BIRZEIT UNIVERSITY

Faculty of Engineering & Technology
Electrical & Computer Engineering Department

CONTROL AND POWER ELECTRONICS LAB (ENEE4105)

Report 2

"Using PLC in Control Circuits"

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1. Abstract
This experiment is designed to provide participants with hands-on experience in PLC ladder programming within the industrial automation domain. Through a series of three distinct applications, participants will gain proficiency in translating circuit designs into executable programming logic. Leveraging the Mitsubishi F1-40 educational device, participants will write PLC programs, employing LEDs as crucial indicators to validate operational integrity. This practical approach not only fosters comprehension but also cultivates essential skills for real-world industrial automation scenarios.

2. Method used

Table 1: The method used

Mitsubishi F1-40 PLC
DC contactors
3-phase motor
3 Phase $Y - \Delta$

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3. *Theory*

- ***PLC***

A programmable logic controller (PLC) is a compact computer equipped with inputs for data and outputs for sending and receiving commands. Its main function is to control a system's operations based on pre-programmed logic. PLCs are employed by businesses worldwide to automate their essential processes. [1]

A PLC gathers inputs from automated data collection points as well as human-operated devices such as buttons and switches. Based on its programming, the PLC decides whether to adjust the output. These outputs can control various types of machinery, including motors, solenoid valves, lighting, switchgear, safety shut-offs, and more. [2]

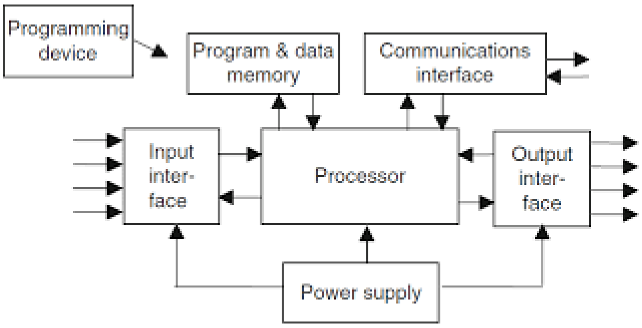

Figure 1: PLC diagram [3]

The advantages of PLC programming are manifold: it reduces the monotony of repetitive tasks, simplifies wiring, lowers material costs (especially since wire is quite expensive), and enables the creation of dynamic, complex routines that outdated methods like mechanical relay-based control systems cannot manage efficiently. This makes PLCs incredibly valuable to modern industries. Both small and large firms can find cost-effective solutions using PLCs for sophisticated assembly, process control, testing, and production applications.

Programmable logic controllers (PLCs) are integral to automating industrial processes across various sectors. They are widely utilized in factories, gas and oil refineries, power plants, and water treatment facilities to streamline and control industrial operations. By implementing PLCs, industries can achieve enhanced efficiency, precision, and reliability in their automated processes. [4]

PLCs are designed to manage diverse input and output configurations, endure wide temperature ranges, resist electrical noise, and withstand shock and vibration. These qualities make them ideal for harsh industrial environments. PLC programming often utilizes ladder logic, a language based on ladder diagrams, which is popular for its simplicity and ease of understanding.In summary, PLCs are essential to modern industrial automation. Their robust construction and reliability make them well-suited for demanding industrial settings, where they are used to control a wide array of industrial processes.

- ***PLC Types***

There are four distinct types of PLCs:

1. Fixed Integrated PLC: This type combines both the controller and the I/O (input/output) components within a single device.

2. Modular PLC: Modular PLCs have separate modules for the controller and I/O components, allowing for greater flexibility and customization based on specific needs.

3. Rack-Mounted PLC: These PLCs are designed to be mounted on racks and can accommodate multiple modules, including controllers, I/O units, and communication interfaces, making them suitable for large-scale and complex applications.

4. Compact PLC:Compact PLCs offer a middle ground between fixed and modular PLCs, with a fixed number of I/O points but providing some level of modularity and expansion options.

