils are used. The Programmable Logic Controller (PLC) Siemens Simatic S7-1200 with cable arrangement is depicted in Figure 8. In the control process, the Siemens S7-1200 PLC operates with a 24V D power supply. PB start input: I0.1, PB stop: I0.0, Sensor X1: I0.2, Sensor X2: I0.3 output; ACTIVE Cycle: Q0.0, Conveyor: Q0.1, Cylinder: Q0.2. As input sensors are sensors X1(I0.2) and X2(I0.3), and use NO contacts for sensor X2 (I0.3) and NC contacts for sensor X1 (I0.2). When the bottle moves on the conveyor line, the sensor detects the bottle, namely Sensor X1(I0.2) detects whether the bottle is fully filled, and sensor (I0.3) detects the bottle and sensor.

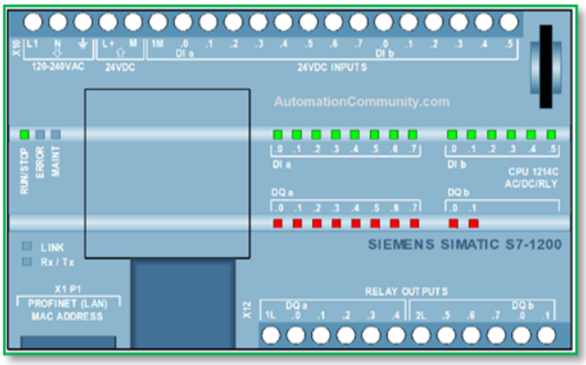

Figure 7: Programmable Logic Controller (PLC) Siemens Simatic S7-1200

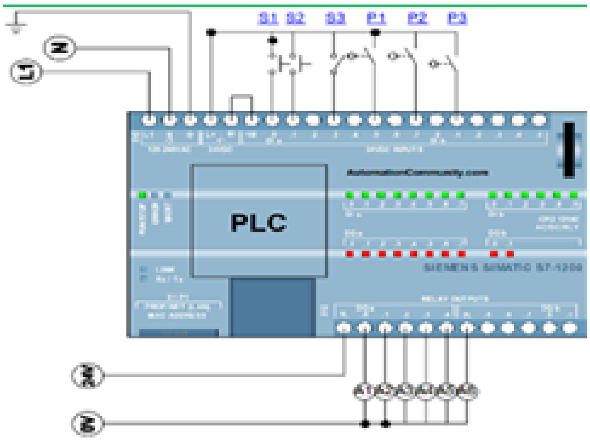

Figure 8: Programmable Logic Controller (PLC) Siemens Simatic S7-1200 with cable arrangement.

In Figure 9 shows the Programmable Logic Controller (PLC) Siemens S7-1200, which is equipped with input-output wiring. The flow diagram of the bottle detection and separation process is shown in Figure 10, which is equipped with a flow diagram of the process of using tools.

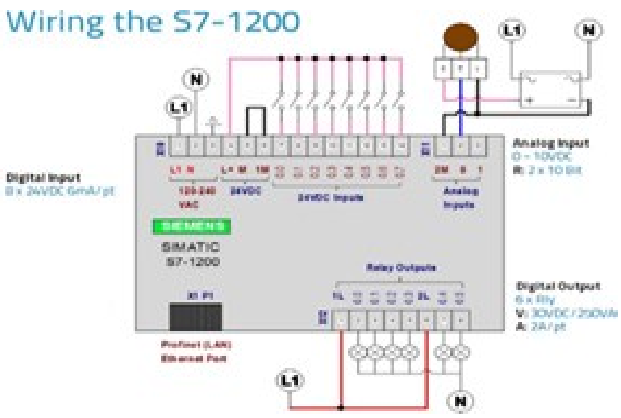

Figure 9: Wiring input-output from PLC S7-1200

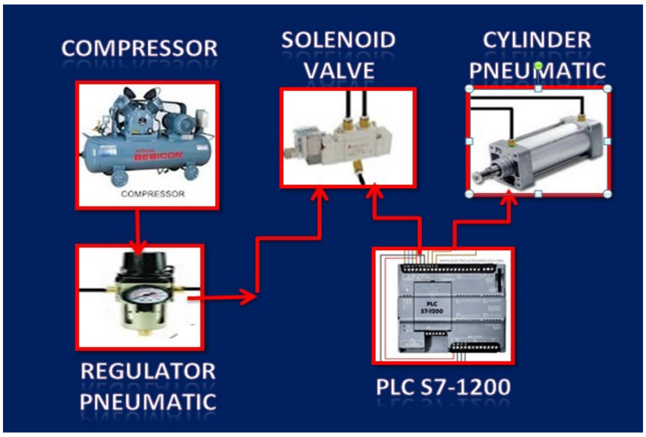

Figure 10: Equipment and process flow diagram for detecting and separating empty bottles.

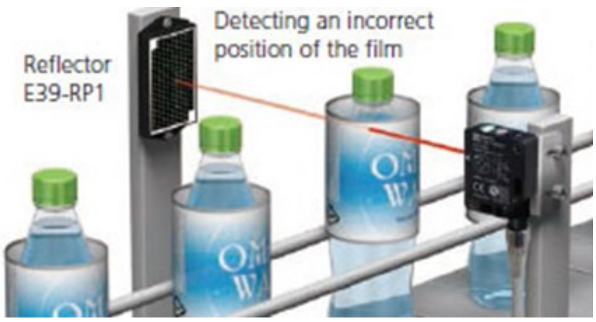

Figure 11: Position of E3S-DB sensor and E39-RP1 reflector for bottle detection.

