

Automation of Different Size Bottle Filling and Capping System using PLC LogixPro Simulation

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Abstract: Industrial automation systems are used to control and monitor a process, machine or device in a computerized manner that usually fulfils repetitive functions or tasks. The application of PLCs is increasing day by day in automation industry. Filling is the task that is carried out by a machine and this process is widely used in many industries. The objective of this paper is to design, develop and monitor different size bottle filling and capping system using PLC LogixPro simulation. To develop the process of bottle filling of different sizes and capping using animated simulation as a study material for PLC based automation system. PLC ladder diagram approach is used for the study. In this study, the bottles lines up for filling automatically. The system checks for broken bottles and open the gate to divert the broken bottles into scrap area where it is collected in a box. The remaining bottles moves continuously on the main conveyor belt. Sensors are added to measure the height of the bottles and to turn on the filling station accordingly. This will avoid overfilling or less filling of the bottles. The filled bottles continue to move on the conveyor belt until the capping station. The sensor at the capping station identifies the presence of the bottles and initiated the capping system. Once capped, the weight sensor attached at the bottom of the main conveyor belt identifies the large size bottles and opens the gate to divert the large size bottles to large size bottle conveyor to make it easier for packaging. The remaining small size bottles in the main conveyor are packaged separately. The operation of the PLC program is tested at each step and results are presented. The results shows that the program is implemented successfully. The developed automated system can be used a case study to teach the PLC basics since all the major components counters, sensors, Indicator lights, switches, are incorporated.

Key Words: PLC, LogixPro, Automatic Bottle Capping System, Ladder Logic, DC Motor, LED sensors

1. Introduction

Industrial automation systems are used to control and monitor a process, machine or device in a computerized manner that usually fulfils repetitive functions or tasks. Filling is one of the common process in food processing and beverage industries. Since filling process is an essential operation, automation of this process will ease many industrial production systems. It can be done by Programmable logic controller (PLC). With graphical programming Ladder diagram, the alteration and adjustment of the PLC system operation can be done easily. The objective of this paper is to design, develop and monitor different size bottle filling and capping system using PLC LogixPro simulation. To develop the process of bottle filling of different sizes and capping using animated simulation as a study material for PLC based automation system.

The literature review of the automated bottle filling starts with the control system developed for this system and the implementation using PLC based controller are as follows. A programmable logic controller (PLC) is an industrial controller that consists of inputs, processor and outputs. The input signals received are processed and outputs are used to control the process (Kamel & Kamel, 2013). The PLC architectures are discussed in Zhang (2010). The basic components of PLC are discussed in Bolton (2015) and the different types of PLC programming are explained in Jones (1998).

In Ref (Md. Liton et al., 2019) design and fabrication of a simple filling system using PLC is proposed by Md. Liton et al. (2019). The bottle position detection is done by Infrared sensor in this proposed system. The fabricated system can be used in small shops where coffee and juice can be dispensed accurately. In Ref (Shweta et al., 2018) water bottle filling using PLC and SCADA is proposed. The automated process is monitored by SCADA. Micrologix 1400 PLC is used in the design. PLC and SCADA interface is done using RS232 cable.

The prototype developed to illustrate the bottle filling system along with capping is proposed by Zar Kyi Win et al. in Ref (Win & New, 2019). The bottle position detection is done by Proximity sensors and DC motor is chosen for conveyor system in this work. Ameer L. Saleh et al, discussed the water filling machine system design and implementation for different sized bottles by using PLC in Ameer L. et al. (2017). The prototype has a flat belt conveyor, solenoid valve and sensors along with PLC controller, considered to be a cost effective system.

An overflow filler model, pre-determined amount of liquid is filled in the bottles using SIMATIC– Siemens S7-1200 PLC is proposed by Abdullaouf I. et al. (2017). The proposed model has been monitored through a wireless network using automation portal software, and user webpage in smart devices. Ref (T.Kalaiselvi et al., 2012) focused on filling and capping bottles simultaneously including a user-defined volume selection menu using PLC and SCADA for monitoring the entire process. The volume to be filled is users choice and the proposed system considered to be a flexible system.

Arduino microcontroller is used to measure volume in an automatic liquid filling machine proposed by Sidik and Ghani . They used solenoid valves to control the flow of liquid. Ultrasonic sensor is used instead of cylinder piston to make it simple and the entire system is controlled by microcontroller. Qijun Gong developed vision based automatic liquid filling system using image technology (Gong, 2017). Detecting the centre coordinate system is done using forward positioning method. Simulink based simulation model is used to control the filling system.

