PLC based Bottle Filling System

DISSERTATION

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Submitted by:

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CERTIFICATE

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Delhi, 2024 ROHAN DHAWAN

ABSTRACT

The objective of our project is to create, build, and oversee a "PLC BASED BOTTLE FILLING SYSTEM." This endeavor offers numerous advantages such as reduced power consumption, lower operational expenses, minimal upkeep, precision, and more. It falls under industrial automation and finds widespread application in various sectors like dairy, chemical, food, mineral water, and other industrial settings. A prototype has been developed as a demonstration of the project.

Bottle filling is a fundamental operation implemented by machinery, widely utilized across industries. In this project, bottle filling is regulated using a PLC controller, which serves as the core component of the entire setup. For the conveyor system, a dc motor was chosen for enhanced performance and operational simplicity. A sensor is employed to identify the bottle's position. By utilizing a reduced number of components in our system, overall costs have been significantly decreased. The programming of the PLC is executed using ladder logic, a commonly utilized and accepted programming language for PLCs. The specific PLC incorporated in this setup is a Siemens S7-1200, enhancing system flexibility and ease of operation.

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CHAPTER 1

INTRODUCTION

1.1 Overview

In this rapidly evolving landscape of automation, electrical machines have become an indispensable component of modern industry. Automating routine tasks in industrial settings enhances productivity and minimizes the likelihood of errors. Traditional industrial operations often rely on manual handling of machinery and processes that require human intervention, which can introduce errors, increase time consumption, and escalate costs. By automating these operations, time and error rates are significantly reduced, leading to improved product quality and overall efficiency.

Nowadays, PLC applications are widely recognized and utilized in the digital world, particularly in industrial sector. Typically, PLCs are being used in industrial settings to command mechanical movements of machinery, ensuring efficient production and precise signal processing. This project delves into the specific application of PLCs, focusing on a machine designed for automatic water bottle filling, fully controlled by a PLC, which serves as the core of the system.

The operation sequence is created using a ladder diagram, and the project is programmed with TIA-Programmer software. Sensors play a crucial role as input signal transmitters for the PLC. In this system, sensors detect the position of bottles moving along a rotating disc at low speed during machine operation. The sensor's input signals are sent to the PLC, serving as reference signals to determine the output signals according to the PLC programming language based on user requirements. The PLC typically controls electronic and electrical devices such as motors, pumps, sensors, and rotating discs.

The entire bottling process is automated by inputting the necessary conditions into the PLC using ladder logic. Ladder logic is a method of programming a PLC, and based on the developed logic, various operations are carried out to complete the bottle filling process. A PLC consists of an I/O unit, a central processing unit, and a memory unit."

The input/output (I/O) unit of the PLC serves as an interface to the real world. Real-world inputs are provided to the input unit, processed according to the programmed instructions, and the resulting outputs are delivered back to the real world via the output unit of the PLC. The central processing unit (CPU) handles all logical and control operations, as well as data transfer and handling tasks. The results and statuses of these operations are stored in the PLC's memory. PLCs are widely used in various applications, particularly in the fields of control and automation.

Present Applications:

1. **Food and Beverage Industry:**

- **Soft Drinks and Juices:** Automated bottle filling systems are extensively used in the production of soft drinks, juices, and other non-alcoholic beverages. These systems ensure precise filling volumes, maintaining product consistency and reducing waste.
- **Bottled Water:** High-speed filling machines are critical for the bottled water industry, enabling efficient production to meet high consumer demand.
- **Dairy Products:** Milk, yogurt, and other dairy products are often packaged using automated filling systems that maintain hygiene standards and product integrity.

· 2. **Pharmaceutical Industry:**

- **Liquid Medications:** Bottle filling systems are used to accurately dispense liquid medications into bottles, ensuring precise dosages and maintaining sterility.
- **Nutritional Supplements:** Automated systems help in the packaging of liquid nutritional supplements, ensuring accurate volume and reducing contamination risks.

· 3. **Cosmetics and Personal Care:**

- **Lotions and Creams:** Automated filling systems are used for lotions, creams, shampoos, and other personal care products, ensuring consistent product quality and efficient packaging.
- **Perfumes:** High-precision filling machines are essential for the perfume industry to avoid product loss and maintain accurate volumes.

· 4. **Chemical Industry:**

- **Cleaning Agents:** Bottle filling systems are employed to package liquid cleaning agents, detergents, and other household chemicals efficiently.
- **Industrial Chemicals:** Automated systems ensure safe and precise filling of various industrial chemicals, reducing handling risks and ensuring proper containment.

<u>Further Advancements:</u>

1. **Technological Advancements:**

- **Smart Automation:** Integration of IOT(Internet of Things) and AI(Artificial Intelligence) can enhance the capabilities of bottle filling systems. Smart sensors and real-time data analytics can optimize the filling process, predict maintenance needs, and reduce downtime.
- **Advanced Robotics:** Incorporating advanced robotics can increase the flexibility and speed of bottle filling systems, enabling them to handle different bottle sizes and shapes with minimal reconfiguration.

2. **Sustainability Initiatives:**

- **Eco-Friendly Packaging:** Future bottle filling systems may focus on handling eco-friendly and biodegradable packaging materials, supporting sustainability goals and reducing environmental impact.
- **Water and Energy Efficiency:** Innovations aimed at reducing water and energy consumption during the filling process can make these systems more environmentally friendly.

3. **Customization and Flexibility:**

- **On-Demand Production:** The trend towards personalized and on-demand production will drive the need for highly flexible bottle filling systems that can quickly switch between different products and packaging formats.
- **Modular Systems:** Development of modular bottle filling systems can offer scalability and customization, allowing industries to expand their operations without significant capital investment.

4. **Regulatory Compliance and Safety:**

- **Enhanced Hygiene Standards:** The pharmaceutical and food industries will continue to demand higher hygiene standards. Future systems will incorporate more advanced sterilization and contamination prevention technologies.
- **Regulatory Compliance:** Compliance with stringent regulatory standards will drive the development of bottle filling systems that can easily adapt to new regulations, ensuring product safety and quality.

5. **Integration with Supply Chain:**

- **Seamless Integration:** Future bottle filling systems will be designed to integrate seamlessly with other components of the supply chain, including packaging, labeling, and distribution systems. This will enhance overall operational efficiency and traceability.

1.2 Thesis Organisation

Chapter 2: This chapter provides a overview of the work conducted on automation using PLCs.

Chapter 3: In this chapter, a concise description on PLC that is used the project is given along with it the programming languages that are widely use has also been discussed.

Chapter 4: This chapter briefly explains the system used which consists of a reservoir tank, pump, process tank, Level switch, Power driver circuit, bottle placement sensor, bottle position sensor, solenoid valve, motor and rotating disc. Each components have been discussed briefly in this chapter.

Chapter 5: It explains the arrangement of various components and provides a comprehensive guide to the PLC programming setup.

Chapter 6: The PLC-controlled bottle filling system demonstrates significant improvements in efficiency, reliability, and user-friendliness. By automating the process and incorporating advanced components, the system achieves high productivity and consistent performance, making it a valuable solution for small-scale industrial applications which has been shown in this chapter.

Chapter 7: The PLC-controlled bottle filling system can become more advanced, efficient, and adaptable, meeting the evolving needs of the industry and contributing to more sustainable manufacturing practices which is briefly explained in this chapter.

1.3 Conclusion

The introduction establishes a clear framework for understanding the importance and impact of PLCs and ladder logic in modern industrial automation. The successful implementation of the bottle filling system serves as a testament to the effectiveness of these technologies in optimizing industrial processes, paving the way for future innovations and applications.

CHAPTER 2

Literature Review

2.1 General

This chapter provides an overview of the work conducted on industrial automation using PLCs. It highlights how a well-designed PLC-based system can save time and money while offering reliable and high-quality control. Emphasis is placed on the importance of focus, attention, and motivation to improve production quality and reduce operating costs. The chapter also discusses PLC-based control schemes used for managing various field devices.

Automation is crucial for significantly increasing the efficiency of any system. The application of PLCs is an optimal choice for achieving energy savings, enhancing production, and minimizing overall costs.

2.2 Literature Review

Greg P. Zimmerman [1] The concept, working principle, and advantages of (PLCs) have been analyzed. Insights into their practical applications and comparisons with other control systems are provided. The explanation includes how PLCs are used to control and monitor system parameters

Z. Tianxia, D. Feng, and Y. Hao [4] discussed the importance of timely adjustments to improve system efficiency during different operations and highlighted the role of program design in identifying system faults. They emphasized that intelligent, secure, and efficient bottle arrangement processes can be achieved through appropriate control measures. PLC technology facilitates automatic control, leading to a reduction in manual labor, lower production expenses, improved efficiency, and increased automation levels, ensuring stability and security in the production process.

David W. Pessen, in his publication by John Wiley & Sons [5], offers insights into addressing industrial challenges. He presents a method for selecting the most suitable control application approach for a specific system and includes details on circuit design. Pessen also explores cost reduction strategies and offers information on enhancing existing systems.

Johnson, C.D.[6] provides insights into the elements of control systems, focusing on their operation and design. The author emphasizes a practical approach to designing control systems, highlighting the use of sensors, signal conditioning elements, and final control elements. The aim is to facilitate the integration of measurement and instrumentation with automation devices like PLCs.

In the work by Bolesław F. Boczkaj cited as [7], the author addresses bridging the divide between theoretical principles and practical applications through case studies. The main goal is to develop a

PLC program that creates a code library for specific actuators, sensors, robots, motion axis arrangements, and work cell configurations.

Jaykumar Patel, Prof. Alpeshkumar Patel, and Mr. Raviprakash Singh [8] detail a process loop applicable to bottle washer machines, with potential applications in oil and chemical industries. This loop regulates three key parameters: level, flow, and pressure, which interact closely. PLC technology is employed to control pressure and flow, enhancing the washing process's efficiency and response time. The authors suggest that this loop can also be adapted for bottle fillers with appropriate hardware modifications, necessitating an additional safety valve. PLCs manage various sensors and valves through programmed instructions, generating signals for precise control. Additionally, Human Machine Interface (HMI) is integrated to enable users to directly set values, further optimizing the system's operation.

Gerardo Gonzalez-Filgueria [9], the focus is on meeting the industry's demand for effective process automation solutions. The paper introduces an algorithm for process control specifically designed for packing liquid products using PLC technology. The primary objective is to streamline the process and reduce processing time. Additionally, the paper includes a comparative analysis of the time required for filling water and detergent in the process. To ensure the smooth operation of the automated process, a SCADA (Supervisory Control and Data Acquisition) system is employed for monitoring and control purposes.

Laurentiu Schiop and Marian [12], the mixing process is characterized as inherently nonlinear and multivariable. A mathematical model focusing on the flow dynamics of a basic holding tank is developed, with the tank's internal pressure determining its output. To facilitate the design of appropriate control mechanisms, particularly PI controllers, a mathematical model for mixing colors is also established. The study compares a nonlinear mathematical model with a linear one. Control of the process is achieved using STEP7 Programming Software for Siemens SIMATIC PLC, with the implementation carried out in the Matlab-Simulink environment. Online implementation of the controlled process is realized using functional block diagrams (FBD) within STEP7. Furthermore, an intuitive Human Machine Interface (HMI) is created in WinCC, catering to operator usage in industrial settings.