Hence, the empty bottles can be separated and bottles that comply with the filling standard provisions will move to the packaging process. The position of the sensor and reflector for detecting full and empty bottles is shown in Figure 11. Detection is carried out with a light beam that is transmitted to the reflector, and captured by the E3S-DB sensor. The position of E3S-DB sensor and E39-RP1 reflector for bottle detection is depicted in Figure 11.

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2.2 Principle of bottle separation

The pneumatic system uses air to move the cylinder forward and backward. This concept is used to push empty bottles out of the conveyor. The main component of the pneumatic cylinder drive consists of several components shown in Figure 13. A pressurized air supply of 5 bar is given to the pneumatic system. All cylinders are in the default position. Each time Push Buttons S1 and S2 are pressed in Figure 12, the process starts. This activates the PLC input and as per PLC programming, relays A1 and A2 are activated.

The relay activates the directional control valve solenoid which activates Cylinder 1 and Cylinder 2 to move forward. Cylinder 1 and Cylinder 2 The next process will only start if we get signals from both proximity sensors. Keeping the safety principle in mind, we use PLC logic to identify the signal status of the proximity sensor. Pressurized air from the compressor passes through the shut-off valve with controlled pressure on the regulator and the air is directed by the solenoid valve to push the piston in the pneumatic cylinder to move the plunger to separate the bottles.

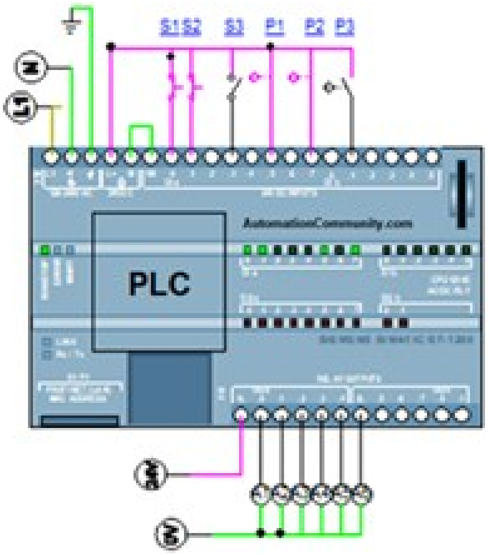

Figure 12: Button Pressing in PLC

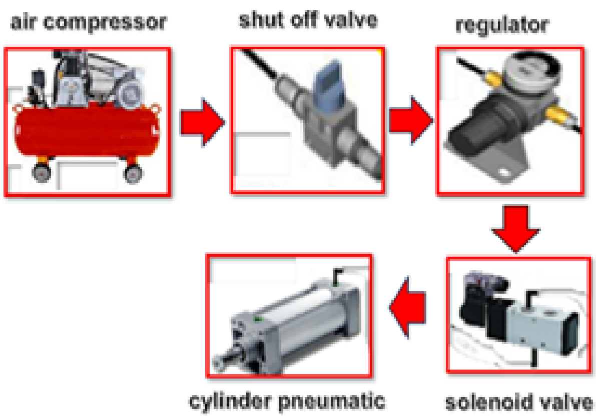

Figure 13: Pneumatic cylinder drive components

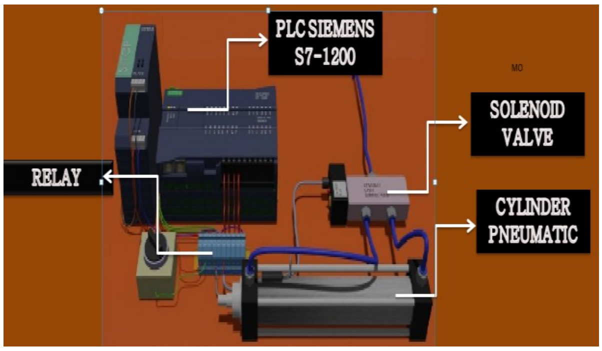

Figure 14: Arrangement of control components connected to the Siemens PLC via EtherNet/IP

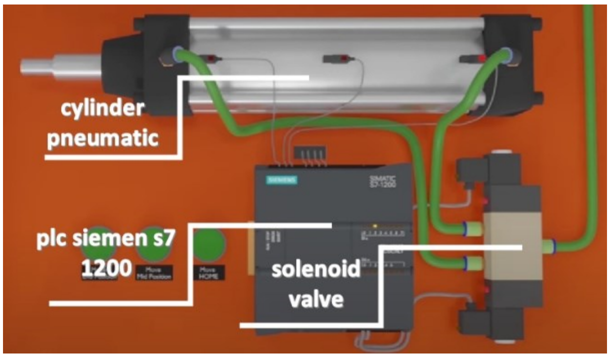

Figure 15: Interfacing PLC with pneumatic cylinder

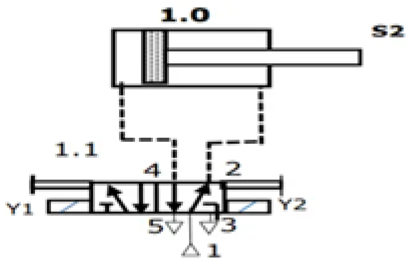

Figure 16: Diagram of compressed air flow in the cylinder through the solenoid valve

To connect to a Siemens PLC via EtherNet/IP, go online to the Siemens PLC and tap on “Go online”. The TIA portal will let you choose the path to take to get to the PLC you specified in the project. Select the interface, as well as the network card (if any). Once selected, you need to press “Start Search” shown below so the software can scan the network for the specified devices. Select your device and press “GoOnline” to connect to the PLC. The flash the physical LED of the Siemens PLC can use the “Flash LED” option, which will flash the physical LEDs on the hardware. Therefore, it can ensure that the PLC selected in this prompt matches to the PLC that connected. To control the process of pushing empty or incompletely filled bottles, it is controlled by the PLC interfacing shown in Figure 14. The cylinder plunger moves forward and backward automatically, according to commands from the PLC, which opens and closes the compressed air path in the solenoid valve. In Figure 16 shows the diagram of compressed air flow in the cylinder through the solenoid valve.

