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PLC BASED AUTOMATIC CONVEYOR SYSTEM

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ABSTRACT

This report details the design, implementation, and evaluation of a PLC-based Automatic Conveyor System engineered to enhance the sorting, processing, and transportation of products within industrial settings. Utilizing advanced sensors, the system identifies the places of the products, ensuring precise sorting based on predefined criteria. The incorporation of various inputs, counters, timers, and outputs allows for meticulous control over the conveyor belts’ machines. The system employs Siemens' SIMATIC STEP7 for PLC programming, leveraging its robust capabilities for system logic and communication tasks. This project not only demonstrates the system’s efficiency and reliability but also underscores the pivotal role of PLC programming in advancing industrial automation technology.

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CHAPTER 1

INTRODUCTION

Programmable Logic Controllers (PLCs) are a key technology in industrial automation that has fundamentally changed the way manufacturing processes. PLCs are specialized, reliable computer systems made to manage and control industrial processes in real-time settings. Their ability to carry out dependable control tasks in the harsh environments of industrial facilities makes them essential in the modern manufacturing industry.

Conveyor systems are a common application of PLC, and they offer an illustration of how automation can improve production line accuracy and efficiency. These systems are essential to many different industries as they make it easier to move materials between production stages swiftly and under control. Conveyor systems in manufacturing facilities are vital for more than just moving goods, they also help to synchronize workflows, which reduces downtime and enhances production.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a literature review on the use of Programmable Logic Controllers (PLCs) in industrial automation, with a focus on automated conveyor systems. It covers key components, programming, system integration, and case studies, offering a foundational understanding essential for the project's context.

2.1. PLCs in Industrial Automation

Programmable Logic Controllers (PLCs) have played a transformative role in industrial automation by offering an adaptable, reliable, and cost-effective solution to manage and optimize various manufacturing and industrial processes. Initially developed to replace cumbersome relay-based systems, PLCs have evolved to feature high processing power, expansive memory, and the ability to support advanced programming languages like Structured Text and Function Block Diagram, enhancing their application across industries [1].

The integration of PLCs with SCADA and HMI systems has been crucial in providing comprehensive monitoring and control capabilities over industrial operations. These systems allow real-time tracking and adjustments to processes, directly impacting productivity and operational efficiency. PLCs, equipped with robust input/output (I/O) options, can handle digital or analog signals allowing them to interact effectively with a range of industrial equipment (Inductive Automation) [2].

One of the pivotal advancements in PLC technology has been their adaptation to support Industry 4.0 initiatives. Modern PLCs are equipped with capabilities for Ethernet connectivity, web-based monitoring, and can be part of cyber-physical systems, playing a significant role in the creation of smart factories. This allows for seamless data exchange and integration with other digital systems, enhancing the automation landscape and paving the way for more advanced manufacturing processes [3].

Furthermore, the adaptability of PLCs is highlighted in their programming flexibility, where they support several standardized languages that provide engineers with the tools to create complex control algorithms. This versatility ensures that PLCs remain at the forefront of technological advancements in industrial automation, continuing to offer solutions that improve efficiency, reliability, and scalability in industrial settings [2].

2.2. Components of PLC-based Systems

In a PLC-based system, various components such as sensors, actuators, and human-machine interfaces (HMIs) are integrated to create an effective automation solution.

Sensors play a critical role by gathering data from the physical environment, which could include measurements like temperature, pressure, or proximity. These devices provide the essential inputs that PLCs need to make decisions. When selecting sensors, considerations include accuracy, response time, sensitivity, and stability to ensure they are suitable for the specific automation application (PLC Basics) [4].

Actuators are devices that act upon the information processed by the PLC. They convert the PLC's output commands into physical actions, such as opening a valve or starting a motor. Actuators receive signals from the PLC and perform the necessary actions to manage the process or machinery (Holik Studios) [5].

Human-Machine Interfaces (HMIs) are the user interfaces that allow interaction between human operators and the automation system. HMIs display data, system statuses, and allow for manual inputs and adjustments to the system. They are vital for operators to monitor and control the automation process, adjusting as needed based on real-time data provided by the PLC [6].

