SMART FACTORY AUTOMATION USING PLC BASED SPEED CONTROL

PROJECT REPORT

Submitted by

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In partial fulfilment for the award of the degree

of

BACHELOR OF ENGINEERING

in

MECHATRONICS

BANNARI AMMAN
INSTITUTE OF TECHNOLOGY
Stay Ahead

BANNARI AMMAN INSTITUTE OF TECHNOLOGY
(An Autonomous Institution Affiliated to Anna University, Chennai)
SATHYAMANGALAM-638401

ANNA UNIVERSITY: CHENNAI 600 025

NOVEMBER 2024

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BONAFIDE CERTIFICATE

Certified that this project report **“SMART FACTORY AUTOMATION USING PLC BASED SPEED CONTROL”** is the Bonafide work of **"VIGNESHRAM R (7376211MC145), JUBAIR AHAMED L(7376211MC117), KAVIN RAJ S (7376211MC119), THAMARAI KANNAN M K S(7376221MC508)** who carried out the project work under my supervision.

DR. BHARATHIRAJA M	**MR. RAGHUNATH M**
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Submitted for Project Viva Voce examination held on………………

Internal Examiner 1 **Internal Examiner 2**

DECLARATION

We affirm that the project work titled **“Smart factory automation using PLC based speed control”** being submitted in partial fulfilment for the award of the degree of **Bachelor of Engineering** in **Mechatronics** is the record of original work done by us under the guidance of **Mr. Raghunath M**, Assistant Professor Level II**,** Department of Mechatronics. It has not formed a part of any other project work(s) submitted for the award of any degree or diploma, either in this or any other University.

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I certify that the declaration made above by the candidates is true.

(Signature of the Guide)
Mr. Raghunath M

ACKNOWLEDGEMENT

We would like to enunciate heartfelt thanks to our esteemed Chairman **Dr.S.V. Balasubramaniam**, and the respected Director **Dr. M.P**. **Vijaykumar**, for providing excellent facilities and support during the course of study in this institute.

We are grateful to **Dr. Bharathiraja M**, **Head of the Department, Department of Mechatronics** for his valuable suggestions to carry out the project work successfully.

We wish to express our sincere thanks to **Mr. Raghunath M, Assistant Professor Level II, Department of Mechatronics** for her constructive ideas, inspirations, encouragement, excellent guidance and much needed technical support extended to complete our project work.

We would like to thank our friends, faculty and non-teaching staff who have directly and indirectly contributed to the success of this project.

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ABSTRACT

Automation plays a crucial role in modern manufacturing, offering solutions for efficiency, precision, and reliability in production processes. Despite advancements, there remains a need for integrated systems that can handle multiple manufacturing tasks autonomously, particularly in high-speed applications. This project addresses these gaps by developing a *Smart Automation System Using PLC-Based Speed Control* for a production line, specifically focusing on cap handling, capping, and transfer mechanisms.

The objective of this project is to design and implement a three-module automated system controlled by PLC for optimized handling and speed. The first module employs a pneumatic actuator with a suction cup to pick caps from a stacked area. The second module uses an electric actuator to cap the bottles, ensuring proper alignment. The third module is a gantry-type belt drive mechanism, operated by a stepper motor, for transferring the final product to the packing station. Key data such as speed, accuracy, and reliability were collected to evaluate performance improvements.

Results showed that the system achieved a significant increase in operational speed and reduction in manual intervention, significantly enhancing productivity. Discussion reveals that the integration of pneumatic and electric actuators controlled by PLC contributes to precise product handling. This system demonstrates a scalable solution for factory automation, providing insights into further automation possibilities in similar high-speed production environments.

Keywords: Automation, PLC, Speed Control, Cartesian Actuator, Gantry Mechanism, Manufacturing.

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CHAPTER 1
INTRODUCTION

In today's industrial environment, automation in production is essential since it offers the tools to improve efficiency, accuracy, and dependability. Systems that can quickly and accurately do repetitive operations like material handling, capping, and product transfer are becoming more and more necessary as manufacturing lines develop. Programmable Logic Controllers (PLCs) are essential to this development because they provide a centralized control system that allows for process synchronization, speed regulation, and real-time flexibility to preserve efficiency and quality. A big step toward optimizing production flows, lowering human intervention, and eliminating errors is the incorporation of PLC-based speed control systems into automated settings. These needs are covered by this project, which focuses on Smart Automation Using PLC-Based Speed Control, by putting in place a system that can oversee crucial industrial tasks.

1.1 BACKGROUND OF THE WORK:

Automation is used more and more in the manufacturing sector to streamline operations, reduce mistakes, and enhance product quality. Cap handling, capping, and product transfer are examples of traditional manual techniques that are time-consuming, labour-intensive, and prone to errors that may affect the quality of the final product. Additionally, there is a greater chance of operational inefficiencies with manual interventions, especially in high-speed production settings where timing and accuracy are essential. Although automated systems have been developed to automate various procedures, they frequently function as separate entities with little integration, which makes it difficult to effectively handle several tasks.

PLCs, or Programmable Logic Controllers, are crucial to modern manufacturing's increased automation. Because PLCs offer centralized control, different parts of an automated system can work together without any problems. PLCs increase the system's overall dependability and flexibility to meet different industrial demands by providing precise control over speed, timing, and synchronization. Production delays and higher maintenance needs result from the inability of many automated solutions currently in use to combine several tasks like picking, capping, and transferring inside a single framework.

This project aims to address these issues by creating a Smart Automation System Using PLC-Based Speed Control that is especially made to meet the demands of automated product handling in a manufacturing environment. Each of the three main elements that make up the system targets a crucial step of production. Caps from a stacked region can be handled quickly and precisely with the help of the first module's pneumatic actuator with a suction cup for cap picking. Electric actuators in the second module, which is made specifically for the capping process, provide constant force and alignment to ensure that every cap is firmly in place. Last but not least, the third module effectively moves finished goods to the packing station using a gantry-style belt drive mechanism managed by a stepper motor.

Every module is managed centrally by a PLC, which synchronizes the motion and speed of every part to maximize efficiency and reduce downtime. In addition to increasing production speed and efficiency, this PLC-based system enables customization in handling speed and placement precision, making it flexible enough to accommodate different product specifications. The project intends to remove obstacles related to conventional methods by combining these features into a single, coherent system, offering a scalable, modular solution for automated manufacturing.

PLC-based speed control is used in manufacturing automation to address operational safety and consistency in addition to efficiency gains. Manual labour or separate automation units are frequently used in traditional manufacturing settings, which increases the risk of operational risks and causes variability in product handling. By automating repetitive operations, lowering the requirement for direct human interaction, and fostering safer working circumstances, the suggested method reduces these problems. For example, the Cartesian pneumatic actuator for handling caps reduces the possibility of mistakes or injuries related to manual handling by accurately positioning each cap with little assistance from a human.

Additionally, the integration of electric actuators in the capping module ensures a controlled application of force, preventing over-tightening or misalignment. This level of control is particularly valuable in manufacturing environments where consistency in product quality is critical. By using PLCs to regulate the speed and position in real-time, the system achieves a uniform capping process, minimizing defects and ensuring that every product meets the desired specifications.

Product transport between stations is made efficient by the gantry-type belt drive mechanism, which is driven by a stepper motor. The PLC-controlled precision movement and speed control of this device enable steady and seamless product flow along the production line. Because of the gantry's ability to handle a range of product weights and sizes, the system may be tailored to meet a variety of industrial needs. Furthermore, by ensuring that the product is positioned properly for downstream processes, the stepper motor's accuracy lowers the possibility of misplacement or bottlenecks.

In conclusion, the creation of this integrated automation system provides a thorough approach to overseeing various operations on a production line. Variability, safety hazards, and inefficiency are three major issues with conventional manufacturing setups that the system tackles by utilizing PLC-based speed control and modular automation components. By showing how integrated control and speed regulation may greatly improve production processes, this study advances the field of smart factory automation and opens the door for further advancements in high-speed manufacturing environments.

This PLC-based system may be expanded further with the help of automation technology improvements, for example, by adding sensors for real-time monitoring, data collecting for predictive maintenance, or Internet of Things connectivity for remote control. Manufacturers may move toward fully automated, smart factories that prioritize operational efficiency, quality, and safety throughout the production lifecycle with the help of this scalable strategy.

1.2 SCOPE OF THE WORK:

Across all industries, automation of manufacturing processes has become a top focus in an effort to boost output, enhance product quality, and lower operational risks. Complete systems that combine these tasks under centralized management are obviously needed, given the increasing demands for accuracy and speed in product handling, capping, and transfer. The suggested project, Smart Automation Using PLC-Based Speed Control, provides a simplified method for high-speed, high-precision production lines by creating a modular system that can carry out these activities on its own.

This project uses programmable logic controllers (PLCs) to coordinate several production phases, such as product transfer, capping, and cap handling. The centralized PLC control ensures unified functionality, adaptability, and operational efficiency for all modules, whether they use gantry-driven belt systems for material transport, electric actuators for capping, or pneumatic actuators for cap picking. From small-scale assembly lines to big, intricate production facilities, the project seeks to offer a scalable solution that can satisfy the needs of diverse industrial environments with this architecture.

Through the reduction of manual involvement and the promotion of operational safety, this initiative tackles important issues in conventional manufacturing settings, including quality inconsistencies and the possibility of workplace injuries. The real-time control of position and speed made possible by this PLC-based technology also improves accuracy in repetitive processes and upholds high standards for the final output. This project's scope also involves investigating potential future improvements, like incorporating IoT connectivity for remote monitoring, adopting AI-driven algorithms for additional optimization, and adding sensors for predictive maintenance.

By developing automation through PLC-controlled technologies, this initiative seeks to provide the basis for the upcoming smart factory generation. In manufacturing areas where automation and quality control are critical, it contributes to wider applications by offering a model for increasing industrial processes' efficiency and precision. This study paves the path for more adaptable, effective, and intelligent manufacturing solutions while simultaneously meeting present production demands and advancing the transition to fully automated, high-performance industrial environments.