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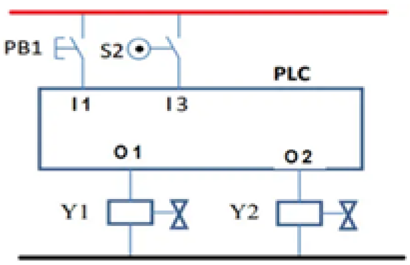

Figure 17: Wiring diagram on PLC

Input-output at the PLC:

Input : PB_1 = i1, S_2 = i3,

Output : Y_1 = O1, Y_2 = O2

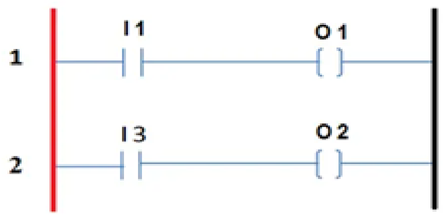

Figure 18: The working principle of a switch on a PLC

The working principle of the switch on the PLC is as shown in Figure 17, namely when the PB1 button is pressed, the state of address I1 changes to 1 so that output 01 will appear. Output 01 operates solenoid Y1 and the cylinder moves forward. When the cylinder reaches the extreme forward position, and the Limit switch S2 is operated, the address state I3 changes to 1 and thus there will be an output of 02. The output of 02 operates the solenoid Y2 and the cylinder returns to the initial position.

2.3 Programming a Siemens PLC in the Totally Integrated Automation (TIA) Portal

To start a Siemens PLC program on the TIA portal, it must configure the CPU hardware and add the program as shown in Figure 17. The CPU used in the research was the 1214C AC/DC/RLY CPU, and CPUs with different features and properties that can be activated or deactivated can also be used. Some features require additional configuration to be created as shown in Figure 18. The process of configure additional features in CPU properties, profinet interface, configure cycle time properties that were depicted in Figure 20-23.

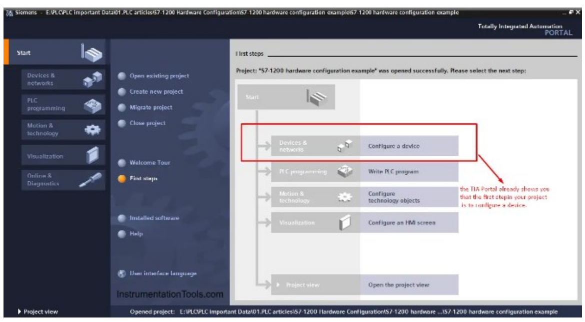

Figure 19: Device configuration on the Totally Integrated Automation (TIA) portal

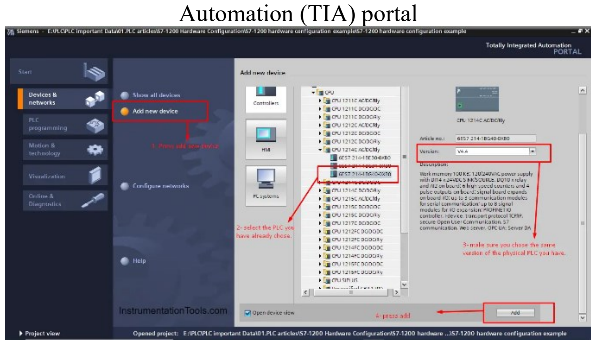

Figure 20: Adding device controllers to the Totally Integrated Automation (TIA) portal

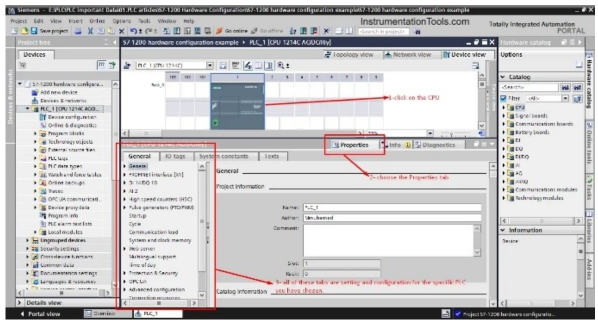

Figure 21: Configure additional features in CPU properties

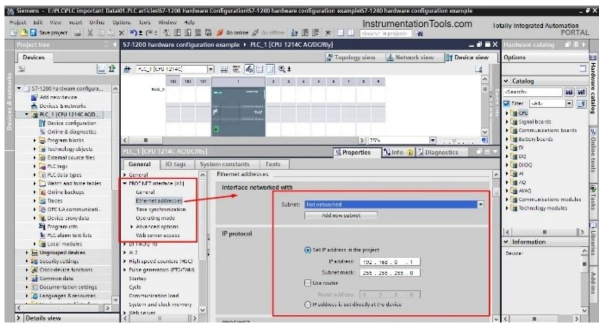

Figure 22: Profinet Interface

Properties that need to be configured and special properties under certain conditions: (1) Communication configuration is critical for any PLC project; because there are likely different modules and devices that need to communicate with each other. Selecting a CPU indicates that it has determined how communication will occur. Some CPUs only work with Profinet, some only work with Profibus and some can use both. The PLC selected in this study only works with Profinet. From the Profinet interface, the IP address for the PLC will be set, the IP must be unique; The same IP cannot be used for two different modules. (2) The program cycle time configuration will depend on how much code you have written and how long it takes the PLC to execute the code. In the cycle time property, it can set the cycle monitoring time. If the PLC takes longer

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than the set time to run the program, the PLC will give an error. From this property it is also possible to determine the minimum cycle time for the CPU, this can be done by triggering “Enable minimum cycle time for cyclic OB”. Next, the desired minimum cycle time is written, and the PLC will adjust its performance to match that time. The time is limited by the CPU's performance capabilities, and it is not possible to lower this time below a certain limit.