Additionally, the organization of these components within a control panel is crucial for efficient operation. Control panels often include wire ducts and DIN rails to neatly arrange and support the various components like transformers, circuit breakers, and Ethernet switches, which facilitate power distribution and communication within the system [3].

2.3. PLC Programming and Simulation

PLC programming, particularly using Siemens' SIMATIC STEP 7 (TIA Portal), is a comprehensive approach to configuring, programming, testing, and diagnosing various types of controllers, including both PLC- and PC-based systems. This software supports a range of programming languages, including Ladder Logic, which is appreciated for its straightforward, visual representation akin to electrical relay diagrams. This feature significantly simplifies the programming process, making complex logic more accessible and understandable for engineers [7].

One of the standout features of SIMATIC STEP 7 is its simulation capabilities, which are vital for validating PLC programs before they are implemented in actual hardware. The software's integration with advanced simulation tools, such as SIMATIC S7-PLCSIM Advanced, allows for thorough testing of the PLC's functions in a virtual environment. This means that no physical controllers are required during the initial testing phase, which can lead to a reduction in development time and cost, as well as minimizing potential downtimes during deployment [7].

2.4. Integration of Sensors and Actuators in PLC Systems

The integration of sensors and actuators in PLC systems is crucial for the efficient and responsive operation of automated industrial systems. Sensors gather vital information from the environment, such as the presence, position, or characteristics of objects, which the PLC processes to make informed decisions. Actuators then execute these decisions by triggering mechanical movements or other actions, such as starting a motor or opening a valve [8].

Effective sensor integration is achieved by selecting the appropriate sensors based on their accuracy, response time, and stability. These sensors must be compatible with the PLC system to ensure reliable data transfer and processing. Actuators, on the other hand, need to be robust and precise, capable of performing the actions dictated by the PLC without failure [9].

Physical installation and correct wiring are critical for the seamless operation of sensors and actuators with a PLC. Sensors may be mounted on machines using various techniques, including screws or mounting brackets, and need to be connected correctly to ensure accurate data transmission to the PLC. The choice between digital and analog sensors will depend on the specific requirements of the application, including the necessary precision and the environmental conditions of the installation site [10].

2.5. HMI Implementation and Its Impact

Human-Machine Interfaces (HMIs) are integral to modern industrial automation, providing a crucial connection between human operators and automated systems governed by Programmable Logic Controllers (PLCs). HMIs enhance operational efficiency and productivity across various industries by enabling real-time monitoring and control of industrial processes. Core Functions and Impact of HMIs:

- Real-time Data Visualization and System Control: HMIs present process data and system statuses visually, allowing operators to interact with and control complex machinery and processes efficiently. This interactive interface facilitates immediate adjustments, which is essential for maintaining continuous production flows and handling potential issues swiftly [11].
- Enhanced Operational Efficiency: By centralizing control functions, HMIs reduce the need for manual checks and adjustments, thereby minimizing the likelihood of human error and enhancing overall process efficiency. Operators can monitor and adjust production settings in real-time, leading to improved machine performance and output [11].
- Safety and Alarm Management: HMIs contribute significantly to industrial safety by providing alarm management systems that alert operators to potential issues before they escalate into serious problems. This prompt notification allows for immediate corrective actions, which is vital in preventing accidents and ensuring the safety of the operational environment [11].
- Wide Applicability Across Industries: HMIs are used in a diverse range of sectors, including manufacturing, power generation, oil and gas, pharmaceuticals, and water treatment. In each of these fields, HMIs tailor control and monitoring

functions to meet specific operational demands, thus supporting industry-specific processes and enhancing productivity [11].

- Trends and Future Directions: The future of HMI technology is closely tied to advancements in digital interfaces and connectivity. Modern HMIs are increasingly incorporating capabilities such as remote access, which allows operators to control and monitor systems via the internet. This development is crucial for managing industrial operations remotely, especially in complex or hazardous environments [11].

HMIs have transformed from basic interfaces to sophisticated systems that integrate with advanced industrial software, providing critical data visualization, enhanced interaction, and operational control. This evolution continues as HMIs integrate more deeply with Internet of Things (IoT) technologies and cloud computing, pushing the boundaries of what can be monitored and controlled, thus driving forward the capabilities of industrial automation [12].

