Integration of PLC, HMI and RFID Technology in an Elevator Model for Training Purposes

Do Huy Tung, Vu Hong Phong

***Abstract*— The paper presents the process of designing, fabricating, and operating a scaled-down elevator model integrated with three modern technologies: PLC programmable control, HMI (Human-Machine Interface), and an RFID card identification system. The model is developed with the goal of supporting the training of engineering students, particularly in the fields of mechatronics and automatic control. The model structure includes three floors, using a DC motor, optical sensors, an RC522 RFID module, and a Siemens S7-1200 PLC as the central controller. The system allows users to select floors, control the automatic door, and access the elevator securely via RFID cards, while visually monitoring the operation through the HMI screen. The control program is built based on sequential logic and event-driven processing to ensure safety and operational reliability. Experimental results show that the model operates stably, has a fast response time, an intuitive interface, and is highly suitable for hands-on technical training environments.**

***Index Terms*— PLC, HMI, RFID, Elevator model, Technical training, Automation control**

I. INTRODUCTION

In the context of rapid industrialization and digital transformation, the field of control and automation plays an increasingly vital role in the production and operation of technical systems. Therefore, the demand for training highly skilled technicians and engineers with in-depth practical knowledge is becoming more urgent. In particular, the ability to work with integrated control systems such as PLCs, HMIs, and identification devices like RFID is a common requirement in many industries. The development of highly applicable simulation models enhances training effectiveness and bridges the gap between theory and practice.

Simulation devices play a critical role in technical education by bringing learners closer to real working environments. Today's modern education focuses on practical competence and problem-solving skills; simulation models allow learners to practice manipulation skills, develop system thinking, and handle technical scenarios—especially in control and automation. Building integrated models is an effective method to help learners visualize and understand real-world systems comprehensively. Among them, the elevator model is considered a typical example for integrating and operating multiple key technologies in mechatronics and automatic control. A complete elevator system requires coordination between programmable logic control (PLC), human-machine interface (HMI), sensors, actuators, and especially secure identification solutions such as RFID cards.

Designing and operating the elevator model allows learners to experience hands-on training in conditions close to industrial reality—from control programming, signal processing, information display to access control. Therefore, the elevator model not only holds value in technical simulation but also serves as a practical platform for developing system thinking, interdisciplinary integration skills, and meeting the demand for high-quality human resources in the era of digital transformation. The objective of this paper is to design and implement an elevator model integrating PLC, HMI, and RFID technology to support hands-on training for students in control and automation engineering.

II. THEORETICAL BACKGROUND & SYSTEM MODEL

PLC S7–1200 controller: is a simple yet highly precise automation device that plays a central role in automatic control systems. It features fast signal processing capabilities and supports communication with HMI, RFID, and sensors via Ethernet communication ports. This device is well-suited for small to medium-sized applications such as elevator models.

Figure 1. Siemens S7-1200 PLC controller (Source: Siemens)

Siemens KTP700 Basic HMI: is a touch screen primarily used for monitoring and controlling both small and large-scale automation systems. The 7-inch Siemens HMI screen is commonly used with various PLC models to create automated systems (Figure 2).

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Figure 2. Siemens KTP700 Basic HMI screen (Source: Siemens)

RFID RC522 module: is a 13.56 MHz RFID card reader, commonly used to interface with microcontrollers or PLCs via an intermediate converter. In the elevator model, the RC522 is used for access control, allowing only authorized cardholders to use the floor selection function (Figure 3).

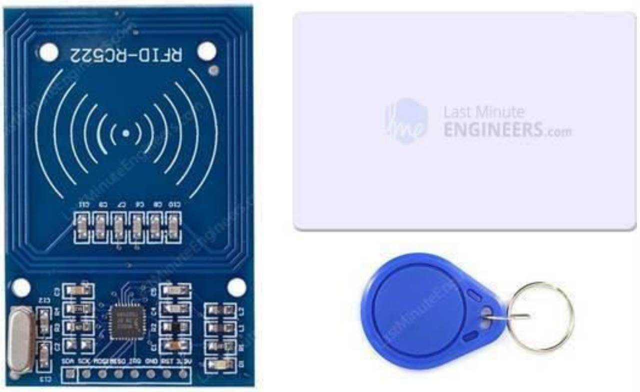


Figure 3. RC522 RFID card reader module

Operating principle: The elevator system operates based on an automatic control sequence programmed by the PLC and consists of two main principles:

Basic operation process: The user brings an RFID card close to the RC522 reader to verify access rights. If the card is valid, the user selects the desired floor via the HMI screen. The PLC processes the signals, opens the cabin door, and then activates the motor to move the cabin to the selected floor. Upon reaching the destination, the door opens automatically and closes again after a preset delay, completing one operating cycle.

