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# Enhancing Productivity: Design and Implementation of an Automated Elevator for the Rohs Wave Machine

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**Abstract:** Automation technologies, particularly programmable logic controllers (PLCs), play a crucial role in optimizing processes and improving efficiency. Integrating automation into industrial environments enhances productivity and responsiveness to market dynamics by emphasizing control, monitoring, and analysis of production processes. With this in mind, our project aimed to develop an automated elevator into the Rohs Wave Machine to eliminate manual labor and boost productivity. The project commenced with a comprehensive needs assessment to delineate specific requirements, ensuring that all operational needs were thoroughly understood. Following this, the technical phase began with meticulous design and simulation using Siemens Step 7 software, focusing on both functionality and reliability. This phase also involved detailed engineering of the robust metal support structure, essential for the system's stability and durability. The next crucial step was programming the TSX Micro PLC with SCHNEIDER PL7pro software, which allowed for seamless integration and precise control of the elevator's operations. Finally, with careful attention to detail, all components were systematically assembled, installed, and calibrated, ensuring optimal performance. This rigorous process culminated in the successful operationalization of the automated elevator system. This project epitomizes a synergy of meticulous planning, advanced technical skills, and thorough execution, resulting in a transformative solution that significantly enhances productivity and operational efficiency.

**Keywords:** Programmable Logic Controller, Automation, Automated Elevator, LADDER language, PL7pro, Step7 software

## 1. INTRODUCTION

The modern industrial landscape is undergoing a profound transformation driven by rapid technological advancements and heightened competition. This era of Industry 4.0 is characterized by an unprecedented pace of innovation, compelling manufacturing companies to continuously evolve and adapt to maintain a competitive edge. In such a dynamic environment, efficiency and flexibility have emerged as critical factors for success. However, many existing production systems are hampered by rigidity and an inability to swiftly respond to changing market demands and production styles. Consequently, there is an urgent need for innovative solutions that can enhance productivity while seamlessly integrating automation technologies into industrial operations[1], [2], [3]. Automation technologies, particularly those facilitated by programmable logic controllers (PLCs), have long been pivotal in optimizing industrial processes. PLCs are specialized computer systems used for the automation of electromechanical processes, such as control of machinery on factory assembly lines. The architecture of a PLC typically comprises three fundamental areas: processing, memory, and input/output (I/O). These areas function cohesively to manage the automation processes. The PLC is programmed based on input instructions, which dictate the output conditions necessary to control connected devices. The execution of these I/O actions relies on the program stored in the PLC's memory, thus ensuring precise and reliable control over industrial operations. [4], [5]. The strategic integration of PLCs and other automation technologies into manufacturing processes enables companies to achieve systems that are not only reliable and efficient but also flexible enough to meet the demands of a rapidly changing market. The ability to control, monitor, and analyze production processes in real-time is fundamental to maintaining competitiveness in today's industrial landscape [6], [7]. The importance of automation in industrial settings cannot be overstated. As industries strive to improve their operational efficiencies, automation technologies offer numerous benefits, including increased production speeds, improved product quality, reduced labor costs, and enhanced safety. The deployment of advanced PLCs and other automation solutions allows for the creation of smart factories where machines and systems communicate and collaborate seamlessly. This connectivity and integration facilitate the collection and analysis of vast amounts of data, providing insights that drive continuous improvement and innovation. PLCs, with their robust processing capabilities and real-time response, provide the necessary control to manage these complex processes effectively. The use of sensors and actuators, integrated with PLCs, enables the continuous monitoring and adjustment of production parameters, ensuring optimal performance and quality. [8]. Another significant advantage of automation is the enhancement of workplace safety. Manual intervention in industrial processes often exposes workers to hazardous conditions. Automation reduces the need for human involvement in dangerous tasks, thereby minimizing the risk of accidents and injuries. PLCs and other automation technologies can be programmed to adhere to stringent safety protocols, ensuring that operations comply with industry standards and regulations. The economic benefits of automation are also substantial. By streamlining processes and reducing manual labor, companies can achieve significant cost savings. Automated systems are typically more efficient than their manual counterparts, leading to lower operational costs and higher throughput. Additionally, the consistency and precision of automated systems result in fewer errors and defects, further reducing costs associated with rework and waste. [9] [10], this paper aims to explore strategies for integrating automation technologies into modern industrial environments to enhance productivity and responsiveness to market dynamics [11]. The objective of this project is to conduct a thorough study of the issue at hand, identify its root causes, propose suitable solutions, and develop a system aimed at eliminating manual intervention while enhancing productivity. To pinpoint the underlying causes of the problem, it is imperative to undertake a comprehensive functional analysis of the operational system of the bench and implement a protective device to safeguard it. Our project focuses on the development of an automated elevator designed to connect the exit of the wave machine to the entry point of the insertion and finishing zone. Initially, we conducted a thorough analysis of the problem and proposed a suitable solution to create a system that eliminates manual operation and increases productivity. Subsequently, we proceeded to the programming phase of the Programmable Logic Controller (PLC) using LADDER language. Following this, we delved into the selection and configuration of the necessary equipment, laying the foundation for the project's implementation. Emphasis was then placed on the design and fabrication of the support structure to facilitate the complete installation of the system.

