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RESEARCH ARTICLE

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Teaching Practice of PLC Programming in Elevator Virtual Simulation Experiment Platform

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Abstract: Virtual simulation technology is now becoming the main focus of the experimental practice teaching link. The article describes how to design the control program of the PLC control system of a single 6-floor elevator based on EET basic elevator simulation experiment platform and combined with Botou V18 and S7-PLCSIM Advanced V5.0 software under Siemens and apply it to teaching practice. The article first introduces the structure of the elevator system and the characteristics of EET basic software, as well as the control principle of the elevator control system. Secondly, the settings of the virtual simulation software, the configuration settings of the Boto, and the communication settings between the software are introduced. Then, the modular and structured programming method of a single elevator control program based on FB block is introduced. Finally, the teaching situation and teaching effect of this virtual simulation experimental platform applied for 4 years are introduced. It is finally concluded that this virtual simulation teaching, not only improves the setting of related courses but also has a great promotion effect on students' systematic mastery of theoretical knowledge and enhancement of innovation ability, which can achieve the purpose of improving the quality of teaching.

Keywords: elevator; virtual simulation technology; EET basic; Boto; elevator control; practical teaching

1. Introduction

PLC as the mainstream control equipment in today's industrial control field, has a pivotal position in industrial automation and industrial intelligence. Undergraduate mechanical automation majors, mechatronics majors, automation majors, and emerging intelligent manufacturing engineering majors will be "PLC programming and application" as an important course within the specialty. At the same time, the skills cultivated in this course have a very high degree of match with the future students' jobs in the field of industrial automation, and the students have a certain positive significance to employment and further education after learning and practicing in this course.

However, the application of PLC control systems in industrial scenarios has a certain complexity of hardware conditions, which is precisely the laboratory conditions more difficult to reproduce the part. So through the application of a virtual simulation experimental platform, not only can solve the real scene is not easy to reproduce the problem, but also increases the interest in teaching, while reducing the risk of damage to the experimental equipment under the misoperation of the students as well as the safety risks arising from the operation of complex electrical equipment.

2. EET Basic Elevator Simulation Experiment Platform Overview

2.1 Overview of elevator system

With the continuous expansion of urbanization, the number of high-rise buildings is increasing, so the demand for elevators is increasing, but the elevator is the convenience of people's daily lives at the same time also accompanied by several potential

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problems, such as whether the elevator can achieve safety and stability, high energy efficiency, anti-interference ability, simple control, low failure rate, low noise, etc., has become a problem that must be considered and solved in the actual project (Zhang et al., 2021). S7-1200 is a Siemens branded elevator system, which has been developed by Siemens. 1200 is a modular, compact new small and medium-sized industrial controller introduced by Siemens, and its features are just right for a series of environmental problems that need to be overcome during elevator installation (Fu, 2019). An elevator mainly consists of external equipment and internal equipment of the elevator. The external equipment includes a car, traction motor, guide wheel, first and second limit switches (both upper and lower end stations), up and down leveling sensors (on each floor), external call buttons, and indicator lights (on each floor). The internal equipment includes floor buttons, floor displays, up and down indicator lights, and lighting fans (Zhou & Cao, 2020). Among them, the interior of the car is also equipped with a weight transmitter that outputs an analog signal for overload protection (Lei, 2022).

2.2 Elevator control principle

In the elevator control program design, it should be noted in advance that elevator equipment as special equipment has safety-based electrical interlocking requirements. As up and down contactor signals, high and low-speed contactor signals are required to realize the electrical interlocking of the PLC program. In addition, note the amount of other safety interlocking functions as follows:

(1) During the operation of the elevator, the lighting and ventilation in the car should be opened to ensure proper lighting and air circulation in the car to provide passengers with a good ride experience.

(2) When the load capacity of the car is more than 900kg, the indicator light of full load shall be kept on, and the door of the car shall be opened at the same time to make it in the state of opening the door in place until the load capacity is back to within the load range before resuming normal operation. It is worth noting that there is no need to open the fault indicator when overweight, and overweight operation is strictly prohibited.

(3) When the infrared light curtain signal of the car door is triggered, to prevent the occurrence of accidental safety accidents, the door of the car should be kept open until the door is opened in place.