2.6. Case Studies and Applications

Reviewing case studies on the implementation of PLC systems in automated conveyor systems reveals several practical benefits and insights that align with theoretical expectations. For example, the deployment of PLCs in these systems has demonstrated improvements in operational efficiencies, reduced error rates, and enhanced product quality across various industries.

Operational Efficiency: Automated conveyor systems controlled by PLCs often result in significant enhancements in the speed and accuracy of material handling. These systems utilize sophisticated control mechanisms to streamline processes, which leads to faster production rates and reduced downtime. For instance, companies have successfully implemented PLC systems to optimize the control of conveyor belts, improving the overall flow of production and minimizing delays [13].

Error Reduction: The precision of PLC programming helps minimize errors in conveyor operations. By automating routine tasks and providing consistent performance, PLCs reduce the likelihood of human error and ensure more reliable system operations. This precision is critical in environments like manufacturing and packaging, where even minor mistakes can cause significant disruptions [13].

Enhanced Product Quality: Through detailed control and monitoring capabilities, PLC systems help maintain high standards of product quality. For example, automated systems with PLC controls are able to perform consistent quality checks and adjustments during production, which helps in maintaining the desired standards throughout the manufacturing process [14].

Safety and Ergonomics: Case studies also highlight the role of PLCs in improving workplace safety and ergonomic conditions. Automated systems reduce the need for manual handling of heavy items or operation in potentially hazardous conditions, thus enhancing safety. For example, one case study discussed the implementation of a vertical conveyor system that helped reduce the physical strain on workers by automating the transport of heavy items across different levels of a facility [15].

CHAPTER 3

PROBLEM & SOLUTION

3.1. Problem Statement

In a conveyor system that produces electronic components, efficient material handling is critical for maintaining production flow and reducing downtime. The existing conveyor system, while robust, presents several challenges:

- Intermittent Operation: The separation, processing, wrapping, and packing machines are dependent on material detection and timing, which can lead to pauses in operation if components are not detected or if there is a timing mismatch.
- Material Spacing: The need for consistent spacing between raw materials on the conveyors requires precise control of the separation machine, which can be disrupted by variations in the speed of conveyor belts or irregular placement of materials by workers.
- Production Bottleneck: The dependency on manual inputs for starting and stopping the conveyor system and a fixed counter for the packing machine can create bottlenecks, particularly when there is a high volume of production or when manual inputs are delayed.

3.2. Problem Solution

To address these challenges, the following solutions are proposed to enhance the conveyor system's efficiency and automation:

- Automated Start-Stop System: Implement an advanced sensor system that automatically starts and stops the conveyors based on the real-time presence of materials, reducing reliance on manual controls and improving the flow of operations.
- Dynamic Spacing Control: Upgrade the separation machine with a feedback loop that adjusts its timing dynamically based on conveyor belt speed and material flow, ensuring consistent spacing irrespective of initial placement or belt speed variations.
- Intelligent Packing System: Integrate an intelligent counter system for the packing machine that can adjust its counting based on current production levels, preventing bottlenecks and ensuring continuous operation without manual reset needs.

These solutions aim to minimize manual intervention, optimize material handling, and improve overall productivity at the facility.

CHAPTER 4

PLC PROGRAM

In this chapter, we discuss a sophisticated scenario for an implementation to the Conveyor System in a medium-size factory.

4.1. Explanation

The automated conveyor system in a medium-sized manufacturing facility utilizes several key components controlled through a programmable logic controller (PLC) programmed with Ladder Logic using Siemens SIMATIC STEP7 (TIA Portal V15). This setup ensures precision in managing the movement of electronic components through different stages: assembly, processing, wrapping, and packing.

- Conveyor Belts (CB1, CB2, CB3, CB4): These belts serve distinct functions. CB1 and CB2 are incoming conveyors where raw materials are fed randomly in CB1, then in CB2 in an organized manner. CB3 is the processing conveyor where materials are transformed into usable components, and CB4 is the final stage where these components are wrapped and packaged.

Figure 1. A Conveyor Belt System.