This introduction outlines the systematic approach undertaken to address the project's objectives and underscores the significance of automation in streamlining industrial processes.

The subsequent sections of this paper are structured as follows: Section II presents the problem statement and the proposed solution, describing the project in detail. In Section III, we present the control panel along with simulation results. Section IV introduces the operational aspect, outlining the steps for the implementation of an automated elevator. Lastly, the paper concludes with a summary of findings.

## 2. METHOD

### *A. The Problem statement:*

In the wave soldering machine, the movement of the frames carrying the card blanks between the upper conveyor and the lower conveyor is done manually, which poses several risks related to personnel, budget, and production. These risks include:

- Safety and health risks for the operator (high temperatures at the wave exit)
- Time loss due to manual frame movement
- Deterioration of frames; the cards are flexible and must be kept level.

Fig 1. wave soldering machine

Fig 2. the gateway of wave soldering machine

### *B. Proposed solution:*

To avoid these risks, the following solution has been proposed: design and construction of an automated elevator to link the exit of the wave to the entrance of the insertion and finishing area. This solution will create a set of advantages such as:

- Increased production output.

- Increased safety and protection of frames and personnel.
- Extended frame life.
- Cost reduction, in terms of the frame purchasing budget.

To implement this solution, there are three possible choices:

- Elevator with two motors.
- Elevator with one motor and one cylinder.
- Elevator with two motors and a vertical conveyor.

*C. Selection criteria:*

Selection of the first choice is based on the following criteria:

- Availability of materials.
- A high level of frame protection, as the motor installed at the bottom of the elevator generates a smooth pulse.
- Free program, allowing new parameters to be added at any time.

*D. Project description*

The project consists in building an automated elevator to link the exit of the wave to the entrance of the insertion and finishing area. The aim is to facilitate the positioning of frames on the production line. The picture below shows the proposed installation.

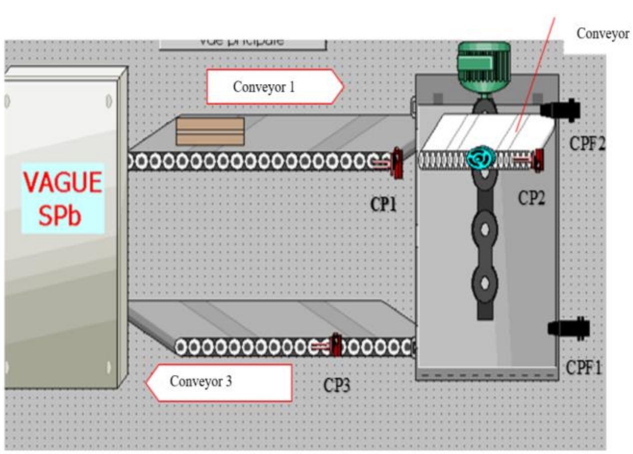



Fig 2. Prototype of an automated elevator.

The work carried out during the project includes :

- Building an automated elevator by assembling various components (conveyors, motors, speed controllers, sensors, PLC);
- Production of an elevator support
- PLC programming (TSX micro 37 21).

*E. Operating principle.*

The description provides a clear and structured overview of the elevator system's operation. Initially, the elevator is at rest. The operator presses button M to start the system.

The frame travels on top conveyor 1 until it reaches the elevator entrance. When presence sensor CP1 detects the frame, motor M2 starts up and drives conveyor 2 in the positive direction. Then, when presence sensor CP2 detects the frame, motor M2 stops and M1 starts up, after which conveyor 2 carrying the frame descends until it reaches limit sensor 1.

When motor M1 stops, motor m2 starts up and steers conveyor 2 in the negative direction to place the frame on conveyor 3.

Motor M1 must run once presence sensor CP3 detects the frame, at the same time stopping motor M2 and allowing conveyor 2 to run up to limit sensor 2.

The paragraph also outlines a safety protocol: If the motor remains in the ascending course and a frame in the elevator entrance, i.e. presence sensor CP4 activates and limit switch 2 CPF2 deactivates, the cylinder blocks the frame until the conveyor is detected by limit switch 2 CPF2.

The figure below illustrates the operational process as a flowchart:

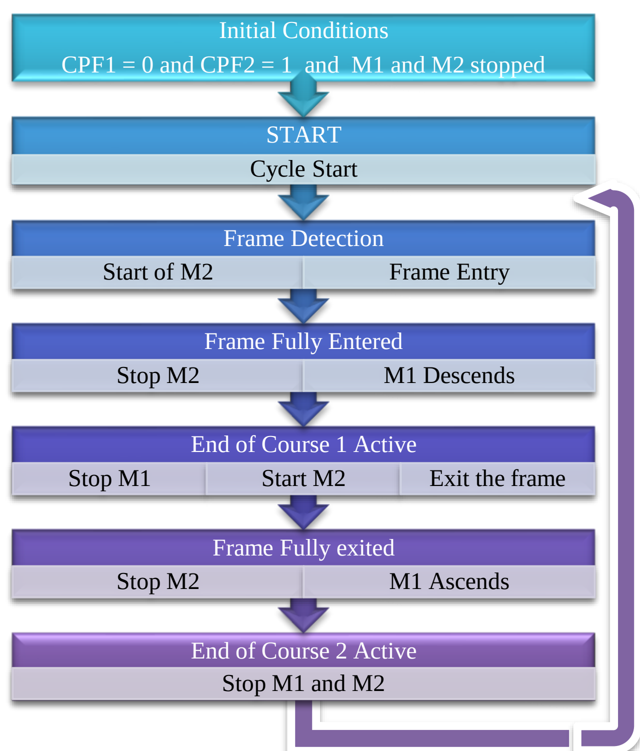



Fig 3. Flowchart of process

## 3. CONTROL PANEL

The control section of an automation system is the decision-making center. It gives orders to the operating part and receives its reports. It can be made up of three parts: a computer, software and an interface. The motors and sensors will be controlled by a Programmable Logic Controller (PLC) [12].

The PLC is programmed by PL7pro software, which stores the program in the PLC processor.

- The needs of this part :
- Windows XP SP3 version 2002
- PL7pro V4.4 software
- Drivers Manager V2.6 IE19
- UNITELWAY Driver V1.10 IE22

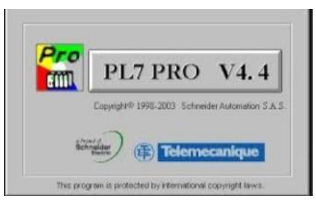



Fig 4. PL7pro V4.4 software

### A. System simulation in step7

After selecting the appropriate hardware, the next step involves programming the PLC to eliminate the need for manual intervention [13],. PLC programming is typically accomplished using ladder logic, a symbolic instruction set that simplifies the coding process compared to other programming languages. Ladder logic reduces complexity, making it an ideal choice for PLC programming. Utilizing the instructions detailed in the previous subsection, we programmed the PLC accordingly. To ensure the program's functionality and efficiency, we chose to simulate the LADDER program using Step7 software [14], [15].This choice was made because Step7 allows for a thorough simulation of the program before deploying it on the actual machine, whereas PL7pro directly interacts with the hardware, making Step7 the preferable option for initial testing and validation.

### B. Identification of input/output variables

The identification of input and output variables is a fundamental step in PLC programming. This process ensures that all necessary signals from sensors and actuators are correctly mapped to the PLC inputs and outputs. The various input/output variables of our system are represented as follows:

TABLE I. INPUTS OF OUR SYSTEM

| Inputs | Initial state | Plc Input |
|---|---|---|
| Presence sensor1: cp1 | NO | E0.3 |
| Presence sensor 2: cp2 | NO | E0.4 |
| Presence sensor 3: cp3 | NO | E0.5 |
| Run button: m | NO | E0.0 |
| Stop button: a | NO | E0.1 |
| Presence sensor 4: cp4 | NO | E0.2 |
| Limit switch 1: cpf1 | NO | E0.6 |
| Limit switch 2: cpf2 | NC | E0.7 |

TABLE II. OUTPUTS OF OUR SYSTEM

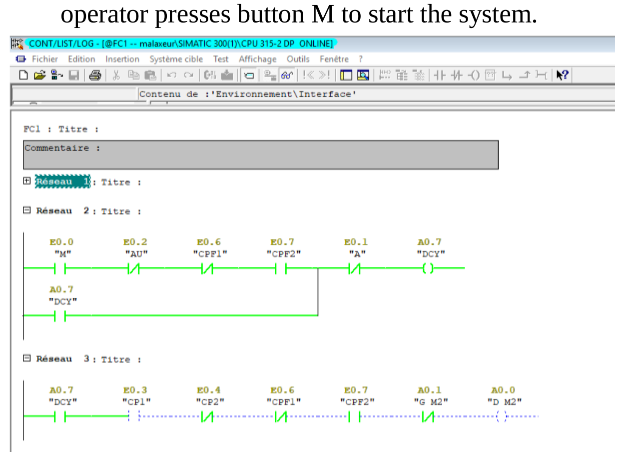
| Outputs | Initial state | PLC Outputs |
|---|---|---|
| Motor1 Down : DIS M1 | - | A0.3 |
| Motor1 Monte : M M1 | - | A0.2 |
| Motor2 Right: D M2 | - | A0.0 |
| Motor2 Left: G M2 | - | A0.1 |
| VERIN Descend : V- | - | A0.5 |
| VERIN Monte : V+ | - | A0.4 |
| Cycle start: DCY | NC | A0.7 |

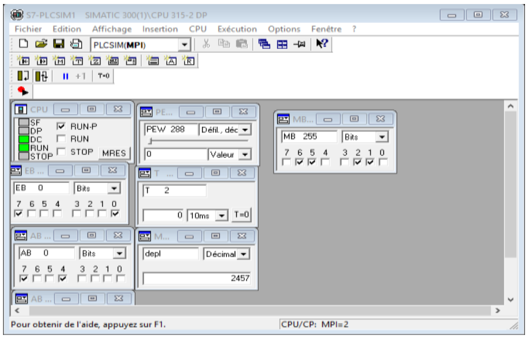
### C. Ladder program simulation with step7

The next phase involved simulating the ladder program using Step7. This part of the process was crucial for validating the logic and functionality of the PLC program before implementation. The simulation allowed us to verify that all input and output variables interacted as expected and that the PLC could effectively control the automated elevator system.