The paper is organized as follows. The methodology is explained in section 2 and the simulation results are discussed in section 3 and the paper end with conclusion.

2. Methodology

In this simulation, the bottles lines up for filling automatically. The system checks for broken bottles and open the gate to divert the broken bottles into scrap area where it is collected in a box. The remaining bottles moves continuously in the main conveyor belt. Sensors are added to identify the height of the bottles and to turn on the filling station accordingly. This will avoid overfilling or less filling of the bottles. The filled bottles continue to move on the conveyor belt until the capping station. The sensor at the capping station identifies the presence of the bottles and initiated the capping system. Once capped, the weight sensor attached at the bottom of the main conveyor belt identifies the large bottles and opens the gate to divert the large bottles to large bottle conveyor to make it easier for packaging. The remaining small bottles in the main conveyor are packaged separately.

The operation of the entire bottle filling system is can be separated into small different sections such as identifying the broken, large and small bottles, scrap the broken bottles into a bin, fill the bottles according to their sizes, sort and fill the boxes according to their sizes. The system uses 4 dc motors for moving the main Conveyor, scrap conveyor, divert conveyor, broken bottle grinder. Sensors are attached to detect the broken bottles, lining up of new bottles and the size of the bottles. The control switches for start and stop of operation are operated by push buttons. The counter display unit displays the number of small bottles and large bottles filled, broken bottles collected at the scrap area and number of boxes packaged.

The input components along with their addresses are shown in Table 1. The output components along with their addresses are shown in Table 2. The counters used are listed in Table 3. The bit registers and their operation is listed in Table 4.

Table.1. The input components along with their addresses

Operation	Type of device	Port Address
Stop	Normally Closed Push Button	I:1/0
Start	Normally Open Push Button	I:1/1
A	Switch Position	I:1/2
B	Switch Position	I:1/3
C	Switch Position	I:1/4
Enter	Normally Open Push Button	I:1/5
Bottle Entry	Limit Switch LS1	I:1/6
Fill Extension	Limit Switch LS4	I:1/9
Large Fill	Limit Switch LS5	I:1/10
Small Fill	Limit Switch LS6	I:1/11
Cap Ram	Limit Switch LS7	I:1/12
Scrap Gate	Limit Switch LS8	I:1/13
Large bottle gate	Limit Switch LS9	I:1/14
Box in place	Limit Switch LS10	I:1/10

Table.2. Output components along with their addresses

Operation	Type of device	Port Address
Main Conveyor	Motor	O:2/0
Scrap Conveyor	Motor	O:2/1
Divert Conveyor	Motor	O:2/2
Broken Bottle Grinder	Motor	O:2/3
Scrap Gate	Valve	O:2/4
Divert Gate	Valve	O:2/5
Fill Tube	Valve	O:2/6
Large Charge Tube	Valve	O:2/7
Small charge tube	valve	O:2/8
Cap Ram	Valve	O:2/9
Run	Lamp	O:2/10

Table.3. Counters used in the study

Address	Operation
C5:1	Large filled boxes
C5:2	Small Filled Boxes
C5:4	Scrap bottle count
C5:5	Scrap Box Count

Table.4. Bit Registers along with thier operations

Address	Operation
B3:0	B3:0/0 Box is full
	B3:0/1 Fill Complete
	B3:0/2 Cap Complete
B3:2	B3:2/9 Existing of bottles at the filler station
B3:3	B3:3/3 Tracks existing of bottles at the caping station
B3:4	Tracks large bottles
	B3:4/7 Large bottles at the filler station
	B3:4/11 Large bottles at the scrap gate
B3:5	B3:5/4 Tracks large bottles at divert gate
B3:6	Tracks broken bottles
	B3:6/8 Broken bottles at scrap gate
	B3:6/5 Broken bottle at filler
B3:7	Adjusted box fill

3. Algorithm

Step 1: Initialization of Bit registers in subroutine 3

Step 2: Run Lamp, divert conveyor and bottle grinder continuously when the start button is pressed

Step 3: Stop Run lamp, divert conveyor and bottle grinder when the stop button is pressed

Step 4: Start the main conveyor after the Run lamp is initiated

Step 5: Stop the main conveyor under any of the following conditions

- a. Scrap conveyor works
- b. Box is full
- c. Fill extend fails
- d. Ram extend fails
- e. Bottle entry fails