In the study conducted by K. Uttekar, R. Gosavi, S. Lad, and J. Kamat as referenced in [13], there's a shift from traditional wired field bus networks to wireless sensory networks due to their cost-effectiveness and faster communication. This transition is particularly evident in various industrial sectors. Specifically, a wireless sensor network is established and deployed for a bottle capping plant assembly station. Data collection is facilitated by smart wireless sensors, with transmission to a Data Supervisory and Control Device (DSCD). To safeguard against physical damage to the system, an interlocking mechanism is provided. The use of smart sensors is shown to enhance efficiency and reduce installation time. Moreover, the current network capacity can be easily expanded through the implementation of the smart sensor network. Additionally, the concept of wire break sensing enables the identification of faulty sensors, further improving system reliability.

In the work by Gerardo Gonzalez-Filgueria as referenced in [15], the focus is on enhancing plant profitability through the implementation of process control strategies. By leveraging scalable control and optimization technologies, the goal of improving profitability can be achieved. The author emphasizes that Small to Medium Enterprises (SMEs) can benefit from adopting more suitable and precise automation systems. Additionally, the proper functioning of automated processes is ensured through the use of SCADA systems, with PLCs employed for control purposes.

In the work by V. Rajeswari, Dr. L. Padma Suresh, and Prof. Y. Rajeshwari as referenced in [16], the focus is on the critical importance of maintaining various parameters related to water quality are identified as crucial in pharmaceutical industries, as any lapses in maintaining these parameters could render the water unfit for use in the plant. Once obtained, water must be appropriately stored and distributed to ensure its quality is preserved. Proper storage and distribution are essential to prevent the proliferation of microorganisms and minimize the risk of contamination. Continuous recirculation and effective sanitization systems are recommended to maintain the integrity of the water supply systems.

Marco Colla [17] discusses the challenges automation engineers encounter during software design, implementation, and transportation. To address these issues, the author conducted a survey. The study highlights the growing need for automation, emphasizing the importance of rapid changes. Additionally, it provides information on control techniques and devices used in automation.

Hassaan Th. H. Thabet and Ma Ysara A. Qasim [18] emphasize the crucial role of the food industry in a country's economy, especially for developing countries striving to reach the developed nations. These countries need to enhance their focus on such industries. Automation plays a vital role in the development policy of any industry, particularly in the food production process. The authors highlight that automation can be achieved effectively by designing systems based on Programmable Logic Controller (PLC) technologies.

S. T. Sanamdikar and Vartak C [19] highlighting the stages involved in this process. With the rising demand for high-quality and efficient production of various colors in today's globalized world, the authors focus on the inputs and components of the color mixing process. The system allows for precise mixing of colors in the required proportions using mixing tanks. SCADA is used for system monitoring, while PLC handles the internal storage of instructions. The authors also discuss the advantages of automation in controlling and monitoring industrial plants, emphasizing the benefits of efficiency and quality improvement.

Xiaoling Yang, Q. Zhu, and H. Xu [20] discuss the operation of two nine-story elevators running in parallel using PLC technology. Previously, these elevators operated independently, resulting in high average and maximum waiting times during peak hours. After implementing parallel operation with PLC control, both average and maximum waiting times were significantly reduced. Overall, the reformed control system has shown improved reliability and performance.

Gediminas Danilevičius [22] proposed a methodology for synthesizing control programs for specific process plans, focusing on advancements in planning, production, and PLC-specific information

Masao Ogawa and Y. Henmi [23] introduced a hybrid control system combining PC and PLC for automating a beer brewery processing plant. This is designed to be both cost-effective and flexible. In this setup, PLCs play a crucial role by integrating into the PID control loop functions and developing a control and monitoring system for tank selection. This integration enhances the manufacturing speed and improves production quality.

Hiroo Kanamaru [24] introduced the concept of safety PLC techniques aimed at minimizing the adverse effects of industrial accidents. The discussion encompasses the installation, configuration, operation, and maintenance of safety PLCs.

2.3 Conclusion

The literature review underscores the critical role of PLCs and ladder logic programming in advancing industrial automation. These technologies have not only replaced traditional relay-based systems but have also opened up new possibilities for more complex, precise, and efficient control processes. The case study on the bottle filling system demonstrates the tangible benefits of PLCs in real-world applications, showcasing their ability to streamline operations and increase productivity. Looking forward, the integration of modern technologies and the continuous improvement of PLC systems promise even greater advancements in industrial automation. The ongoing evolution of PLCs and ladder logic will likely lead to smarter, more adaptable, and more sustainable industrial processes, solidifying their importance in the future of manufacturing and process control.

CHAPTER 3
ABOUT PLC

3.1 General

Programmable Logic Controllers (PLCs):

Definition and Function:

- **Programmable Logic Controllers (PLCs)** are specialized digital computers used for the automation of industrial processes. They are designed to control a variety of mechanical processes, such as those found on factory assembly lines or in machinery operation."
- **Functionality:** PLCs monitor inputs, make decisions based on their programmed logic, and control outputs to automate machines or processes.

Key Components:

- **Input/Output (I/O) Unit:** It serves as the interface between the PLC and the external world, receiving signals from sensors (inputs) and sending signals to actuators (outputs).
- **Central Processing Unit (CPU):** The brain of the PLC, which processes input signals based on the programmed instructions and generates output signals accordingly.
- **Memory Unit:** Stores the PLC program, operational data, and configuration settings.

Programming:

- **Ladder Logic:** A logical programming language which is used to create PLC programs. It resembles a ladder with two vertical rails and horizontal rungs, where each rung is representing a control operation.
- **Ease of Use:** Ladder logic is intuitive and resembles electrical relay logic diagrams, making it accessible to engineers and technicians with electrical backgrounds.

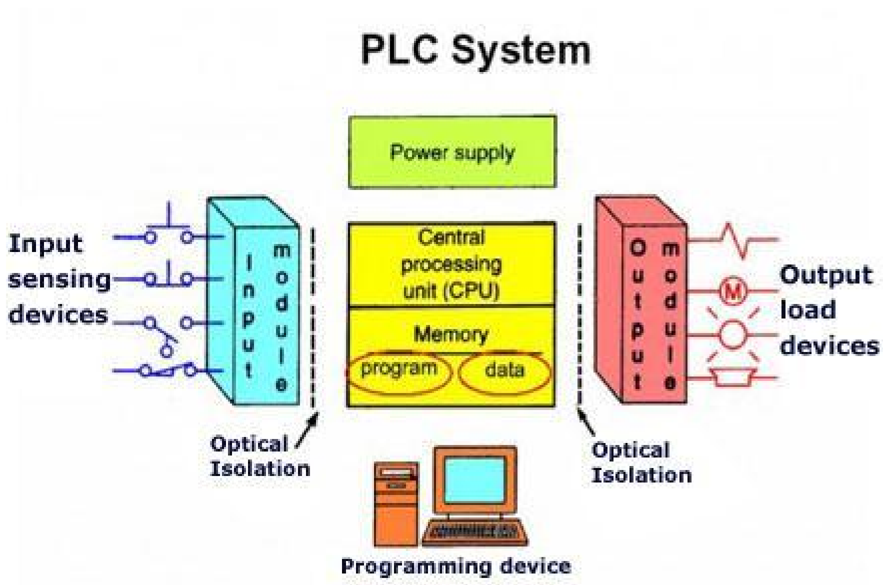
Applications:

- PLCs are widely used in various industrial sectors for tasks such as automation of manufacturing processes, control of machinery, monitoring of production lines, and complex process control.

3.2 Basic parts of PLC

A Programmable Logic Controller (PLC) is essentially a micro-controller having four fundamental components: the processor, input/output (I/O) interface, power supply, and programming module. The processor, acting as the brain of the controller, makes decisions and generates outputs based on the commands received as inputs from interfacing devices. The power supply is distributed over all parts of the PLC, while the programming module assists in creating the necessary commands to instruct the processor.

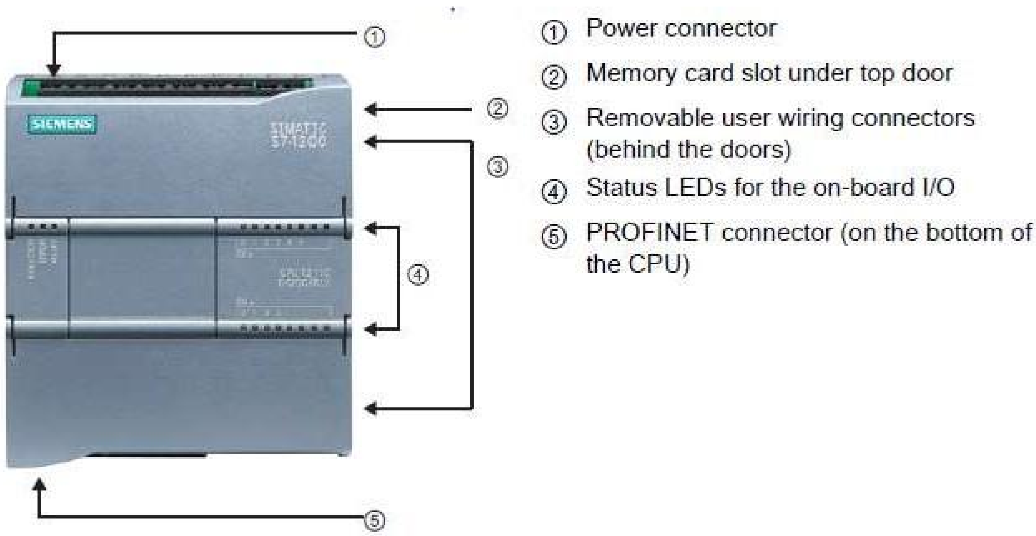
The block diagram (refer to Fig. 3.1) illustrates the various components and their interconnections, highlighting the direction of instruction flow. The processor includes the CPU and memory, while the PLC features an Input/Output Rack where I/O modules are inserted. Input modules connect to input devices such as toggle switches and press switches, whereas output modules connect to devices like solenoids, starters, and indicators, as depicted in the block diagram. The program panel is used to create logic that is comprehensible to users and converts this logic into machine instructions for the processor.



[*Fig 3.1: A block diagram of PLC*]

PLCs offer several advantages, including ease of programming and maintenance. They are particularly useful for diagnosing process faults, as indicated by the lights on their modules. Quick installation and adaptability for different applications provide a high degree of flexibility. Additionally, advanced PLCs come with communication and networking modules, enhancing their functionality.

3.3 Technical Specification of PLC Used



[*Fig 3.2: Front view of Siemens S7 1200*]

A powerful controller system is created by CPU, which combines a microprocessor, integrated power supply, input and output circuits, PROFINET capability, high-speed motion control I/O, and on-board analog inputs into a small container. Once a program has been uploaded, the CPU has all the necessary logic to monitor and control the hardware in the system. The CPU modifies the outputs in accordance with the user's program logic by keeping an eye on the inputs. Furthermore, for PROFINET network connectivity, the CPU has a dedicated PROFINET port.