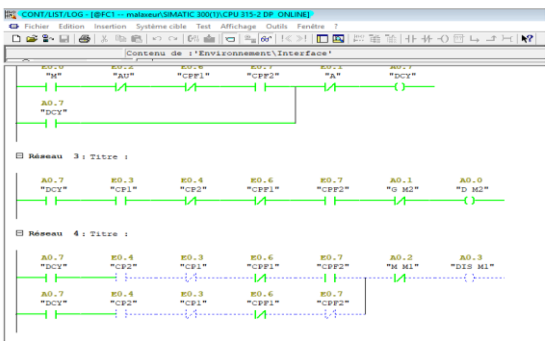
In the simulation process, each input sensor and button was virtually activated to observe the corresponding output actions. This step ensured that:

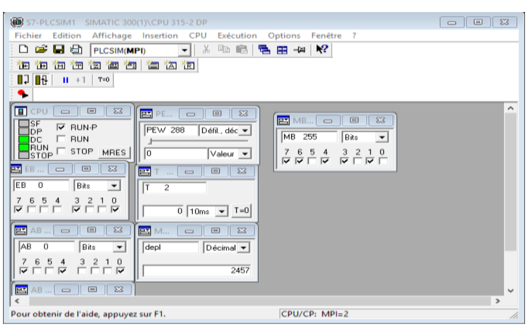
- Initial state Initially, the elevator is at rest. The operator presses button M to start the system.



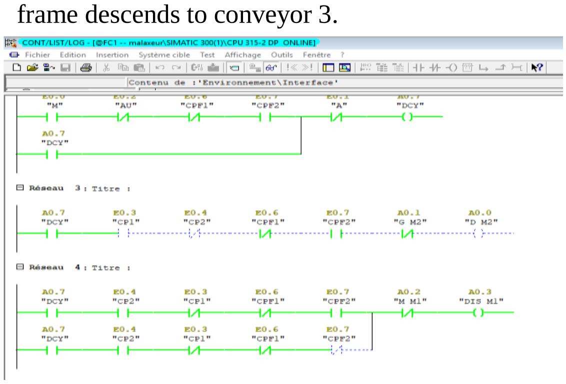


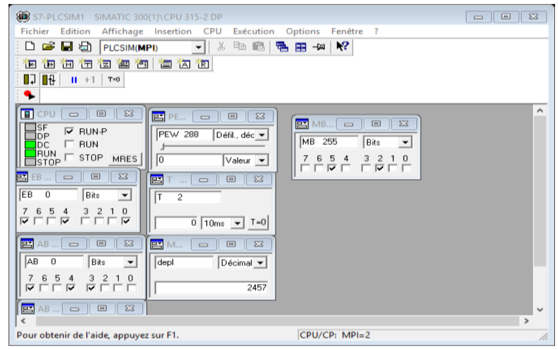
- When the CP1 presence sensor detects the frame, it sends a signal to the PLC, which then starts the M2 motor.



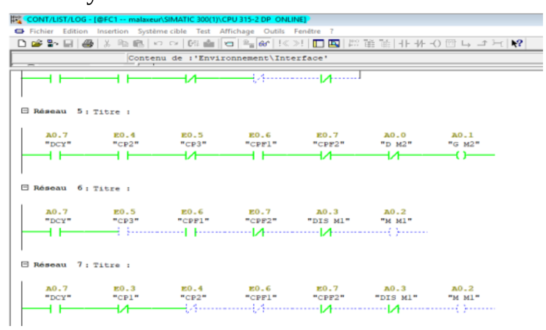


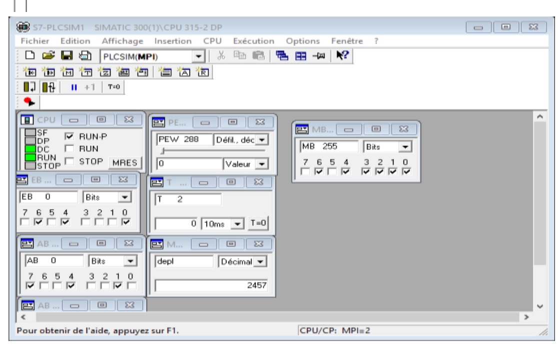
- presence sensor CP2 detects the frame, motor M2 stops and M1 starts, so conveyor 2 carrying the frame descends to conveyor 3.



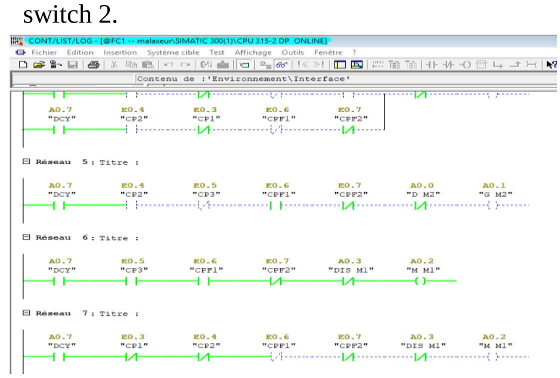


- When the limit switch 1 detects and sends a signal to the machine, the motor M1 stops and the motor m2 starts, taking the frame out and placing it on the conveyor 3.