(4) Forced direction change and speed change function, through the end station switch (i.e. the 1st limit) set in the shaft, realize the forced direction change and speed change in the fixed position of the end station, and during the period, it must be operated at a low speed.

(5) Terminal over-travel protection function, through the end station switch (the 2nd limit) set in the shaft, when it is actuated, the elevator shall be stopped urgently and the fault shall be reported.

(6) Wrong selection command elimination function, when the elevator runs to the lowest or highest floor, the unresponsive internal call signal (regarded as the wrong selection signal) in the car shall be eliminated. At the same time, passengers in the car can eliminate the wrongly selected signal by certain operation methods (such as double-clicking the wrongly selected floor button or long-pressing the wrongly selected call button).

3. Communication and Configuration Settings

PLCSIM advanced V5.0 is the PLC advanced simulation software of Siemens, using an advanced virtual controller can be a virtual simulation of Siemens S7-1500 series PLC. EET basic software as a controlled object can be controlled by the S7-1200/1500 series PLC as well as S7-300/400 series of the real machine control can also be used. PLCSIM Advanced to control by virtual simulation. In this project, the communication between EET Basic software, Botou V18, and PLCSIM Advanced V5.0 adopts Ethernet communication, and in the whole communication system, the engineer station the virtual PLC, and the virtual PLC and EET Basic are connected via Ethernet.

In the communication setting, you need to pay attention to the following aspects.

(1) When searching for the address of the network card, be sure to note that the device description of Siemens PLCSIM is "Siemens PLCSIM Virtual Ethernet Adapter".

(2) When setting the IP address, make sure that the client, virtual PLC, and EET basic are in the same network segment. Finally, open the EET Basic software and log in, select the upper right corner of the "Communication Settings" button to show the

"Ethernet Communication Configuration" interface, change the IP address and the virtual PLC IP consistent, click on the "connect test" button, to carry out the "connect test". Click the "connect test" button to test the connection, as shown in **Figure 1**, indicating that the communication between the simulated PLC and EET Basic is successfully connected.

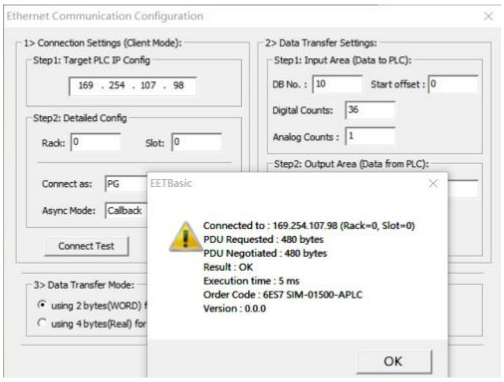

Figure 1. EET Basic software IP address settings

In the configuration settings, we select any one of the 1500 series PLCs can be, at the same time, right-click on the project name, click "Properties", in the pop-up dialog box, select "Protection", the "block compilation to support the simulation of In the pop-up dialog box, select "Protect", put a "√" in front of "Support emulation during block compilation", and select "OK button". In addition, you need to right-click the PLC option under the project tree, select "Properties", and in the pop-up dialog box, select "General-Protection and Security-Connection Mechanisms" and put a tick in the box in front of "Allow PUT/GET communication access from remote objects", and select "OK button". communication access from remote objects" in front of the box with a "√".

4. PLC Elevator Control Program Design Method

PLC program design thinking is the programmer's use of the given preconditions and process requirements, to design the PLC program and the process of analysis, synthesis, judgment, reasoning, and other cognitive activities (Zhang, 2014). The traditional PLC programming method follows the method of designing relay circuit diagrams for program design, and the programming language is the LAD wedge diagram language. This method does not have a general law to follow, has a great deal of tentativeness and arbitrariness, the final result is not unique, the time used for design, the quality of the program is very much related to the experience of the designer, so it is known as the empirical design method, which is generally used for simpler program design (Liao, 2008).