Power Budget

The CPU has an built in power supply that provides power to a number of parts, such as the CPU itself, signal boards, communication modules, signal modules, and other parts that require 24VDC power. The CPU also meets the 5VDC power needs of the signal boards, communication modules, and signal modules by supporting a 5VDC logic budget. In addition, the CPU powers the relay coils on the signal modules and supplies a 24VDC sensor supply for input locations. An external 24VDC power supply needs to be added if the system's 24VDC power requirements are more than the sensor supply budget.

Within the S7-1200 system, certain 24VDC power input ports are interconnected, linking multiple M terminals through a common logic circuit. Circuits designated as "not isolated" on data sheets, such as the 24VDC power supply of the CPU, relay coil power input of an SM, or power supply for a non-isolated analog input, are interconnected.

3.4 PLC Concepts

Execution of the user program

The CPU provides support for various types of code blocks that help in creating a streamlined structure for our user program:

- **Organization blocks (OB)** establish the program's framework. While some OB come with preset behaviors and start events, it's also possible to design OB with customized start events.
- **Functions (FC)** and **function blocks (FB)** include the code needed to run the program for a given job or set of parameters. A variety of input and output parameters are available for data exchange with the calling block on each FC or FB. An FB uses a related data block, called an instance database, to store value states that other program blocks can access in between executions. The permissible range for FC and FB numbers is 1 to 65535.
- **Data blocks (DB**) save data that the program blocks can use. The range of acceptable DB numbers is 1 to 65535.

One or more optional start-up organization blocks (OB) that run once when the program enters the RUN mode precede one or more program cycle OB that run repeatedly during the user program's execution.

Operating Modes of the CPU

The central processing unit (CPU) operates in three different modes: STOP, STARTUP, and RUN, which are indicated by status LEDs on the CPU's front panel.

- The CPU is inactive and not running the program, allowing for project downloads" is how STOP mode describes the CPU.
- The startup organizational blocks (OB) are executed once, with interrupt events not being processed is how STARTUP mode operates.

PLC data type

The PLC data types editor enables us to specify data structures that may be used repeatedly in our application. Double-clicking the "Add new data type" option after navigating to the "PLC data types" section of the project tree is the first step in creating a PLC data type. We can quickly alter the default name of the newly created PLC data type with two simple clicks, and we can further edit it by double clicking to open the PLC data type editor.

Similar to the data block editor, we follow the same editing procedures to construct a personalized PLC data type structure. By adding new rows for the necessary data types, we can shape the data structure as needed. Upon the creation of a new PLC data type, its name will automatically appear in the data type selector drop-down menus within the DB editor and code block interface editor.

3.5 Programming Concepts

Structuring the user program

When developing a user program for automation tasks, the instructions are inserted into code blocks:

- An organization block (OB) is triggered by a specific CPU event and can pause the user program's execution. The default cyclic execution block (OB 1) establishes the foundation of the user program and is essential. Additional OBs included in the program will interrupt OB 1's execution, serving distinct functions like initiating tasks, managing interruptions.

- A function block (FB) is a subroutine executed upon being called from another code block (OB, FB, or FC). Parameters are passed to the FB from the calling block, and a designated data block (DB) contains the necessary information for that specific call. Altering the instance DB enables a standard FB to regulate multiple devices individually. For instance, one FB can oversee various pumps or valves, where separate instance DBs hold respective operational settings for each.

- A function (FC) that is called from another block (OB, FB, or FC) operates as a subroutine.FC does not have an instance database in common with FB. The FC receives input parameters, and its output values need to be stored in a global database or a memory location.

Programming Language

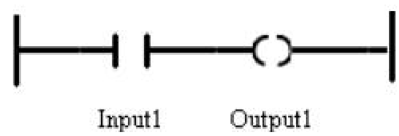
STEP 7, a programming environment provided by Siemens for their automation systems, offers several standard programming languages for the S7-1200 series of PLCs. These languages cater to different programming needs and preferences, and each has its unique characteristics and applications. Here are the three main languages provided:

- **LAD (Ladder Logic)**: Best for users familiar with electrical control systems and relay logic, suited for sequential and simple control tasks.
- **FBD (Function Block Diagram)**: Great for modular, graphical design of complex control functions, suitable for integrating multiple logical operations.
- **SCL (Structured Control Language)**: Ideal for complex and advanced control tasks, preferred by users with traditional programming experience.

Choosing the right language depends on the specific requirements of the automation task, the complexity of the control logic, and the background and preference of the programmer. Each language offers unique advantages, making it possible to tailor the programming approach to the needs of the application and the skills of the development team.

Ladder Logic (LAD)

Ladder logic is a graphical language widely used for programming Programmable Logic Controllers (PLCs) and creating electrical logic schematics. It was initially developed to represent relay-based logic. The name "ladder logic" comes from the visual similarity of its programs to ladders, which feature two vertical "rails" and a series of horizontal "rungs" between them. A simple ladder logic circuit with one input and one output can illustrate how ladder logic programming works.



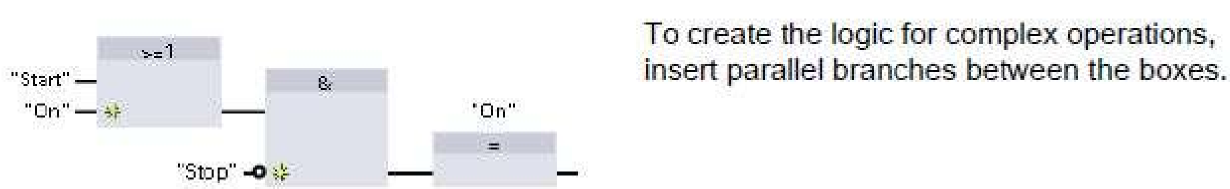
[*Fig 3.3: PLC Ladder Logic*]

It is possible to construct parallel circuits by inserting branches to build the logic for intricate operations. You terminate parallel branches upward and they either open downward or immediately connect to the power rail.
"Box" instructions are provided by LAD for a number of purposes, such as arithmetic, timer, counter, and move operations.
The number of instructions (rows and columns) in a LAD network is not limited by Step 7.

Function Block Diagram

Like Fellow, FBD is additionally a graphical programming dialect. The representation of the rationale is based on the graphical rationale images utilized in Boolean variable based math.

Numerical capacities and other complex capacities can be spoken to straightforwardly in conjunction with the rationale boxes.



[*Fig 3.4: Function Blocks*]

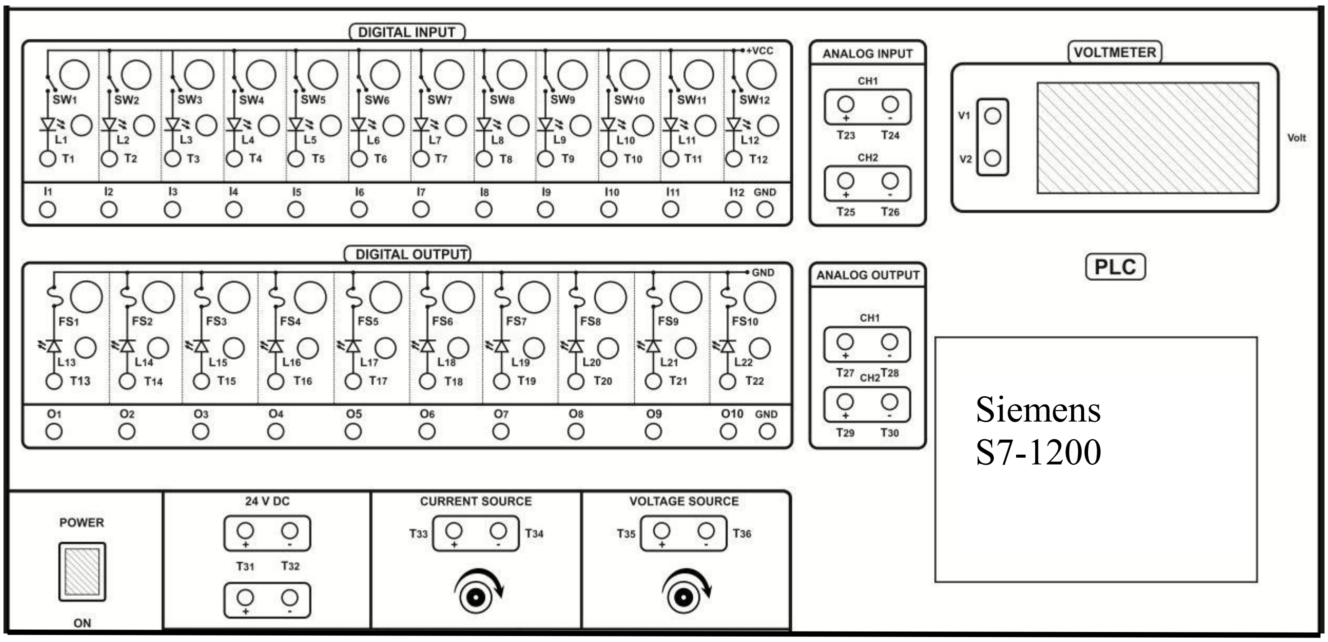
STEP 7 does not constrain the number of informational (lines and columns) in an FBD arrange.

SCL

The high-level programming language used in structured control is derived from PASCAL. SCL is specifically made for SIMATIC S7 CPUs, which are its domain. Because of this, STEP 7's block structure is supported by SCL as well. The basic programming operators as a kind of assignment, such as =; mathematical functions like + for sum, – for difference, * for multiplication, and / for division, form the foundation of the SCL instructions employed. The typical PASCAL control operations—if-then-else, case, repeat-until, goto, and return—are also included in SCL. Therefore, PASCAL-programming parts may be provided using any PASCAL reference. Additionally, the majority of SCL instructions—such as timers and counters—are compatible with those for LAD and FBD.

3.6 Experimental Setup

FRONT PANEL DIAGRAM:



[*Fig 3.5: Front view of PLC Panel*]

FRONT PANEL DESCRIPTION:

1. Power ON - To switch ON/OFF the PLC trainer
2. I1 - Digital input 1
3. I2 - Digital input 2
4. I3 - Digital input 3
5. I4 - Digital input 4
6. I5 - Digital input 5
7. I6 - Digital input 6
8. I7 - Digital input 7
9. I8 - Digital input 8

10. I9 - Digital input 9
11. I10 - Digital input 10
12. I11 - Digital input 11
13. I12 - Digital input 12
14. GND - Ground terminal
15. O1 - Digital output 1
16. O2 - Digital output 2
17. O3 - Digital output 3
18. O4 - Digital output 4
19. O5 - Digital output 5
20. O6 - Digital output 6
21. O7 - Digital output 7
22. O8 - Digital output 8
23. O9 - Digital output 9
24. O10 - Digital output 10
25. T1 - To measure voltage of digital input 1
26. T2 - To measure voltage of digital input 2
27. T3 - To measure voltage of digital input 3
28. T4 - To measure voltage of digital input 4
29. T5 - To measure voltage of digital input 5
30. T6 - To measure voltage of digital input 6
31. T7 - To measure voltage of digital input 7
32. T8 - To measure voltage of digital input 8
33. T9 - To measure voltage of digital input 9
34. T10 - To measure voltage of digital input 10
35. T11 - To measure voltage of digital input 11
36. T12 - To measure voltage of digital input 12
37. T13 - To measure voltage of digital output 13
38. T14 - To measure voltage of digital output 14

39. T15 - To measure voltage of digital output 15
40. T16 - To measure voltage of digital output 16
41. T17 - To measure voltage of digital output 17
42. T18 - To measure voltage of digital output 18
43. T19 - To measure voltage of digital output 19
44. T20 - To measure voltage of digital output 20
45. T21 - To measure voltage of digital output 21
46. T22 - To measure voltage of digital output 22
47. SW - Push button
48. FS - Fuse Holder
49. T23, T24 - Analog Input 1 (0-5 V DC)
50. T25, T26 - Analog Input 2 (0-5 V DC)
51. T27, T28 - Analog Output 1 (0-5 V DC)
52. T29, T30 - Analog Output 2 (0-5 V DC)
53. Voltmeter - To display the voltage

3.7 Conclusion

In this chapter, a brief description on PLC that is used the project is given along with it the programming languages that are widely use has also been discussed. In the context of the project, the use of a PLC to automate a bottle filling system highlights the advantages. This project demonstrates how PLCs can simplify complex processes, ensure consistent output, and adapt to varying operational requirements, providing a tangible example of the trans-formative impact of PLCs in industrial automation.