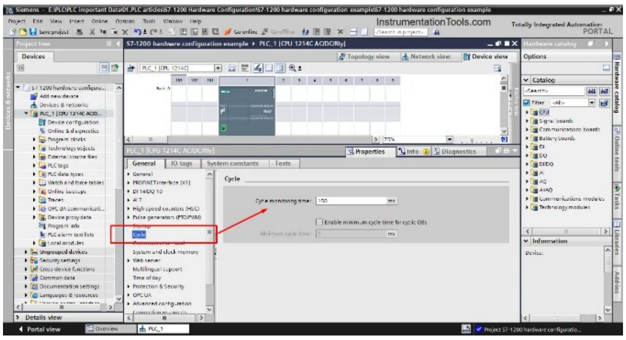

Figure 23: Configure cycle time properties

2.4. Simulation with Factory IO Software

Simulation using Factory IO software requires a Windows operating system, namely a Windows 7 virtual machine, TIA portal version 15, and a USB device for generic storage. This Factory IO simulation software is very helpful because it will show you in real life what is done with the three-dimensional image results. The simulation process steps are as follows:

• Setting up S7-PLCSIM

Condition

- Siemens Edition or Ultimate Edition
- TIA Portal V13-18
- S7-PLCSIM V13-18

• Setting up S7-PLCSIM with TIA Portal

1. Download and open the template project that corresponds to the version of the TIA Portal and the PLC family to be simulated.
2. Save the project with the desired new name.

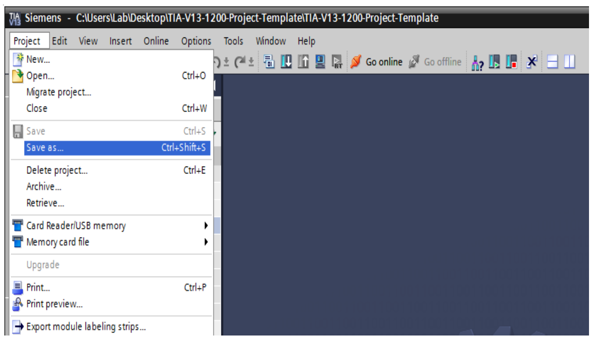

Figure 24: Templates on the TIA portal

3. Write a Warning program on OB1 which already has Network 1. Do not delete this network. Otherwise, the connection will not work.
4. Select the device and start the simulation by pressing Start Simulation.

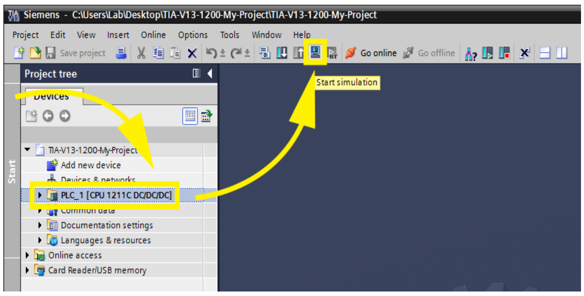

Figure 25: Interface templates on the TIA portal

5. Select PN/IE (1) as the PG/PC interface type and on the PG/PC interface select PLCSIM S7-1200/S7-1500 (2). Press “Start Search” (3) when scanning is complete, select device (4) and press Load (5).

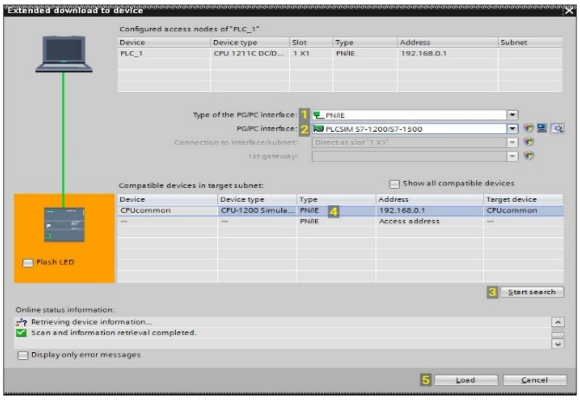

Figure 26: PN/IE, PG/PC templates, on the TIA portal

6. On S7-PLCSIM select RUN to set the CPU to Run Mode.

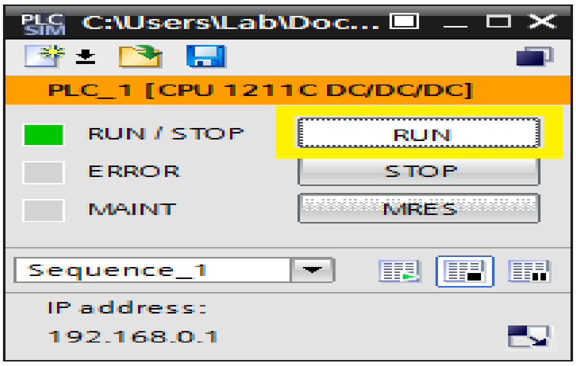

Figure 27: RUN Mode template on the TIA portal

7. Connect Factory I/O to S7-PLCSIM

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Figure 28: Configure the driver to open the driver window by clicking FILE in the I/O factory