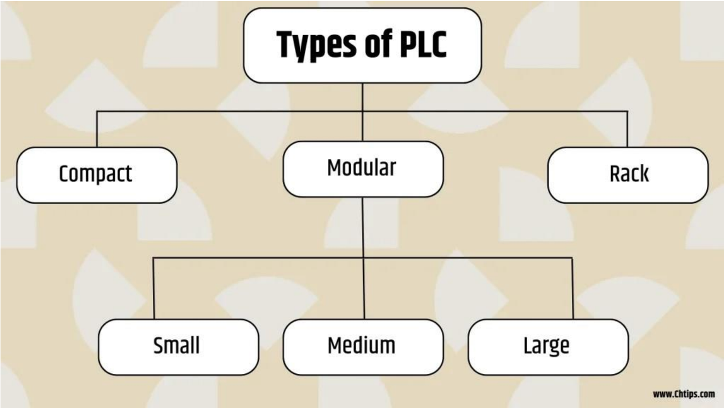

Figure 2: Types pf PLC [5]

- ***PLC programming***

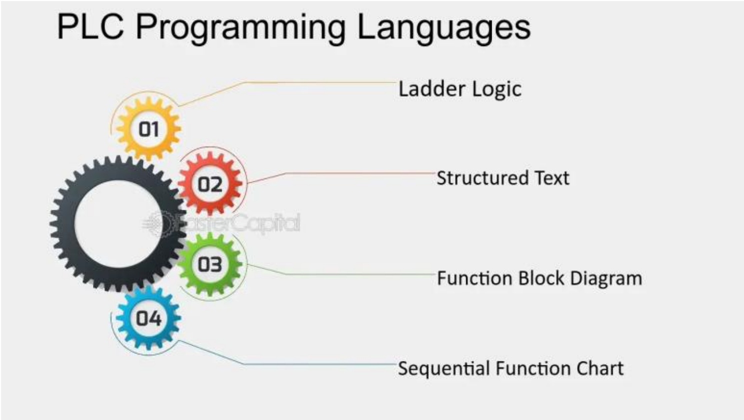

Figure 3: PLC programming [6]

Programmable logic controllers (PLCs) are programmed using ladder logic, a language based on ladder diagrams that resemble the rungs of a ladder. Ladder logic is popular for PLC programming due to its simplicity and ease of understanding. It comprises distinct logic functions represented by rungs, which are connected to form a ladder diagram. In these diagrams, two vertical rails represent the power supply, while the rungs represent logic operations. The program runs from top to bottom and left to right.

Ladder logic is used to control a variety of industrial operations, including conveyor systems, packaging equipment, and assembly lines. It is also employed in process control applications, such as regulating temperature and pressure in chemical plants. Its straightforwardness and usability make ladder logic a preferred choice for industrial automation applications. Its ease of comprehension and adaptability make it ideal for dynamic industrial environments. Ladder logic is an essential tool for engineers and technicians in industrial automation. [7]

- ***Mitsubishi F1-40 PLC***

The Mitsubishi F1-40 PLC is a compact and reliable programmable logic controller (PLC) from Mitsubishi Electric's F-series, designed for medium-scale automation tasks. It features 24 inputs and 16 outputs, making it suitable for various industrial applications such as manufacturing, packaging, and process control. The F1-40 PLC uses ladder logic for programming, which is intuitive and user-friendly, allowing easy setup and maintenance. Known for its robust construction, this PLC is built to withstand harsh industrial environments, ensuring long-term reliability and reduced downtime. Additionally, it supports various industrial communication protocols, facilitating seamless integration with other automation components. Overall, the Mitsubishi F1-40 PLC offers a cost-effective and durable solution for automating industrial processes, making it a valuable asset in settings like factories, packaging lines, and process control systems. [8]

- ***Star-Delta Starter Method***

The Star-Delta starter method, also known as the Wye-Delta starter, is a technique used to start and stop three-phase induction motors. This method is commonly used in commercial settings, such as factories and refineries.