- Sensors (PS1-PS5): Proximity sensors are strategically placed to detect the presence of materials along the conveyor system. Each sensor serves a specific conveyor belt—PS1 and PS2 for the input stages on CB1 and CB3, PS3 for detecting materials ready for wrapping on CB4. However, PS4 is for detecting the finished (processed) materials in CB3, and PS5 is for detecting the finished (wrapped) materials in CB4.
- Motor Starters (MS1, MS2, MS3, MS4): These control the operation of the conveyor belts' motors, initiating or halting the belts as required, ensuring that materials are moved through each stage of the process efficiently.

4.2. Implementation

1. Start and Stop Buttons (SB1, STB1): The system can be manually started or stopped via these buttons. Pressing SB1 energizes the motor starters, setting all conveyors in motion and activating the green indicator lights (IL1, IL2, IL3, IL4) to signal operational status. Pressing STB1 halts all operations, de-energizing the motors and extinguishing the indicator lights, providing a clear visual cue that the system is inactive.

2. Separation Machine (SM1): Activated by sensor PS1 when materials are detected, this machine functions with a timer to separate goods into equal spaces on CB2. It is a critical component for ensuring that materials are evenly distributed before processing, enhancing consistency in the product quality.

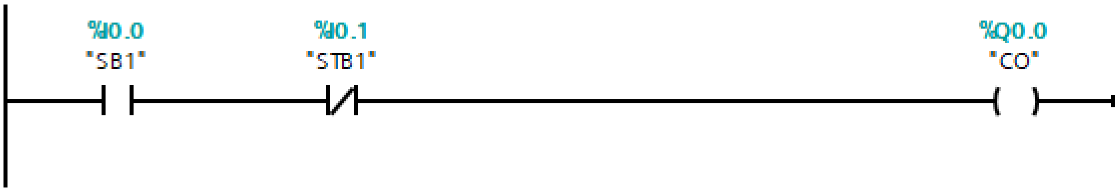
Figure 2. Separation Machine Visualization.

3. Processor (P1): Positioned on CB3, it begins processing materials when PS2 is triggered and ceases once PS4 detects the processed materials have reached the end of the conveyor. The inclusion of a delay of 2 seconds allows precise timing for the materials to arrive at the processing unit, ensuring efficient handling.
4. Wrapping and Packing Machines (WM1, PM1): WM1 starts wrapping materials once PS3 is activated and stops when PS5 detects the wrapped materials. PM1 counts the wrapped goods and packs them once a count of 50 is reached, then it restarts the counter. This sequential operation ensures that products are neatly packaged in consistent batch sizes, crucial for order fulfillment.

Here is the implementation, with the proper mechanism for each network, by Siemens program:

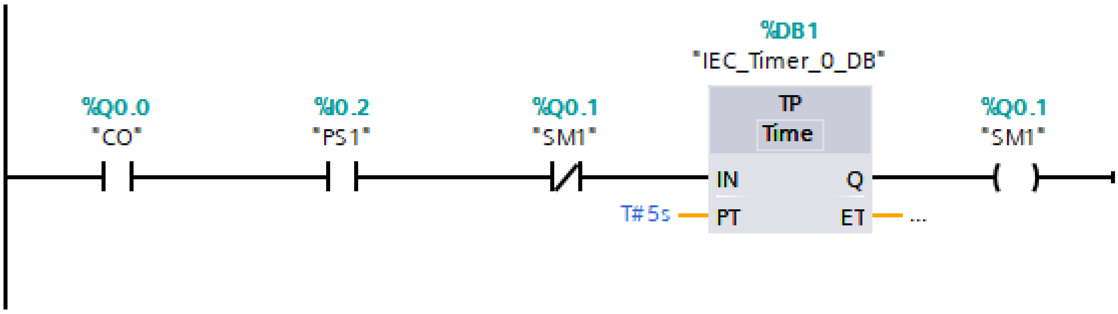
Network 1: Convery Operation

It includes operating all motors (MS1, MS2, MS3, MS4) and all lights (IL1, IL2, IL3, IL4).