- Once the presence sensor CP3 detects the frame, motor M1 must run and at the same time stop motor M2, allowing conveyor 2 to run up to limit switch 2.



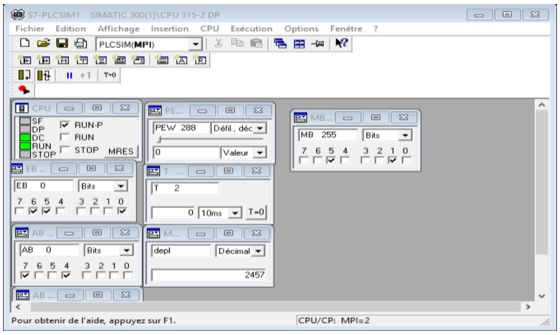
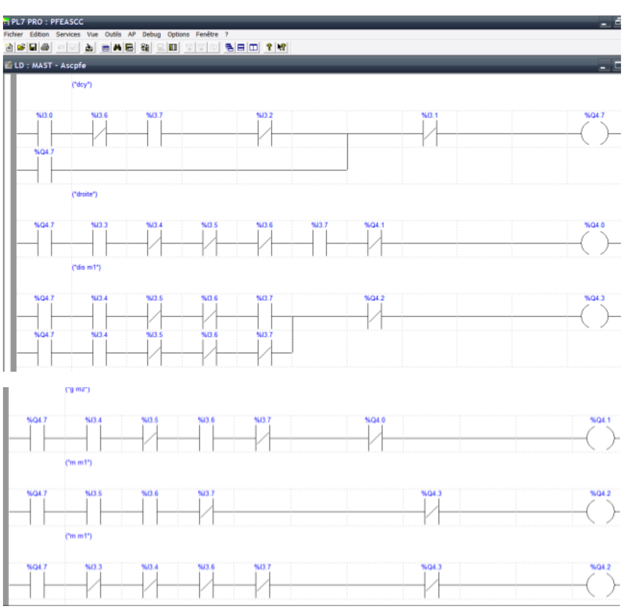


Fig 5. Ladder program simulation with step7.

By rigorously testing these conditions in the Step7 environment, we confirmed the reliability and efficiency of our ladder logic program. This thorough simulation process mitigated potential errors and ensured a smooth transition when deploying the program on the actual hardware. Through this meticulous approach, we demonstrated the critical role of simulation in PLC programming, highlighting its importance in achieving a robust and error-free automated system.

### *D. Program in PL7pro :*

The ladder program simulation using Step7 was crucial for validating the logic and functionality of the PLC program before implementation. This allowed us to verify that all input and output variables interacted as expected and that the PLC could effectively control the automated elevator system. The steps of the ladder program simulation using PL7pro are presented in this section as follows:



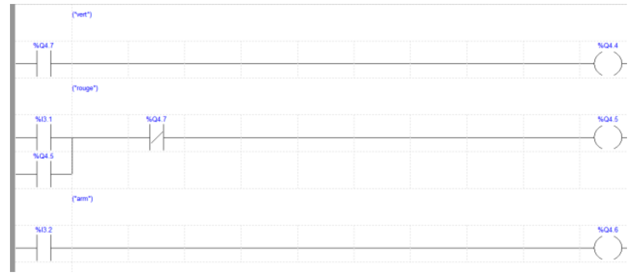


Fig 6. Ladder program in PL7pro.

## 4. THE OPERATING PART

In this section, we present the technical choices made, the various concepts studied, and the solution chosen for the operative part of this automated elevator. To ensure the selection of necessary and suitable equipment that meets the specified requirements, detailed measurements were taken. These measurements are crucial for choosing the right motor and ensuring the system's overall efficiency and reliability.

To select the appropriate equipment, we first measured the weight of the frame with the maximum number of blanks, which is 2.5 kg. This helps in choosing a motor capable of turning the conveyor easily in both upward and downward directions, thereby avoiding overloading issues. Additionally, we considered the spatial constraints for the conveyor length. The frame width is 40 cm, and its length ranges from 46 to 55 cm at maximum. The time interval between two frames is 32 seconds, and the length between conveyors is 96 cm.

### *A. Equipment Selection:*

The equipment chosen for this automated elevator system includes the following components:

- TSXMicro PLC: A robust and versatile programmable logic controller for managing the automation processes.
- Photoelectric Sensors: For detecting the presence of objects and controlling the movement of the elevator.
- Roller Limit Switches (Télémécanique XCM-A1155, 2 units): To provide precise positional feedback and ensure safety.
- 24V Two-Way Motor: For driving smaller movements within the system.
- 380V Three-Phase Two-Way Asynchronous Motor: To handle larger loads and ensure powerful and reliable operation.
- Cylinder: Used for linear motion control within the system.