Step 6: Identify the broken bottles to scrap and large bottles to large divert and increment the counter each time

Step 7: Activate the fill extender and cap extender when good bottles exists at the appropriate station

Step 8: Fill bottles according to their sizes and increment the counter

Step 9. Assert “Fill complete” and “cap complete” to move the main conveyor

Step 10: Adjust the box fill tally to account for the small and large bottles and activate the box full flag to stop the main conveyor

Step 11: Move the box into position

Step 12: Update muxed LEDs in subroutine 4

1. Program Execution

- a. The initialization of bit registers are done in subroutine 3 is the first step of the main program. The program sequence is shown in figure 1



Figure.1 Call for subroutine 3 to initialize the bit registers

The subroutine3 sequence is shown in figure 2.

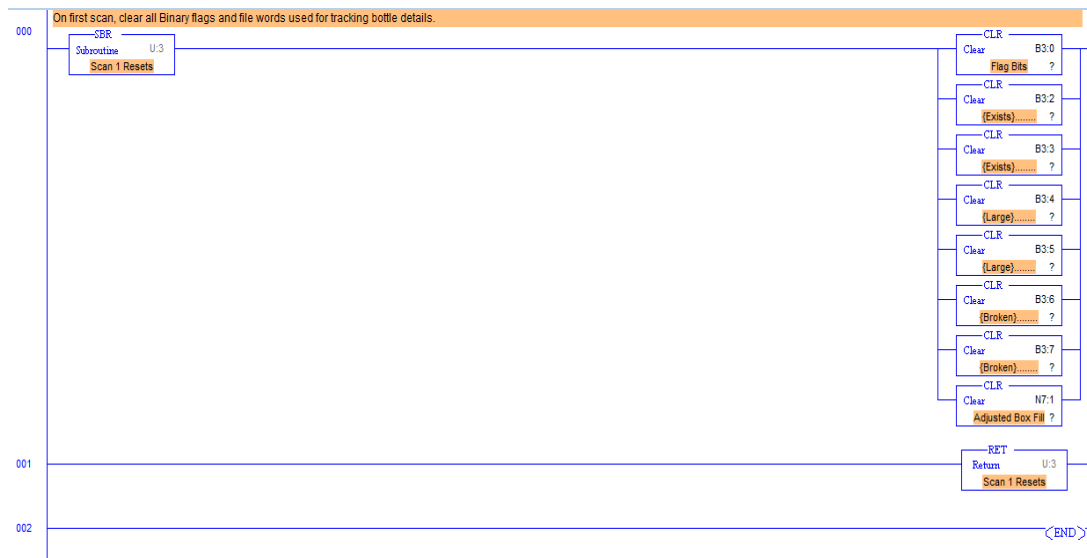


Figure.2 Subroutine 3 to initialize the registers

- a. The “Run Lamp (O:2/10) , Bottle Grinder (O:2/3) and Divert Conveyor (O:2/2)” need to be started when the “Start (I:1/1)” button is pressed. It is required that these outputs need to run continuously until “Stop (I:1/0)” is pressed. The screenshot of the program is shown in figure 3.



Figure.3 Initialization of “Run Lamp, Bottle Griner and Divert Conveyor” outputs

- b. The main conveyor should run when the Fill Complete bit (B3:0/1) and Cap Complete bit (B3:0/2) is activated. The main Conveyor runs continuously until the bottles are at the capping or filling station. This is identified by the position switch LS1 (I:1/6), Fill extend LS4 (I:1/9) , Ram Extend LS7 (I:1/12). Also, it is required to stop the main conveyor when the “box full bit (B3:0/0) and “Scrap Conveyor bit (O:2/1) ” is activated. This is shown in figure 4.

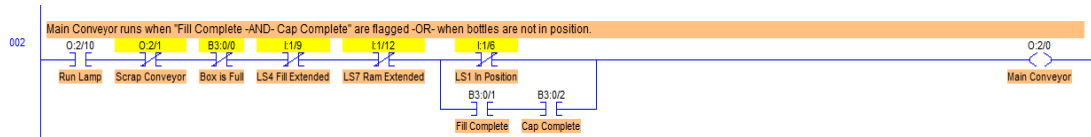


Figure.4 Activation of Main Conveyor by Run Lamp

- c. Shift the bits to track bottle exists (B3:2), large bottles (B3:4) and broken bottles (B3:6). This is shown in figure 5



Figure.5 Tracking bottle exist, large bottles and broken bottles

- d. Divert broken bottles to scrap gate (O:2/4) by using the broken tracking bit at scrap gate (B3:6/8). The scrap bottle counter (C5:4) should be incremented at every time the scrap gate (O:2/4) is operated. The large bottles need to be diverted to lower divert conveyor. The large bottle tracking bit (B3:5/4) at the Divert Gate is used to activate the Divert Gate (O:2/5). The divert gate output (O:2/5) and scrap gate output (O:2/4) should not be activated when the fill complete bit (B3:0/1) and cap complete bit (B3:0/2) is activated. This is to prevent the good bottles getting diverted at the scrap gate as a fail proof system. This is shown in figure 6.