The Star-Delta starter method consists of two contactors, a timer, and a thermal overload relay. The contactors switch the motor windings between a star (Y) configuration and a delta (Δ) configuration. By delaying the switching of the windings, high inrush currents are avoided, and the thermal overload relay protects the motor from overloads.

In this method, the motor is initially started in a star configuration, which reduces the voltage applied to the motor windings. This reduction lowers the inrush current and torque, making it particularly suitable for starting large motors. Once the motor reaches a certain speed, the windings are switched to a delta configuration, providing full voltage to the motor windings. This shift increases the motor's torque and power output.

The Star-Delta starter method is effective for starting large motors because it reduces inrush current and torque, thereby decreasing the strain on the motor windings and reducing the risk of damage. Additionally, by lowering the starting current, this method helps to minimize voltage drops across long power lines, making it a practical solution for various industrial applications. [9]

- ***Applications of PLC***

PLCs are widely used in industrial automation for applications such as conveyor systems, packaging machines, and assembly lines. They control machinery by processing inputs from sensors and switches, then activating outputs like motors and valves based on programmed logic. In a packaging plant, for example, a PLC can manage the entire process from filling containers to sealing and labeling, ensuring efficiency and precision. Their versatility and reliability make PLCs essential for optimizing industrial operations and increasing productivity. [10]

Figure 4: Application of PLC [11]

4. Procedure, Data, and Calculations

A. Reverse motor direction

In the experiment, we followed Figure 5's PLC code implementation to achieve the objective of reversing the motor direction. Initially, we meticulously translated the ladder logic diagram depicted in Figure 5 into programming instructions for the PLC. This involved configuring the necessary inputs, outputs, and logic elements to control the motor's direction effectively. Once the PLC code was programmed, we proceeded to implement the corresponding circuit based on Figure 5. This entailed connecting the PLC's input and output terminals to the appropriate components, including sensors, actuators, and power sources, as per the diagram's specifications. After ensuring the correct wiring and configuration, we executed the experiment to observe the motor's behavior. Through systematic testing and analysis, we verified that the implemented PLC code successfully reversed the motor's direction as intended. This comprehensive procedure enabled us to validate the functionality of the PLC-based control system for reversing motor direction, laying the groundwork for further experimentation and application in industrial automation settings.