- Pushbuttons and Emergency Button: For manual control and safety measures.
- Conveyor: The primary mechanism for moving items within the elevator.
- Variable Speed Drive: To control motor speeds and enhance operational flexibility.
- Relays, Circuit Breakers, and Fuses: For protecting the electrical circuits and ensuring safe operation.
- Transformer (230V to 24V): To step down the voltage for compatible equipment operation.
- Cables and Terminals, Contactors, Signal Lamps: For wiring and indicating system status.
- Elevator Support: The structural framework supporting the elevator system.

The careful selection and integration of these components ensure that the automated elevator system operates efficiently and reliably. By addressing the technical requirements and spatial constraints, we have developed a solution that meets the operational demands and enhances the overall functionality of the automated elevator. This approach underscores the importance of precise measurements, appropriate equipment selection in designing effective industrial automation systems.

### *B. The communication sections*

The TSX PCX 1031 programming cable, with the converter set to TER DIRECT, is used for communication. This cable is connected to the TER pin of the PLC, facilitating seamless programming and control of the system.


Fig 7. The TSX PCX 1031 programming cable.

### *C. Connections panel*

For mounting and connecting the patch panel, we employed a 19" 6U wiring board equipped with oblong holes measuring 8.4 x 30 mm. These oblong holes facilitate the fastening of equipment with cage nuts, providing a high degree of adjustability during assembly. This flexibility is crucial for aligning and securing various components efficiently, ensuring a tidy and organized setup. The patch panel incorporates several key components essential for the operation and control of the automated elevator system. At the heart of the system is the "TSX Micro" programmable logic controller (PLC), which serves as the central processing unit, executing the programmed instructions to manage the elevator's functions. Additionally, a variable speed drive is included to control the speed and direction of the motors, enhancing the system's efficiency and precision.

A 24VDC AC/DC power supply is used to provide the necessary voltage to the control elements, including the PLC, photoelectric sensors, and drives. This ensures that all control components receive a stable and reliable power supply. For electrical safety, a protective circuit breaker is installed to safeguard the mains supply, preventing potential electrical hazards. The panel also includes several relays and fuses, which are critical for managing electrical loads and protecting the circuit from overcurrent conditions. Contactors are utilized for controlling high-power devices, ensuring robust and reliable operation. Various accessories, such as wires, ferrules, cords, and DIN rails, are also integrated into the panel, facilitating proper electrical connections and organization.

Fig 8. Connections panel

In summary, the patch panel is meticulously designed with essential components and accessories to ensure the efficient and safe operation of the automated elevator system. This setup highlights the importance of a well-organized and flexible wiring solution, capable of accommodating various control elements and ensuring reliable performance.

### *D. Power Diagram and Control Diagram.*

This process highlights the importance of both the Power Diagram and the Control Diagram. The Power Diagram ensures that all components receive the correct power supply and are properly connected for safe and efficient operation. Meanwhile, the Control Diagram is crucial for defining how the system components interact with each other, detailing the logic and sequence of operations that the Ladder program follows to achieve the desired automation. Together, these diagrams are essential for the successful design, implementation, and troubleshooting of automated systems.