Figure.6 Divert broken bottles to scrap and large bottles to lower divert conveyor

- e. When the main conveyor is halted by any of the inputs shown in fig. 2 or fig. 6, start filling and/or capping the good bottles at the appropriate station. To fill the good bottle at the filling station, the fill extender (O:2/6) need to be activated. The can be done by using the tracking bit for bottle exists at the filling station (B3:2/9). The capping extender (O:2/9) can be activated by using the tracking bit for bottle exists at the

capping station (B3:3/3). The fill extender should be deactivated when the fill complete bit (B3:0/1) or broken bottle at the filler bit (B3:6/5) is activated. Also, the cap extender need to activated when the cap complete bit (B3:0/2) is activated. This is shown in figure 7.

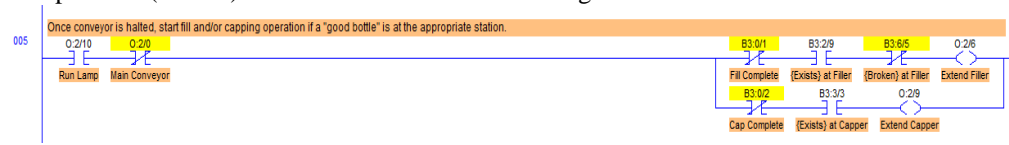


Figure.7 Activate fill extend and cap extend

- f. When the fill tube is extended, then fill the bottle according to their sizes. This can be done by using the large bottle tracking bit (B3:4/7), large fill charge output (O:2/7) and small fill charge output (O:2/8). Two counters, C5:1 and C5:2 are used to count the large filled bottles and small filled bottles respectively. At any time, either large fill charge or small fill charge output should be activated. To do this, small fill charge can be deactivated when the large filler tracking bit (B3:4/7) is activated. This is shown in figure 8.



Figure.8 Fill the bottles according to their sizes

- g. To move the main conveyor, the fill complete bit (B3:0/1) and cap complete bit (B3:0/2) should be activated. To do these, the position exists limit switch, LS1 (I:1/6) is used. To activate fill complete bit (B3:0/1), the limit switch LS1 (I:1/6) and either one of large fill input (I:1/10), small fill input (I:1/11), broken filler tracking bit (B3:6/5) or fill complete tracking bit (B3:0/1) should be active. Also, to activate, cap complete bit (B3:0/2), the limit switch LS1 (I:1/6) and either one of ram extend input (I:1/2), bottle exist tracking bit at the capper station (B3:3/3) or cap complete bit (B3:0/2) should be active. This is shown in figure 9.

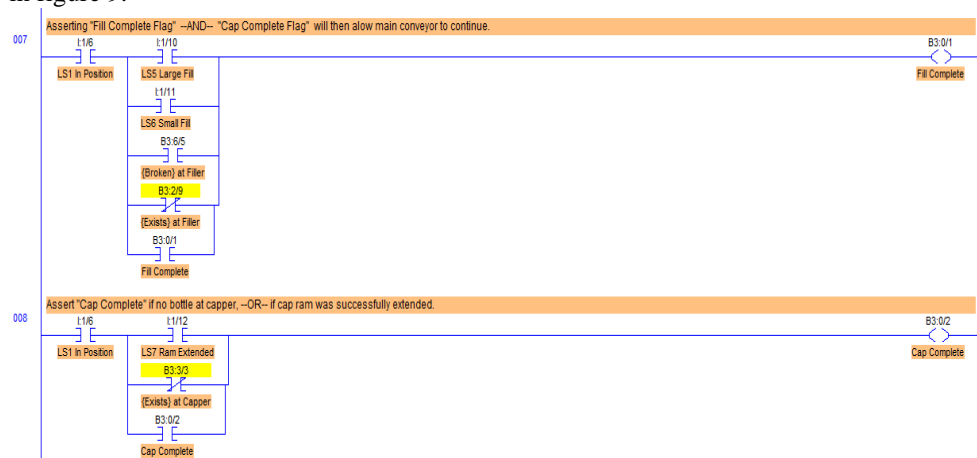


Figure.9 Fill complete and cap complete

- h. In the event of full box at the scrap gate, the main conveyor need to be stopped to avoid sending more broken bottles to the scrap bottle collection box via scrap gate (I:1/13). The box full bit (B3:0/0) can be activated by calculating the small and large bottles. The small bottles are 2/3 of size of large bottles. The box full calculation can be adjusted to tally this ratio. This is shown in figure 10.