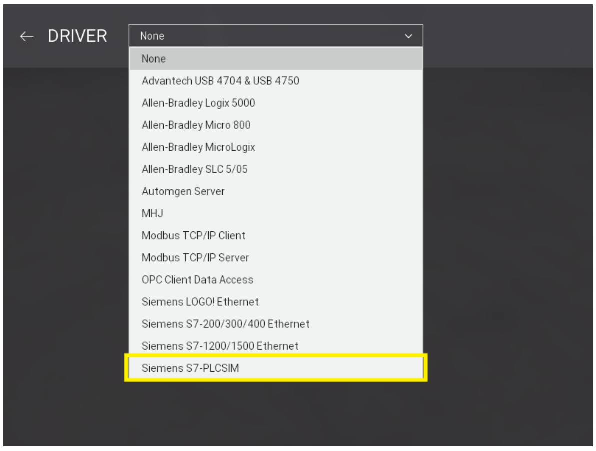

Figure 29: Configure Siemens S7-PLC SIM selection in the driver drop-down list.

8. Open the driver configuration panel by clicking CONFIGURATION as shown in Figure 26.
9. Select the appropriate CPU model for your project in the Model drop-down list (S7-1200 or S7-1500) as shown in figure 28.
10. Press Esc to return to the main driver window. And continue by clicking CONNECT to connect to the simulator. A successful connection is indicated by a green icon next to the selected driver, as well as next to the driver name displayed on the status bar.

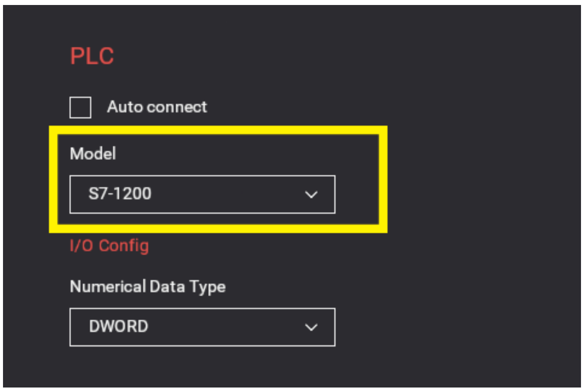

Figure 30: CPU selection configuration

2.5. Downloading PLC programs using TIA Portal and USB

To download PLC programs using the TIA portal and USB is to connect an ethernet cable to the PC and the PLC X1 port. Make sure the PLC port IP address is on the same subnet as the PLC and HMI and make sure the PLC and HMI are in the ON position. Go to the TIA Portal and the program that has added the HMI and PLC devices. Change the TIA Portal to "Project View" by clicking the button at the bottom left of the window. Select "Online" from the menu at the top of the window and select "Accessible Devices", from here the TIA Portal can connect to any available device before continuing to the next section.

In the project tree, right click on the PLC device name and select "Download to device". This displays a window showing a list of devices that are accessible, compatible, or with the same IP address based on selection. Click "Start Search" and connect to the device. Note that the "Flash LED" feature on the left can be used to flash the LEDs on the actual PLC device to ensure that it is the correct device. Once the device is displayed in the list of target devices, select it. Click the Load button at the bottom of the pop-up. If asked to confirm adding an IP address in the subnet, confirm and continue. Correct any errors and click the Load button at the bottom of the new pop-up. Click the Finish button when the download is complete. Downloading an HMI program using TIA Portal is very similar to downloading a PLC program using TIA Portal.

After opening the project in the TIA Portal and switching to "Project View", navigate to the HMI name in the project tree. Select "Online" from the menu at the top of the window and select "Accessible Devices", from here the TIA Portal can connect to any available device before continuing to the next step. In the project tree, right-click on the HMI device name and select "Download to device". This will bring up a window showing a list of devices that are accessible, compatible, or with the same IP address based on the selection. Click "Start Search" and connect to your device. Just like on a PLC, the "Flash LED" feature on the left can be used to flash the entire screen of the actual HMI device to ensure it is connected correctly. Once the device is displayed in the list of target devices, select it and click the Load button at the bottom of the pop-up. If asked to confirm adding an IP address in the subnet, confirm and continue. Correct any errors and click the Load button again at the bottom of the new pop-up. Click the Finish button when the download is complete. In the next section, you will learn how to download HMI and PLC programs to devices without TIA Portal. Please note that the TIA Portal is still required to program/configure SD memory cards and USB devices to program the PLC and HMI.

3.0 RESULT AND DISCUSSION

The results of compiling the research module are shown in figure 3.1 which is the Programmable Logic Controller module. Figure 3.2. shows the power supply module and Figure 3.3. shows the pneumatic cylinder module.