CHAPTER 4
HARDWARE AND SOFTWARE REQUIREMENT

4.1 General

This system consists of a reservoir tank, pump, process tank, Level switch, Power driver circuit, bottle placement sensor, bottle position sensor, solenoid valve, motor and rotating disc. Reservoir tank is used to store the required amount of water for the process. Water in the reservoir tank is pumped to reach the process tank by the output of power driver. Power Driver circuit is used to regulate the pump based on the controlled output of PLC. The Power driver circuit output goes to the solenoid valve. Solenoid valve is used to drain the water from the process tank to the bottle on the rotating shaft based on the output of PLC. The sensors used to sense the bottle placement and the position of the bottle. The sensor output goes to the PLC as Digital input.

[*Fig 4.1: Bottle Filling Trainer*]

TECHNICAL SPECIFICATIONS:

1. Reservoir Tank

Length - 250 mm

Breadth - 150 mm

Height - 200 mm

Material - MS with fiber coating

Capacity - 8 Liter

2. Pump

Type - Submersible

Supply - 230V AC/50Hz

Max head - 3.0 m

Flow - 750 LPH

3. Process tank

Height - 200 mm

Diameter - 150 mm

Material - Acrylic

Capacity - 3 liter

4. Level switch

Type - Magnet

Supply - 24V DC

Body - Nylon

Mounting - 1/4” thread

5. POWER DRIVER CIRCUIT:

Supply - 230V/50Hz AC

Control Input - 24V DC

Output - (0-230) V, 12 V DC

6. Bottle Placement sensor(Proximity sensor):

Type - Capacitive

Supply - 24 VDC

Output - PWM

7. Bottle Position sensor(Opto coupler):

Type - Photo diode

Supply - 12 VDC

Output - PWM

4.2 Photoelectric Sensor

[*Fig 4.2: Diffused photoelectric Sensor*]

The sensor operates within the voltage range of 6 to 36 volts DC, with an output current of 300 mA. It has response frequency of 0.5 kHz. The output type of the sensor is n-p-n 3-wire, with wire colors are black, blue, and brown. It can be constructed from brass or plastic materials.

In this project, sensor is employed to detect the position of bottles. This round-shaped sensor is capable of detecting opaque, transparent, and various other types of objects. Basically, it is used to identify different plastic bottles. The sensor utilized is of the diffused reflective type, featuring a sensing range of up to 100 mm.

4.3 DC Geared Motor

[Fig 4.3: *12V DC geared Motor*]

The geared DC motor in this arrangement has its shaft attached to the roller shaft. It needs an input current of between 600mA and 14A and runs on a 12 Volt input voltage. 50 RPM is the motor's no-load speed. This motor was chosen to provide the required high torque at a steady speed; its torque of 70 kgcm is enough for the load.

The motor features a metal gearbox and a centered shaft, with bearings on the shaft to enhance wear resistance. The high torque selection is necessary due to the heavy rollers used on either side of the hardware, which are mounted with a conveyor belt.

4.4 Water Pump

[*Fig 4.4: 12V DC submersible water pump*]

The water pump has a net weight of 150 grams and features inlet and outlet dimensions of 15 mm outer diameter (O.D.) and 5 mm outer diameter (O.D.) respectively. It operates at a working voltage of 12 volts DC, with a working current ranging from 0.1 to 0.5 amperes.

At 12 volts DC, the pump is capable of achieving a lift of 130 cm and has a flow rate of 300 liters per hour (L/H).

In this project, the water pump is submerged in the reservoir, where it will draw water and pump it up to the main tank in the event that it becomes empty.

4.5 Solenoid Valve

[Fig 4.6: 24V DC Solenoid valve]

A solenoid valve is an electromechanical device which is used to control the flow of liquid or gas. It consists of a coil of wire and a valve. When an electric current passes through the solenoid, it generates a magnetic field that actuates the valve, either open or close it. This allows for precise control over the flow in various applications.

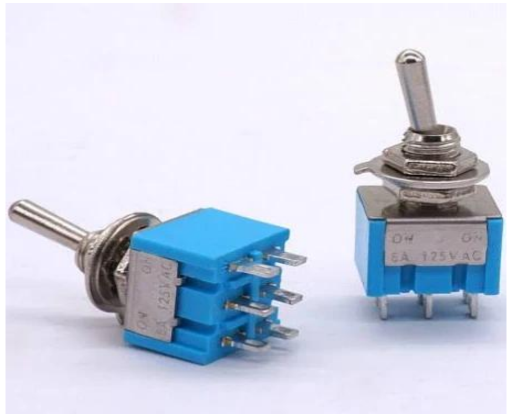
In this project, the solenoid valve is used to control the flow of water or other liquids. When the solenoid is energized, the valve opens, allowing the liquid to pass. Conversely, when the solenoid is de-energized, the valve closes, stopping the flow of water. The solenoid valve is powered by a 24V DC supply, ensuring reliable operation within the system.

4.7 Water Tank

[Fig 4.7: Water tank]

The water tank serves the purpose of storing water to be filled into the water bottle through a solenoid valve. Within the water tank, level sensors LS1 and LS2 are installed to monitor the water level. When the water level in the tank decreases, it triggers the refilling process. Water stored in the reservoir is then pumped into the tank via a narrow pipe, ensuring that the water level is maintained.

4.8 Switches



[*Fig 4.8: Toggle switches of the PLC*]

A toggle switch is a type of electrical switch that is operated by a lever or handle that moves back and forth to open or close an electrical circuit. It is commonly used to turn devices on and off, and it is known for its simple operation and reliable performance. Here are some key points about toggle switches:

Operation

- Lever Mechanism: The switch is actuated by a lever that moves between two or more positions.
- ON/OFF Positions: The most common toggle switches have two positions, ON and OFF, but some may have three positions or more, depending on their design and application.
- Manual Control: The user manually moves the lever to change the switch position and control the circuit.

Types

- SPST (Single Pole Single Throw): This type of toggle switch has one input and one output, allowing the circuit to be either connected or disconnected.
- SPDT (Single Pole Double Throw): This switch can connect one input to one of two outputs, allowing for more complex control circuits.
- DPST (Double Pole Single Throw): This type of switch can control two circuits simultaneously, with a single input connected to two outputs.
- DPDT (Double Pole Double Throw): This switch allows for controlling two circuits, each with two different outputs, providing even more control options.

Applications

- General Use: Toggle switches are used in a variety of applications, from household appliances to industrial equipment.

- Automotive: Commonly used in vehicles to control lights, fans, and other electrical components.
- Electronics: Often used in electronic devices and circuits for switching purposes.
- Industrial: Employed in industrial machinery and equipment for controlling operations.

Advantages

- Simplicity: Easy to operate and install.
- Reliability: Known for their durable and reliable performance.
- Clear Feedback: Provides tactile feedback, making it clear when the switch is in the ON or OFF position.

4.9 Totally Integrated Automation(TIA) Overview

Totally Integrated Automation (TIA) is an automation concept developed by Siemens that integrates various components and systems into a unified framework, aiming to enhance efficiency, productivity, and flexibility in industrial automation. Here's a detailed overview of TIA:

Key Components of TIA:

1. **TIA Portal:**

- **Definition:** TIA Portal is the engineering software within TIA, providing a unified interface for programming and configuring all automation components.
- **Features:** It integrates various engineering tools for PLCs, HMIs, drives, and networks into a single development environment, streamlining the engineering process.
- **User-Friendly Interface:** The portal offers a graphical user interface that simplifies the configuration, programming, and diagnostics of automation systems.

2. **PLCs (Programmable Logic Controllers):**

- **Integration:** TIA seamlessly integrates Siemens PLCs, such as the S7-1200 and S7-1500 series, enabling efficient programming and diagnostics.
- **Ladder Logic and More:** TIA Portal supports various programming languages, including ladder logic, function block diagrams, and structured control language (SCL).

3. **HMI (Human-Machine Interface):**

- **Interface Design:** TIA includes tools for designing and configuring HMIs, providing intuitive control and monitoring interfaces for operators.
- **Connectivity:** HMIs configured in TIA Portal can easily communicate with PLCs and other system components.

4. **Drives and Motors:**

- **Configuration and Control:** TIA enables the configuration and control of Siemens drives and motors, ensuring synchronized and efficient operation.
- **Parameterization:** The portal simplifies the process of parameterize and tuning drives, enhancing system performance.

5. **Networking:**

- **Integrated Communication:** TIA supports various industrial communication protocols and networks, such as PROFINET and PROFIBUS, ensuring seamless data exchange between components.
- **Network Configuration:** TIA Portal includes tools for designing and configuring complex network topologies, optimizing communication efficiency.

Benefits of TIA:

1. **Enhanced Productivity:**

- **Single Engineering Framework:** By integrating all engineering tools into one platform, TIA Portal reduces engineering time and effort, increasing productivity.
- **Reusable Libraries:** Engineers can create and reuse libraries of code and configurations, further speeding up development and deployment.

2. **Improved Flexibility:**

- **Scalability:** TIA supports systems of varying sizes and complexities, from small machines to large-scale industrial plants.
- **Modular Design:** The modular approach allows easy expansion and modification of automation systems.

3. **Comprehensive Diagnostics:**

- **Real-Time Monitoring:** TIA provides real-time diagnostics and monitoring capabilities, helping to quickly identify and resolve issues.
- **Predictive Maintenance:** Advanced diagnostics and monitoring features support predictive maintenance, reducing downtime and maintenance costs.

4. **Seamless Integration:**

- **Compatibility:** TIA ensures compatibility and seamless integration between all Siemens automation products, enhancing system coherence and reliability.

- **Open Architecture:** The platform supports third-party devices and systems, providing flexibility in component selection.

Application in the Bottle Filling System Project:

In the context of the automated bottle filling system project:

1. **PLC Programming:** TIA Portal was used to program the PLC, implementing the ladder logic required to control the system.
2. **System Integration:** TIA enabled the seamless integration of sensors, actuators, and other components, ensuring efficient and reliable operation.
3. **Diagnostics and Monitoring:** The project benefited from TIA's real-time diagnostics, allowing for quick identification and resolution of any issues during operation.