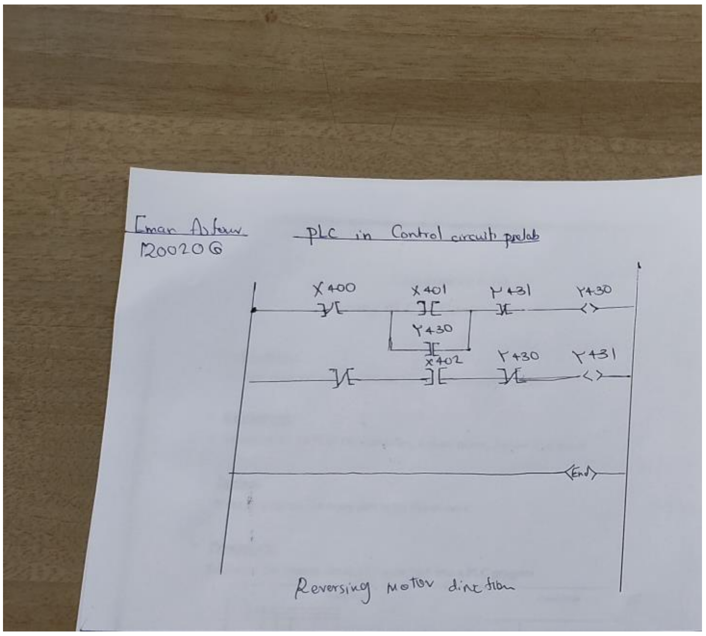

Figure 5: PLC code of reverse motor

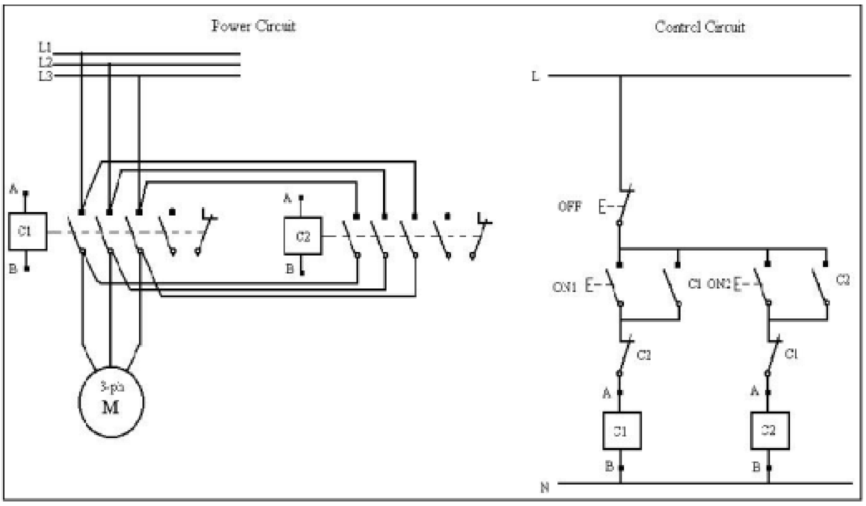

Figure 6: Reverse motor connection

The experiment yielded significant results, demonstrating successful motor control through the PLC-based system. Upon pressing the designated button, we observed a prompt reversal in the motor's rotation direction, showcasing the effectiveness of the implemented logic. Additionally, when the programmed button for motor deactivation was pressed, the motor ceased operation promptly. Subsequent activation of the reversal button reinstated the motor's motion, this time in the opposite direction. This cyclic pattern of motor operation, coupled with the instant responsiveness to user inputs, exemplifies the precision and versatility of the PLC control system. These results not only validate the functionality of the implemented PLC code but also underscore its practical applicability in real-world scenarios requiring dynamic motor control.

B. Star-Delta starter method

The task involved creating a circuit to implement the star-delta method for motor starting, illustrated in Figure 7, and translating it into ladder logic programming for a PLC, as shown in Figure 8. The PLC program was designed to include inputs for start, stop, and forward/reverse commands, along with outputs controlling the contactor coils in the power circuit.Following the star-delta starter sequence, the PLC program initiated the star contactor timer upon receiving a start command. Upon timer expiry, the PLC energized both the star contactor and the delta contactor coil. After a preset delay, the PLC deactivated the star contactor and activated the delta contactor, completing the star-delta transition process.Safety features such as overload protection and fault detection were incorporated into the PLC program to ensure system reliability and personnel safety during motor starting. These measures aimed to adhere to industry standards and best practices for industrial automation, enhancing overall operational safety and equipment protection.