Logic conditions for safety and security: The system allows floor selection only after successful authentication. The door opens only when the cabin is stationary at the correct floor and no obstacles are detected. The cabin will perform an emergency stop if there is a loss of sensor signal, overspeed, or an electrical fault. All system statuses and errors are displayed on the HMI screen, allowing for easy monitoring and increased reliability.

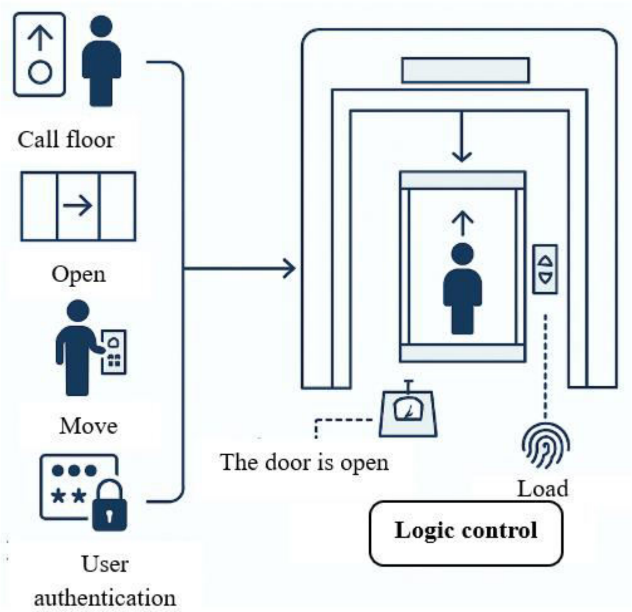


Figure 4. Logic control for elevator system

III. DESIGN AND IMPLEMENTATION

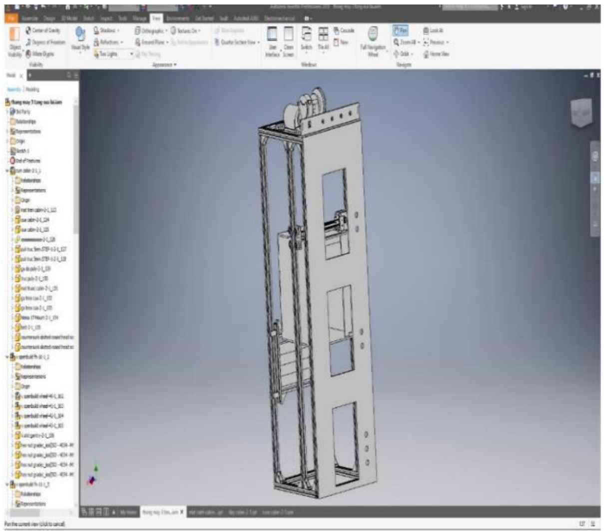


Figure 5. Design of 3-storey elevator model

3.1. Mechanical design of elevator model

The elevator model in (Figure 5) is mechanically designed with a sturdy aluminum frame, consisting of three floors and using a mica cabin, pulleys, and steel cable for lifting. The drive system employs a DC motor with a balanced counterweight and position sensors, ensuring smooth, accurate, and safe operation throughout the working process.

The drive mechanism of the elevator model uses a DC motor as the main driving source, combined with a pulley and lifting cable system to raise and lower the cabin. A counterweight is symmetrically designed relative to the cabin to balance the load, reduce stress on the motor, and help the system operate stably, save energy, and extend equipment lifespan.

3.2. Electrical and control system connection diagram

The electrical and control system of the elevator model is connected according to a block diagram that includes: the Siemens S7-1200 PLC as the central controller, interfacing with the KTP700 HMI for floor selection and display, connecting to the RFID RC522 module for user authentication, floor sensors, door switches, and the cabin drive motor via a control module.

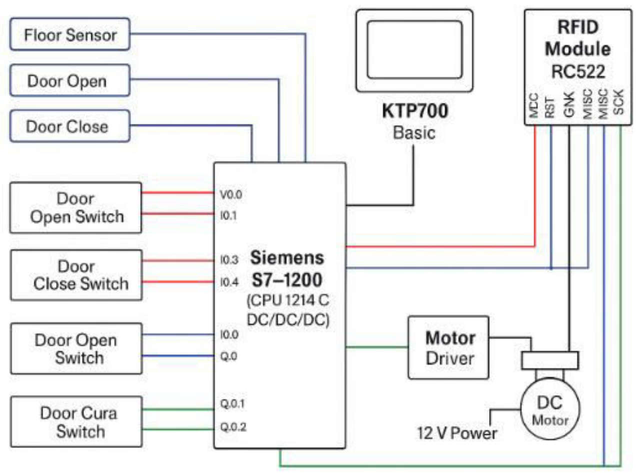


Figure 6. Electrical and control system connection diagram

3.3. Instruction Blocks

Control Command Block

This is the program block used to issue floor-calling commands to activate the elevator. It forms the connection between the physical floor call buttons on the elevator and the intermediate relays in the PLC program. When one of the buttons is pressed, the coil of the corresponding intermediate relay is energized. At this point, the relay contacts change state, generating signals for other functional blocks to operate.