In addition in the PLC program design process, the program design method based on the idea of step sequence can also be used. The use of auxiliary variables M for each step of the control set, so that the need for a large number of intermediate components to complete the self-locking, interlocking, interlocking, and other functions intertwined with the problem, only needs to be analyzed by the logical steps into several small program modules can be analyzed, not only the complexity of the problem simplified, but also to enhance the program's readability and comprehensibility, even if the modification of a certain program segment, the other segments of the program will not have too great an impact on other program segments (Yu, 1999). This programming method based on the idea of the stepwise sequence allows students to master only the basic programming language of PLC, which can be programmed for more complex control problems, so that when they get the design task, the design of the design, which greatly enhances the student's interest in learning, but also enhances the effectiveness of classroom teaching (Xu, 2017).

Botou software has more powerful programming applications. The use of modular and structured programming ideas in the process of elevator program design helps students carry out complex automation system program design. At the same time, developing the habit of modularization and structured programming is also in line with the cultivation of engineering quality advocated by the current engineering quality education. Adopting the module design structure based on FB block can effectively optimize the elevator control program, and at the same time make the program more concise and clear, and enhance readability and portability.

4.1 Elevator initialization and action module

When the elevator is started for the first time, there should be upward initialization or downward initialization action. As shown in the initialization flow chart in **Figure 2**, the initialization action of the elevator is that the PLC, after receiving the elevator start signal, controls the elevator to run at high speed upward (or downward), and after passing the first limit of the upper-end station (or the lower end station), it will force the speed change and change the direction and start to run at a low speed, and then it will stop at the designated initialization floor, and then it will return to the ready signal at last, thus completing the initialization process (**Figure 2**).

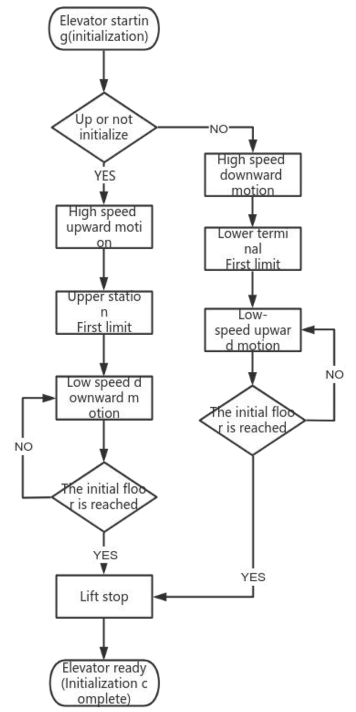

Figure 2. Initialization flowchart

During the operation of the whole elevator, we can consider putting elevator actions such as elevator up, elevator down, elevator door open, elevator door close, and elevator three-stage brake into different FB blocks. Then we can call the relevant intermediate variables to start or stop each action in the elevator operation. However, it should be noted that the value of the variable output from the FB block cannot be changed by the next FB block.

4.2 Outbound and inbound elevator selection module

When scheduling a single elevator, the core logic must be the outbound call and inbound selection function of the elevator (as shown in **Figure 3**). Here can be combined with the actual situation of daily elevator operation, to analyze the auxiliary programming.

(1) When an external call or internal selection is made, the elevator can automatically remember the request signal.

(2) If there is a request signal for a certain floor, the elevator will automatically stop at the same floor when it arrives in the right direction, respond to the signal and release the memory of the signal at the same time. If the elevator arrives in the reverse direction, it will not sound the signal and still keep the memory of the signal.

(3) No matter how the elevator runs, the floor it is on should be displayed.

(4) The running status of the elevator is given by the up and down signal indicator, which does not light up when the elevator does not move and there is no call signal.

(5) When there are multiple request signals, the direction of elevator travel is determined by the internal selection signal and call signal, and the downward direction is given priority. When there is no internal selection and no downward call signal, the elevator shall travel to the furthest reverse call signal position to stop the car. When there is only an internal selection signal, the direction of travel is prioritized.

In addition, we should also note that the elevator can respond to the call signals of all floors in the same direction and the floor selection instruction signals in the car in the course of operation, and automatically stop at the level of the floor designated by these signals. After the elevator has responded to all call signals and floor selection command signals during the operation, it stops at the target floor of the last operation and stands by.