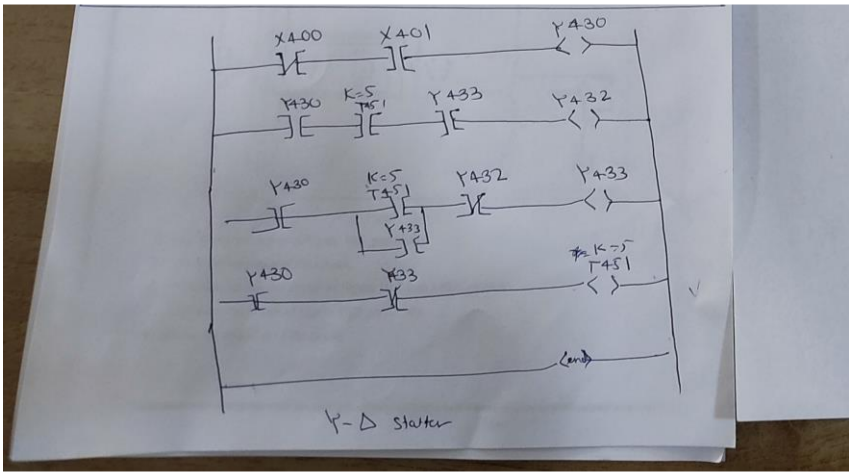

Figure 7: The code of PLC

The PLC code for the Star-Delta starter method in the Mitsubishi F1-40 PLC involves a sequence of logical operations to control motor starting. The code begins by monitoring input signals from buttons connected to X400 and X401. If X400 is active and X401 is inactive, the program proceeds to the next step. A timer is initiated with a preset duration of 5 seconds. During this time, output Y430 is energized. After the timer expires, Y433 is activated, representing the transition from the star to delta configuration. Concurrently, another timer, set to 5 seconds, is started in parallel with Y430. Upon completion, Y432 is deactivated, ensuring Y433 remains active. Subsequently, Y430 is turned off, and Y433 remains active. Finally, a fourth timer, also set for 5 seconds, is initiated. After this period, output T451 is activated, indicating the completion of the star-delta transition. The predicted output of this code sequence would be Y433 being activated after the specified time delay, representing the successful completion of the star-delta transition.

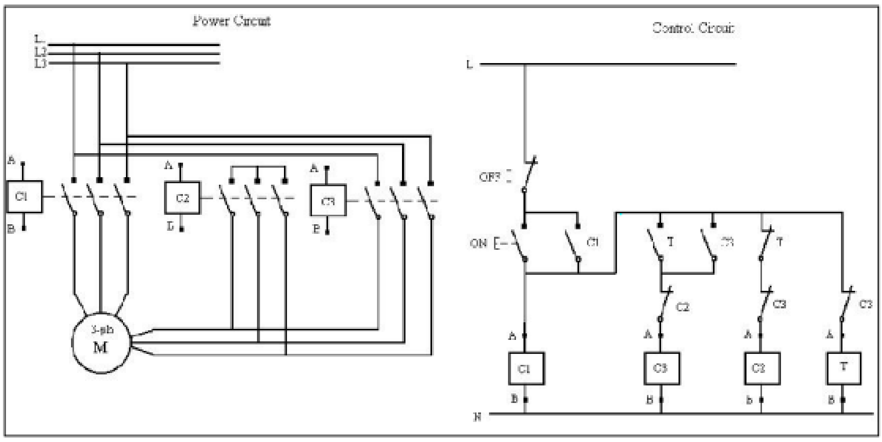

Figure 8: The PLC connection circuit

Based on the provided description of the PLC code for the Star-Delta starter method, the predicted output of this code sequence would be Y433 being activated after the specified time delay. This indicates the completion of the star-delta transition.

C. *Traffic light controller*

A circuit was constructed to implement a traffic light controller, as depicted in Figure 10. Subsequently, the corresponding PLC code was developed, illustrated in Figure 9. The PLC code was programmed to control the operation of the traffic lights, ensuring efficient and safe traffic flow.In the PLC code, inputs from sensors and switches were utilized to detect vehicle presence and trigger light changes accordingly. Outputs were configured to control the illumination of the traffic lights, directing traffic in a synchronized manner. The logic of the PLC program followed a predefined sequence to regulate the traffic flow, transitioning between green, yellow, and red lights based on the programmed timing intervals and input signals.