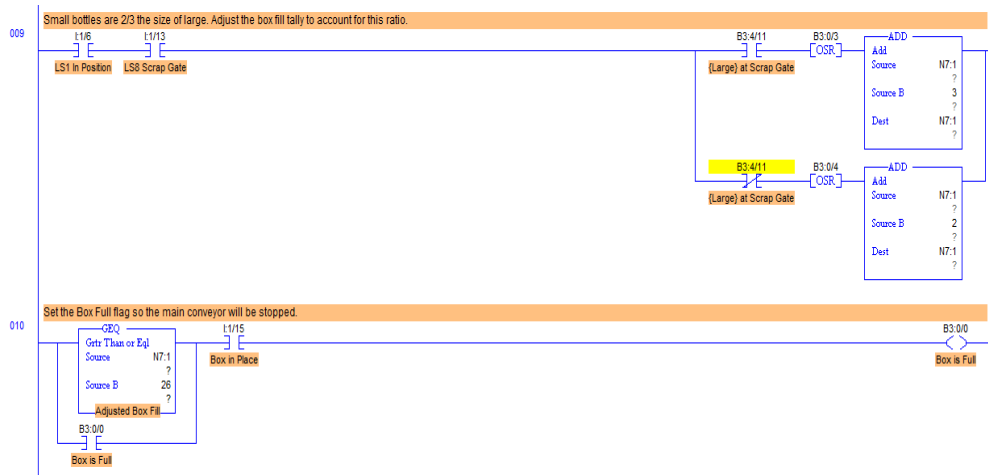


Figure.10 Box full by mathematical and logical operation

- i. Count the number of scrap boxes collected by using box full bit (B3:0/0). This operation can be done by connecting the counter C5:5 in parallel with the scrap conveyor. The scrap conveyor is activated by run lamp (O:2/10) and normally closed main conveyor (O:2/0) and either of box full bit (B3:0/0) or normally closed box in place input (I:1/15). This is shown in figure 11.



Figure.11 Activate scrap conveyor and scrap box counter

- j. When the full scrap box is removed and new box is brought in place, clear the box full count to restart the counter. This is shown in figure 12.



Figure.12 Restart the scrap box counter

- k. The LED display multiplexing can be done in the subroutine 4 as shown in fig. 13a and fig.13b.