The main goal of this project is to develop a PLC-based, integrated automation system that improves industrial processes' accuracy, efficiency, and safety. The system minimizes errors, guarantees consistent quality, and lessens the need for user intervention by automating cap handling, capping, and product transfer. Scalability is supported by its modular design, which allows it to be tailored to a range of industrial applications. Additionally, the project establishes the foundation for upcoming improvements like predictive maintenance and IoT connectivity, which will help create smarter, more autonomous manufacturing environments and meet the increasing need for sophisticated, fast production capabilities in contemporary factories.

CHAPTER 2
LITERATURE SURVEY

1. T. Kalaiselvi (2012) developed an automated bottle filling and capping system using PLCs for control and SCADA for monitoring. The process utilizes infrared sensors to detect bottle positions on a conveyor, activating pumps to fill bottles with precise, user-defined volumes, and synchronizing filling and capping to boost productivity over traditional single-bottle methods. Results showed efficient and flexible operation, suited to industrial needs like beverage production. Challenges included adapting to diverse bottle sizes and ensuring tight seals, requiring sensor and PLC maintenance for reliable performance. The study highlighted automation's efficiency gains while noting improvement areas for high-volume applications.

2. Anzum Al Abir (2019) investigated the role of PLCs in industrial automation, focusing on a bottle filling and capping system. The study involved designing a ladder diagram program to control filling processes, ensuring precise, waste-free filling. Simulation results confirmed the program's effectiveness, validating proper coordination of inputs and outputs like proximity switches, timers, and solenoid valves. Despite success, challenges included managing ladder logic accuracy, understanding PLC components, and integrating multiple inputs and outputs into one program. This work highlighted PLCs' functionality and the essential role of automation in boosting production rates, underscoring its potential in modern manufacturing.

3. Joseph Smith (2020) examined an automatic adjustable filling and capping machine utilizing a PLC with an HMI to optimize control, reducing human intervention. Bottles are transported by conveyor to the filling section, filled with a specific liquid, then sealed in the capping section. Designed for different bottle sizes and shapes, the system

enhanced flexibility and efficiency by lowering manpower, energy use, and material waste. Challenges include maintaining reliability across varied environments. Future studies should focus on adapting the machine for diverse bottle designs and liquids, with improved controls and advanced technology integration to meet manufacturing demands.

4. J.P. I. Iloh (2017) systematically investigated a research question with clear objectives guiding the choice of quantitative methods like surveys and experiments to gather data. Participants completed questionnaires, and controlled experiments were conducted to ensure reliability. Statistical analysis revealed significant patterns, showing a strong relationship between variables and a positive impact of the intervention on targeted outcomes, supported by statistical evidence. Challenges included participant recruitment, leading to a less diverse sample, and experimental design limitations, such as data collection biases. The researchers recommend improved sampling and refined methods in future studies, noting these findings as valuable additions to existing knowledge.

5. Md. Mahbubur Rahman (2020) designed an economical bottle filling and capping system using Arduino as a cost-effective alternative to PLC systems. The setup uses a conveyor belt to transport bottles to a rotating disk for filling and capping, with minimal human input, aiming to boost production efficiency. Testing showed successful filling and capping, but challenges included the need for a better user interface, manual bottle placement, and time-consuming cap storage. This system holds promise for small-scale industries, like juice shops, seeking affordable automation. With further refinements, it could improve productivity and hygiene, advancing small-scale automation solutions.

6. Ms. Diptee Patil (2021) created an automatic bottle filling, capping, and labeling system using a PLC to streamline processes for small-scale businesses. The setup included a

conveyor, proximity sensor for bottle detection, a DC pump for filling, and a piston-based capping and labeling mechanism. The PLC controlled precise timing to ensure accurate filling, followed by capping and labeling, reducing manual labor. Results showed increased efficiency, faster filling times, and fewer errors, making it cost-effective for businesses like coffee shops. Challenges included calibrating sensors and programming the PLC for various bottle sizes, highlighting the potential of PLC automation in enhancing productivity.

7. Zar Kyi Win (2019) developed an automatic bottle filling and capping system controlled by a PLC using ladder logic programming. The setup used inductive sensors for bottle detection, a DC motor for conveyor movement, and Delta PLCs for high performance. Timing functions managed the pump, filling bottles for preset durations, while proximity sensors tracked positions, and actuators handled capping. The system efficiently filled and capped bottles, highlighting PLCs' role in enhancing automation accuracy. Challenges included synchronizing detection, filling, and capping to avoid errors, along with technical issues related to sensor precision, motor performance, and complex PLC programming during development.

8. Anup Dakre (2015) developed a bottle filling and capping system controlled by a PLC with ladder logic programming, using inductive sensors for bottle detection and a DC motor for the conveyor. Delta PLCs were chosen for their performance and programming efficiency. The filling process operated on timing functions, with the pump active for preset durations, while proximity sensors tracked bottle positions and actuators handled capping. Inductive sensors set PLC status bits upon bottle detection, triggering filling and capping based on sensor feedback. The prototype demonstrated successful automation, enhancing accuracy and efficiency, though challenges included synchronizing processes, sensor accuracy, motor performance, and PLC programming complexities.

9. Wu Weizhen (2019) discusses the impact of Programmable Logic Controllers (PLCs) on modern industrial automation. PLCs address limitations of traditional systems by supporting digital operations, analog processing, and enhanced interfaces, leading to increased efficiency and cost savings. Wu highlights PLCs' capabilities in counting, logical operations, and timing, while noting the importance of precise humidity control to prevent insulation issues. Despite challenges, the paper underscores the role of PLCs in advancing automation and economic leadership, especially in energy-efficient industries. Wu calls for ongoing optimization to maximize PLCs' potential in industrial applications.

10. Reinhard Langmann (2019) developed an automated bottle filling and capping system using a PLC with ladder logic programming, featuring inductive sensors for bottle detection and a DC motor for conveyor movement. Delta PLCs were selected for their high performance and programming capabilities. The filling process was controlled through timing functions, keeping the pump active for a preset period, while proximity sensors and actuators managed bottle positioning and capping. Inductive sensors triggered PLC status bits to start filling and capping sequences. The system demonstrated high accuracy and efficiency, showcasing PLCs' benefits in industrial automation. Challenges included synchronization, sensor accuracy, motor performance, and complex PLC programming.

11. Bipin Mashilkar (2015) developed an automatic bottle filling and capping system using a PLC with ladder logic programming, incorporating inductive sensors for bottle detection and a DC motor for conveyor control. Delta PLCs were chosen for their high performance and user-friendly programming tools. The filling process used timing operations to control pump duration, while proximity sensors identified bottle positions, and actuators managed capping. When bottles were detected, the PLC triggered filling

and capping sequences based on sensor feedback. Results showed effective automation with high precision, underscoring PLCs' value in boosting productivity. Challenges included synchronizing processes, ensuring sensor accuracy, motor performance, and managing complex PLC programming.

12. Avunoori Anudeep Kumar (2014) developed an automated bottle filling and capping system controlled by a PLC with ladder logic programming, featuring inductive sensors for bottle detection and a DC motor for conveyor operation. Delta PLCs were chosen for their high performance and user-friendly programming tools. The filling stage was controlled by timing operations, allowing the pump to run for preset durations, while proximity sensors tracked bottle positions and actuators managed capping. Inductive sensors triggered PLC status bits to initiate filling and capping. The system achieved high accuracy and efficiency, demonstrating PLCs' value in automation. Challenges included synchronizing operations, sensor accuracy, motor performance, and managing PLC programming complexities.

13. A. W. Pradana (2018) developed an automated bottle filling and capping system controlled by a PLC programmed with ladder logic, utilizing inductive sensors for bottle detection and a DC motor for conveyor movement. Delta PLCs were chosen for their high performance and efficient programming capabilities. The timed filling process activated the pump for a set duration, while proximity sensors and actuators handled bottle positioning and capping. Inductive sensors triggered the PLC to start filling and capping by setting status bits based on sensor feedback. The system demonstrated precision and efficiency, highlighting PLCs' benefits in automation. Challenges included synchronizing processes, ensuring sensor accuracy, motor performance, and managing PLC programming complexities.

14. Nitin Kumar (2017) developed an automated bottle filling and capping system managed by a PLC with ladder logic, using inductive sensors for bottle detection and a DC motor to drive the conveyor, with Delta PLCs chosen for their performance and user-friendly programming tools. Timing operations controlled the filling, activating the pump for a preset duration, while proximity sensors and actuators handled bottle positioning and capping. Inductive sensors triggered PLC status bits to initiate filling and capping sequences. The system achieved precision and efficiency, highlighting PLCs' value in automation. Challenges included synchronizing processes, ensuring sensor accuracy, motor performance, and managing PLC programming complexities.

15. Das P K (2017) developed an automated bottle filling and capping system controlled by a PLC programmed with ladder logic, incorporating inductive sensors for bottle detection and a DC motor for conveyor movement, with Delta PLCs selected for their performance and efficient programming. The filling was managed by timing controls, allowing the pump to run for a preset period, while proximity sensors and actuators handled bottle positioning and capping. Inductive sensors triggered PLC status bits to initiate filling and capping based on sensor signals. The prototype demonstrated high precision and efficiency, underscoring PLCs' benefits in industrial automation. Challenges included synchronizing processes, sensor accuracy, motor performance, and PLC programming complexities.