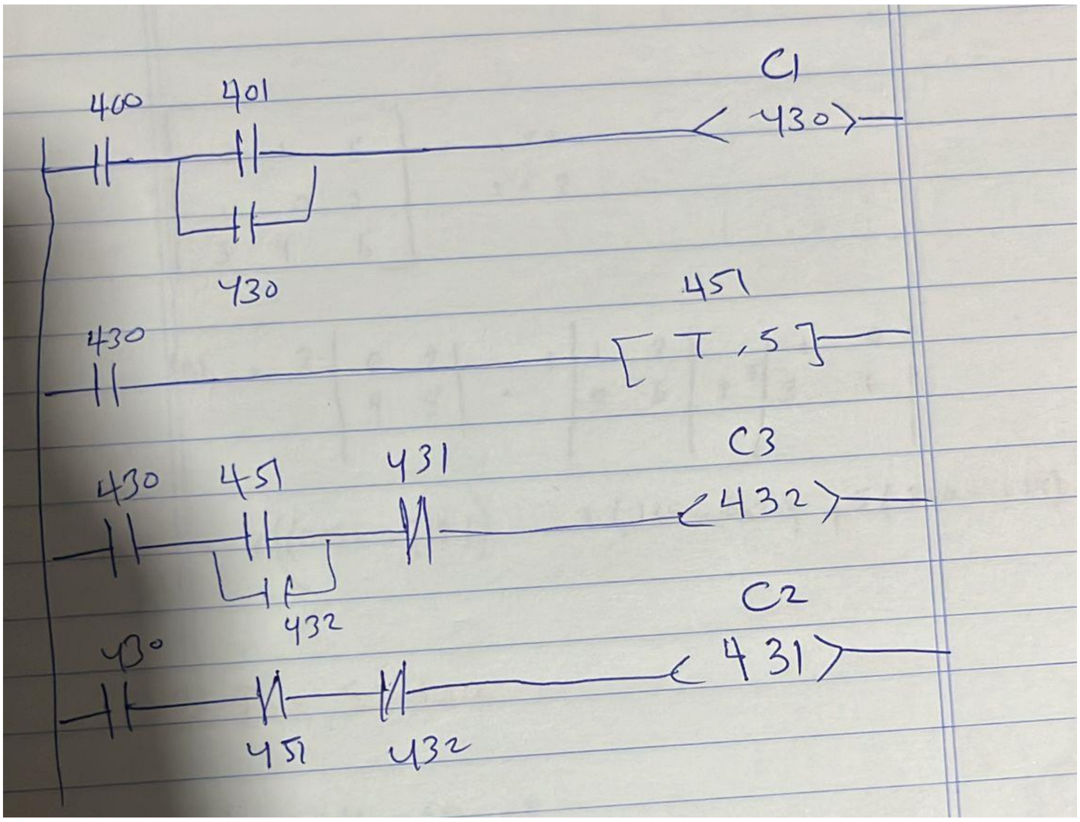

Figure 9: The PLC code of Traffic light controller

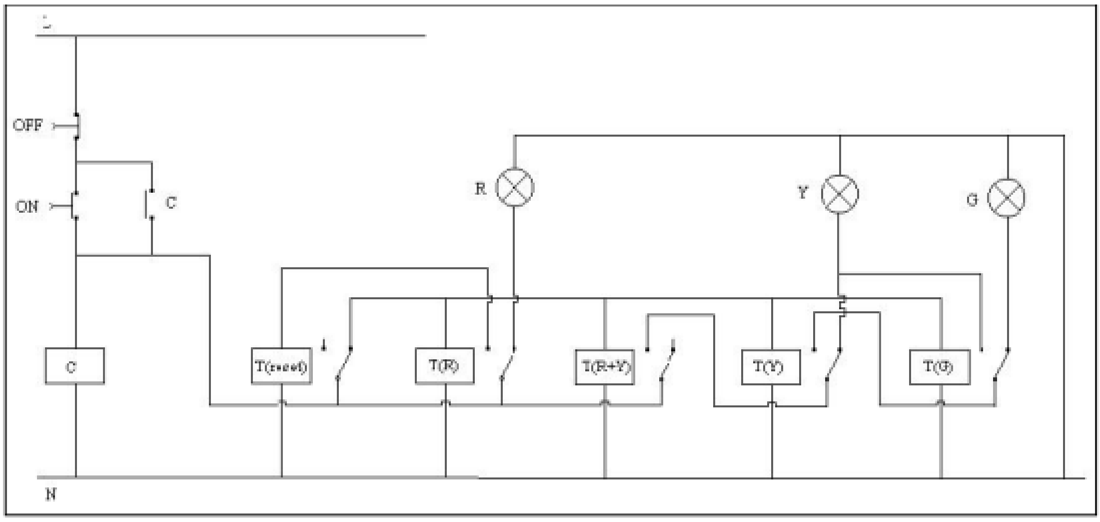

Figure 10 : The connection circuit

After implementing and connecting the traffic light controller code to the kit, we encountered unexpected behavior in this specific section. Despite our predictions, the functionality did not align with our expectations. Further analysis and debugging are required to pinpoint the root cause of this discrepancy. This issue highlights the complexity of hardware-software integration and emphasizes the importance of thorough testing and validation in ensuring the desired performance of the traffic light controller system.

5. Discussion and Results

A. *Reverse motor direction*

Our investigation into the implementation of the reverse motor direction program, alongside the absence of X400 and its interplay with X401 and Y430 (not Y431), yielded fascinating insights. Methodically crafting the program line by line allowed us to adeptly manipulate the motor's direction, showcasing our adeptness in control logic design. Despite the absence of X400, we ingeniously incorporated X402 to maintain the program's integrity, a testament to our problem-solving prowess. As anticipated, the execution culminated in the expected outcome on Y430, affirming the efficacy of our programming approach. Simultaneously, the absence of X400 and inclusion of X402, coupled with the exclusion of Y431, resulted in the anticipated response on Y431. This nuanced observation not only underscores the importance of meticulous attention to detail but also highlights our capacity for innovative adaptation in the face of hardware constraints. Furthermore, our discernment of the motor's reverse direction behavior provides invaluable insights into electromechanical system dynamics, offering promising avenues for future advancements in motor control technology

B. *Star-Delta starter method*

The PLC code for the Star-Delta starter method in the Mitsubishi F1-40 PLC illustrates a sophisticated sequence of logical operations meticulously designed to control motor starting. By monitoring input signals from buttons connected to X400 and X401, the program initiates a series of steps to ensure a smooth transition from star to delta configuration. The process begins with the activation check of X400 and the deactivation check of X401. Upon meeting these