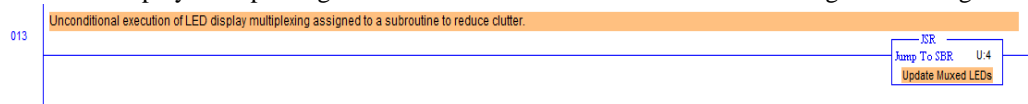


Figure.13a call the subroutine 4 to run the LED display multiplexing

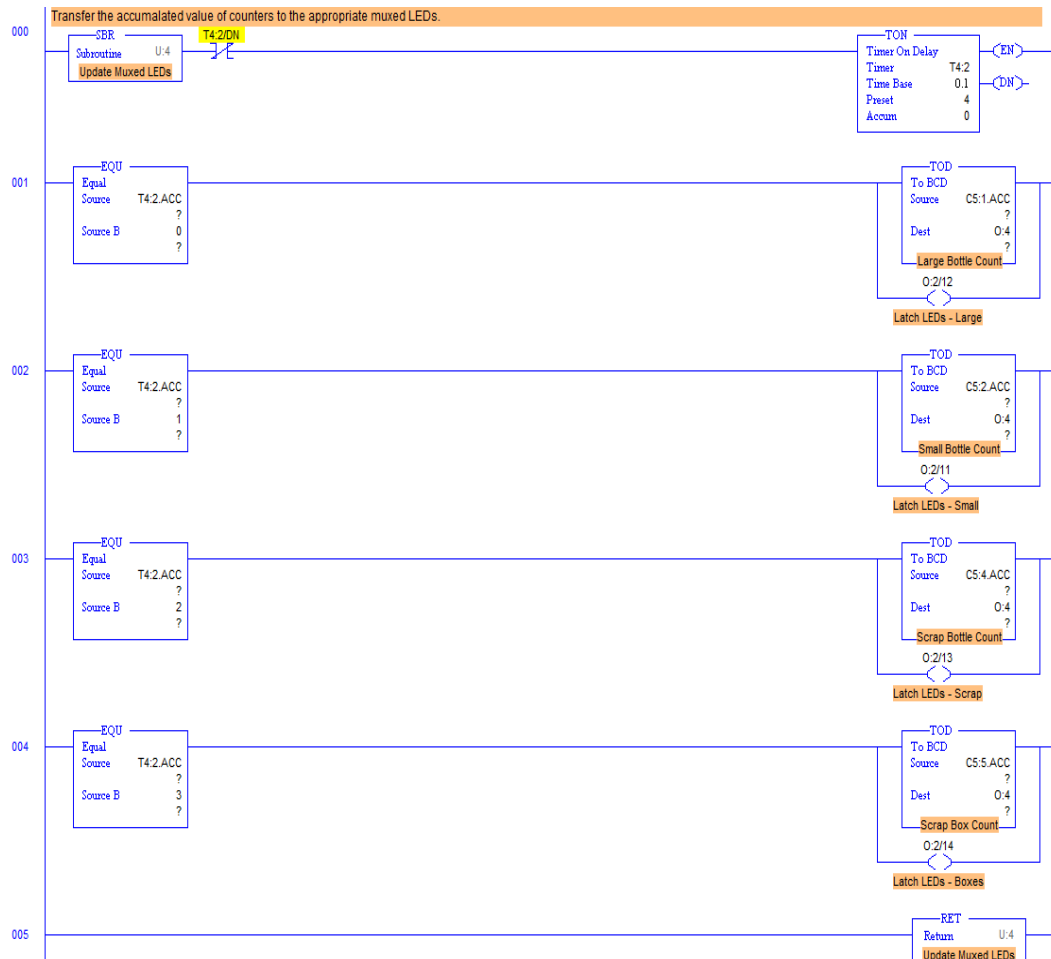


Figure.13b LED display multiplexing subroutine

4. Results and Discussion

The program is designed to run the bottle line simulation using LogixPro Simulator. The bottle line simulation is shown in figure 14.

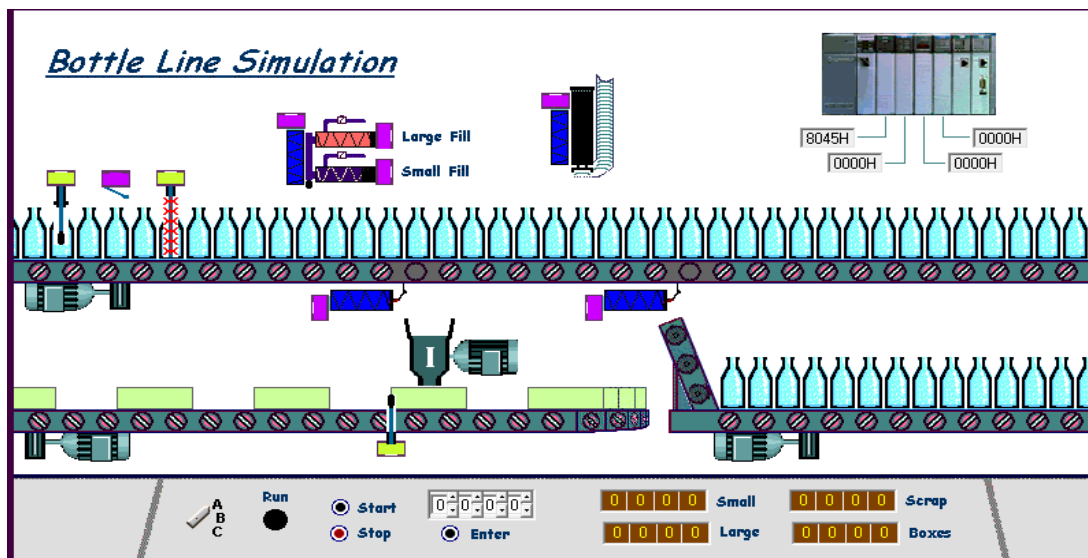


Figure.14 Bottle line simulation environment

The processor details such as processor selected, driver link and the reply timeout chosen to run the process is shown in figure 15.