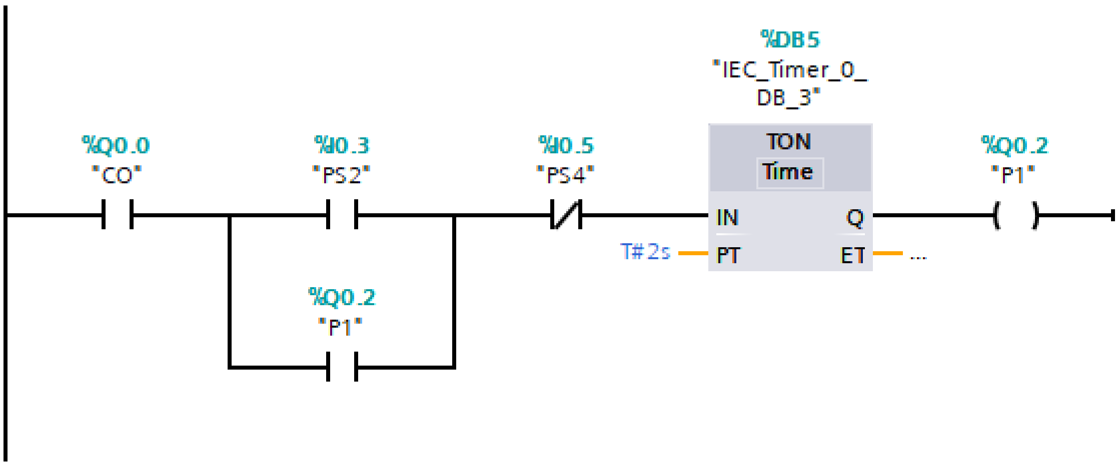
Network 2: Separation Machine 1

Starts working when PS1 detects materials, when it does not, it stops. It has a timer that makes it function every 5 seconds. Having constant speed for the belt, with equal timing, creates an equal space between materials in CB2. After 5 seconds are reached, the time is reset.



Network 3: Processor

Starts working when PS2 detects materials, it stops when PS4 detects the processed (finished) materials. It processes the materials in CB3. Also, there is a 2 second delay for the materials to arrive from PS2 to the place of P1.