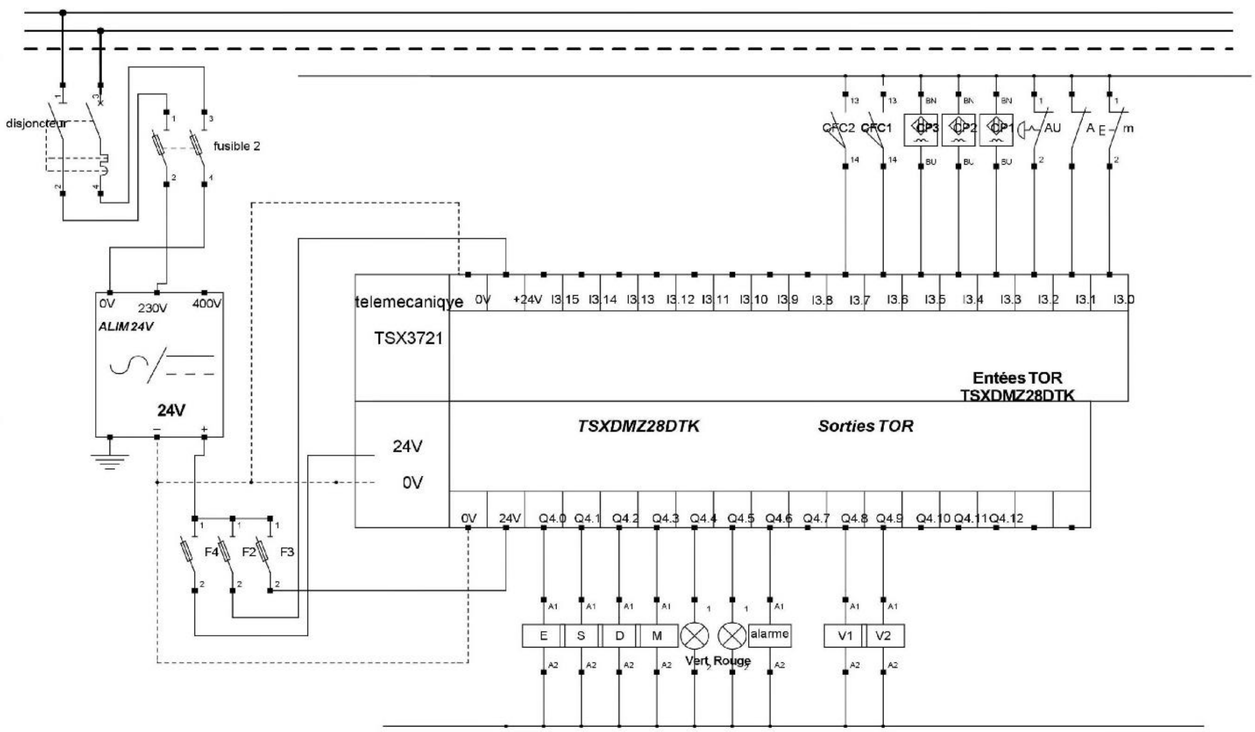


Fig 9. Control Diagram

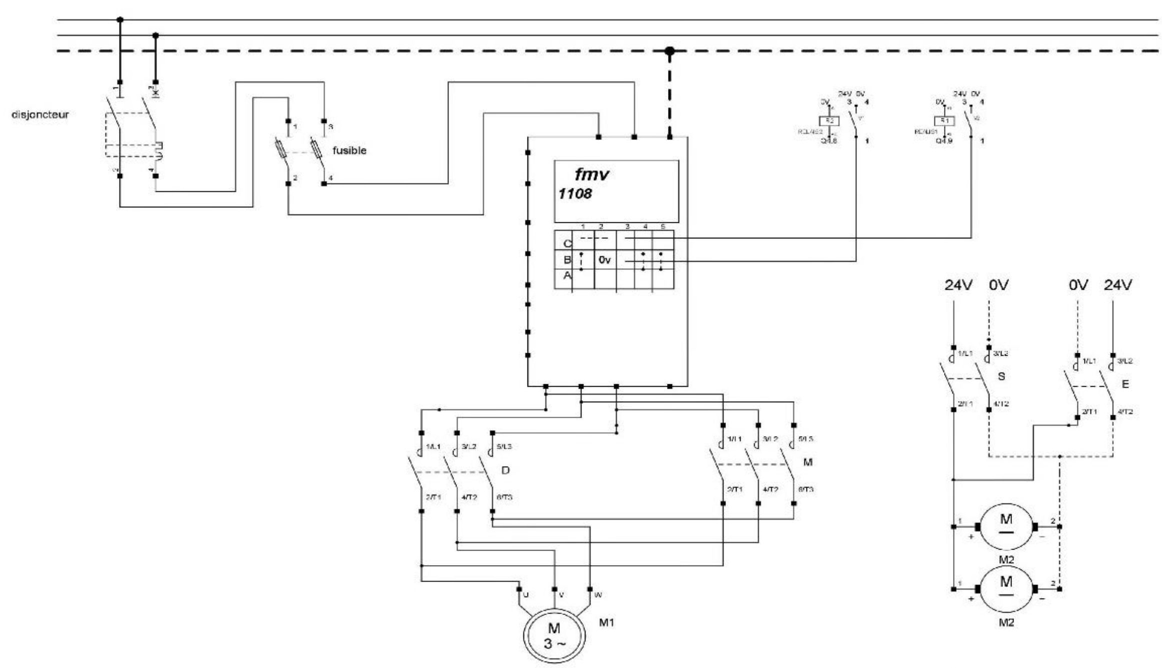


Fig 10. Power Diagram

## 5. Steps for the Implementation of an Automated Elevator:

The following steps outline the development process for implementing an automated elevator system through its various stages:

### *A. Disassembly of the Old Machines*

The initial phase involved disassembling the old machinery, which included removing the existing conveyor system from inside the elevator.

### *B. Removal of the Conveyor*

Following the disassembly, the old conveyor system was carefully removed to make space for the new installation.

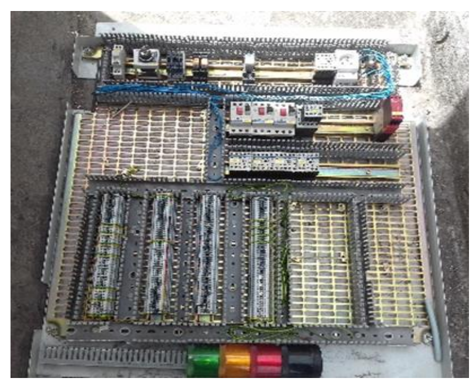
### *C. Installation of the New Conveyor Inside the Elevator*

A new conveyor was installed within the elevator, ensuring it was securely placed and properly aligned for optimal operation.

### *D. Disassembly of the Control Cabinet*

The control cabinet, housing the central control components, was disassembled, and all sensors and actuators were removed.

Devices and cables inside the cabinet were disconnected to prepare for the new system integration.



### *E. Testing of the PLC Functionality*

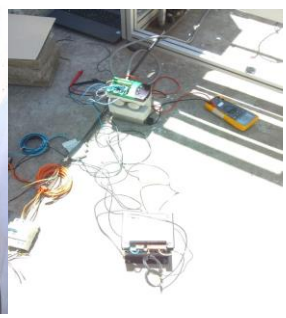
The functionality of the Programmable Logic Controller (PLC) was tested independently to ensure it was operating correctly.