4.10 Conclusion

The integration of these components into the automated bottle filling system demonstrates a well-coordinated effort to leverage the strengths of each part. The PLC's central role in controlling the sensors, motor, solenoid valves, and pump highlights the importance of a robust and flexible control unit in industrial automation.

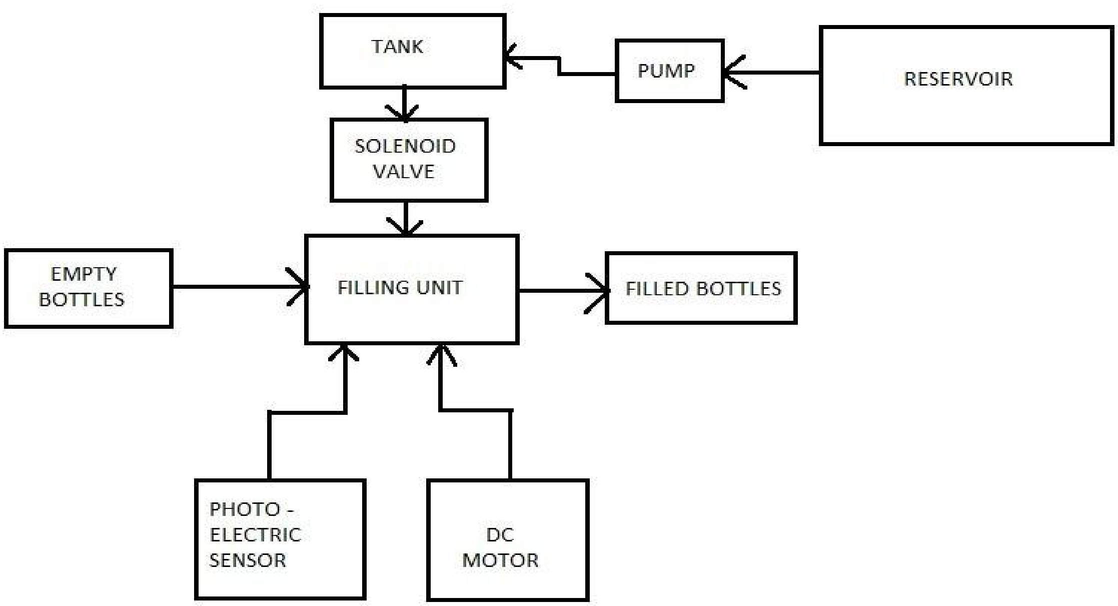
Totally Integrated Automation (TIA) by Siemens offers a robust and comprehensive framework for industrial automation, enhancing efficiency, flexibility, and reliability. Through its integrated engineering platform, TIA Portal simplifies the development, configuration, and management of complex automation systems, making it an invaluable tool for modern industrial applications. In the bottle filling system project, the use of TIA exemplifies how advanced automation technologies can streamline processes, improve accuracy, and increase overall productivity.

CHAPTER 5
SYSTEM DESIGN AND IMPLEMENTATION

5.1 General

This chapter details the design and implementation of an automated bottle filling system, covering both the level control and bottle filling operations. It explains the organization of various components involved in the system and provides a comprehensive overview of the settings required for programming the PLC

Block Diagram



[*Fig 5.1: Block Diagram of bottle filling system*]

5.2 Methodology

The bottle filling process involves using a machine to pack liquid products, such as water or soft drinks. Manual filling processes present numerous issues, including water spillage, inconsistent fill levels, and delays caused by human factors. This project targets small industries, aiming to address the challenges faced by small-scale bottle filling systems. The entire operation is governed by PLC programming, making the system more flexible, time-efficient, and user-friendly.

When the transport stops, the solenoid valve is energized, allowing water to fill the bottle. After a set time, the solenoid valve is de-energized, stopping the water flow, and the conveyor belt resumes moving. The valve remains de-energized until another bottle is detected by the sensor. As the process continues, the water level in the tank decreases. A float switch, submerged in the water tank, helps manage this. The switch's buoyancy changes with the water level, controlling the pump that refills the tank when the water level drops too low.

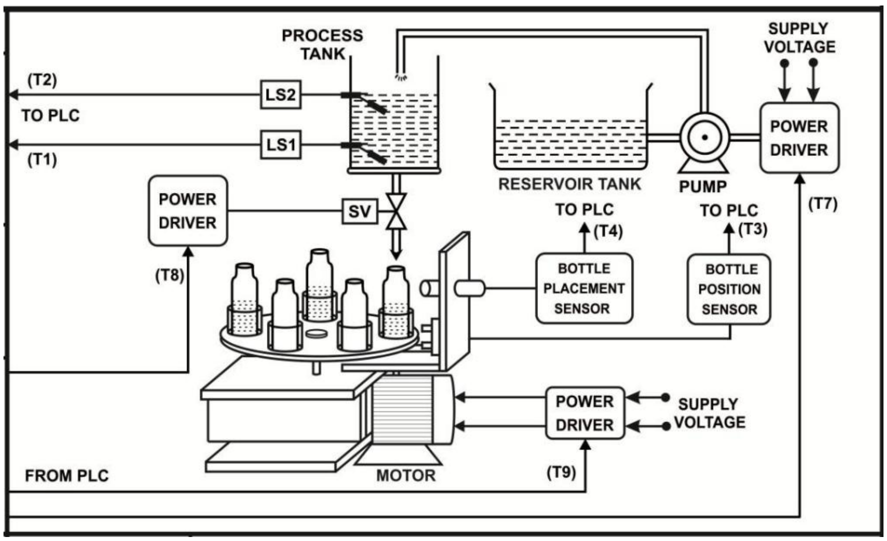
The float switch is designed to operate at temperatures up to 80 degrees Celsius and has both NO (Normally Open) and NC (Normally Closed) contacts. When the water level drops, the switch descends, closing the circuit and activating the pump to refill the tank. Once the water reaches a certain level, the float switch rises, breaking the circuit and de-energizing the pump.

The system automatically turns off when the tank reaches the desired water level and only resumes when the water level is appropriate. The electrical connections integrate the hardware with the PLC, using an Ethernet cable to link the computer to the PLC. The control logic has been implemented using SIEMENS software, enabling real-time monitoring of the system's operational status.

This automated approach significantly enhances operational efficiency in small-scale bottle filling systems, providing a reliable and consistent solution for liquid packaging.

5.3 Schematic Diagram

FRONT PANEL DIAGRAM:



[*Fig 5.2:Bottle filler diagram*]

FRONT PANEL DESCRIPTION:

Switch (Power ON) : To power ON/OFF the unit.

Switch (Pump ON) : To switch ON/OFF the pump.

T1, T2 : To measure the Level switch output in V

T3 : To measure the bottle position sensor output.

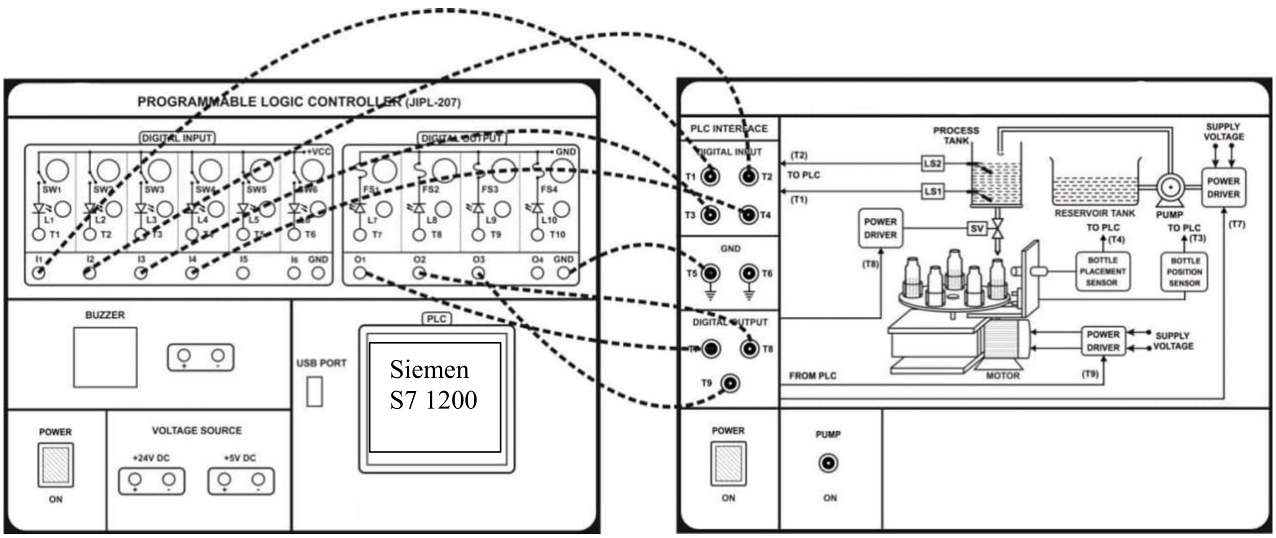
T4 : To measure the bottle placement sensors output.

T5, T6 : GND terminals of the trainer

T7, T8, T9 : To measure the output voltage from PLC.

SV : To drain the water from the process tank based on the PLC output.

INTERFACING DIAGRAM:



[*Fig 5.3: Interfacing between PLC and Bottle filling Trainer*]

5.4 Implementation

- Fill the reservoir tank with sufficient distilled water (80% of the tank).
- Switch ON the unit.
- Connect the PLC with PC using USB cable.
- Switch ON the PLC and the PC.
- Connect the equipment as per the Interfacing diagram.
- Double click BOTTLE FILLING.ccwsln to open the ladder logic program.
- Click compile option and click download option to download the program.
- Click connect option to execute the program.
- Run the program as per the program procedure.
- Switch ON the Pump.
- Place the empty bottle on the slot present in the rotating disc.
- Stop the program.

- Switch off the PLC.
- Switch off the trainer.
- Remove the bottle from the rotating disc which has water in it.
- Pour the water present in the bottle to drain after completion of one cycle,and again place the bottle in the slot and repeat the above procedures

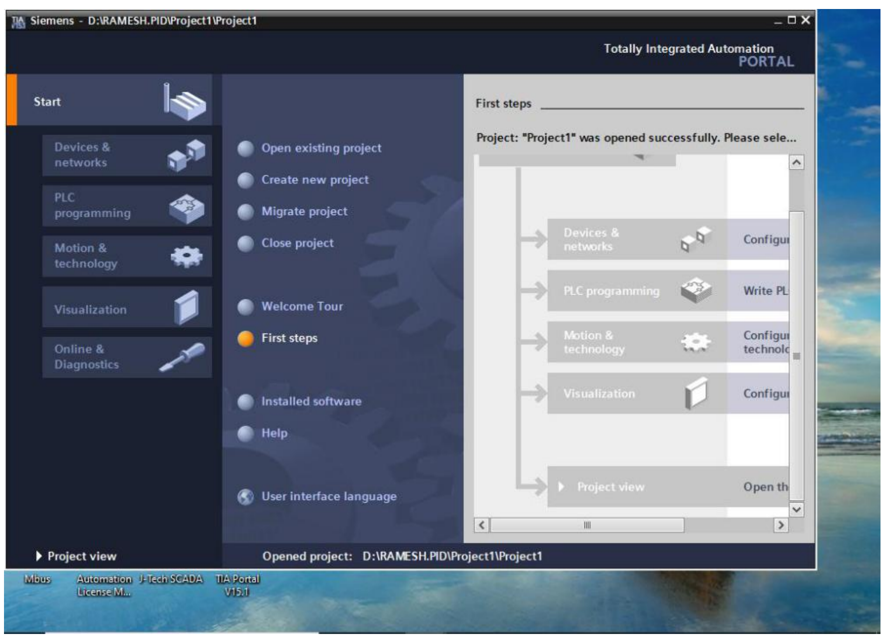
[*Fig 5.4: Front view of Our Hardware implementation*]

PROGRAMMING PROCEDURE:

- switch on the PC which has TIA portal(PLC) software.
- double click the TIA portal icon as shown in image below.