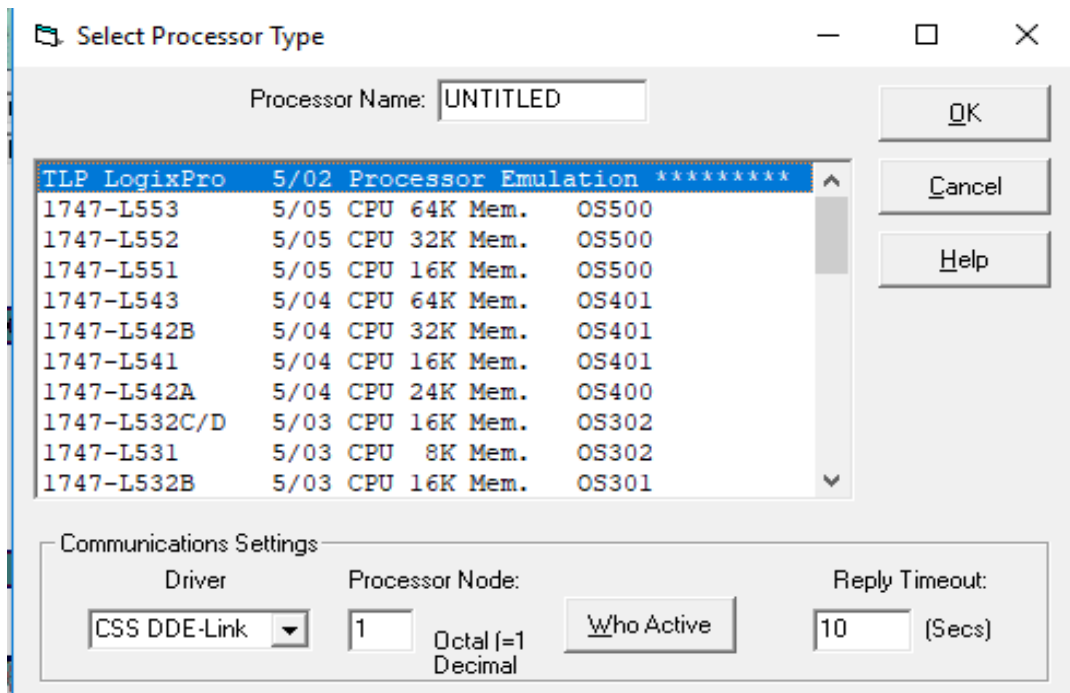


Figure.15 Processor details

The broken bottle identification, opening of scrap gate , the number of small and large bottles filled is also shown in figure 16.

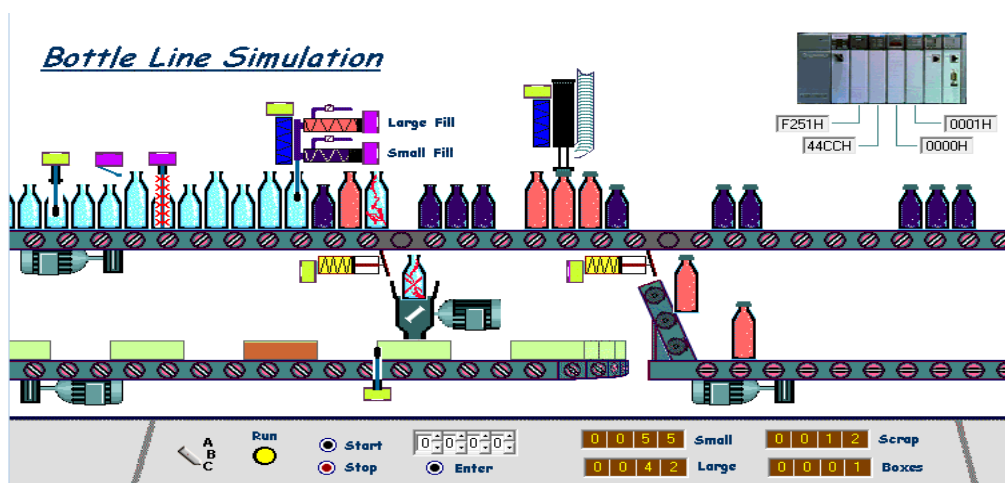


Figure.16 Simulation of program

The small bottle filling and capping, number of normal boxes collected, scrap boxes collected, number of small bottles filled and large bottles filled can be seen in figure 16.