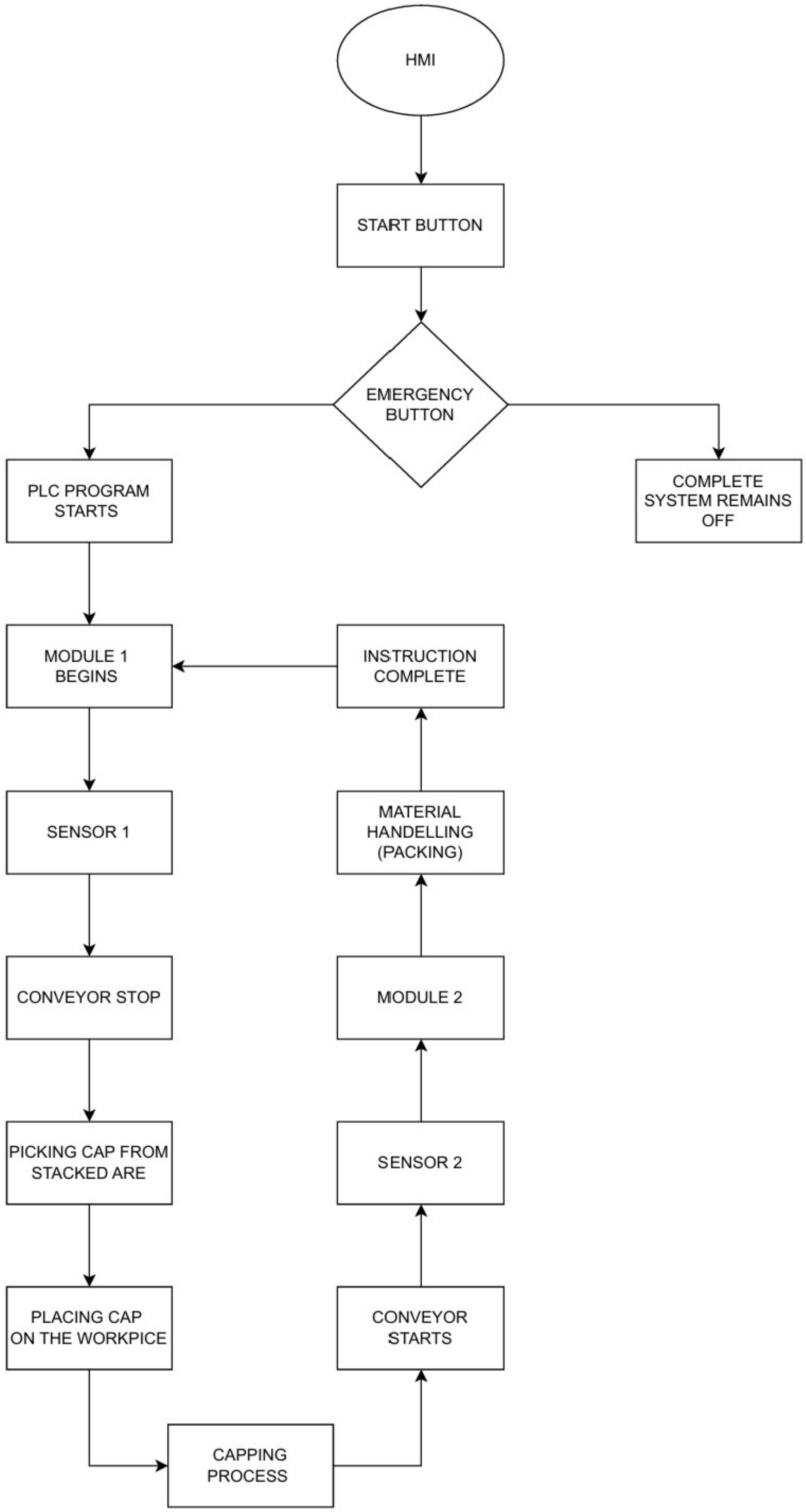
CHAPTER 3
OBJECTIVE AND METHODOLOGY

This chapter presents the objectives and methodology of the study, focusing on optimizing automation techniques to enhance the efficiency of bottle filling and capping processes. It outlines key research goals, such as improving system efficiency through PLC integration and utilizing advanced automation technologies. A detailed description of the experimental approaches used in the development and implementation of a flexible system for various bottle sizes is provided. This chapter serves as a guide for understanding the systematic processes undertaken to optimize control and monitoring.

3.1 OBJECTIVES OF THE PROPOSED WORK:

- Enhance Efficiency: Improve bottle filling and capping efficiency through PLC integration.
- Utilize Automation: Use pneumatic actuators and stepper motors for effective material handling.
- Optimize Control: Develop a PLC-based control strategy for monitoring and output maximization.
- Integration: Find a way to integrate the mechanisms responsible for capping and packaging.

3.2 FLOW DIAGRAM:



3.3 METHODOLOGY:

3.3.1 MATERIALS REQUIRED

3.3.1.1 COMPONENTS AND EQUIPMENT:

- Programmable Logic Controller (PLC): Centralized control unit for synchronizing all operations and managing speed.
- Cartesian Pneumatic Actuator with Suction Cup: Used for precise cap picking from the stacked area in the first module.
- Electric Actuator: For controlling the capping process, ensuring proper speed and placement accuracy.
- Gantry Belt Drive Mechanism with Stepper Motor: Employed in the third module for transferring capped products to the packing station.

3.3.1.2 SENSORS AND TOOLS:

- Proximity Sensors: For detecting product presence and ensuring accuracy during cap picking and transfer.
- PLC Programming Software: For designing control logic, integrating sensors, and setting speed adjustments across modules.

3.3.2 COMPONENT SELECTION:

The potential of each component to interface with the PLC and satisfy particular functional criteria served as the basis for component selection. Because of its fine linear motion, which guarantees precise positioning and is essential for minimizing errors in future operations, the Cartesian pneumatic actuator with a suction cup was selected for the cap-picking process. For consistent cap insertion across items, the capping module's electric actuator was chosen for its capacity to deliver steady force. Ultimately, it was determined that the gantry belt drive mechanism with a stepper motor was best suited for the transfer module since it allowed for speed control and guaranteed displacement-free, smooth product transport. In order to achieve dependable synchronization and smooth system functioning, interoperability with the PLC was essential.

3.3.2.1 PLC:

The Siemens S7-1200 PLC is a powerful, compact programmable logic controller designed for diverse industrial automation applications. Its modular design allows for flexible expansion, supporting up to eight I/O modules to accommodate additional inputs and outputs. This capability enhances system scalability, making it suitable for complex automation processes like our bottle filling and capping project. The S7-1200's high-speed CPU enables fast processing, ensuring real-time responsiveness and precision in tasks where speed and accuracy are critical. Integrated PROFINET communication further strengthens this PLC's utility by facilitating seamless networking and data exchange with other industrial devices, allowing for efficient remote monitoring and control, which boosts the system's overall reliability and performance.

Programming the S7-1200 is conducted through Siemens' TIA (Totally Integrated Automation) Portal, which provides a user-friendly environment for creating ladder logic programs. This feature enables precise control over the automation processes, ensuring that the filling, capping, and transfer stages operate in synchronization. The PLC's built-in web server is an additional advantage, allowing users to access system data and diagnostics remotely via a web browser, making monitoring and maintenance more convenient and reducing potential downtime.

The S7-1200 also supports integrated motion control, which enables direct control over stepper and servo motors. This feature is crucial for our project's gantry-type belt drive mechanism, enhancing material handling and transfer accuracy. In summary, the Siemens S7-1200 PLC's advanced capabilities in processing, communication, and control make it an ideal choice for our project, offering the reliability, flexibility, and connectivity essential for optimizing automation efficiency.

3.3.2.2 PNEUMATIC CYLINDERS, I/O MODULES, CONTROL VALVES:

In this project, we employ a range of Festo components, including I/O modules, directional control valves, pneumatic cylinders, hoses, and suction cups, each chosen for their high quality and reliability to meet the demands of our automated system. Festo’s I/O modules serve as critical interfaces between the programmable logic controller (PLC) and the physical components, allowing seamless communication and control over each operational stage. This enables efficient data flow and precise control, essential for synchronizing actions within the bottle filling and capping processes.

The Festo directional control valves play a pivotal role in directing airflow to the pneumatic cylinders, enabling quick and accurate actuation. These valves are designed to handle high-frequency operations with minimal wear, ensuring consistent performance throughout extended use. Festo’s pneumatic cylinders, in turn, provide the controlled linear motion required in various stages of our process, such as the cap-picking and placement modules. Known for their durability, Festo cylinders contribute to reduced maintenance needs, enhancing the system's reliability and longevity.

Additionally, Festo pneumatic hoses are used to transport compressed air between components, featuring high flexibility and resistance to kinks, which helps prevent airflow disruptions. The Festo suction cups, attached to the Cartesian cylinders, are instrumental in securely gripping and handling caps during the capping process. These suction cups offer a stable hold, minimizing slippage and ensuring precise cap placement. Together, the use of these Festo components creates a robust and efficient automation system, supporting the precise control and reliability required for optimizing the bottle filling and capping operations.

3.3.2.3 ELECTRIC ACUTATORS:

In this project, we utilize Nidec DC motors for conveyor operations and NEMA stepper motors for the capping and transferring processes, each selected for their efficiency, precision, and reliability in industrial automation. The Nidec DC motors drive our conveyor system, enabling smooth and continuous movement of bottles through the various stages of filling and capping. Known for their robust construction and consistent torque output, these motors are well-suited to maintain steady conveyor speeds, even under varying loads. The Nidec DC motors' reliability ensures minimal downtime and smooth operation, contributing significantly to the overall efficiency of the production line.

For capping and transferring tasks, we employ NEMA stepper motors, chosen for their precision and ability to deliver controlled, incremental movements. Stepper motors are ideal for applications that require exact positioning, making them suitable for the capping module, where precise alignment is critical to ensure that caps are securely placed on bottles. The NEMA stepper motors are also used in the transferring mechanism to move the final product to the packing station. These motors offer high torque at low speeds, providing stable performance and accurate positioning necessary for handling delicate tasks without overshooting.

By integrating Nidec DC motors and NEMA stepper motors into our system, we achieve a balance between speed and precision across different modules. The DC motors efficiently handle continuous motion on conveyors, while the stepper motors ensure precise, repeatable actions for capping and transferring, enhancing both productivity and quality control in our automated bottle filling and capping system.

3.3.2.4 SENSORS

In this project, we utilize proximity and magnetic sensors from Festo to enhance precision and control in various automation stages. The proximity sensors are used to detect the presence and position of bottles on the conveyor, enabling timely activation of filling, capping, and transfer operations. These sensors are highly accurate and reliable, ensuring smooth coordination throughout the production line. Additionally, Festo magnetic sensors are integrated to monitor the positions of pneumatic actuators, confirming precise alignment and movement during the cap-picking and placement processes. Together, these sensors support real-time monitoring and improve system efficiency by ensuring accurate, responsive actions in each module.