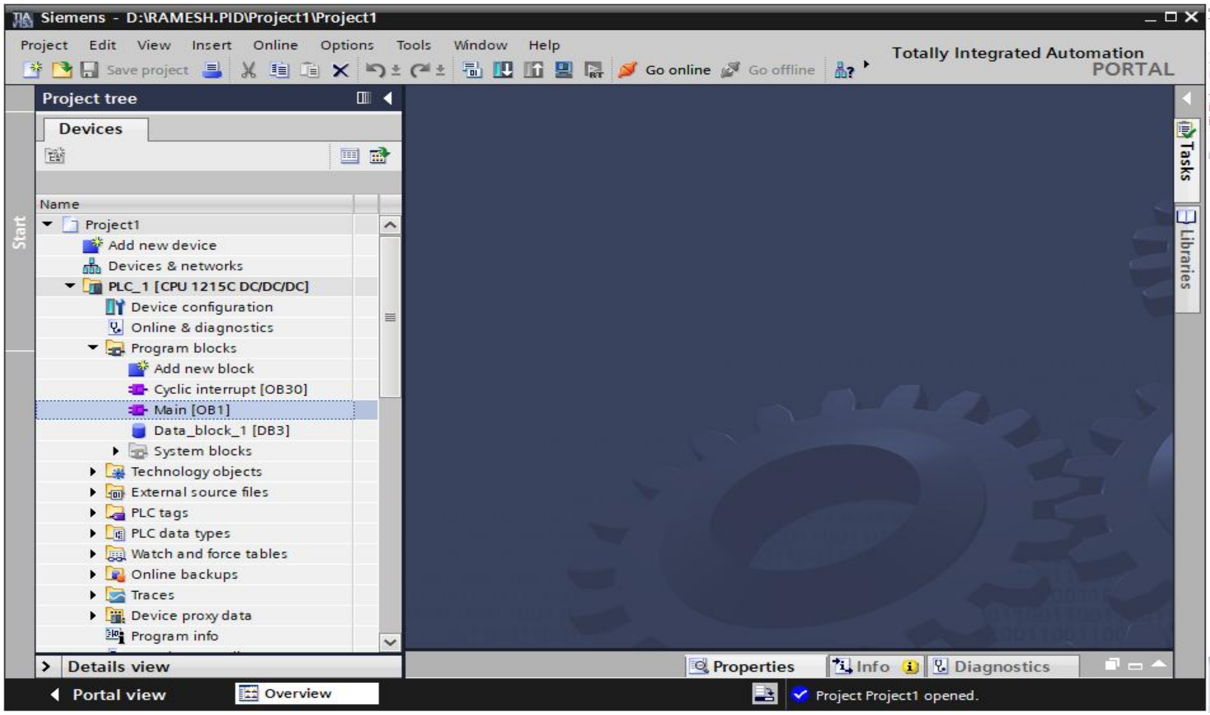
[*Fig 5.5: Window showing TIA Portal*]

- Click Open the Project and select the program.



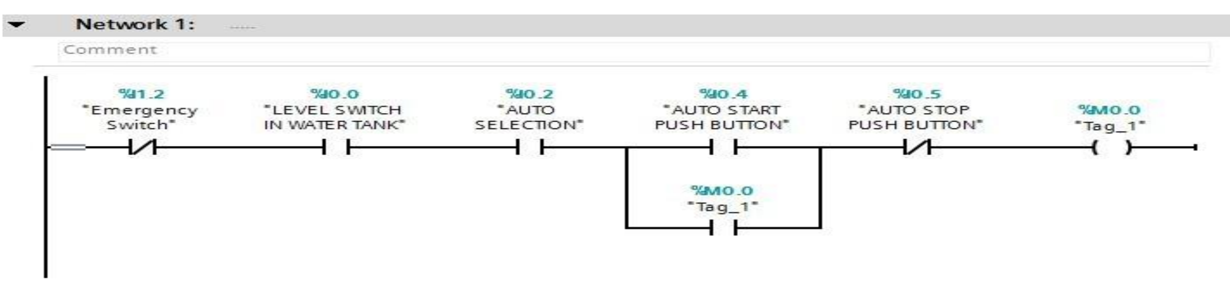
[*Fig 5.6: Window showing opening of project*]

- Click program block and select Main (OB1).

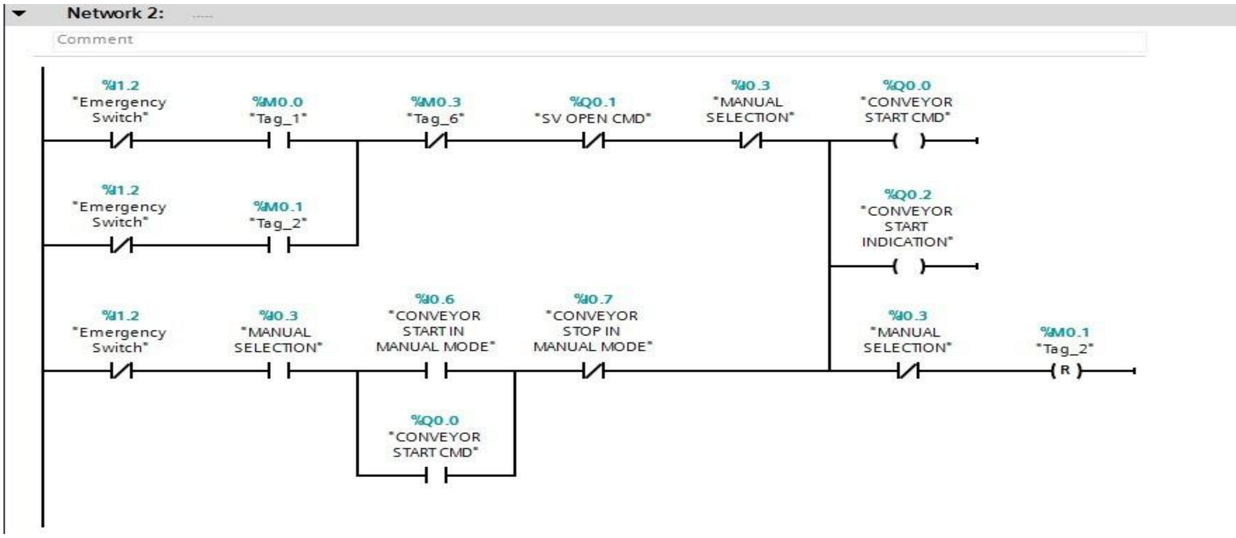


[*Fig 5.7: Window showing program block and select Main (OB1)*]

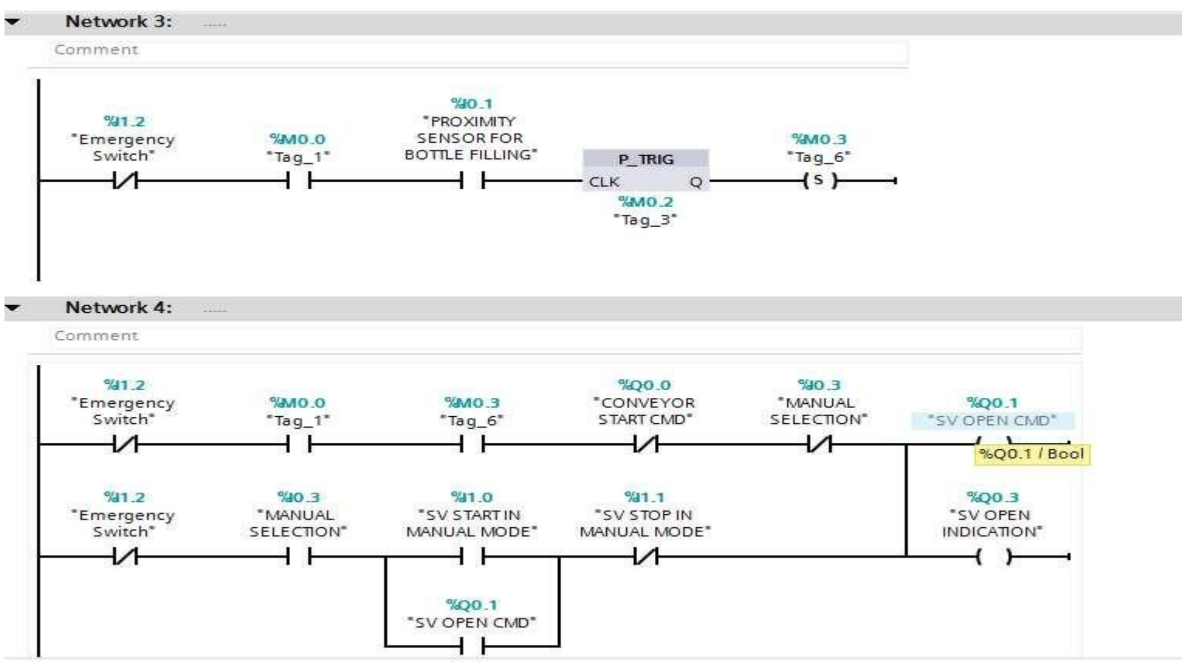
- PROGRAMMING WINDOW



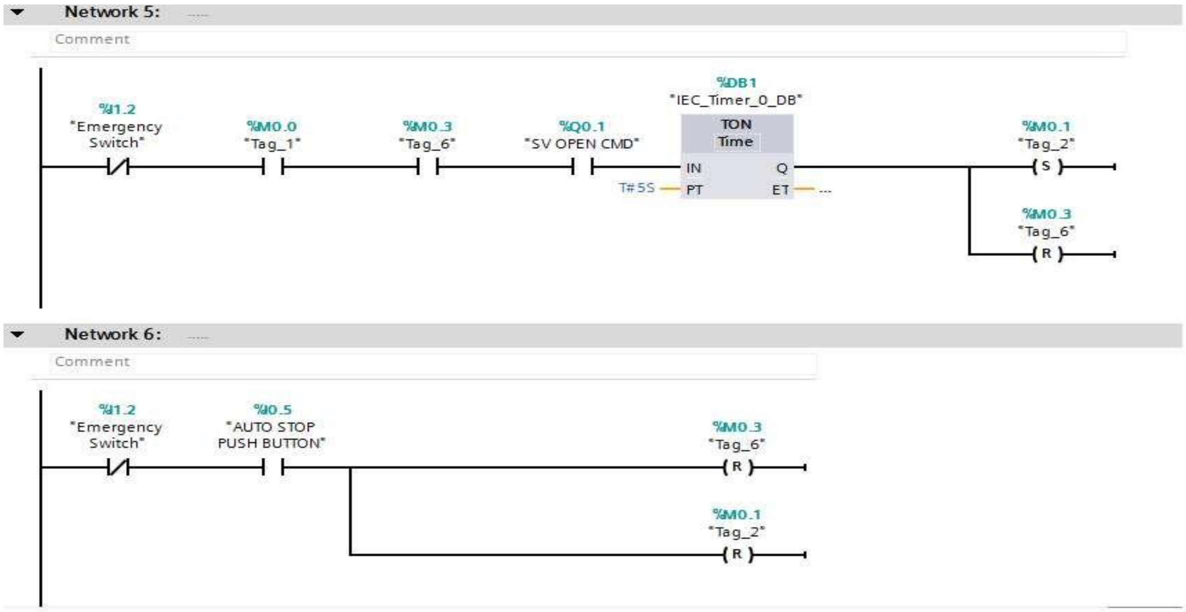
[*Fig 5.8: Program Window*]