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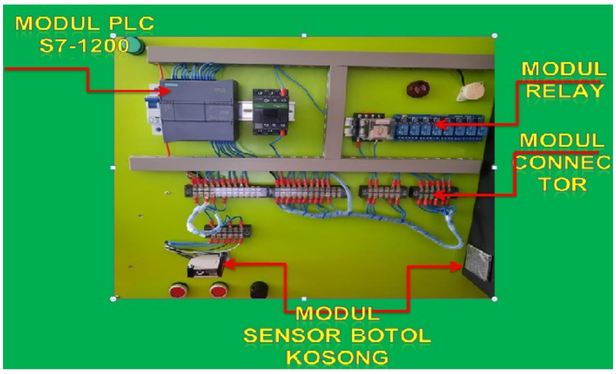

Figure 31: PLC Module

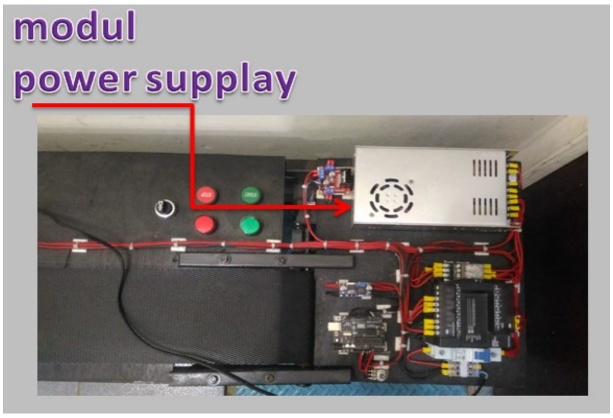

Figure 32: Power Supply Module

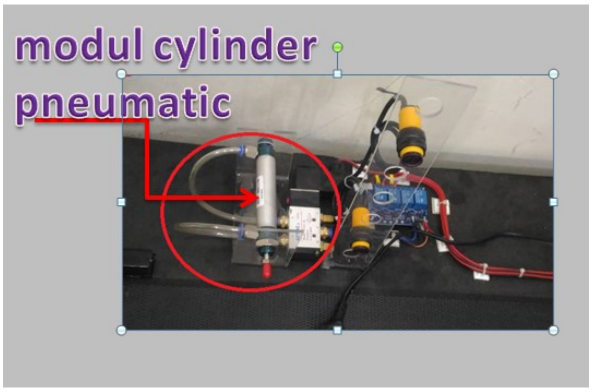

Figure 33: Bottle Pusher Module

Input/Output Design PLC S7 1200 programming with TIA portal ie:

- Inputs ; start PB : I0.1, stop PB : I0.0, Sensor X1 : I0.2, Sensor X2 : I0.3
- Outputs; ACTIVE Cycle: Q0.0, Conveyor: Q0.1, Cylinder: Q0.2

The PLC program for the Automatic Bottle Rejection System has been carried out using Siemens S7-1200 PLC Software and TIA Portal for programming and logic design with relay circuits.

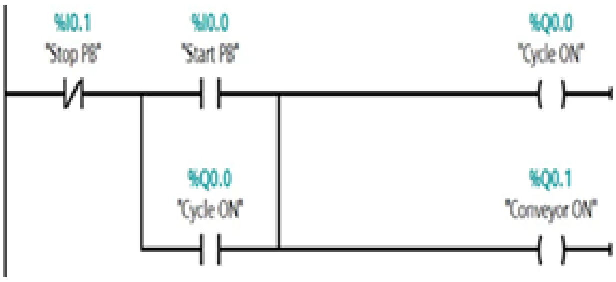

Figure 34: Cycle ON program

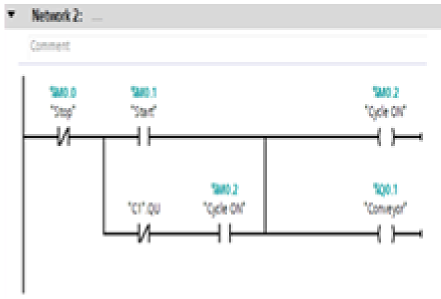

Figure 35: Conveyor Control Ladder Control Diagram

Figure 36: Bottle pusher Ladder diagram

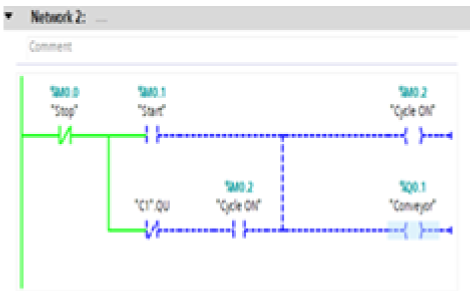

Figure 37: Control Program 1: move the conveyor

After testing on the ladder program line 1, by taking the ON cycle condition for the machine, namely for START PB (I0.1) to start the cycle and STOP PB (I0.1) for the STOP cycle. Then the branching continues for parallel output, from the conveyor (Q.1) with the ON cycle (Q0.0). to operate the conveyor with the ON cycle condition. Control program analysis 2: Moving the Cylinder on for the empty bottle pusher.

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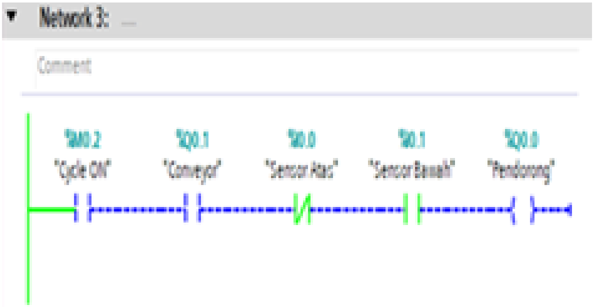

Figure 38: Control program 2: Moving the cylinder

In ladder program line 2, sensors X1(I0.2) and X2(I0.3) have been taken as input. Using NO contact for sensor X2 (I0.3) and NC contact for sensor X1 (I0.2). When bottles are moved on the conveyor, this sensor detects whether the bottles are full or not. Sensor X1(I0.2) detects the presence of a bottle, then Sensor X2(I0.3) detects whether the bottle is empty or not filled. In the PLC, a circuit is designed that follows the command that if sensor X2(I0.3) detects a bottle and sensor.
The test results show that if the input IO.00=1(start) is operated, then the output is Q0.0 and the output Q is 0.1(cycle and active conveyor). And if inputs IO.02 and IO.03 are active, a bottle is detected and it is not fully filled. then the output Q0.2=1 (cylinder ON). If input IO.01=1(STOP) is enabled. Then the output Q0.0 .Q0.1, Q0.2 = 0 (all processes stop).