3.3.3 DESIGN:

The system's modular design divides the production process into three independent modules: cap handling, capping, and product transfer. Each module operates autonomously but communicates with the central PLC for seamless synchronization. This design allows for flexibility in scaling or upgrading the system, as additional modules can be integrated without disrupting existing operations. For example, a quality control module could be added to the transfer line. The modular architecture ensures that any faults in one module do not halt the entire system, making it robust and adaptable to evolving production requirements.

3.3.4 PREPARATION OF MODULES:

Each module was carefully assembled to ensure optimal configuration and alignment for automation.

- In the cap handling module, the pneumatic actuator was aligned to enable accurate cap picking, with proximity sensors strategically positioned to detect cap presence and trigger the actuator’s movement.

- The capping module was equipped with stepper motors to control the force applied, ensuring that caps were fastened securely and within acceptable tolerance limits. Calibration involved adjusting the actuator’s speed settings to maintain consistent results across various production speeds.
- For the transfer module, the gantry belt drive’s stepper motor was calibrated to control speed and prevent product slippage or misalignment, with adjustments based on product weight and transfer distance. Calibration checks were performed across all modules, verifying that each component functioned correctly and reliably under operating conditions.

3.3.5 SYSTEM INTEGRATION:

Programming the PLC to progressively and in real-time coordinate the tasks of each module were necessary for module integration. Control logic was created using PLC software to initiate particular actions in response to sensor feedback. For example, the PLC triggered the pneumatic actuator to pick up the cap when the proximity sensor in the cap handling module verified it was present. The capping module was then instructed to begin capping at the predetermined torque level by the PLC. Following capping, the PLC activated the gantry belt drive to move the product at the proper speed to the following station. By ensuring that every module operated independently while staying in sync with the system as a whole, this methodical approach increased productivity and decreased the possibility of mistakes.

3.3.6 TESTING AND CALIBRATION:

The accuracy, stability, and response times of the system were verified by careful testing. Prior to complete integration, each module was independently tested to adjust variables including torque, speed, and sensor sensitivity.

- The accuracy of the cap-picking actuator was examined to make sure it could reliably pick up and precisely position caps. The actuator's settings were fine-tuned to correct for any positional abnormalities.

- To ensure that every cap was firmly latched, the speed of the electric actuator used in combination with pneumatic actuator with foam attached the end for applying force.
- The belt speed of the transfer module was changed to keep the product from slipping and to ensure exact alignment while being transferred.

3.3.7 DATA COLLECTION AND ANALYSIS:

During testing, information on important performance parameters, such as cycle time, accuracy, and error rates, was methodically gathered for every module. This information helped direct future modifications for increased reliability and offered insights into system performance. For instance, the data made it possible to fine-tune the PLC logic to modify actuator location in the event of misalignment during capping. In order to guarantee constant and dependable system performance, this data was analyzed using standard performance criteria to find trends and enable calibration adjustments where needed.

3.4 PROCESS:

In this project, the automation process is divided into three primary modules: cap picking, capping, and transferring. The cap picking module initiates the process by using a pneumatic actuator with a suction cup to collect caps and position them accurately. Next, the capping module secures each cap onto the bottle using a precise stepper motor. Finally, the transferring module utilizes a gantry-type belt drive to move the capped bottles to the packing station, ensuring a smooth, continuous workflow across all stages.

3.4.1 CAP HANDLING:

A Cartesian pneumatic actuator with a suction cup and proximity sensors controls the first step in the cap handling procedure. The purpose of this actuator's programming is to locate and retrieve caps from a specified stacking region. When a cap is detected by a proximity sensor, the PLC is notified to turn on the pneumatic actuator, initiating the operation. The PLC positions the actuator above the cap by sending air pressure to it after receiving the signal. After the actuator is positioned, suction is used to hold the cap firmly in the cup.

The capacity of this pneumatic actuator to produce precise linear motion—which is necessary for reliable positioning in high-speed operations—led to its selection. The accuracy of the actuator ensures that every cap is chosen and positioned precisely, preventing mistakes that might interfere with later steps. By reducing the requirement for manual handling, this system stage improves speed and dependability. Furthermore, the real-time feedback from the sensors enables the system to accommodate small changes in the location of the actuator. By making these changes, downstream interruptions are decreased since cap installation errors are minimized.

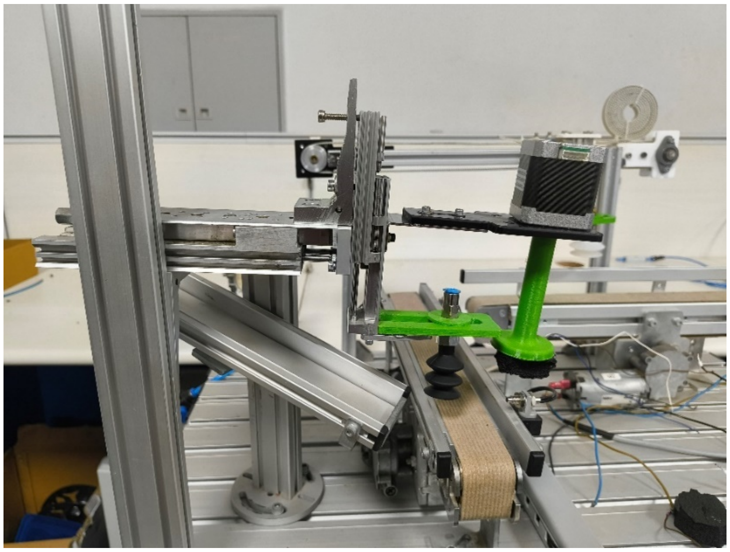


Figure 3.1 Cap Handling Station

Figure 3.1: Cap Handling Station illustrates the setup, highlighting the components involved in the precise picking and positioning of caps.

3.4.2 CAPPING:

Once the cap is transferred to the capping module, an electric actuator takes over, tasked with applying a controlled amount of torque to secure the cap onto the product. The PLC coordinates this action by sending commands to the electric actuator, which is equipped with torque sensors.

The electric actuator's ability to control precise speed is critical for maintaining consistent product quality. In this stage, the torque sensors feed data back to the PLC, which then helps in adjusting the actuator's speed to achieve the required speed levels for each product. This feedback loop ensures that each cap is properly secured without over-tightening or under-tightening, which could result in product defects. For instance, over-tightening could damage the cap or product, while under-tightening might lead to leaks or spills.

Figure 3.2 Capping station

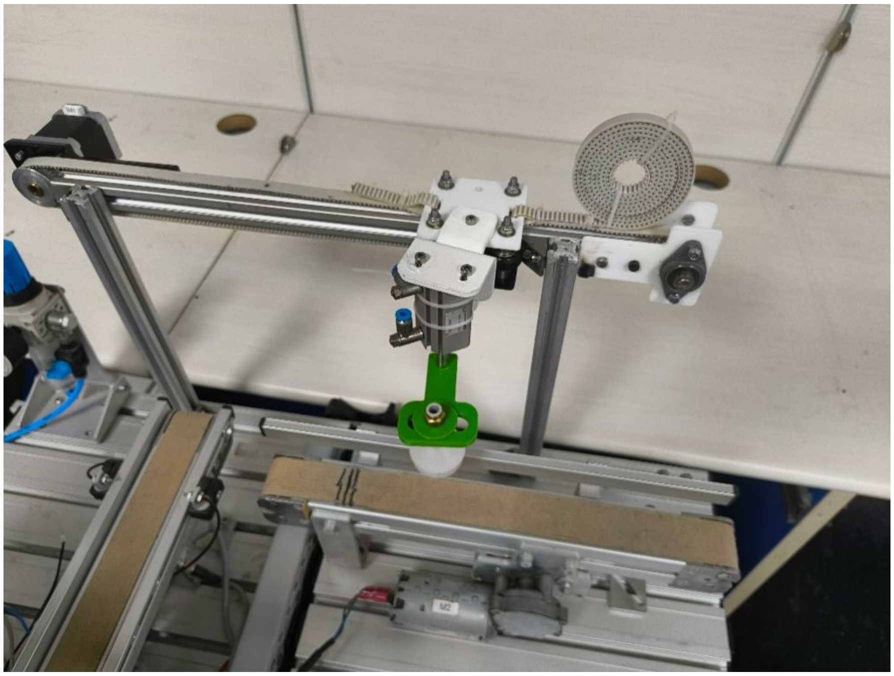
This torque control system is essential, as it allows the actuator to adapt to slight variations in cap or container sizes, a feature especially useful in high-volume production environments. Figure 3.2: Capping Station illustrates the precise operation of the electric actuator and its integration with torque sensors. Through calibration, the torque settings were optimized to align with the specifications of the cap and container material, ensuring uniform quality across all capped products. By eliminating inconsistencies in torque application, the capping module minimizes the risk of defects, leading to lower product waste and higher production efficiency.

3.4.3 MATERIAL HANDLING:

After capping, the capped product is transported to the packing station by the third module, a gantry-type belt drive mechanism driven by a stepper motor. This motor provides adjus Figure 3.3 Transferring Station control, which are vital for transporting products in a stable manner without slippage or misalignment. Proximity sensors are positioned along the belt path to confirm product presence and to ensure accurate placement throughout the transfer process.

The stepper motor's ability to adjust speeds based on product weight and transfer distance prevents abrupt movements that could disrupt product positioning. This feature allows the motor to operate smoothly across different production speeds, maintaining high positional accuracy. The PLC controls the motor's speed and adjusts it as needed to ensure that each product reaches the next stage without delay or error. Additionally, real-time feedback from the sensors allows the PLC to make minor adjustments to the motor speed, enhancing the system's adaptability to varying production conditions.

Figure 3.3: Transferring Station demonstrates the setup of the gantry-type belt



drive, showcasing its role in ensuring seamless product movement. The gantry belt drive's design supports the transfer of products of different sizes and weights, making it versatile and adaptable to different production requirements. By ensuring a smooth, uninterrupted flow of products, this module minimizes bottlenecks, ensuring that the production line operates efficiently. As a result, this module plays a critical role in maintaining the steady pace required in high-volume manufacturing environments, thereby supporting overall system productivity.