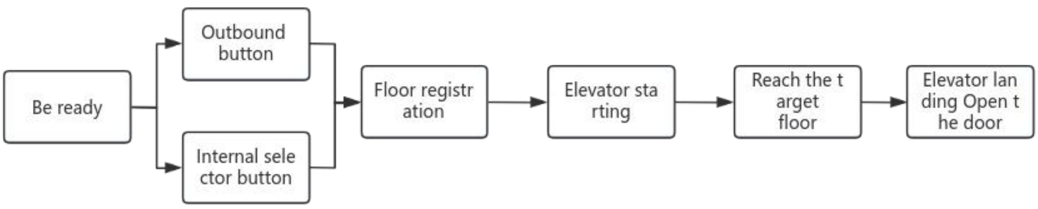

Figure 3. Single six-floor elevator outbound call inbound selection function flowchart

4.3 Overview of other module programming

Given the powerful functions of the Botou software, in the process of PLC programming for other elevator modules, we do not have to stick to the LAD language, we can also use the SCL language programming.SCL language is a PLC programming language introduced by Siemens, its full name is "Structured Control Language", which is translated into Chinese as "Structured Control Language" (Li Gong, 2022). "SCL language is a high-level language, has a simple syntax, powerful features, suitable for dealing with complex scenarios of logic algorithms and data processing. Its programming rules are based on the computer PASCAL language, so it is very easy for people who have computer programming skills in high-level languages to get started. As industrial automation data processing is becoming more and more complex, with the increasing number of functional tasks, the advantages of SCL language are showing up. We are in the elevator floor display LED light control, the use of SCL language CASE conditional statements written to help reduce the code workload, but also simple and easy to read.

5. Teaching Application

The experiments in PLC programming and application based on the virtual elevator simulation experimental platform have been embedded as an important experimental practice link in the relevant courses of the Mechanical Design and Manufacturing and Automation, Automation, and Electrical Engineering and Automation majors of our university. The course experiments began to be used for the first time as an open independent experiment for the class of 2018 in the automation major from 2020, and through four years of construction, it has become a basic experimental link in the PLC programming and application technology course with an annual audience of more than 200 people. At the same time, the experimental content of the course has been incorporated into the Intelligent Manufacturing Practical Technology course of the Intelligent Manufacturing Specialty, which is the focus of our university, as the main practical teaching content in the direction of logic algorithms in the discrete automation industry. As shown in **Table 1**, it is the statistics of the teaching situation of the experimental content of the course.

Serial number	profession	Laboratory period	Number of students enrolled	Open laboratory period	Number of open experiment courses
1	Mechanical design manufacturing machine automation	6	98	10	5
2	Automation	16	113	16	30
3	Electrical engineering and automation	8	119	8	3
4	Intelligent manufacturing engineering	16	35	16	10

Table1.Experimental teaching situation of virtual elevator simulation experiment platform

Through four years of teaching practice application, we have set three levels of difficulty for PLC programming and application experimental projects based on the elevator virtual simulation experimental platform. The first level of difficulty is mainly applied to the basic teaching application. In this part, we split the basic motion unit of the elevator, select the basic function realization as the teaching task module, and require students to realize the relevant functions through programming. For example, "lighting up the LED lighting in the car through any button", "switching the elevator up and down through buttons", "controlling the elevator to open and close the door" and so on. The difficulty of the second level is mainly to select the function that is more complete and contains relatively complex logic as part of the teaching task for teaching. For example, "initialization", "floor registration and up and down judgment", "load detection and overweight feedback", "stopping signal and action control "etc. The highest level of difficulty is the overall control program design of a single elevator, which is suitable to be applied in a 32-hour practical class.

Conclusion

Since 2020, virtual simulation technology has made an important contribution to experimental practical teaching. Now various colleges and universities have fully resumed offline experimental teaching, but for professions that require heavy investment in experimental equipment, virtual simulation experimental technology still has an irreplaceable role. This paper mainly introduces the teaching practice of "PLC Programming and Application" through the elevator-based virtual simulation experimental platform. Virtual simulation teaching, not only improves the richness of the relevant course curriculum but also increases the depth of the course and practical significance while training the students' hands-on practical ability. It has a great promotion effect on students' systematic mastery of theoretical knowledge and enhancement of innovation ability, and ultimately achieves the purpose of improving the quality of teaching (Cheng et al., 2013).

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Conflict of Interest

The authors declare that they have no conflicts of interest to this work.

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