Table 1. Empty bottle rejection test results

Inputs	Outputs	Physical Elements
10.0=1	Q0.0&Q0.1	Cycle and Conveyor ON
IO.2=0&IO.3=0	QO.2=1	Cylinder ON
IO.1=1	Q0.0,Q0.1,Q0.2=0	Cycle STOP

3.1 Control Programming 1 test results for empty bottle rejection with a pneumatic cylinder.

The cylinder produces a continuous back-and-forth movement in this in-depth program test. The cylinder should move forward when the PB1 button is pressed and after reciprocation begins. And the cylinder is expected to continue moving until the PB2 stop button is pressed. Switching boundaries are used for final position sensing. Memory signal from I1 =set and memory signal input 2 reset. If given M1 -1 i3=1 then output q01 =1 , if i4 =1 qo.2 = 1.

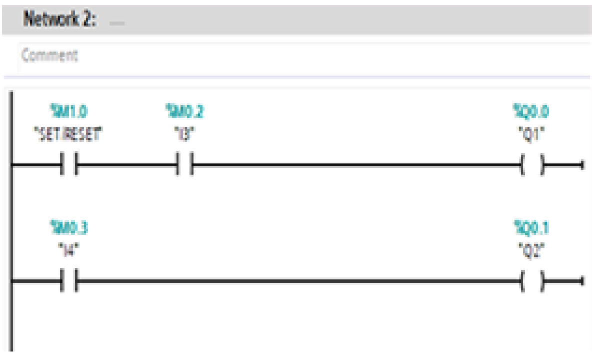

Figure 39: Cylinder movement back and forth

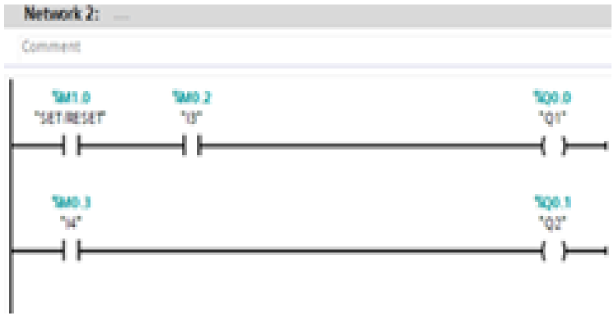

Figure 40: START control movement

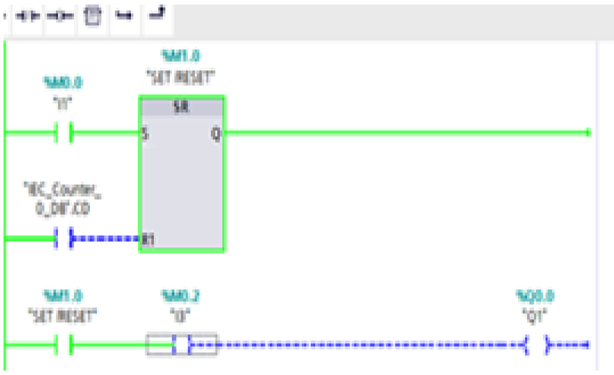

Figure 41: Movement control STOP

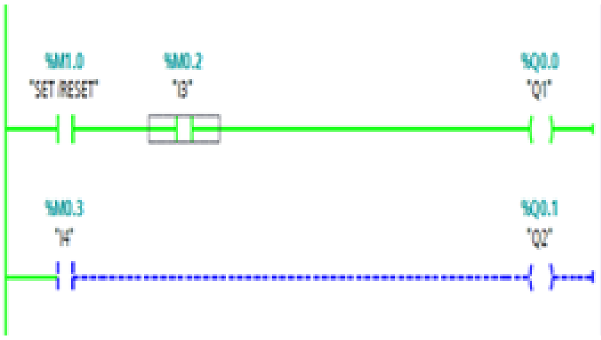

Figure 42: Reciprocating Double Cylinder Movement START

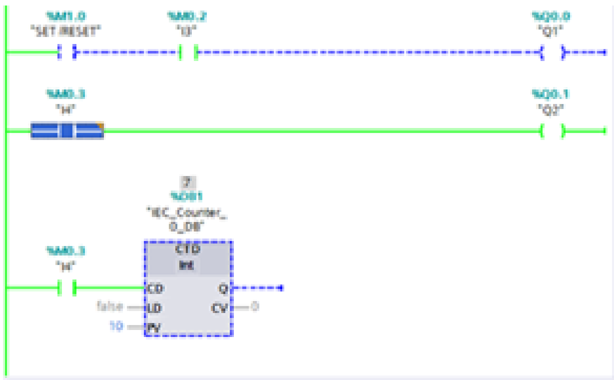

Figure 43: Reciprocating Double Cylinder Movement STOP

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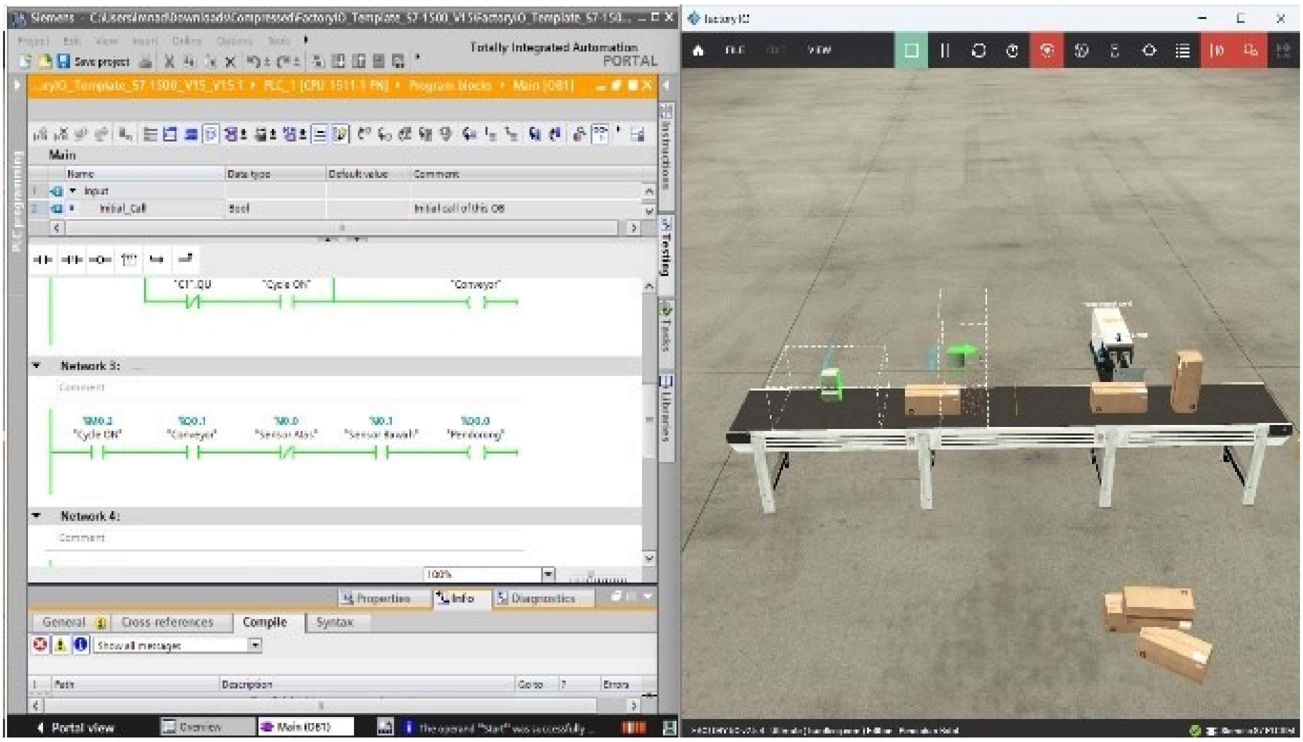

Figure 45: Control movements in factory I/O simulation and bottle separation results with automatic control equipment

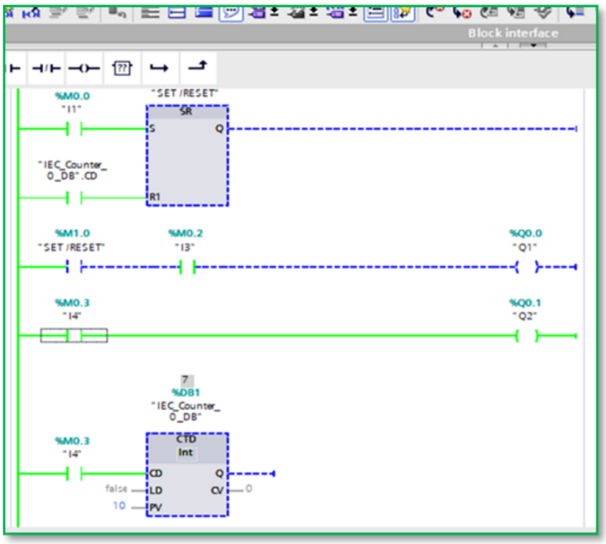

Figure 44: Cylinder Control Movement with three-dimensional I/O

Start and stop operations can be implemented using memory flags with address M1 which are set by PB1 and reset by PB2. The state of the memory element M1 is scanned via the NO contact, combined in series with the state of the sensor S1 to obtain the start and stop control.