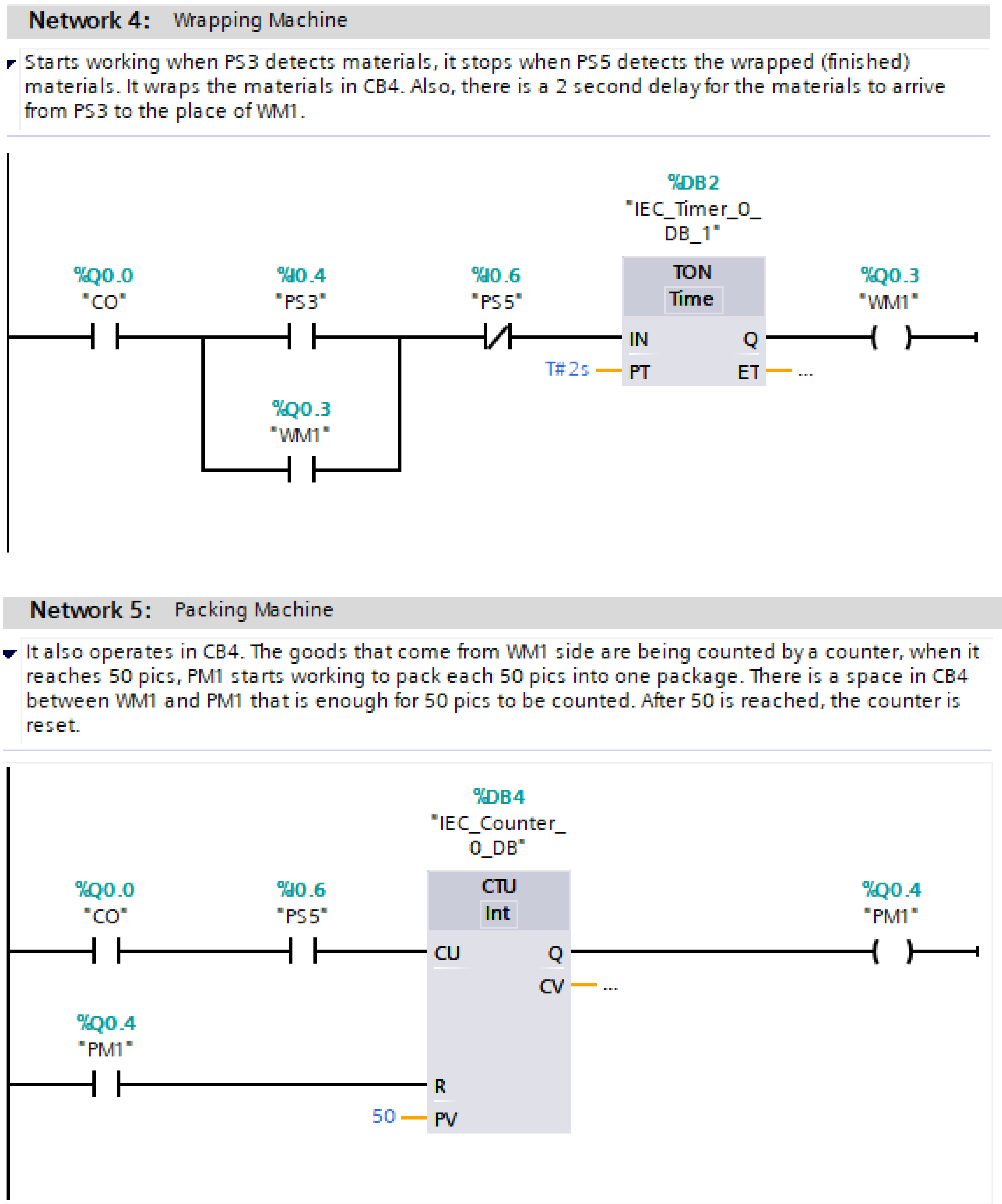


Figure 3. TIA Portal V15 Implementation.

4.3. Analysis

The design and implementation of the PLC system enable a high degree of automation, significantly enhancing productivity and reducing human error. Each component and sensor is strategically placed to optimize the workflow and material handling from raw inputs to packaged goods. The system’s flexibility allows for adjustments in processing times and operations through simple changes in the PLC program, accommodating different product types and sizes with minimal downtime.

The integration of sensors and timed operations via Ladder Logic programming ensures that each stage of the conveyor system is closely monitored and controlled, allowing for immediate response to any discrepancies in the process flow. This setup not only improves the efficiency of the manufacturing process but also enhances the safety and reliability of the entire system, as all components are designed to work in harmony to prevent bottlenecks and ensure continuous production flow.

Overall, this PLC-controlled conveyor system illustrates a sophisticated approach to manufacturing automation, showcasing how integration of technology can lead to significant improvements in operational efficiency, product quality, and system reliability.

Please note that Appendix 1 has the resultant Program Report of the project.

CONCLUSION

The PLC-based Automatic Conveyor System presented in this project exemplifies the innovative integration of sensor technology, motor control, and various machines into a unified system managed via PLC programming. The successful deployment and operation of this system underscores its effectiveness in sorting, processing, and transporting products by places, counts, and time criteria with high reliability and efficiency. The implementation of the separation machine, processor, wrapping machine, and packing machine ensures versatile control over the conveyor system functioning and automation, enhancing the adaptability of the system to varied operational demands.

The use of Siemens' SIMATIC STEP7 software for the PLC programming provides robust control and scalability and flexibility in system design and functionality. In addition, we have applied many essential concepts and practices from the PLC Course Learning Outcome, on of the most important is the problem solving for real-world scenarios by designing and implementing an efficient and reliable PLC program.

Furthermore, the project's outcomes reveal the potential for significant improvements in operational efficiency and productivity within industrial settings. The system's reliability and the successful handling of the processed and packed products demonstrate the potential of PLC-based systems to revolutionize industrial automation practices. Looking ahead, the foundational work laid out by this project suggests ample opportunities for further enhancements. Future work could explore the integration of artificial intelligence and machine learning algorithms to enable more dynamic decision-making processes and adaptive sorting mechanisms, potentially increasing the system's efficiency and applicability across different industries.

Overall, this project not only validates the practical applications of PLC programming in enhancing industrial automation capabilities but also sets the stage for future innovations that could further leverage the technological advancements in automation, sensor technology, and system integration. The convergence of these technologies in industrial applications heralds a promising future for manufacturing processes, driving towards more automated, accurate, and efficient systems.