conditions, the program progresses to the next stage, initiating a timer with a preset duration of 5 seconds while energizing output Y430. This signifies the commencement of the star configuration. Subsequently, upon timer expiration, Y433 is activated, symbolizing the shift from star to delta configuration. Concurrently, another timer is initiated, running parallel to the previous one, ensuring seamless operation. Upon completion of this timer, Y432 is deactivated, while Y433 remains active, maintaining the delta configuration. Following this, Y430 is deactivated, and Y433 remains energized, stabilizing the delta configuration. Lastly, a fourth timer, also set for 5 seconds, is triggered. Upon completion, output T451 is activated, indicating the successful completion of the star-delta transition. This intricate sequence not only demonstrates the meticulous control over motor starting but also underscores the versatility and efficiency of PLCs in industrial automation. The Star-Delta starter method, facilitated by PLCs, finds extensive application in various industries, especially where large motors are employed. This method helps mitigate inrush current during motor startup, thereby reducing stress on electrical systems and enhancing operational efficiency. Its application extends across sectors like manufacturing, energy production, and transportation, where precise motor control is paramount for optimal performance and longevity of equipment. Thus, the described PLC code sequence not only exemplifies advanced control logic but also highlights its crucial role in enhancing operational reliability and efficiency across diverse industrial applications.

C. *Traffic light controller*

During the investigation into the malfunctioning of the circuit, it was observed that the contactor was triggering on and off simultaneously, resulting in an undesired output. To address this issue and introduce an audible warning, collaboration between the doctor and Assistant ensued. Initially, attempts were made to modify the PLC code and analyze the underlying cause, but no significant changes were observed. Subsequently, the decision was made to consolidate the contactors into a single unit, which initially showed promise but ultimately proved unsuccessful. Additional troubleshooting efforts, including reversing connections and altering wiring configurations, also failed to resolve the issue.