This block is responsible for generating control signals from push buttons (switches) and limit switches. When a push button is pressed, it creates a switching pulse from an active to an inactive state. This bit pulse is sent to the processing unit. Each push button is connected to an input of the controller.

Floor Calling Block

This block is arranged from floor 1 to floor 3:

- Floor 1 has only one "up" call button;
- Floor 2 has both "up" and "down" call buttons;
- Floor 3 has only one "down" call button.

PLC Block

This is the most important block, responsible for receiving input signals and processing them according to a pre-programmed logic sequence. The challenge lies in the fact that the input signals are generated by push-button switches. After completing input signal processing, the PLC makes decisions to control power devices.

Cabin Position Determination Block

This block allows the system to determine the cabin's position. It combines input X012 with programming instructions such as INC and DEC.

X012 essentially refers to the floor stop sensor, which ensures the cabin stops at the correct floor. The INC instruction increases the D28 register value by 1, while DEC decreases it by 1. An important command is DECO, which decodes the 4-bit value in register D28 into bits M10 to M25. Combined with the stop sensor, this command ensures the cabin stops precisely at the desired floor.

Up/Down Motor Control Block

The motor is activated based on floor stop sensor signals and the decoded data levels in register D28. When a floor call is made, the corresponding relay coil is energized. The elevator moves up when the normally open relay contact closes, supplying power to the motor. Conversely, it moves down when the relay operates in reverse.

Door Motor Control Block

The cabin door only opens after the motor has completely stopped. Once the cabin reaches the designated floor, the door opens after a 4-second delay and closes automatically after another 4 seconds.

Power Block

This block executes the control signals received from the PLC and drives the mechanical components of the elevator.

Cabin Lifting Mechanism

The lifting system is driven by a 12VDC motor with a gearbox, connected to a system of cables and guide pulleys. The cabin is suspended from one end of the cable, while the opposite end is attached to a counterweight. As the pulley rotates, one side of the cable winds in while the other unwinds-meaning when the cabin moves up, the counterweight moves down, and vice versa.

Cabin Door Mechanism

This mechanism is implemented using a closed loop between a 12VDC motor with a gearbox and a drive pulley. Two doors are fixed to the same cable-one at the top and one at the bottom-ensuring they open and close simultaneously. When the system receives an open-door signal, the motor rotates forward until it reaches position 2, then stops. Upon receiving a close-door signal, the motor reverses until it returns to position 1 and stops again.

3.4. Communication between PLC and peripheral devices

In the elevator model, the Siemens S7-1200 PLC communicates with peripheral devices through digital input/output ports. Specifically, the floor call buttons, floor sensors, door switch, and RFID signal are connected to input ports I0.0 to I0.7. Output ports Q0.0 to Q0.4 control the cabin motor (up/down), door open/close, and warning lights. The entire connection is illustrated in a circuit diagram, showing the interaction between the PLC, HMI, sensors, relays, and actuators. This diagram helps learners easily visualize the control process, effectively supporting teaching purposes and the simulation of an automated system.

3.5. PLC control programming

The PLC control program is developed using TIA Portal software and written in LAD (Ladder Logic) language. The PLC processes signals from the RFID module, floor sensors, door switches, and HMI, then controls the motor, cabin door, and monitors the entire elevator operation process in a safe and reliable manner.

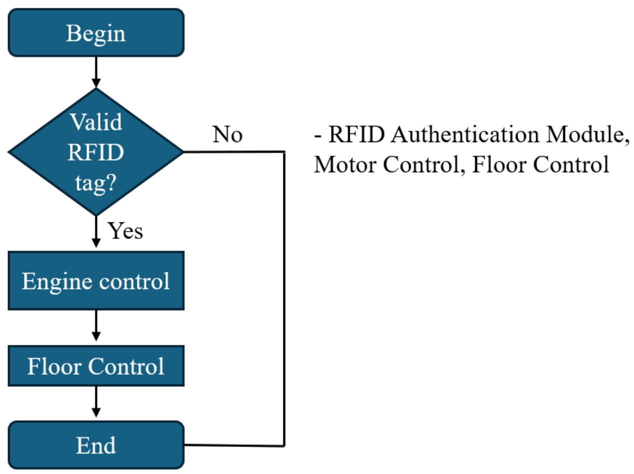


Figure 7. Main program flowchart.