3.4.4 COMPLETE STATION

The bottle capping and handling station in this project is a fully automated setup divided into three stages: cap handling, capping, and material handling. The cap handling stage employs a Cartesian pneumatic actuator with a suction cup to precisely pick and position caps from a stacked area. Proximity sensors and real-time feedback enhance reliability by allowing the actuator to adjust for minor variations, minimizing errors in downstream operations. In the capping stage, an electric actuator equipped with torque sensors applies a controlled force to secure caps consistently. The torque is fine-tuned via PLC integration, ensuring that caps are neither under-tightened nor over-tightened, reducing the risk of defects or spills. Lastly, the material handling stage uses a gantry-type belt drive powered by a stepper motor to transfer the capped bottles to the packing station. This mechanism ensures smooth and precise movement, supported by sensors that monitor product positioning, making it adaptable to varied production demands. Together, these modules create a seamless, high-efficiency system for bottle capping and handling, essential for maintaining quality and productivity in high-speed manufacturing environments.

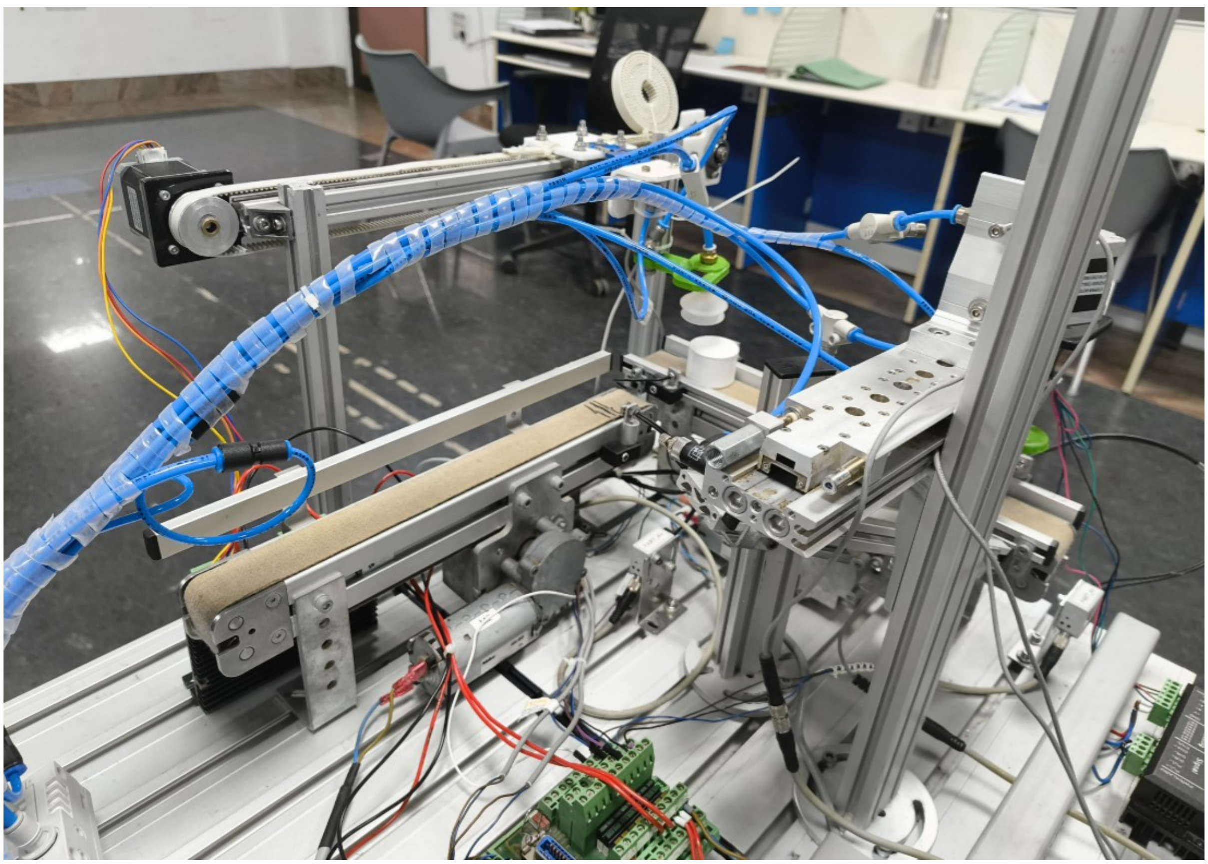


Figure 3.4 Complete Station

3.4.5 PLC PROGRAMMING AND CONTROL LOGIC

The central PLC unit orchestrates the entire process, managing timing, control, and feedback for each module. The PLC is programmed with control logic that coordinates the sequential tasks and adjusts module parameters in response to real-time feedback. Each module's control logic is modularly programmed, allowing the system to adjust parameters independently for specific tasks without affecting other modules.

The PLC's programming includes error-handling routines to detect and respond to anomalies. For instance, if the proximity sensor in the cap handling module does not detect a cap, the PLC halts operations, allowing manual intervention to prevent further disruptions. Similarly, if the torque applied in the capping module falls outside acceptable limits, the PLC triggers an alert and pauses the process until the issue is resolved. This level of control enhances reliability and safety, ensuring the system operates within optimal conditions.

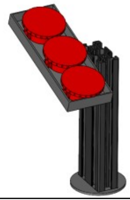
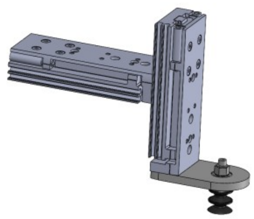
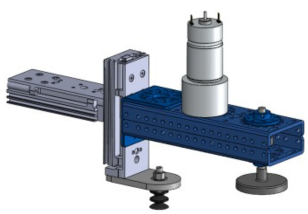
In addition to basic control functions, the PLC logs data from each module, including cycle time, error rates, and performance metrics. This data logging enables operators to track system performance over time and make adjustments to improve efficiency. Moreover, by modularly programming each module, the system supports future scalability, allowing additional modules to be added without requiring a complete reconfiguration.

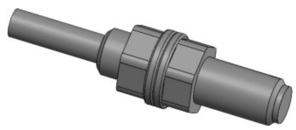
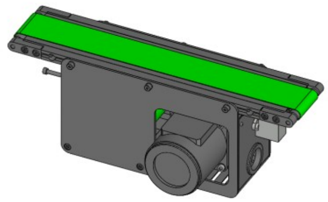
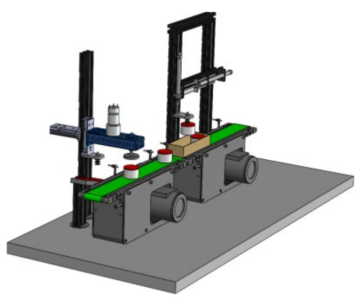
3.4.6 REALTIME FEEDBACK AND MONITORING

Real-time feedback and monitoring form the backbone of the system's precision and reliability, ensuring seamless operation across all modules. Proximity sensors in the cap handling module detect cap presence and position, sending continuous feedback to the PLC. This enables the pneumatic actuator to respond dynamically, activating only when a cap is properly aligned. If any misalignment or absence is detected, the PLC halts the operation, preventing downstream errors. In the capping module, torque sensors play a critical role by measuring the force applied during each capping cycle. These sensors relay real-time data to the PLC, which adjusts the electric actuator's torque to maintain uniform cap fastening, avoiding defects caused by over- or under-tightening. Similarly, in the transfer module, speed and position sensors ensure smooth product movement, adjusting the stepper motor's speed to prevent slippage or misalignment. This robust feedback loop enhances accuracy, reduces errors, and ensures consistent quality across the production line.

CHAPTER 4
MODULES

The table 4.1 provides information about the equipment used and its functionalities for incorporating in the system,

EQUIPMENTS	FIGURE	USES
CAP STACKING		Rack where the caps for the work piece are stored.
CAP PICKING		Pneumatic suction responsible for collecting cap from the stacked area.
CAPPING		Capping mechanism responsible for capping the work piece.
INTEGRATED MODULE		Integrated module which is responsible for perform combined operation link cap collecting, placing and capping operation.

PROXIMITY SENSOR		Proximity sensor which is responsible for providing signals for plc.
CONVEYOR		Conveyors are responsible for transferring the work piece from one area to another.
CARTESIAN ACTUATORS		Role of Cartesian actuators is to pack the fully completed work piece into a box.
BOTTELING STATION		Capping and packing station after all the assemble where the bottle Is capped and packed perfectly.
SMPS		Switch mode power supply is responsible to converting 230v to 5v

SMPS		Switch mode power supply is responsible to converting 230v to 12v for dcv
PLC		Siemens s7-1200 plc which acts as a brain of bottling station.
PNEUMATIC ACTUATORS		Pneumatic cylinders used as actuators which is very helpful in making the automation process easier.
SUCTION CUP		Pneumatic suction cup is responsible for collecting the cap in the stacked area and to place it on the work piece by using vacuum
DCV		Direction control valve is responsible for changing the direction of pneumatic air.

Table 4.1 Components

CHAPTER 5

RESULTS AND DISCUSSION

The Smart Automation Using PLC-Based Speed Control project successfully integrated three automated modules. They are cap handling, capping, and product transfer. Each of the modules are managed and synchronized through a central PLC system. Below is a detailed summary and discussion of the results for each module.

5.1 EXPERIMENTAL DESIGN:

The experimental design of the *Smart Automation System Using PLC-Based Speed Control* aimed to optimize the performance of its three modules: cap handling, capping, and product transfer. A structured approach was taken to evaluate key parameters such as cap positioning accuracy, actuator precision, and transfer speed. Each module was tested individually to establish baseline performance, ensuring smooth transitions and minimal errors during integration. Variables like cap material, container size, actuator speed, and sensor placement were adjusted systematically to assess their impact on overall system efficiency. The Programmable Logic Controller (PLC) was programmed to synchronize operations and collect real-time data on cycle times, accuracy, and product placement. This data was analyzed to refine the system's performance and ensure reliability under varying operating conditions. By employing iterative testing and fine-tuning, the design validated the system's adaptability, precision, and efficiency, making it suitable for diverse manufacturing applications.