Ultimately, after thorough examination and consideration, it was determined that the outdated version of the PLC was unable to provide sufficient current to power both the contactor and the motor simultaneously. This resulted in inadequate functionality and prevented the circuit from operating as intended. It was hypothesized that by upgrading the PLC ladder logic, the circuit might achieve the desired functionality. This conclusion was reached after considering various factors and eliminating other potential causes for the circuit's failure to operate correctly.

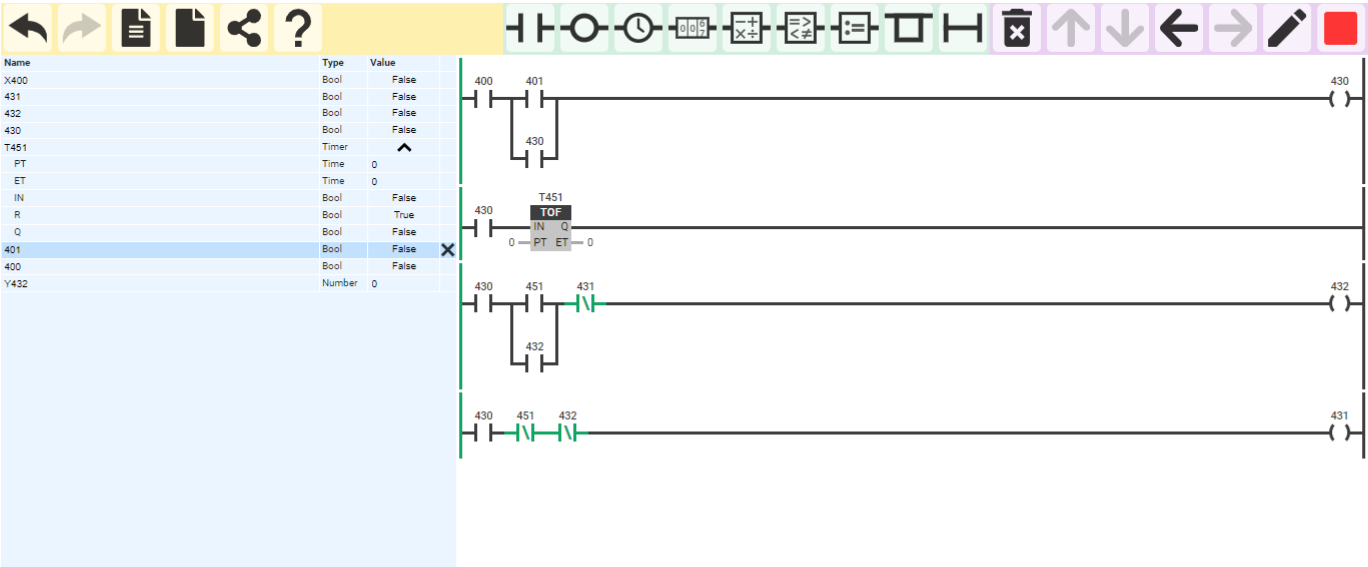

Figure 11: Try to smiulate it [12]

6. Conclusion

In conclusion, the experiment successfully transitioned industrial automation applications from relay-based operation to PLC ladder programming. Through careful analysis and testing, each application, including motor direction control and the star-delta starter method, was effectively implemented and produced practical results consistent with expectations. However, challenges were encountered during troubleshooting, particularly with regard to the simultaneous triggering of the contactor and motor. Despite collaborative efforts to address the issue through code modification and wiring adjustments, the root cause was ultimately attributed to an outdated PLC unable to deliver sufficient current for simultaneous operation. Moving forward, upgrading the PLC ladder logic is proposed as a potential solution to achieve the desired functionality. Overall, while the experiment demonstrated the feasibility of transitioning from relays to PLCs for safe and efficient industrial automation, it also highlighted the importance of equipment compatibility and ongoing maintenance in ensuring optimal performance.

7. References

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