3.2 Control Programming 2 test results for rejecting empty bottles with pneumatic cylinders

To be able to double acting cylinders can work to perform reciprocating operations. The cylinder should move forward when the PB1 button is pressed and continue back and forth until 10 operating cycles have been performed. START and STOP operations can be implemented using memory flags with address M1 set by PB1 in I1 and reset by the NC contact of the lower counter. The M1 memory status flag scanned via the NO contact (rung 2) is combined in series with the S1 status sensor to obtain start and stop control. Control testing with three-dimensional I/O simulation to depict the actual bottle rejection process, and by simulation using factory I/O so that actual process activities can be shown. In Figure 45 can be seen the control movements in factory I/O simulation and bottle separation results with automatic control equipment.

4.0 CONCLUSION

The contents of the bottle can control automatically and properly may need a tool and a control program. This research was carried out to be able to control the contents of transparent bottles, using a Siemens S7-1200 PLC. The test results of control module 1 were successful in detecting empty bottles and rejecting them well. The test results of control module 2 show the success of continuous movement of the pneumatic cylinder until the stop button is pressed. The test results of control module 3 show that the movement of the pneumatic cylinder is limited to 10 repeated movements until it stops. Test results using a 3-dimensional simulation method using factory I/O software can replace the bottle or bottle rejection process, which is close to an industrial process.

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