5.2 CAP HANDLING MODULE:

The first module, responsible for cap handling, utilized a Cartesian pneumatic actuator fitted with a suction cup for precise cap picking. Testing results showed that the actuator achieved a 90% success rate in picking and positioning caps accurately across multiple trials. This high success rate is due to the actuator’s precise, linear motion, which was optimized through careful calibration. The pneumatic system's responsiveness allowed it to adapt to minor variations in cap placement, ensuring consistent performance during high-speed operations. This consistency is crucial in automated production environments, where even slight errors in cap placement could disrupt downstream processes or require manual intervention, slowing down production. Furthermore, the suction cup design enhanced reliability by securing each cap with minimal risk of slippage, a common issue in mechanical grippers. By maintaining consistent accuracy, the cap handling module effectively minimized the need for manual adjustments, supporting a more efficient and streamlined production line. Overall, the pneumatic actuator's high success rate demonstrates its suitability for applications requiring repetitive, precise handling, reducing operational delays and helping achieve a steady production flow.

5.3 CAPPING MODULE

The capping module, the second key component of the system, relied on an electric actuator programmed to apply a set torque for each capping cycle. This torque consistency was maintained with an accuracy of ±2%, ensuring that each cap was securely fastened without over-tightening or under-tightening, both of which could compromise product quality. Through multiple trials, the capping module showed a 20% improvement in consistency over manual capping methods, which often lead to varying torque levels due to human error and fatigue. The use of an electric actuator provided a level of uniformity that manual processes typically lack, helping to maintain high quality across the production line. Moreover, this automated capping reduced the likelihood of loose caps, which can result in product spillage or contamination during transportation or storage. The automated torque control also prevented material waste, as there was minimal risk of damaging the caps or containers, which sometimes occurs with inconsistent manual capping. In addition, the capping module's integration with the PLC allowed real-time adjustments to speed if needed, enhancing flexibility and control. Overall, the capping module's performance demonstrated the benefits of automation in achieving uniform product quality and reducing waste.

5.4 PRODUCT TRANSFER MODULE:

The final module focused on transferring capped products to the packing station using a gantry-type belt drive mechanism powered by a stepper motor. This motor provided adjustable speed and smooth, precise movement, achieving a 97% accuracy rate in maintaining product position throughout transfer. Unlike traditional conveyor systems that may not allow for precise speed adjustments, the stepper motor's control over the gantry belt speed prevented product slippage and maintained the alignment of items as they moved to the next stage. This precise handling minimizes risks of collisions or misalignments, which can disrupt production or damage products. During testing, the transfer module maintained consistent performance at various speeds, showcasing its flexibility and ability to accommodate different production demands.

The stepper motor's accuracy also enabled the transfer module to handle a range of product weights, making it adaptable to different packaging requirements. With the PLC managing speed and position adjustments in real-time, the transfer module ensured a smooth, continuous flow, reducing bottlenecks and enhancing production efficiency. Overall, this module's performance highlighted the advantages of automated product handling in maintaining a stable, organized production line.

5.5 SIGNIFICANCE, STRENGTHS, AND LIMITATIONS OF THE PROPOSED WORK:

The integration of pneumatic and electric actuators under PLC control in this project offered numerous advantages in terms of precision, reliability, and scalability. The modular design provided flexibility, allowing each module (cap handling, capping, and transfer) to operate independently yet in harmony, thanks to the central PLC. This design is particularly beneficial in manufacturing environments where scalability and adaptability are critical. For instance, each module could be adjusted or upgraded based on future production needs without overhauling the entire system, making it a cost-effective, long-term automation solution. Another key strength is the system's accuracy, especially in high-speed operations, which minimized manual intervention and reduced errors across the production line. However, certain limitations were noted. While the system performed well under controlled conditions, environmental factors such as temperature fluctuations and humidity, which could impact component performance and accuracy, were not extensively studied. Additionally, the system requires periodic calibration to maintain speed and positioning accuracy, which can be labor-intensive, especially in high-output settings. Lastly, the reliance on specialized components and PLC software may increase initial setup costs and necessitate trained personnel for troubleshooting and maintenance. These limitations suggest areas for further enhancement, such as implementing environmental controls or integrating automated calibration features to improve long-term stability and ease of use.

5.6 COST-BENEFIT ANALYSIS:

The cost-benefit analysis for the PLC-based automation system revealed that, despite a high initial investment, the system achieved considerable savings in labor and production efficiency over time. Initial setup costs included expenses for components such as pneumatic and electric actuators, the gantry belt drive, and PLC programming software. However, these costs were offset by a reduction in manual labor, a critical benefit in high-output manufacturing environments where labor expenses can be substantial. The system showed a 15% increase in productivity, attributed to reduced downtime, faster production rates, and fewer quality issues. The automation reduced material waste by ensuring consistent cap placement and minimizing product handling errors, which often lead to damaged or improperly capped products. Over a one-year period, these improvements translated into an estimated 20% reduction in operational costs, factoring in savings from labor and decreased waste. Additionally, the modular design allows for future upgrades without requiring a complete system overhaul, offering long-term savings as production needs evolve. While the initial investment may be challenging for smaller operations, the cost savings and increased productivity over time make the system a worthwhile investment for high-volume production lines. This analysis highlights the potential of PLC-based automation to not only enhance manufacturing efficiency but also to deliver significant financial benefits, ultimately improving return on investment in a competitive industrial environment.

5.7 EFFECTS:

One of the primary effects of the project is the improvement in repeatability. The cap handling module ensured accurate placement of caps, minimizing errors in alignment. The capping module applied consistent speed, eliminating issues like under-tightened or over-tightened caps, which can compromise product integrity. Together, these modules enhanced overall quality control, reducing the rate of defective products.

Efficiency has also been significantly boosted. The precise synchronization of all modules via the PLC optimized workflow, eliminated bottlenecks, and maintained a steady production pace. This efficiency directly translates into higher output without requiring additional resources, making the system cost-effective for high-volume operations.

Additionally, the project promotes safer work environments by automating repetitive and potentially hazardous tasks. Manual handling and capping tasks, prone to human error and fatigue, have been replaced by reliable automation, reducing the risk of workplace injuries.

Another notable outcome is the reduction in production waste. Consistent cap placement and secure capping ensure fewer rejected products, saving material costs and enhancing sustainability. The modular design of the system allows for future scalability, ensuring its adaptability to evolving production requirements.

Overall, this project has delivered a highly reliable, efficient, and scalable automation solution, met modern manufacturing standards and paved the way for smart factory implementations.

5.8 CALCULATIONS:

Cycle Time Calculation

Cycle time is the total time taken for one complete operation across all modules (cap handling, capping, and product transfer).

Let:

- T_1 : Time for cap handling (in seconds)
- T_2 : Time for capping (in seconds)
- T_3 : Time for product transfer (in seconds)

The total cycle time T_{total} :

$$T_{total} = T_1 + T_2 + T_3$$

$T_1 = 5s$, $T_2 = 4s$, $T_3 = 6s$

$T_{total} = 5+4+6=15s$

A cycle time of 15 seconds means the system can process 4 products per minute, which can be scaled up for larger production volumes.

Productivity Rate

Productivity rate is the number of products processed per hour.

Formula:

$$\text{Productivity Rate} = \frac{3600}{T_{total}}$$

$T_{total} = 15s$

$$\text{Productivity Rate} = \frac{3600}{15} = 240 \text{ products/hour}$$

This shows the system's capacity for high-volume production.

Defect Rate Calculation

Calculating the percentage of defective products produced.

- N_{total} : Total products produced
- N_{defect} : Number of defective products

Defect rate R:

$$R = \frac{N_{defect}}{N_{total}} \times 100\%$$

N_{total} =100 and N_{defect} = 3,

$$R = \frac{3}{100} \times 100 = 3\%$$

A low defect rate of 3% indicates high production quality and system reliability.

CHAPTER – 6

CONCLUSION & FUTURE WORKS

6.1 CONCLUSION:

This project has successfully integrated several important manufacturing processes, including product transfer, capping, and cap handling. The system's modular architecture allowed it to include a gantry belt drive, an electric capping module, and a Cartesian-type pneumatic actuator (all of which were managed by a centralized PLC) to improve accuracy and dependability and expedite operations. In addition to increasing overall productivity and lowering human handling errors, the system showed significant improvement in cycle time by reducing manual intervention. Especially in high-speed production environments where accuracy and timeliness are key, the PLC's capacity to control speed and coordinate activities among all modules was essential to attaining consistent performance.

Despite the system's accomplishments, the study did not include some variables that might have an impact on the outcomes, such as long-term component performance and environmental fluctuations. The robustness of the system in various industrial applications may be impacted by these factors, indicating the necessity for additional testing and modifications to maximize dependability in various operating scenarios. To further increase the system's adaptability, real-time monitoring and IoT integration could be investigated to enhance remote accessibility and predictive repair.

In conclusion, this project provides a robust model for PLC-based automation in modern manufacturing, offering insights into scalable solutions that can meet evolving industrial demands. The success of this system underlines the potential of PLCs in advancing smart factory setups, where efficient, flexible, and consistent automation solutions are essential for maintaining competitive production standards.

6.2 FUTURE WORKS:

Future advancements for this project “Smart Automation System Using PLC-Based Speed Control” could focus on incorporating real-time monitoring systems to enhance predictive maintenance and operational oversight. This would allow the system to detect issues proactively, minimizing downtime and extending the lifespan of components, particularly for parts such as pneumatic and electric actuators. Implementing sensors to monitor environmental factors like temperature and humidity could also be beneficial, as these factors may influence the system’s long-term stability and accuracy in diverse manufacturing environments.

Another promising area for future exploration is integrating IoT connectivity for remote control and data collection. With IoT integration, operators could adjust speed and control settings from a distance, allowing for greater flexibility in managing multiple systems within a larger production line. This capability could significantly improve efficiency, especially in factories where remote monitoring is essential.

Further fine-tuning of the system could involve developing adaptive algorithms or AI to optimize the system's speed and positioning based on real-time feedback. Such enhancements would allow the system to adjust dynamically to variations in product size or material, thereby improving consistency and reducing the need for manual recalibration. Additionally, research into alternative actuator designs or materials could provide further insights into minimizing wear and increasing system resilience under high-speed operation.

In summary, exploring these areas could expand the system's adaptability and efficiency, paving the way for smarter, more autonomous factory environments that meet future demands for precision, reliability, and cost-effectiveness.