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APPENDIX 1

Totally Integrated Automation Portal		

Conveyor System / PLC_1 [CPU 314] / Program blocks

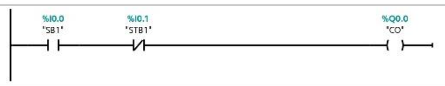
Main [OB1]

Main Properties							
General							
Name	Main	**Number**	1	**Type**	OB	**Language**	LAD
Numbering	Manual						
Information							
Title	"Conveyor System"	**Author**		**Comment**	The System is built per as the project report. Check the report for variables' names and explanation.	**Family**	
Version	0.1	**User-defined ID**					

Main				
Name	**Data type**	**Offset**	**Default value**	**Comment**
▼ Temp				
OB1_EV_CLASS	Byte	0.0		Bits 0-3 = 1 (Coming event), Bits 4-7 = 1 (Event class 1)
OB1_SCAN_1	Byte	1.0		1 (Cold restart scan 1 of OB 1), 3 (Scan 2-n of OB 1)
OB1_PRIORITY	Byte	2.0		Priority of OB Execution
OB1_OB_NUMBR	Byte	3.0		1 (Organization block 1, OB1)
OB1_RESERVED_1	Byte	4.0		Reserved for system
OB1_RESERVED_2	Byte	5.0		Reserved for system
OB1_PREV_CYCLE	Int	6.0		Cycle time of previous OB1 scan (milliseconds)
OB1_MIN_CYCLE	Int	8.0		Minimum cycle time of OB1 (milliseconds)
OB1_MAX_CYCLE	Int	10.0		Maximum cycle time of OB1 (milliseconds)
OB1_DATE_TIME	Date_And_Time	12.0		Date and time OB1 started
Constant				

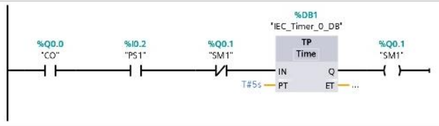
Network 1: Convery Operation

It includes operating all motors (MS1, MS2, MS3, MS4) and all lights (IL1, IL2, IL3, IL4).



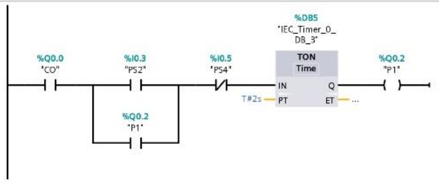
Network 2: Separation Machine 1

Starts working when PS1 detects materials, when it does not, it stops. It has a timer that makes it function every 5 seconds. Having constant speed for the belt, with equal timing, creates an equal space between materials in CB2. After 5 seconds are reached, the time is reset.



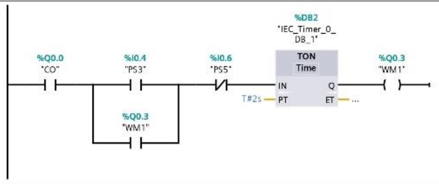
Network 3: Processor

Starts working when PS2 detects materials, it stops when PS4 detects the processed (finished) materials. It processes the materials in CB3. Also, there is a 2 second delay for the materials to arrive from PS2 to the place of P1.



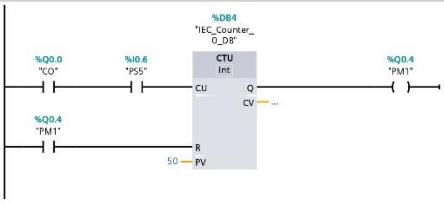
Network 4: Wrapping Machine

Starts working when PS3 detects materials, it stops when PS5 detects the wrapped (finished) materials. It wraps the materials in CB4. Also, there is a 2 second delay for the materials to arrive from PS3 to the place of WM1.



Network 5: Packing Machine

It also operates in CB4. The goods that come from WM1 side are being counted by a counter, when it reaches 50 pics, PM1 starts working to pack each 50 pics into one package. There is a space in CB4 between WM1 and PM1 that is enough for 50 pics to be counted. After 50 is reached, the counter is reset.



WORK DISTRIBUTION

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Hamza	Abstract + Literature Review + Conclusion
Marwan	PLC Program Chapter writing + Program implementation
Abdulrahman	Introduction + Problem Statement + Solution