3.6. HMI interface programming

The HMI interface is programmed using TIA Portal software (Figure 6) and includes main screens such as floor selection, cabin position display, door status, and error warnings. Control buttons are directly linked to the PLC via the Ethernet protocol, ensuring fast response and enabling users to operate and monitor the system easily.

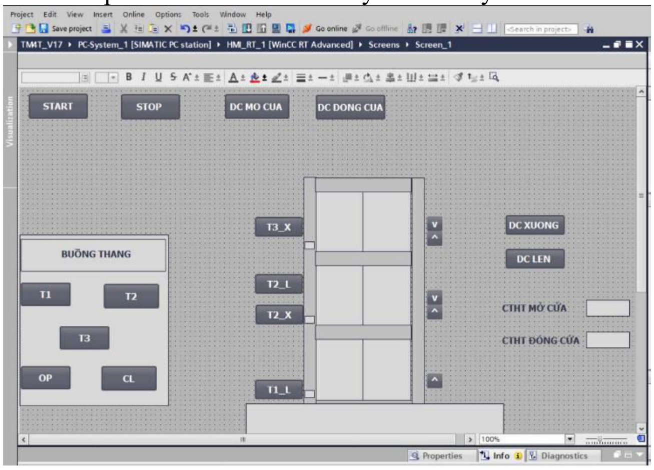
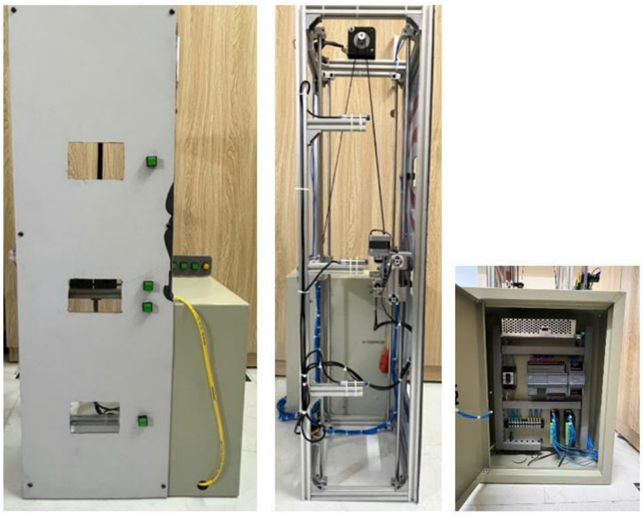


Figure 8. HMI interface

IV. RESULTS AND EVALUATION

The elevator model is designed to simulate basic automation control functions, making it suitable for technical training environments. The system allows the cabin to move to the selected floor based on user commands entered via the KTP700 HMI screen. When the user scans an RFID card at the RC522 reader, the system verifies the card's validity. If the card is valid, the PLC enables floor selection; if not, the request is denied and a warning is displayed on the HMI KTP700.



a) Front view of elevator model b) Side view of elevator model c) Power source

Figure 9. 3-storey elevator product model

Once the move command is accepted, the cabin travels to the desired floor. Upon arrival, the cabin door opens automatically and closes again after a preset delay. The KTP700 HMI displays the full system status, including current floor position, door status, user authentication, and error alerts if any occur. All functions are operated automatically through the PLC, ensuring stable and safe operation of the model.

The elevator model, after installation and programming, has demonstrated high efficiency in terms of stability and accuracy. The cabin moves precisely to the selected floor with fast response time, without signal delays or loss of connection between components. The use of the Siemens S7-1200 PLC and KTP700 HMI ensures reliable logic processing, making the system suitable for continuous training environments. The system is also highly rated for its scalability, allowing integration of advanced features such as remote control, network-based monitoring, or fault alerts via SMS/email. Additionally, the control program and wiring diagram are flexibly designed, enabling easy troubleshooting, component replacement, or function upgrades when needed. As a result, the model not only meets the needs of hands-on learning but is also well-suited for extended research in control and automation engineering.

The elevator model integrated with PLC, HMI, and RFID technology offers a high level of interaction for learners through hands-on operation and visual observation of the control process. The system closely simulates the actual operation of an industrial elevator, allowing students to easily approach specialized technical knowledge. This model is especially suitable for teaching skills in PLC programming, HMI interface design, and embedded system integration, thereby fostering students' abilities in logical thinking, event-driven processing, and structured, in-depth automation programming.

V. CONCLUSION

The model has successfully integrated PLC, HMI, and RFID into a scaled-down elevator system, fully meeting the functions of floor calling, access control, and safe operation. The product has high applicability in technical training, supporting learners in practicing control programming and gaining in-depth understanding of automation systems.

The system can be expanded with modern technologies such as remote control via network, IoT integration, or voice-controlled operation.

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