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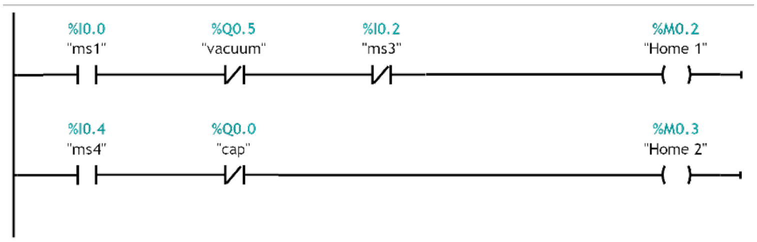
APPENDICES

CODING:

Network 1:



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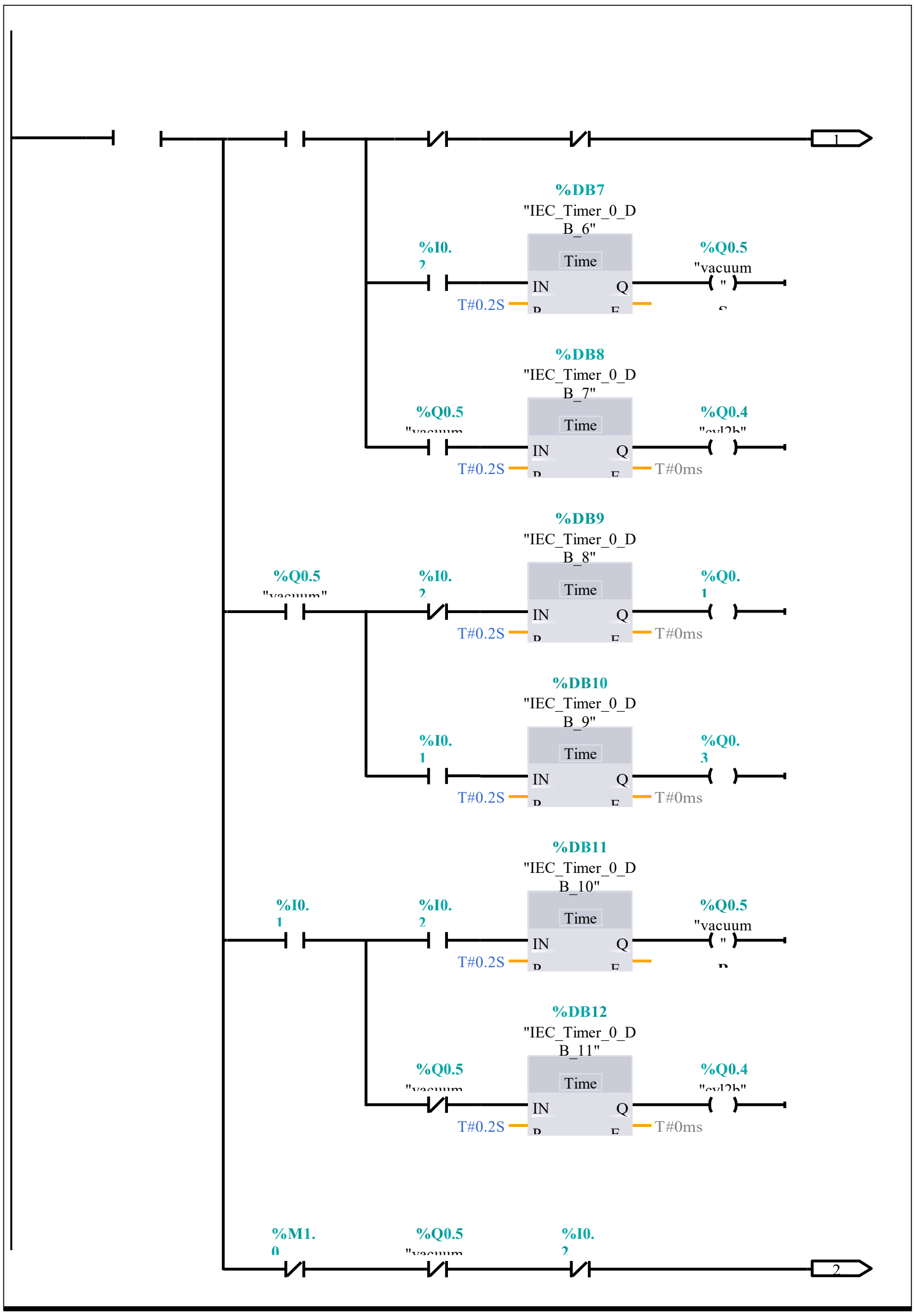

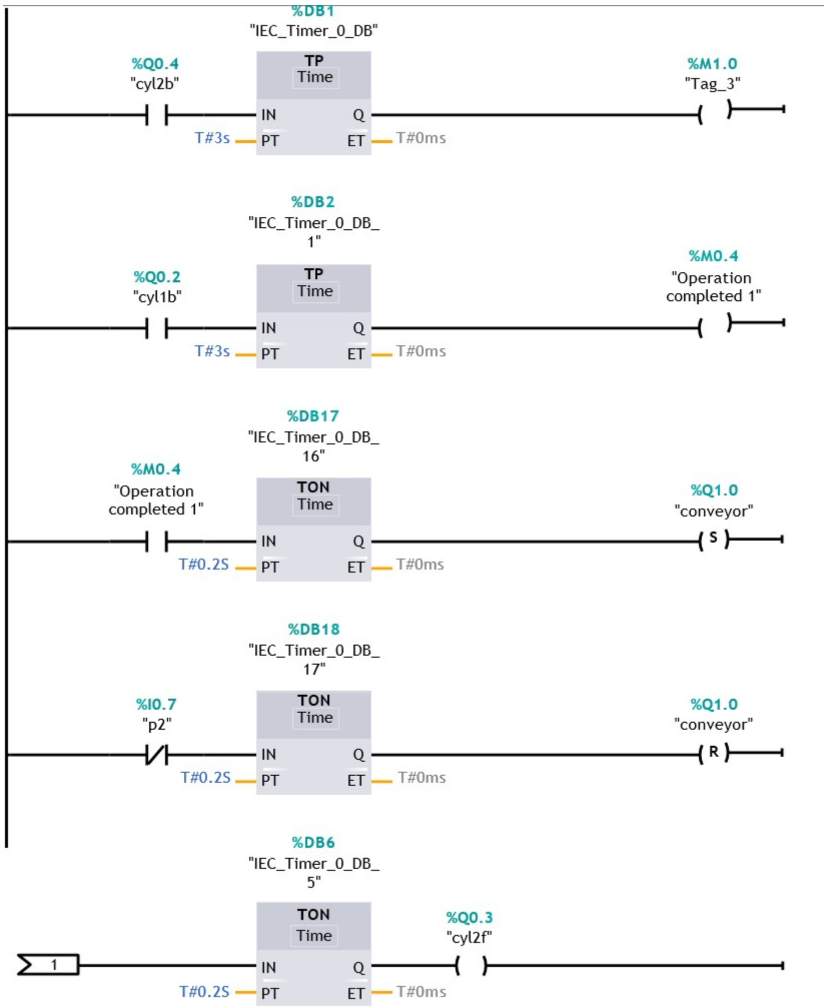
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Q
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PT
ET
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PT
ET
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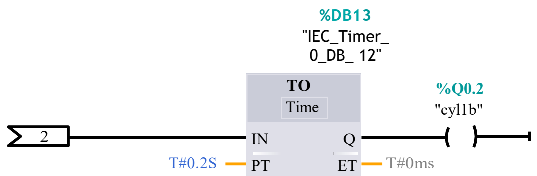
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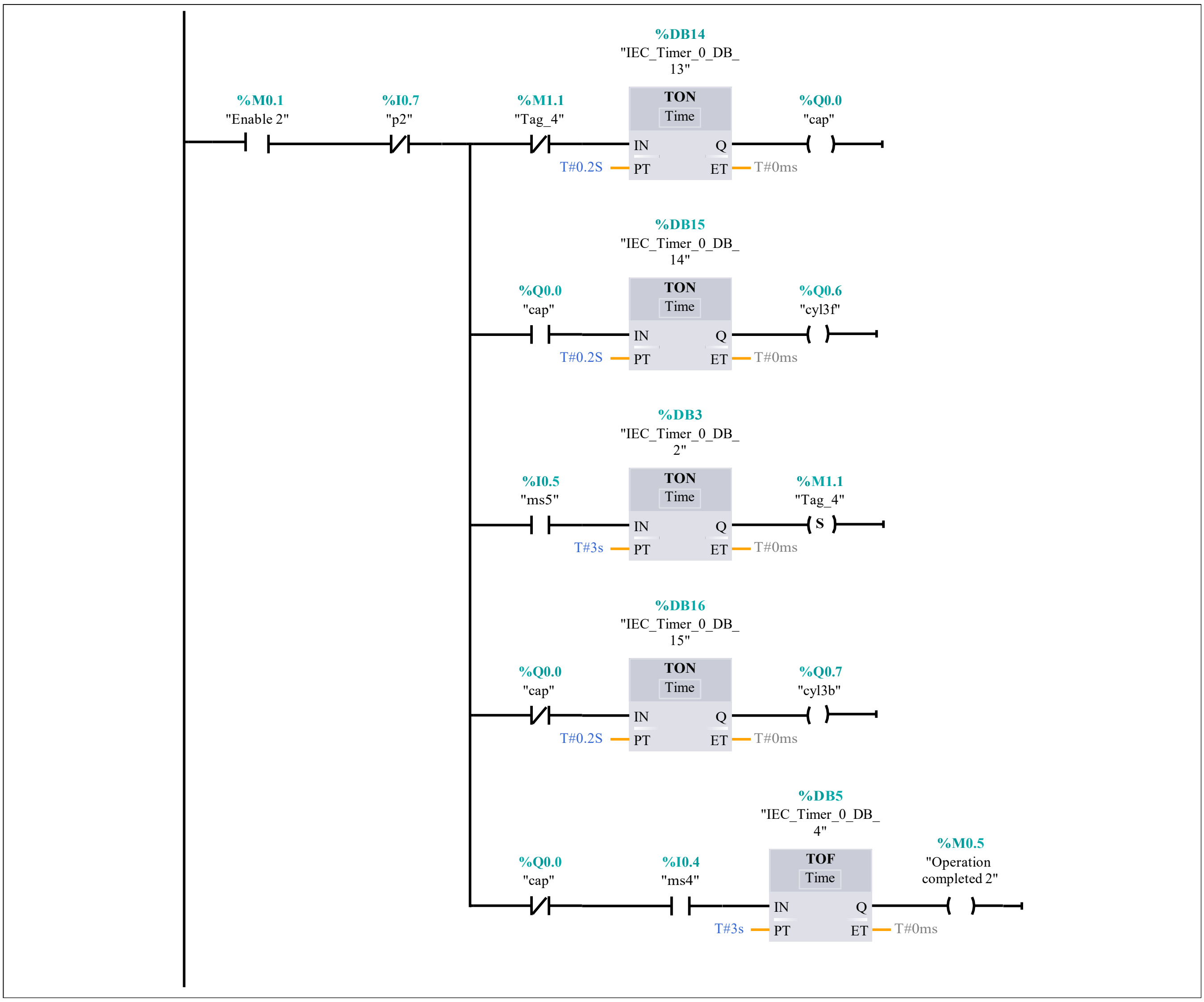