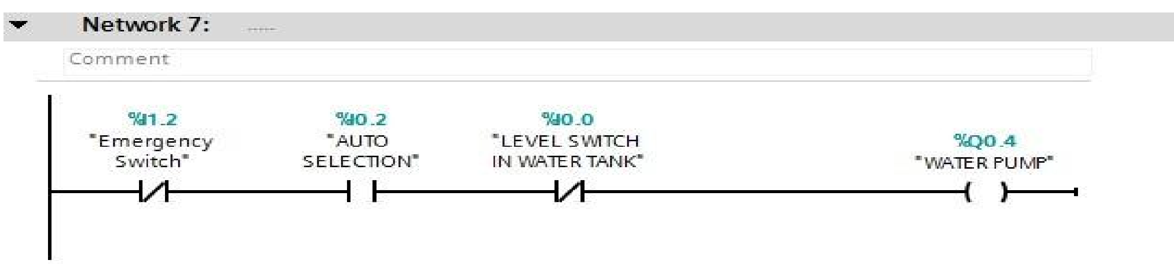
[*Fig 5.8.1: Program Window*]



[*Fig 5.8.2: Program Window*]

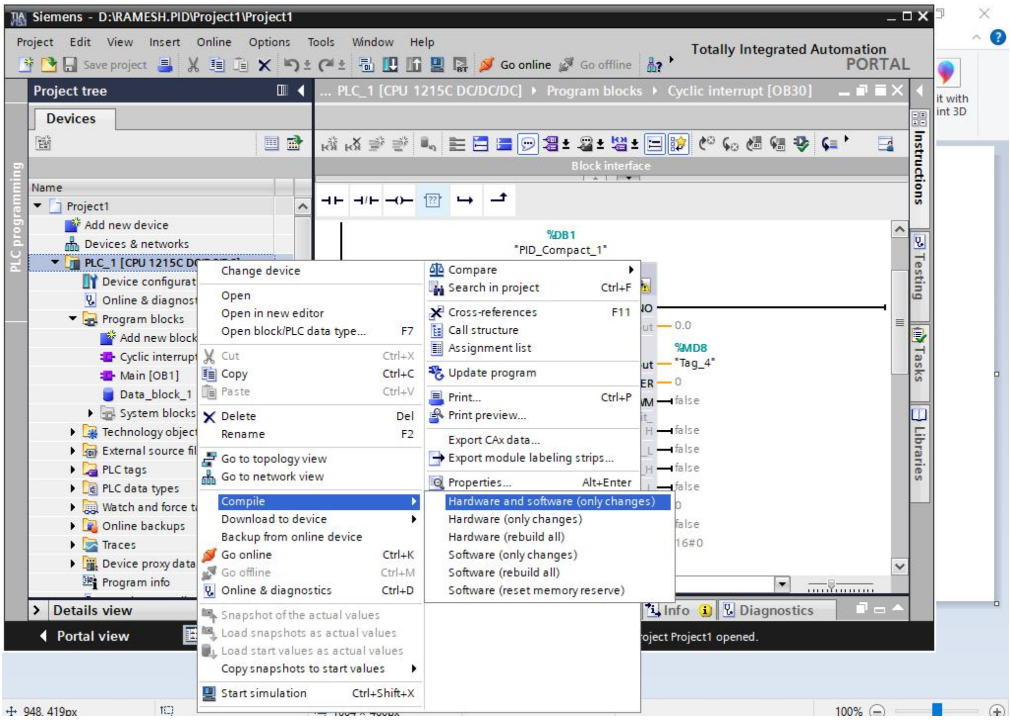


[*Fig 5.8.3: Program Window*]



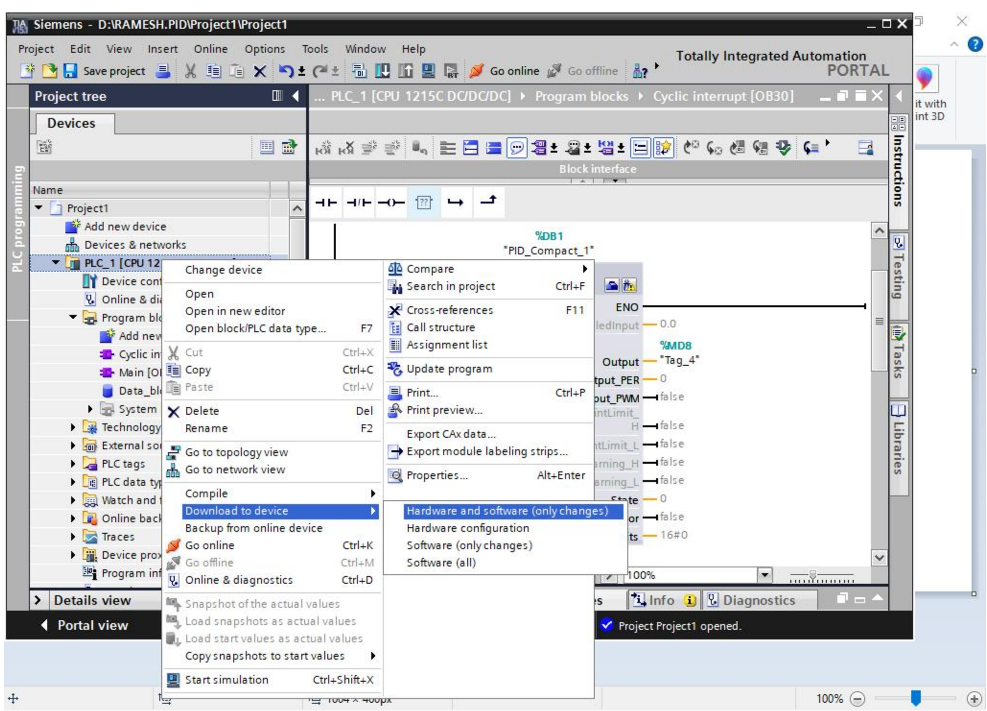
[*Fig 5.8.4: Program Window*]

- Right click PLC_1 and select compile.



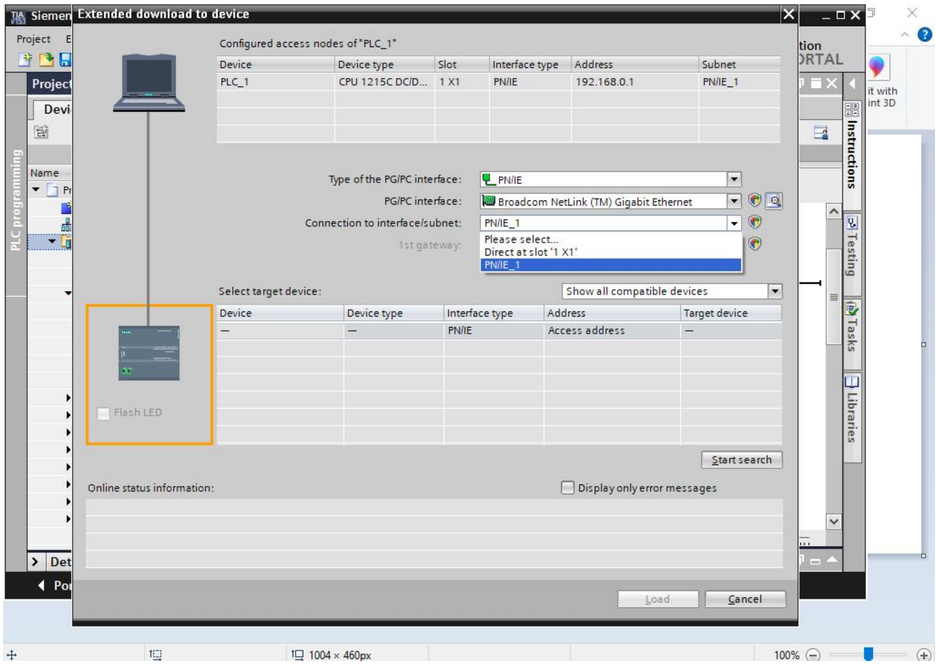
[Fig 5.9: Right click PLC_1 and select compile]

- Right click PLC_1 and select download to device.



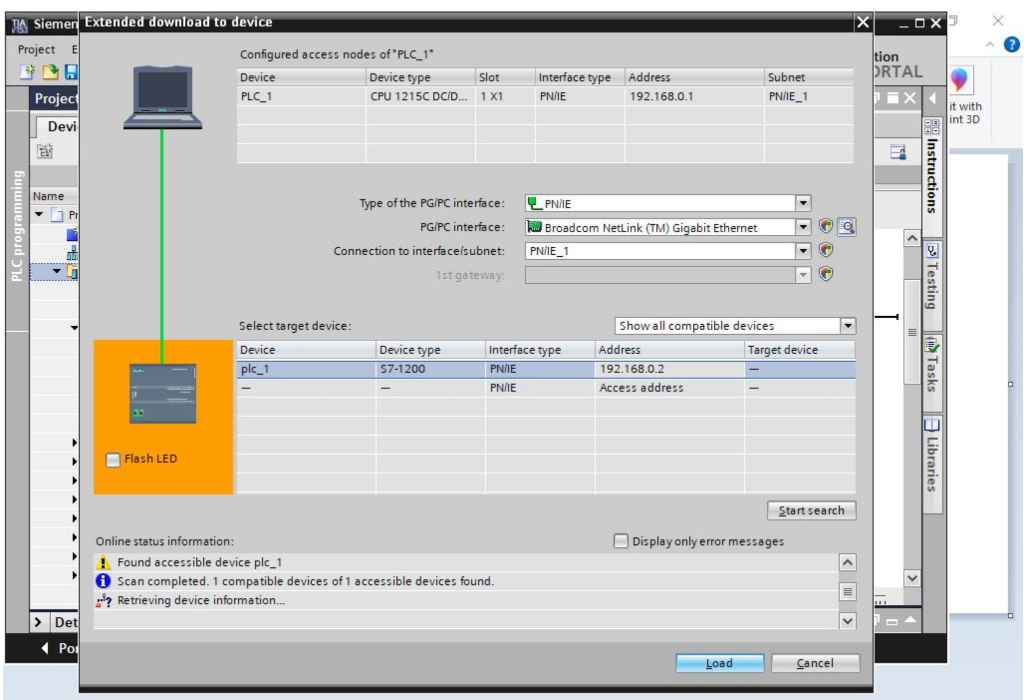
[Fig 5.10: Right click PLC_1 and select download to device]

- A new window will open. Click Start Search.