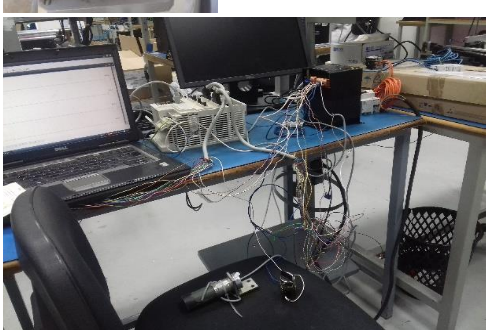
Verification of communication between the PLC and the PC was performed to establish a reliable connection.

*F. Testing of the Motor and Speed Variator Functionality*

The motor and speed variator were tested to confirm they were functioning as expected.

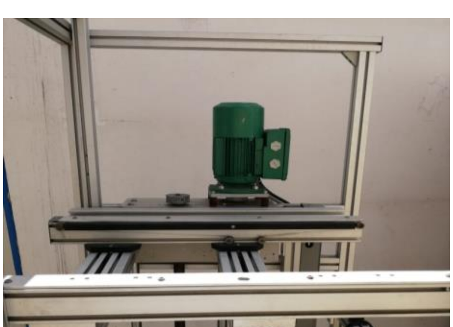
Further testing of the PLC with inputs (selector and sensor) and outputs (24V motor) was conducted.





*G. Mounting of the Conveyor*

The new conveyor was mounted securely in place, ensuring proper alignment and stability.



*H. Cutting of Frames and Mounting of the Cabinet*

Frames were cut to fit the new cabinet, which was then mounted to house the control components.

Sensors and actuators were installed to facilitate the automated operation of the elevator.

*I. Testing of the Elevator's Proper Functioning*

The elevator system underwent comprehensive testing to ensure proper functioning.

The system was divided into subprograms, with each subprogram tested individually to verify performance.

*J. Preparation for the Elevator's Movement Beside the Wave*

Final preparations were made for the elevator's operational movement beside the wave, ensuring all components were synchronized and function.

Fig 11. Automated Elevator

This The implementation of an automated elevator system exemplifies the strategic integration of PLCs into industrial automation. The project began with the disassembly of old machinery, including the removal of the existing conveyor system. Following this, a new conveyor was installed within the elevator, ensuring it was securely placed and properly aligned for optimal operation. The control cabinet, housing the central control components, was then disassembled, and all sensors and actuators were removed. Devices and cables inside the cabinet were disconnected to prepare for the new system integration.

Next, the functionality of the Programmable Logic Controller (PLC) was tested independently to ensure it was operating correctly, followed by verification of communication between the PLC and the PC to establish a reliable connection. The motor and speed variator were tested to confirm they were functioning as expected, and further testing of the PLC with inputs (selector and sensor) and outputs (24V motor) was conducted. The new conveyor was then mounted securely in place, ensuring proper alignment and stability.

Frames were cut to fit the new cabinet, which was then mounted to house the control components. Sensors and actuators were installed to facilitate the automated operation of the elevator. The elevator system underwent comprehensive testing to ensure proper functioning. The system was divided into subprograms, with each subprogram tested individually to verify performance. Final preparations were made for the elevator's operational movement beside the wave, ensuring all components were synchronized and functional.

This project highlights a meticulous focus on each stage, particularly in designing and constructing a support structure crucial for the system's installation. The strategic problem-solving approach effectively tackled the challenge of eliminating manual labor while enhancing productivity. Technical endeavors, encompassing design, simulation, and PLC programming, showcased a harmonious blend of creativity and technical expertise. The culmination of these efforts led to the successful realization of the automated elevator system. This achievement not only signifies the project's success but also underscores the potential of strategic planning and technical proficiency in overcoming industrial challenges and achieving operational excellence.

The implementation process was comprehensive and detailed, ensuring that each step was executed with precision and care. The project's success serves as a testament to the importance of thorough planning, rigorous testing, and a well-coordinated approach in engineering and industrial automation. The successful integration of PLCs into this project demonstrates the transformative impact of automation technologies on industrial processes.

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## CONCLUSION

In conclusion, the successful completion of the final project, "Design and Implementation of an Automated Elevator for the Rohs Wave Machine," marks a significant milestone in the pursuit of innovation and efficiency. By meticulously addressing the need to eliminate manual labor and enhance productivity, the project exemplifies a strategic approach to problem-solving. The rigorous needs assessment process ensured that the project was firmly anchored in the specific requirements of the task at hand. The subsequent technical endeavors, from design and simulation to programming the PLC, showcased a blend of creativity and technical expertise. The culmination of these efforts resulted in the seamless realization of the automated elevator system, which now stands as a testament to the power of ingenuity and collaboration. Moving forward, the impact of this project extends beyond its immediate application, serving as a catalyst for future advancements in automation and process optimization. Ultimately, the successful implementation of the automated elevator system not only signifies the attainment of project objectives but also heralds a new era of efficiency and innovation in the realm of industrial automation.

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