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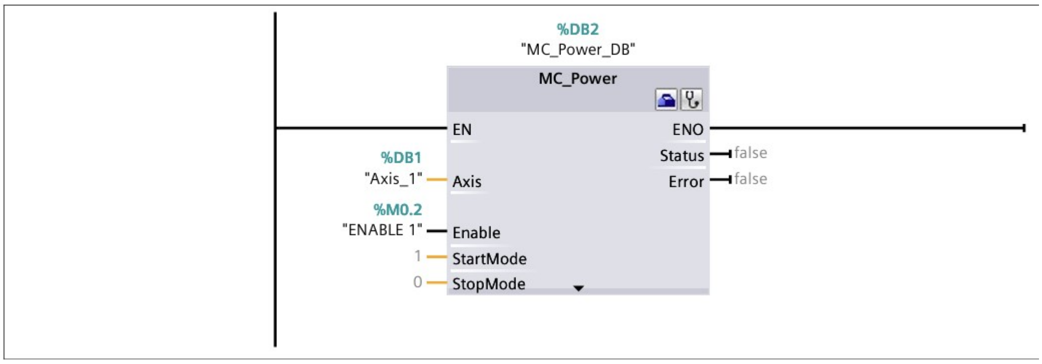
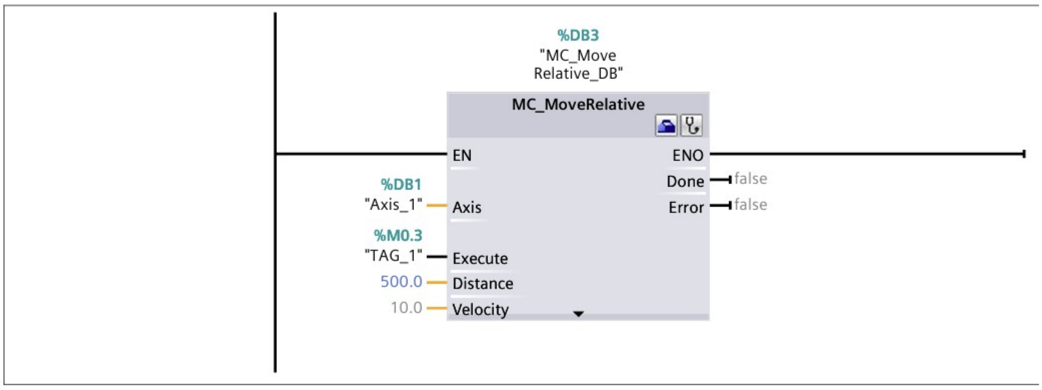
STEPPER MOTOR CODING:

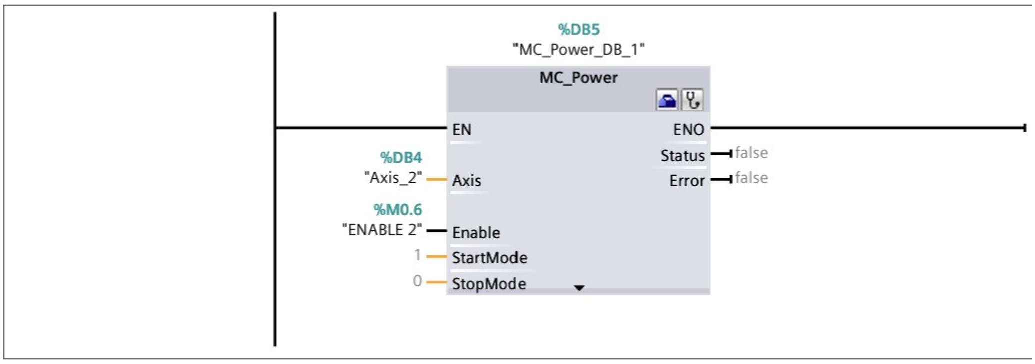
Network 1:



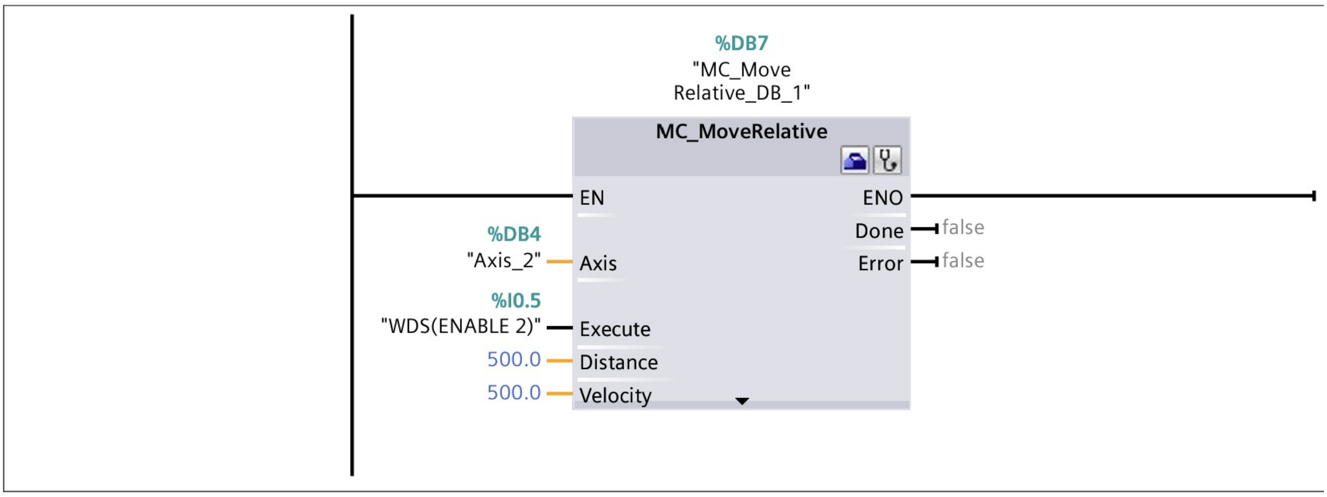
Network 2:



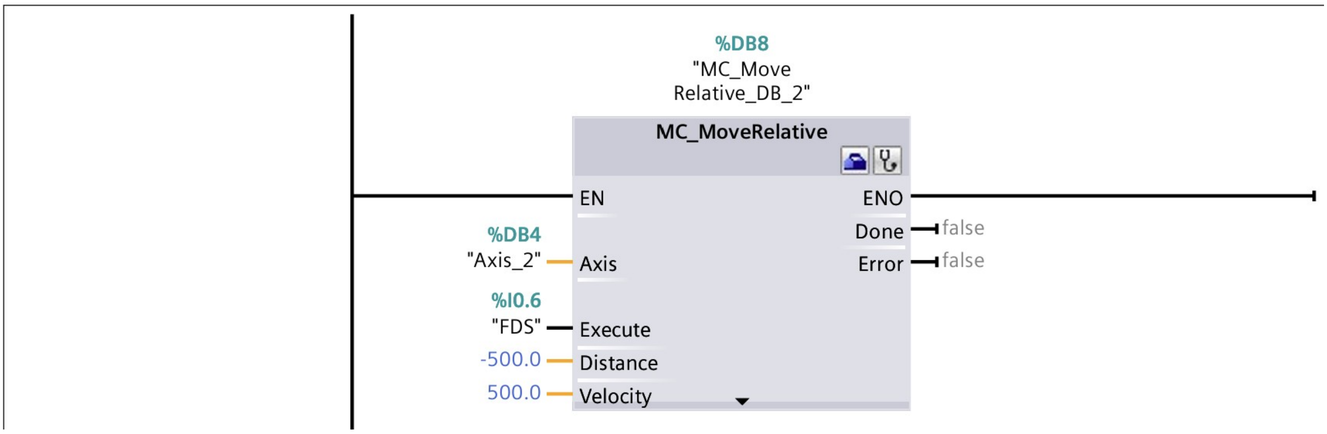
Network 3:



Network 4:



Network 5:



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Assistant Professor Dept of EEE Bannari Amman Institute of technology Sathyamangalam-638401

CBR Detail:

Sr. No.	App. Number	Ref. No./Application No.	Amount Paid	C.B.R. No.	Form Name	Remarks
1	202437530819	TEMP/E-1/97364/2024-CHE	1600	837283	FORM 1	SMART FACTORY AUTOMATION USING PLC-BASED SPEED CONTROL

Transaction ID	Payment Mode	Challan Identification Number	Amount Paid	Head of A/C No
N-100534408227	Online Bank Transfer	0704220002960	1600.00	1475001020000001

Total Amount : ₹ 1600.00
Amount in Words: Rupees One Thousand Six Hundred Only

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5	B Lakshmi Prasanna, G MadhusudhanaRao, Shashikant Kaushaley, Srinivas Nakka, Prasanta Kumar Jena. "Automatic Bottle Filling and Capping Machine using SCADA with the Internet of Things", 2022 OPJU International Technology Conference on Emerging	<1%