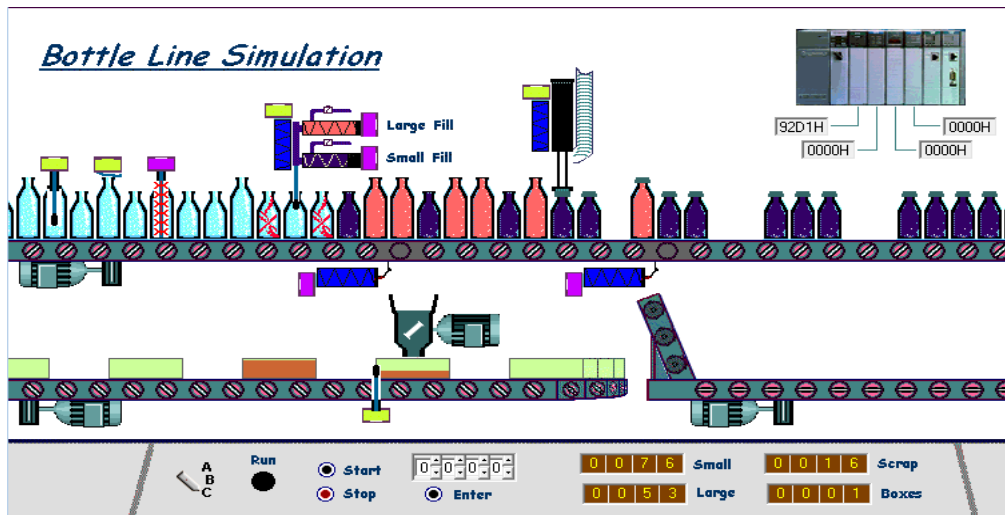


Figure.17 Small fill and capping operation

It can be seen that the program works successfully to automate the bottle filling, capping, packaging the bottles in a box and scraping the broken bottles as required by the industry.

5. Conclusion

The application of PLCs is increasing day by day in automation industry. The bottle filling and packaging automation system was considered for study in this paper. The step-by-step procedure to develop the program was discussed. The program was run using LogixPro simulation package for Allan-Bradley PLCs. The operation of the program was tested at each step and results were presented. The results show that the program is implemented successfully for the bottle line automation simulation.

References

- Abdulraouf I., A., Mohammed A., M., & Osman D., A. (2017). Automated and Monitored Liquid Filling System using PLC Technology. International Conference on Communication, Control, Computing, and Electronic Engineering (ICCCCEE), Sudan.
- Ameer L., S., Lawahed F., N., & Mohammed J., M. (2017). PLC Based Automatic Liquid Filling System For Different Sized Bottles. *International Research Journal of Engineering and Technology (IRJET)*, 4(12), 58-66.
- Bolton, W. (2015). *Programmable logic controllers*. Newnes.
- Gong, Q. (2017). Application of Computer Image Technology in Automated Liquid Filling Machine. *Chemical Engineering Transactions*, 62, 859-864.
- Jones, C. T. (1998). *Programmable logic controllers: the complete guide to the technology*. Brilliant-Training.
- Kamel, K., & Kamel, E. (2013). *Programmable logic controllers: Industrial control*. McGraw Hill Professional.
- Md. Liton, A., Shantonu, K., & Rafiquzzaman, M. (2019). Automatic Bottle Filling System Using PLC Based Controller" *Journal of Advancement in Mechanics*. *Journal of Advancement in Mechanics*, 4(1), 17-24.
- Shweta, S., Dhananjay, S., Akshay, P., & Mangesh, T. (2018). Automatic Bottle Filling Systems Using PLC. *International Journal of Advance Research in Science and Engineering*, 7(3).
- Sidik, M., & Ghani, S. C. Volume Measuring System Using Arduino for Automatic Liquid Filling Machine. *International Journal of Applied Engineering Research*, 12(24), 14505-14509.
- T.Kalaiselvi, R.Praveena, Aakanksha.R, & Dhanya.S. (2012). PLC Based Automatic Bottle Filling and Capping System With User Defined Volume election. *International Journal of Emerging Technology and Advanced Engineering*, 2(8).
- Win, Z. K., & New, T. T. (2019). PLC Based Automatic Bottle Filling and Capping System. *International Journal of Trend in Scientific Research and Development*, 3(6).
- Zhang, P. (2010). *Advanced industrial control technology*. William Andrew.