[*Fig 5.11: A new window will open. Click Start Search*]

- Click Load Option and Run the program.



[*Fig 5.12: Click Load Option and Run the program*]

5.5 Conclusion

The project successfully achieved its objectives by creating a reliable, efficient, and user-friendly solution. The integration of hardware and software components was carried out meticulously, ensuring accurate and consistent operation. The system's flexibility and scalability provide a solid foundation for future enhancements, making it adaptable to evolving industrial needs. This project not only meets current operational requirements but also sets the stage for ongoing improvements and increased productivity in the bottle filling process.

CHAPTER 6
OPERATION AND RESULTS

6.1 General

Operation Description:

The automated bottle filling system operates through a sequence of well-coordinated steps, managed by a Programmable Logic Controller (PLC) using ladder logic programming. The process can be summarized as follows:

1. System Initialization:

- **Auto Selection:** The system is set to automatic mode using an auto selection switch. This prepares the system to operate automatically without manual intervention.
- **System Start:** The toggle switch is activated. This triggers the DC geared motor, which in turn starts the conveyor belt moving.

2. Conveyor and Bottle Positioning:

- **Conveyor Operation:** The DC motor, selected for its high torque and constant speed capabilities, drives the conveyor. The motor is connected to the conveyor , ensuring smooth movement of the belt.
- **Bottle Placement:** Bottles are placed on the moving conveyor. The system can handle two or more bottles simultaneously.

3. Bottle Detection:

- **Sensor Activation:** As bottles move along the conveyor , they pass by a photoelectric sensor. This sensor detects the presence of a bottle and sends a signal to the PLC.
- **Conveyor Stop:** Upon detecting a bottle, the PLC halts the conveyor to position the bottle correctly under the filling nozzle.

4. Filling Process:

- **Solenoid Valve Control:** The PLC energizes the solenoid valve, allowing water to flow through the nozzle into the bottle. The valve remains open for a predefined duration to ensure the bottle is filled to the desired level.
- **Filling Completion:** After the set time, the solenoid valve is de-energized, stopping the water flow. The conveyor belt then resumes its movement, advancing the filled bottle and positioning the next one for filling.

5. Water Level Management:

- **Float Switch Monitoring:** A float switch in the water tank monitors the water level. If the water level drops below a certain point, the float switch sends a signal to the PLC.

- ·**Pump Activation:** The PLC energizes the water pump, which replenishes the water tank from the reservoir. Once the tank reaches the desired water level, the float switch triggers the pump to stop.

6. System Shutdown:

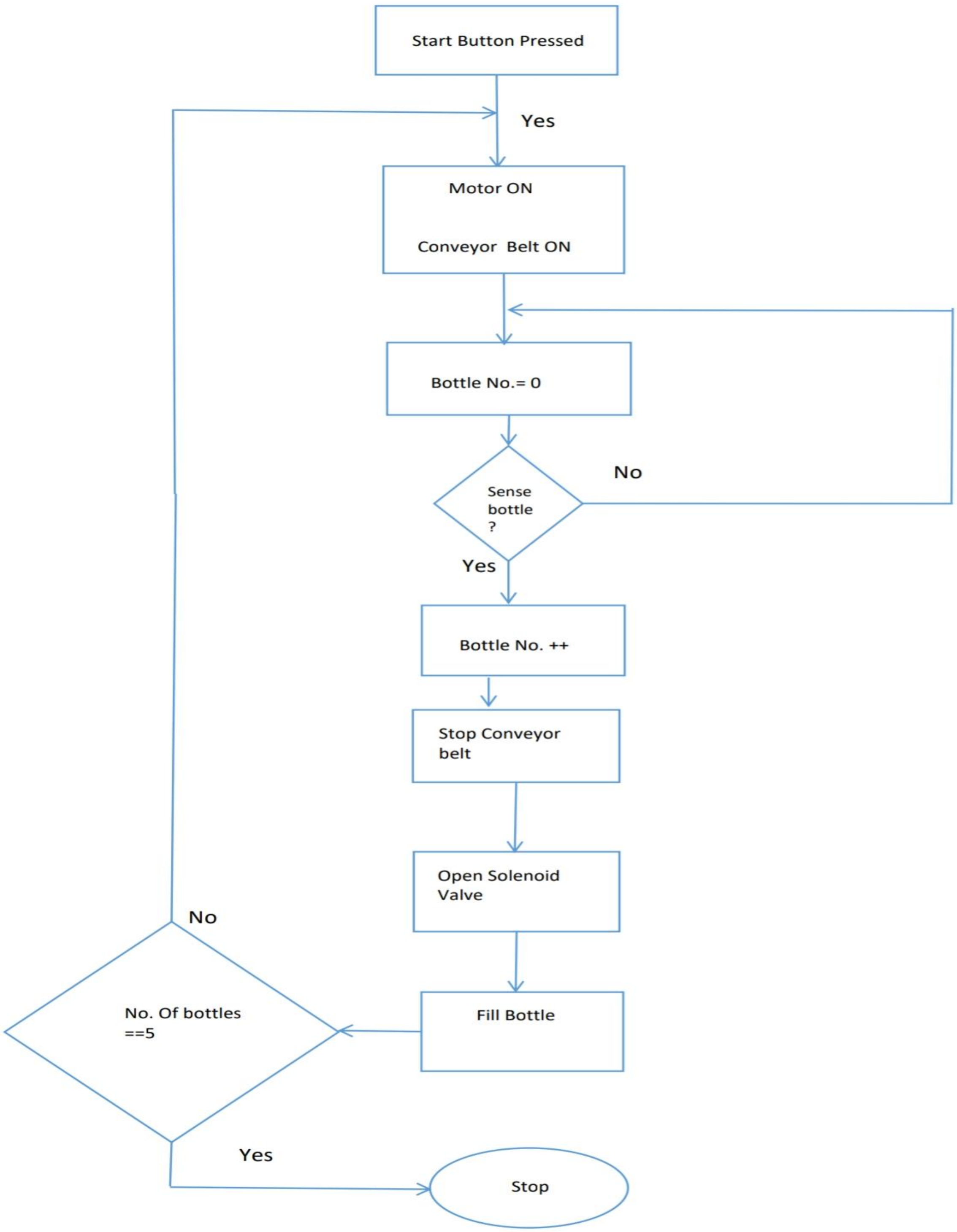
- **Automatic Shutdown:** The system continues the filling process until it is manually stopped or all bottles have been filled. The system can be turned off using the same toggle switch that started the operation.

6.2 Sequence of Operation

TABLE 6.1: Operation Sequence

STEP 1	:	To initiate the bottle filling process, press the "START" button. This action activates the system, allowing the subsequent steps to proceed automatically.
STEP 2	:	Following the activation of the system by pressing the "START" button, the motor initiates operation, causing the conveyor belt to move forward. This movement facilitates the transportation of bottles along the filling line, enabling the subsequent stages of the filling process to occur seamlessly.
STEP 3	:	If the sensor identify the presence of a bottle aligned with the solenoid valing process, optimizing efficiency and accuracy in the system.ve, the conveyor's movement halts automatically. This pause in the conveyor's operation ensures that the bottle is in the correct position to undergo the fill.
STEP 4	:	In the event that the sensor fails to detect the presence of a bottle, the conveyor will continue its motion uninterrupted. This ensures that the system maintains a continuous flow, preventing any delays in the overall process.
STEP 5	:	Following a brief delay, the solenoid valve is activated, allowing the liquid to flow into the bottle. This continues until the predetermined timer expires, ensuring that the bottle is adequately filled with the desired quantity of liquid.
STEP 6	:	Once the bottle is filled, a delay is introduced before the conveyor motor resumes operation. This delay ensures that the filling process is completed before the conveyor moves the filled bottle to the next stage of the production line.
STEP 7	:	And the process respects itself repeats itself from step 3After the delay, the process repeats itself from step 3, where the sensor detects the presence of the next bottle, and the conveyor stops to begin the filling process again. This cyclical operation continues until the "STOP" button is pressed or the system is otherwise halted.

6.3 Flow Chart



[*Fig 6.1: Flow Chart*]

6.4 Results

The PLC based automated bottle filling system was tested thoroughly to evaluate its performance and efficiency. Here are the key results observed:

1. Accuracy and Consistency:

- **Precise Filling:** The system consistently filled bottles to the desired level with minimal spillage. The accurate timing of the solenoid valve ensured uniform filling across all bottles.
- **Reliable Sensor Feedback:** The photoelectric sensor accurately detected bottle positions, allowing for precise stopping of the conveyor and correct positioning of bottles under the nozzle.

2. Efficiency and Speed:

- **High Throughput:** The automated system significantly increased the filling speed compared to manual operations. The continuous movement of the conveyor and the quick response of the solenoid valve contributed to higher productivity.
- **Reduced Downtime:** The system's design minimized downtime. The automatic refilling of the water tank ensured that the filling process was not interrupted due to low water levels.

3. User-Friendliness:

- **Automated Operation:** The automation reduced the need for manual intervention, freeing up operators to focus on other tasks and improving overall operational efficiency.

4. Reliability and Maintenance:

- **Robust Performance:** The system demonstrated reliable performance during extended operation. The use of high-quality components and precise programming ensured minimal wear and tear.
- **Ease of Maintenance:** The comprehensive documentation and modular design made maintenance straightforward. Operators could easily replace components and troubleshoot issues without extensive downtime.

[*Fig 6.2: Hardware Architecture in run mode*]

6.5 Conclusion

The automated bottle filling system operated as intended, achieving high levels of accuracy, efficiency, and reliability. The integration of a PLC with ladder logic programming provided precise control over the entire process, from bottle detection to filling and water level management. The system not only met the project's specifications but also demonstrated the potential for future enhancements and scalability. Overall, the project successfully automated the bottle filling process, delivering consistent performance and significant productivity improvements.

CHAPTER 7
CONCLUSION AND FUTURE SCOPE

7.1 CONCLUSION

In this project, PLC technology has been employed to automate the control and monitoring of a bottle filling system. Through PLC ladder logic programming, the operations of level control and bottle filling are efficiently managed, ensuring smooth functionality of motors. By automating the command process, manual intervention and associated costs are minimized. Due to its user-friendly nature and cost-effectiveness, this system is well-suited for industrial environments.

All things considered, this system uses cutting-edge PLC technology to provide a reliable and adaptable automated control, mixing, and bottle filling solution. It makes industrial applications more accurate and productive by enabling precise and effective operation.

7.2 Future Scope

As part of the project's future scope, the following tasks can be completed:

To keep track of the number of bottles brought to the process and those that are filled at the conclusion, counters might be used both before and after the filling procedure. To guarantee an all-encompassing industrial process, an actuator-based automated capping system can also be used.automated method for marking the bottle upon its closure.It is also possible to create an automated packing system for the conveyor belt's terminus. It is possible to create an automated system that maintains and regulates the pressure and temperature needed to fill the bottle.Productivity may be increased by making system improvements such adding a strong solenoid valve and a jet nozzle, which can shorten the time needed to fill bottles.

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